ICCS madrid 16

Second International Conference on Concrete Sustainability

13-15 June 2016

Book of Abstracts

Universidad Politécnica de Madrid / Technical University Madrid

POLITÉCNICA "Engineering the future"

INTERNATIONAL CAMPUS OF EXCELLENCE

Second International Conference on Concrete Sustainability - ICCS16

13 – 15 June 2016
Madrid, Spain

ICCS16

Book of Abstracts of the II International Conference on Concrete Sustainability, held in Madrid, Spain on 13 - 15 June 2016

Edited by:

Jaime C. Gálvez
Technical University of Madrid

Antonio Aguado de Cea
Technical University of Catalonia

David Fernández-Ordóñez
International Federation for Structural Concrete (fib)

Koji Sakai
ICCS

Encarnación Reyes
Technical University of Madrid

María J. Casati
Technical University of Madrid

Alejandro Enfedaque,
Technical University of Madrid

Marcos G. Alberti,
Technical University of Madrid

Albert de la Fuente
Technical University of Catalonia

A publication of:

International Center for Numerical Methods in Engineering (CIMNE)
Barcelona, Spain

International Center for Numerical Methods in Engineering (CIMNE)
Gran Capitán s/n, 08034 Barcelona, Spain
www.cimne.com

ICCS16 – Concrete Sustainability

J. C. Galvez, A, Aguado de Cea, D.Fernández-Ordóñez, K. Sakai, E. Reyes, M. J. Casati, A. Enfedaque, M. G. Alberti and A. de la Fuente (Eds.)

First edition, June 2016

Printed by: Artes Gráficas Torres S.A., Huelva 9, 08940 Cornellà de Llobregat, Spain

ISBN: 978-84-945077-8-6

CONTENTS

PREFACE

This volume collects the abstracts of all contributions to the Second International Conference on Concrete Sustainability (ICCS 16), held at *Escuela de Ingenieros de Caminos, Canales y Puertos of Universidad Politécnica de Madrid (Civil Engineering School of the Technical University of Madrid).* Madrid, Spain, 13-15 June 2016.

The conference program includes four plenary lectures and 168 contributions articulated in 34 sessions.

Abstracts are presented in the following order:

Plenary lectures (4):

Environmental impact, performance and service lifetime - pillars of sustainable concrete construction
Harald S. Müller
President of fib
Institute of Concrete Structures and Building Materials, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Expanding knowledge and resources for modern concrete professionals: innovation, sustainability, and resilience
Mike Schneider
President (2016-2017), American Concrete Institute
Senior Vice President, Baker Concrete Construction, Monroe, OH, USA

Recycling of construction and demolition waste an overview of RILEM achievements and state of the art in the EU
Johan Vyncke
President of RILEM
Director Research & Innovation Belgian Building Research Institute – BBRI, Brussels, Belgium

Sustainability evaluation of the concrete structures
Antonio Aguado[1], Jaime C. Gálvez[2] , David, Fernández-Ordóñez[3], Albert de la Fuente[1]
[1]Technical University Catalonia, Barcelona, Spain
[2]Technical University Madrid, Madrid, Spain
[3]Secretary of fib, Lausanne, Switzerland

Parallel sessions:

- Case Studies (2)
- Construction aspects (4)
- Durability (11)
- Environmental design (6)
- Materials (11)

Full papers are enclosed in the E-book available at the Conference website: www.iccs16.org

ICCS16 is the second international conference on this topic, which is organised by the Technical University of Madrid and co-organised by the Spanish Association for Structural Concrete (ACHE), the American Concrete Institute (ACI), the Latin American Association for Pathology of Constructions (ALCONPAT), the International Federation for Structural Concrete (fib), the Japan Concrete Institute (JCI), and the International Union of Laboratories and Experts in Construction Materials (RILEM).

Madrid, 20 May 2016

The Editors,

Jaime C. Gálvez
Technical University of Madrid

Antonio Aguado
Technical University of Catalonia

David Fernández-Ordóñez
International Federation for Structural Concrete (fib)

Koji Sakai
ICCS Chairman

Encarnación Reyes
Technical University of Madrid

María J. Casati
Technical University of Madrid

Alejandro Enfedaque,
Technical University of Madrid

Marcos G. Alberti,
Technical University of Madrid

Albert de la Fuente
Technical University of Catalonia

SUMMARY

PLENARY LECTURES

TECHNICAL SESSIONS

CONTENTS

PLENARY LECTURES

TECHNICAL SESSIONS

Case studies

Construction aspects

Durability

Environmental design

Materials

PLENARY LECTURE

ENVIRONMENTAL IMPACT, PERFORMANCE AND SERVICE LIFETIME – PILLARS OF SUSTAINABLE CONCRETE CONSTRUCTION

HARALD S. MUELLER, MICHAEL HAIST, JACK S. MOFFATT AND MICHAEL VOGEL

Institute for Concrete Structures and Building Materials (IMB)
Karlsruhe Institute of Technology (KIT)
Gotthard-Franz-Str. 3, 76131 Karlsruhe, Germany
e-mail: harald.mueller@kit.edu, michael.haist@kit.edu, jack.moffatt@kit.edu, michael.vogel@kit.edu
www.imb.kit.edu

Key words: Sustainability, green concrete, service life design, reliability

Abstract. Green concretes with reduced cement content may provide an alternative for improving concrete sustainability independently of supplementary cementitious materials. However, concrete sustainability is not merely a function of the absolute technical performance, durability and ecological impact, but also dependent on the degree to which these co-dependent properties are optimized and exploited within the design of concrete structures. The resulting uncertainties make an objective evaluation of concrete sustainability during mix design difficult. To aid in this process the Building Material Sustainability Potential is introduced, allowing a first estimate of the potential of a concrete mix to comply with the principles of sustainable engineering. Considering the low cement content of cement-reduced concrete, a proper prediction of the service life of structures made of this material is essential for the evaluation of the sustainability potential. The paper at hand outlines the service life prediction of cement-reduced concrete by probabilistic methods and discusses the subsequent evaluation of the sustainability potential of cement-reduced concrete.

1 INTRODUCTION

The building industry is affected by the ongoing sustainability debate more than any other industry, due primarily to the pronounced environmental impact resulting from the production of building materials, the erection of buildings and structures and the subsequent use thereof [1]. This holds especially true for concrete structures, as the production of this material – and here especially the production of the raw material cement – is highly energy intensive and the source of substantial emissions of CO_2 [2]. Reducing the environmental impact of concrete production independently of resulting consequences for the performance and durability of the material, however, is inadequate. Since the required service life of concrete structures normally ranges between 50 to 100 years, their environmental impact is spread over a long time period. Therefore, increasing the sustainability of building structures requires a reduction of the environmental impact associated with the erection, maintenance and operation processes and a concurrent increase of the durability of the structures at their maximum technical performance. This relation is described in Eq. 1 (see also [3]).

$$\text{Building Material Sustainability Potential (BMSP)} \sim \frac{\text{Service Life} \cdot \text{Performance}}{\text{Environmental Impact}} \quad (1)$$

Even though the definition given above differs from standard definitions of the term sustainability, it is well in line with the latter, addressing the three basic pillars of sustainability – i.e. environmental aspects (by introducing the environmental impact) as well as social and economic aspects (hidden in the service life and performance parameters). As social and economic aspects, however, are extremely difficult or even impossible to evaluate during the concrete development process (i.e. the mix design), the definition given in Eq. 1 provides engineers with a simple tool to quantify the advantages and disadvantages of a specific concrete type with regard to its potential as a sustainable material. The exploitation of this potential during the design and construction process depends on the designer and user of the building or structure.

According to Eq. 1, three basic approaches to a sustainable use of concrete exist: 1st is the optimization of the composition of the concrete regarding its environmental impact while maintaining an equal or better performance and service life; 2nd is the improvement of the concrete's performance at equal environmental impact and service life; 3rd is the optimization of the service life of the building material and the building structure at equal environmental impact and performance. Finally, a combination of the above named approaches seems reasonable.

In this paper the sustainability of so-called eco-concretes, i.e. concretes with a strongly reduced cement content, will be discussed. The development principles applied during the mix design procedures of the presented concretes are explained in the contribution of Moffatt et al. [4] to this conference. The focus of the paper at hand rather is placed on outlining the calculations related to the Building Material Sustainability Potential (BMSP) of such materials.

2 INVESTIGATED RAW MATERIALS

Following the approach of minimizing the environmental impact of concrete during the design phase, materials were selected with low environmental impact as judged by environmental impact indicators. Table 1 presents an overview of environmental impact indicator data representative of the materials used. The data in Table 1 demonstrate that the constituent material cement is critical for the environmental impact of concrete due to its high global warming potential (GWP). While the (GWP) of superplasticizers is similar to that of cement, it is of minor importance on account of the small dosages of this substance in concrete.

Table 1: Typical life cycle inventory data for cements and inert granular concrete constituent materials

Material	Primary energy consumption		Global Warming Potential **GWP**	Ozone Depletion Potential **ODP**	Acidification Potential **AP**	Eutrophication Potential **EP**	Photochem. Ozone Creation Potential **POCP**	Source
	Non-renew. [MJ/kg]	Renew. [MJ/kg]	[kg CO_2 /kg]	[kg R11 /kg]	[kg SO_4 /kg]	[kg PO_4 /kg]	[kg C_2H_4 /kg]	
Cements								
CEM I 32.5	5.650	$8.74 \cdot 10^{-2}$	0.951	$1.64 \cdot 10^{-8}$	$5.31 \cdot 10^{-4}$	$3.30 \cdot 10^{-5}$	$2.20 \cdot 10^{-6}$	[5]
CEM I 52.5	5.800	$9.71 \cdot 10^{-2}$	0.476	$1.79 \cdot 10^{-8}$	$5.74 \cdot 10^{-4}$	$3.50 \cdot 10^{-5}$	$2.36 \cdot 10^{-5}$	
Cement industry (EPD)	2.451	$6.58 \cdot 10^{-2}$	0.691	$1.50 \cdot 10^{-8}$	$8.30 \cdot 10^{-4}$	$1.2 \cdot 10^{-4}$	$1.0 \cdot 10^{-4}$	[6]
Stone powders and aggregates								
Quartz powder 0-0.22 mm	0.820	$3.16 \cdot 10^{-2}$	$2.34 \cdot 10^{-2}$	$4.98 \cdot 10^{-9}$	$1.58 \cdot 10^{-4}$	$6.75 \cdot 10^{-6}$	$5.57 \cdot 10^{-6}$	[5]
Quartz sand	0.539	$1.29 \cdot 10^{-2}$	$1.02 \cdot 10^{-2}$	$2.10 \cdot 10^{-9}$	$7.54 \cdot 10^{-5}$	$3.00 \cdot 10^{-6}$	$2.58 \cdot 10^{-6}$	
Sand	0.022	$1.49 \cdot 10^{-3}$	$1.06 \cdot 10^{-3}$	$2.30 \cdot 10^{-10}$	$6.57 \cdot 10^{-6}$	$2.99 \cdot 10^{-7}$	$2.39 \cdot 10^{-7}$	
Gravel	0.022	$1.49 \cdot 10^{-3}$	$1.06 \cdot 10^{-3}$	$2.30 \cdot 10^{-10}$	$6.57 \cdot 10^{-6}$	$2.99 \cdot 10^{-7}$	$2.39 \cdot 10^{-7}$	
Superplasticizer (PCE based)	27.95	1.20	0.944	$3.29 \cdot 10^{-8}$	$1.19 \cdot 10^{-2}$	$5.97 \cdot 10^{-3}$	$5.85 \cdot 10^{-4}$	[7]

As binders, two cements, the first being a CEM I 52.5 R according to [8] and the second being a micro-cement with strongly reduced particle size, were selected for the investigations. No product specific life cycle inventory data were available for the micro-cement, but as it is produced by separating the fine particles from a CEM I 52.5 R, it is expected that the data will be very similar with a slight increase in renewable primary energy consumption, assuming the separation process is powered by a renewable energy source. As the availability of secondary cementitious binder materials may decline relative to future concrete demand, no secondary cementitious materials were included in this research.

Coarse and fine aggregate fractions consisting of inert quartz gravel and sand fractions, inert quartz powders and a silica fume were selected to make up the majority of the solid material in the granular matrix of the concretes. Selected properties of the cements and inert materials used are presented in Table 2.

Table 2: Properties of cements and inert aggregates investigated

Reactive components Property	Dimension	CEM I 52.5 R	Micro-cement	Silica fume
Density [9]	[g/cm³]	3.117	3.110	2,225
Blaine value [10]	[cm²/g]	5800	6900	-
Time of initial set [11]	[min]	170[1)]	77	-
Compressive strength $f_{c,28d}$ [12]	[MPa]	68.0[1)]	106.3	-

Inert aggregates Property	Dimension	Quartz powder 1	Quartz powder 2	Sand 0.1/1 mm	Sand 1/2	Gravel 2/8 mm	Gravel 8/16 mm
Density[9, 13]	[kg/dm³]	2.648	2.650	2.650	2.61	2.51	2.54
Water absorbtion [13]	[m.-%]	-	-	0.2	0.3	1.8	1.5
Blaine value [10]	[cm²/g]	18.000[1)]	1448	-	-	-	-

1) Data supplied by producer

The particle size distribution of all granular constituents was optimized using the CIPM Model by Fennis [14] and adjusted to yield mixes with maximum packing density and minimum voids content. A detailed description of this procedure can be found in [3, 4]. The particle size distribution of the solid materials used is shown in Fig. 1. The silica fume is not included in herein, as agglomeration causes the measurement of an unrealistically coarse particle size distribution in densified product. Additionally, a superplasticizer was also included in the mixtures and dosed according to the recommendations made in [14].

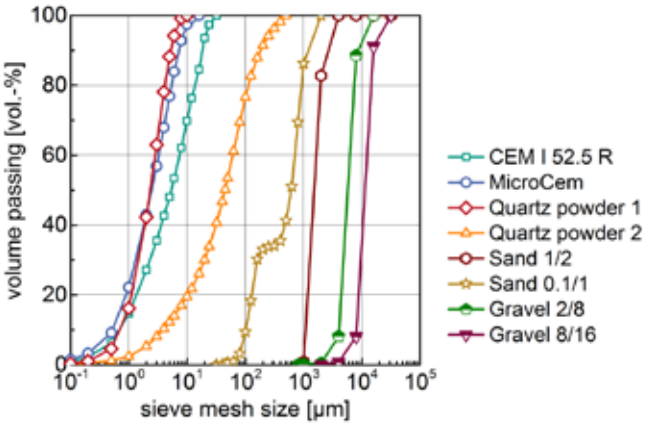

Figure 1: Particle size distribution curves of the cements and inert granular constituent materials used

3 COMPOSITION AND PROPERTIES OF INVESTIGATED MIXES

Based on the raw materials detailed in Sec. 2, a total of 6 different concrete mixes with cement contents ranging between 4 vol.-% and 10 vol.-% of all solid particles were developed. The composition and selected properties of the mixes are detailed in Table 3.

Table 3: Mixture composition of the developed concretes

Raw material / characteristic value	Dimension	Concrete mixture					
Mixture parameters							
Cement content in dry mix	[vol.-%]	4.0	4.0	4.0	5.0	6.0	10.0
Grain size distribution (fit parameter n)	[-]	0.34	0.34	0.34	0.34	0.34	0.34
Cement type	[-]	CEM I	µCEM	SF-CEM I	CEM I	CEM I	CEM I
Mixture composition							
Cement	[kg/m³]	113	111	109	138	162	268
Quartz powder 1		96	96	96	94	92	91
Quartz powder 2		120	121	120	118	69	23
Sand 0.1/1 (mm)		519	520	520	490	497	441
Sand 1/2 (mm)		434	435	434	424	415	436
River gravel 2/8 (mm)		482	483	482	471	461	459
River gravel 8/16 (mm)		506	507	506	495	484	482
Water		87	85	87	106	126	130
Superplasticizer (PCE based)		6.5	6.4	6.5	6.0	5.7	6.2
w/c-ratio	[-]	0.64	0.64	0.65	0.67	0.69	0.43
Mixture properties							
Compressive strength $f_{cm,28d}$ [18]	[MPa]	76.9	79.0	76.6	69.8	58.2	102.6
Degree of compactability c [16]	[-]	1.25	1.21	1.19	-	-	-
Flow value a [17]	[mm]	-	-	-	390	450	480
Inverse carbon. resistance R_{ACC}^{-1} Mean value / standard deviation	[(10^{-11} m²/s)/ (kg/m³)]	18.91 / 6.83	0.39 / 0.33	14.74 / 5.63	29.59 / 9.69	42.91 / 12.95	--
Global warming potential (GWP)	[kg CO_2/m³]	75	74	76	87	97	146

The mix design process consisted of the following steps: Firstly, the raw materials of the concrete were selected with the objective of minimizing the content of materials with pronounced environmental impact within the concrete mixture.

Secondly, the cement content within the concrete was defined to be decreasing from 10 vol.-% to 6, 5 and 4 vol.-% of the total solids volume contained in each mixture. Each mixture contained only one cement, either the CEM I 52,5 R or the micro-cement described in Sec. 2

Thirdly, the volume content of each inert granular material was adjusted to maximize the inert material content in the concrete while taking into consideration the influence of cement particles on the packing density. The particle packing model CIPM by Fennis [14] was used to judge the particle packing density while adjusting the granular mixture composition.

Finally, the fresh concrete properties of the mixtures were optimized by adjusting the water content in each mixture. Each mixture was provided with a PCE-based superplasticizer according to the recommendations made in [14].

The composition of the mixes detailed in Table 3 is characterized by cement contents between 113 kg/m³ to 268 kg/m³ in the fresh concrete of either the CEM I 52.5 R or the micro-cement. Additionally, in one mixture the cement CEM I 52.5 R was combined with micro-silica fume by replacing 5 % by mass of the cement by the corresponding mass of micro-silica fume (referred to as SF-CEM I). Hereby the effect of an improved interfacial transition zone was studied. The reference concrete was adjusted to have a w/c-ratio of 0.43 with a cement content corresponding to the minimum requirements of EN 206-1 [15].

The fresh concrete was tested for its compactability c according to [16] or its flow value a according to [17] depending on the flow characteristics of the mixture. Specimens were casted, demolded at the age of 2 days, cured in water until the age of 7 days and stored at 20 °C and 65 % r. h. until the age of 28 days, then tested for their compressive strength according to [18]. The corresponding results are detailed in Table 3 and show that the investigated concretes provide high compressive strengths combined with significantly reduced environmental impact compared to standard concretes. The environmental impact of each concrete is represented here by its global warming potential (GWP) and has been calculated based on the environmental impact and content of each raw material as specified in Sec. 2.

Besides the properties in the fresh state and the mechanical properties, the concretes were also tested for their durability under common environmental exposures such as freeze-thaw attack with de-icing salt, carbonation and chloride ingress. These experimental results served in the calculation of the service-lifetime expected of these concretes.

Fig. 2 shows the results of freeze-thaw tests conducted according to the CDF-method as described in [19] and [20].

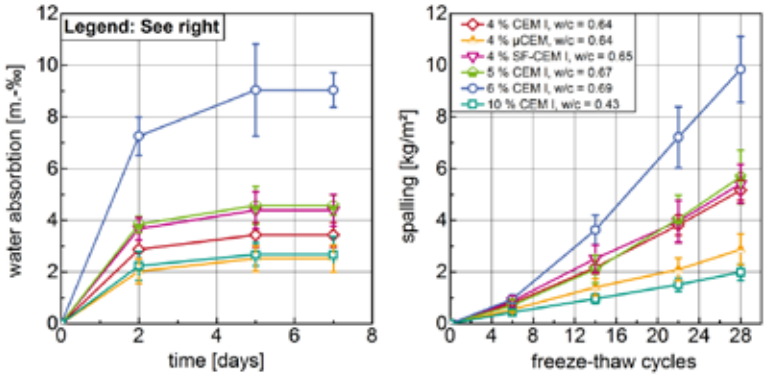

Figure 2: Measured capillary suction (left) and concrete spalling (right) of investigated mixes in the CDF-test according to [19] and [20].

As can be seen from the results detailed in Fig. 2, neither the tested reference concrete with

a cement content of 10 vol.-% corresponding to 268 kg/m³, nor the concretes with reduced cement content fulfilled the requirements for a concrete corresponding to exposure class XF4 (high water content with chloride attack) according to [15] with a maximum allowable spalling of 1500 g/m². This result was expected. However, the experimental data also shows that the capillary suction and the freeze-thaw resistance of mixes with 4 vol.-% of cement show lower water absorption and a lower spalling than mixes with cement contents of 5 and 6 vol.-%, respectively. Despite its significantly higher w/c-ratio of approximately 0.63, the mix containing 4 vol.-% of micro-cement exhibited a similar, though slightly inferior freeze-thaw resistance than the reference concrete with a cement content of 10 vol.-% and a w/c-ratio of 0.43.

This result in combination with the declining performance of mixes with increasing cement content can be explained by the reduced surface area of hardened cement paste per unit area of concrete under attack as the cement content is reduced. Since only the hardened cement paste is susceptible to a freeze-thaw attack, this effect obviously offsets in part the detrimental effect of an increased w/c-ratio. Unfortunately, the amount of data available is still too small to derive a general law which quantifies both effects.

In order to investigate the influence of the interfacial transition zone (ITZ) on the durability of concretes with low cement content, in the mix designated "4 % SF-CEM I", 5 % by mass of the Portland cement were replaced by a micro-silica fume. It was dosed to the coarse aggregates in order to enhance a localization of these particles on the coarse aggregate surfaces. The comparison of this mix with the corresponding reference mixture, i.e. the mix containing 4 vol.-% of Portland cement, does not show any difference in the free-thaw-behaviour. Here it appears the w/c-ratio of the cement matrix is generally too high for the ITZ to have any significant effect on the freeze-thaw resistance. Small differences, however, become apparent when comparing the results of the water absorption test. Here the mix containing micro-silica fume exhibits higher water absorption than the mix without silica.

A very important aspect in the evaluation of the durability of the investigated concretes is their resistance against a CO_2-induced carbonation. Therefore, beam shaped samples with dimensions of 100 x 100 x 440 mm³ were casted, demoulded after 2 days and stored in water at 20 °C until the age of 7 days. Then the beams were removed from water storage and exposed to dry conditions at 20 °C and 65 % r. h. until the age of 28 days. At this age, half of the beams were removed from the climate chamber and exposed to an increased CO_2 concentration of 2 vol. % at 20 °C and approximately 70 % r. h. Both the samples carbonating under normal and under increased CO_2 concentration were investigated for their carbonation depth by splitting the samples at four points along the length of the beam and applying phenolphthalein to the surfaces of the split cross sections. The carbonation depth of each concrete was determined using one beam, measuring inward at 3 points along each of the 4 edges of the split surfaces. The mean value of the carbonation depth was formed for each mixture out of the 48 measurements taken from the corresponding beam.

As can be seen from Fig. 3 (left), the reference concrete (w/c = 0.43) subjected to normal carbonation (i.e. approximately 0.04 vol.-% of CO_2) does not show any carbonation at all, whereas the samples with reduced cement content exhibit a significantly increased carbonation. The worst performance in this comparison was also observed with the mix containing 6 vol.-% of cement, followed by the mixes with 5 and 4 vol.-% cement. While the differences between the 6 vol.-% mix compared to the 4 and 5 vol.-% mixes are of statistical

significance, the differences between the latter two are not. The same is true regarding the differences between the composite cement containing micro-silica fume and the corresponding mix without silica. Similar results with regard to the ranking of the performance of the investigated concretes can be found for the samples exposed to an accelerated carbonation at 2 vol.-% of CO_2 in Fig. 3 (right). In this test setup the reference concrete also did not exhibit any carbonation. The best performance of all cement-reduced concretes was found for the mix with 4 vol.-% of micro cement. Independently of the test set-up, the carbonation depth was lower than 1 mm, showing a good carbonation resistance, albeit a diminished carbonation resistance when compared to the reference mixture.

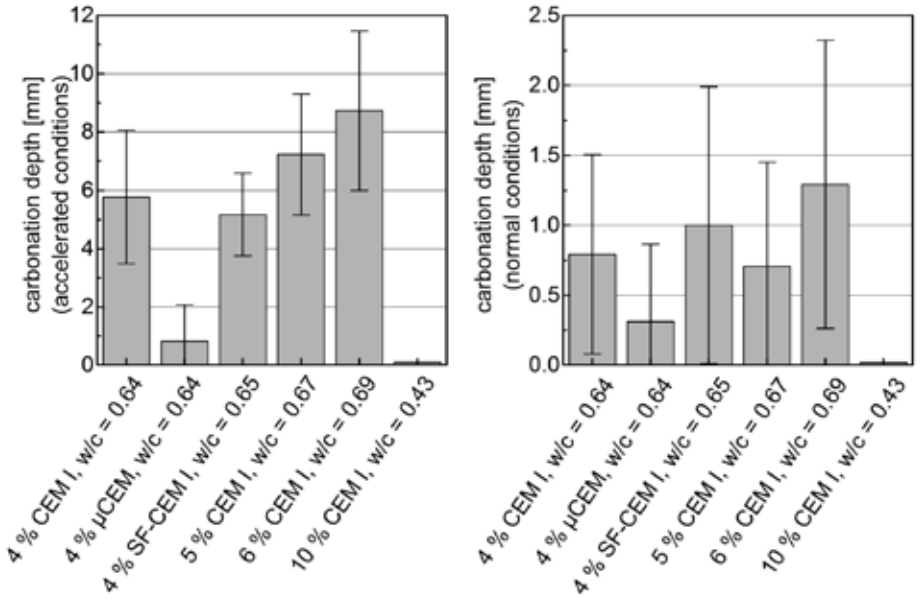

Figure 3: Carbonation depth of concretes exposed to natural CO_2 environment at 20 °C and 65 % r. h. (left) and 2 vol.-% of CO_2 at 20 °C and approximately 70 % r. h. (right) at an age of 56 d (test procedure see text)

4 SERVICE LIFE DESIGN AS A KEY TO SUSTAINABLE BUILDINGS AND STRUCTURES

As illustrated by Eq. 1, maximizing the lifetime of a building or a structure is a very efficient way to improve the sustainability of our built environment. Methods to predict the service life of a concrete structure and to design the structure accordingly are essential tools in the sustainability assessment process for sustainable buildings and structures. However, this aspect is often neglected in the current life-cycle assessment debate, leading to a single sided focus on a pure reduction of environmental impact while neglecting the durability and thus the sustainability of the designed structures.

The service life design process is dominated by assessing the alteration – i.e. ageing and

often deterioration – of the material on one hand and the varying environmental exposures on the other. This requires in-depth knowledge of the deterioration mechanisms of concrete and on the variance of the influencing factors over time. The procedure of service life prediction will, in the following, be illustrated by means of the carbonation process applied to green concretes as presented in Sec. 3.

The time dependent carbonation of concrete can be described using Eq. 2, in which $x_c(t)$ describes the carbonation depth in (mm) at the time *t*. The dimensionless parameters k_e, k_c and k_t take into account environmental conditions, curing and testing effects. R_{ACC}^{-1} is the inverse effective carbonation resistance of concrete and ε_t is the corresponding error term in $((mm^2/years)/(kg/m^3))$. C_S describes the surrounding CO_2-concentration in (kg/m^3) and W(t) is the dimensionless weather function, see [21]. With the experimental data depicted in Fig. 3, R_{ACC}^{-1} can be calculated for the green concretes (see Table 3).

$$x_c(t)=\sqrt{2\cdot k_e\cdot k_c\cdot\left(k_t\cdot R_{ACC,0}^{-1}+\varepsilon_t\right)\cdot C_S\cdot\sqrt{t}}\cdot W(t) \tag{2}$$

As a limit state criterion $x_c(t) = c$, with *c* being the concrete cover, is introduced. The failure probability p_f is defined as the probability for exceeding this limit state within a defined reference time period.

The loss of durability, i.e. the increase of the deterioration with time, reduces the reliability of a structure. In order to be able to evaluate this reliability at any age of the structure, a reference period for the service life has to be specified [22]. Based on Eq. 2, the time at which depassivation of the reinforcement occurs can be determined and an appropriate maintenance management established, which can significantly increase the intended service life. By introduction of the reliability index β, a direct correlation between β and the failure probability p_f is obtained. In case of a normally distributed limit state function Z = R – S (R: Resistance, S: Action), the failure probability p_f can be directly determined using Eq. 3.

$$p_f=p\{Z<0\}=\Phi(-\beta) \tag{3}$$

The variable Φ(-β) denotes the distribution function of the standardized normal distribution (see [23]). The correlation between various values for the failure probability p_f and the reliability index β is shown in Table 4. Note e.g. that the often used 5 % quantile in civil engineering is equal to a failure probability of $5\cdot10^{-2}$, which corresponds to a reliability index β = 1.645.

Table 4: Values for the failure probability p_f and the related reliability index β [23]

p_f	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
β	1.28	2.32	3.09	3.72	4.27	4.75	5.20

The target values of the reliability index, β_{target}, depend on the consequences of failure (loss of serviceability) and the relative cost of safety measures. Table 5 contains target values of the reliability index β for building components in the serviceability limit state (SLS), see [24, 25]. Considering the case of depassivation of the reinforcement due to carbonation or chloride ingress, the target reliability index is recommended as β = 1.3 according to [21].

Table 5: Target values of the reliability index β depending on the relative cost of safety measures

Relative cost of safety measures	Reliability index β [24]	Reliability index β [25]
High	1.3 ($p_f \approx 10$ %)	1.0 ($p_f \approx 16$ %)
Moderate	1.7 ($p_f \approx 5$ %)	1.5 ($p_f \approx 7$ %)
Low	2.3 ($p_f \approx 1$ %)	2.0 ($p_f \approx 2$ %)

Fig. 4 shows a comparison of the resulting service life prediction for concrete structures subjected to carbonation with 40 mm mean concrete cover thickness (8 mm standard deviation) using a green concrete containing 113 kg/m³ (see Fig. 3, 4% CEM I, w/c-ratio = 0.64) and a reference concrete containing 320 kg/m³ of a CEM I 42.5 R with a w/c = 0.60 as described in [26, 27]. Further parameters in Eq. 2 were set according to the example in [27], representing environmental exposure conditions in the city of Munich, Germany. The reference concrete reaches the chosen target reliability index of $\beta_{target} = 1.5$ after 100 years, the selected green concrete after 72 years.

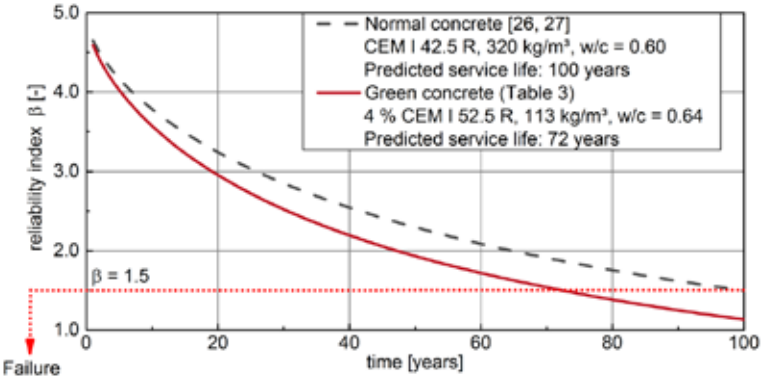

Figure 4: Comparison of exemplary service life predictions between a developed green concrete and a normal concrete taken from literature data [26, 27]

Combining the measured performance of the green concretes with the durability parameters determined by experiment and the probabilistic service life prediction, it is now possible to evaluate the sustainability potential as described in Eq. 1. Table 6 contains the results for the BMSP of a green concrete as compared to a normal concrete evaluated for a moderate reliability index of 1.5 (see Table 5) in the case of CO_2-induced carbonation described above. Although the predicted service life of the green concrete is thirty years shorter than that predicted for the normal concrete, its high performance and reduced environmental impact compensate for this deficit within the sustainability potential index.

Table 6: Evaluation of the sustainability potential of a green concrete in comparison to a standard concrete

Concrete type	Dimension	Normal concrete	Green concrete 4 % CEM I 52.5 R
Cement type	-	CEM I 42.5 R	CEM I 52.5 R
Cement content	kg/m³	320	113
Water to binder ratio	-	0.60	0.64
Inverse carbonation resistance R_{acc}^{-1} (mean value / standard deviation)	$(10^{-11}$ m²/s)/(kg/m³)	13.4 / 5.2	18.9 / 5.6
Calculated service life	years	100	72
Compressive strength	MPa	38.4	76.8
Environmental impact	kg CO_2/m³	214	76
BMSP (See Eq. 1)	MPa·years/(kg CO2/m³)	17.9	72.8

4 CONCLUSIONS

The sustainability of concrete is difficult to quantify during the concrete mix design process, as the three interdependent parameters of performance, durability and environmental impact must be evaluated and concurrently optimized. The Building Material Sustainability Potential (BMSP) is thus introduced as a simple indicator for sustainability during mix design.

It has been demonstrated that cement-reduced concrete can be produced while maintaining or even improving performance in compressive strength, raising potential for discussion of minimum cement contents within concrete standards. To evaluate the sustainability potential of the resulting concretes, however, their durability characteristics must also be considered.

Probabilistic service life design methods, relying on experiments and improved deterioration mechanism models, can be used to predict effectively the service life of concrete structures under defined environmental exposures. While experimental results indicate a deficit in the durability characteristics of cement-reduced concretes, this deficit may be insignificant depending on the intended exposure conditions. Due to significant increases in performance and strongly reduced environmental impact, the evaluation of the BMSP for one such concrete compared to a standard concrete indicates potential for a significant sustainability benefit when choosing the green concrete. Whether this benefit outweighs any potential drawbacks will also depend on the proper management of necessary maintenance measures when the service life of the structures indeed expires.

The cement-reduced concrete mixtures presented are a first step toward producing sustainable concrete and abstaining from supplementary cementitious materials. While the BMSP of the examined green concrete greatly exceeds that of the reference concrete presented, more research regarding the durability of these mixtures must be performed.

ACKNOWLEDGEMENTS

The authors would like to thank the Helmholtz Association for funding this research.

REFERENCES

[1] O'Brien, M. et al., Eco-Innovation Observatory Thematic Report, April 2011, available:

http://wupperinst.org/uploads/tx_wupperinst/EIO_WP4_ResEff_Constr_Report.pdf; last access: Oct. 2013
[2] International Federation for Structural Concrete (2012), Guidelines for green concrete structures. *fib* bulletin 67, Lausanne, Switzerland
[3] Haist, M. et al. (2014), Development principles and technical boundaries of concrete production with low cement content. In: Beton- und Stahlbetonbau 109, No. 3, pp. 202-215
[4] Moffatt, J. S.; Haist, M.; Mueller, H. S.: A study of the sustainability potential of cement reduced concrete. In: Proceedings of the II International Conference on Concrete Sustainability (ICCS16), Madrid, Spain, (2016)
[5] Bundesverband der Deutschen Ziegelindustrie e. V.: Green Building Challenge Handbuch. http://www.ziegel.at/gbcziegelhandbuch/default.htm
[6] Institut für Bauen und Umwelt (Hrsg.): Umweltproduktdeklaration nach ISO 14025 für Zement; Deklarationsnummer: EPD-VDZ-2012111-D, Inhaber: Verein Deutscher Zementwerke e.V., Düsseldorf, Ausstellungsdatum: 16.03.2012
[7] Schiessl, P.; Stengel, Th.: Nachhaltige Kreislaufführung mineralischer Baustoffe. Forschungsbericht der Technischen Universität München, Abteilung Baustoffe, München, 2006
[8] DIN EN 197-1:2011-11: Cement – Composition, specifications and conformity criteria for common cements. Beuth Publishers, Berlin
[9] DIN EN 1097-7:2008-08: Tests for mechanical and physical properties of aggregates – Determination of the particle density of filler – Pyknometer method. Beuth Publishers, Berlin
[10] DIN EN 66126:2015-08: Determination of specific surface area of disperse solids by the gas permeability technique – Blaine method. Beuth Publishers, Berlin
[11] DIN EN 196-3:2009-02: Methods of testing cement – Determination of setting times and soundness. Beuth Publishers, Berlin
[12] DIN EN 196-1:2005-05: Methods of testing cement – Determination of strength. Beuth Publishers, Berlin
[13] DIN EN 1097-6:2013-09: Tests for mechanical and physical properties of aggregates – Determination of particle density and water absorption. Beuth Publishers, Berlin
[14] Fennis, S. A. A. M. (2010), Design of ecological concrete by particle packing optimization. PhD Thesis, Technical University of Delft, The Netherlands
[15] DIN EN 206:2014-07: Concrete – Specification, performance, production and conformity. Beuth Publishers, Berlin
[16] DIN EN 12350-4:2009-08: Testing fresh concrete – Degree of compactability. Beuth Publishers, Berlin
[17] DIN EN 12350-5:2009-08: Testing fresh concrete – Flow table test. Beuth Publishers, Berlin
[18] DIN EN 12390-3:2009-07: Testing hardened concrete – Compressive strength of test specimens. Beuth Publishers, Berlin
[19] Bundesanstalt für Wasserbau, „BAW-Merkblatt: Frostprüfung von Beton“ Karlsruhe, 2012
[20] M.J. Setzer, G. Fagerlund, D.J. Janssen, RILEM recommendation for Test Method for the Freeze Thaw Resistance of Concrete – Test with Sodium Chloride Solution (CDF). In: Concrete Precasting Plant and Technology 4 (1997), pp. 100-106
[21] International Federation for Structural Concrete (2006), Model Code for Service Life Design. fib bulletin 34, Lausanne, Switzerland
[22] European Standard EN 1990:2010-12 (2010): Eurocode – Basis of structural design; German version EN 1990:2002 + A1:2005 + A1:2005/AC:2010. Beuth Publishers, Berlin, Germany
[23] Melchers, R. E. (2002), Structural Reliability Analysis and Prediction. John Wiley & Sons
[24] Joint Committee on Structural Safety (JCSS) (2001), Probabilistic Model Code – Part I: Basis of Design
[25] Rackwitz, R. (1999), Zuverlässigkeitsbetrachtungen bei Verlust der Dauerhaftigkeit von Bauteilen und Bauwerken. Bericht zum Forschungsvorhaben T 2847. Fraunhofer IRB Verlag, Germany, 1999
[26] Gehlen, Ch. (2000), Probabilistische Lebensdauerbemessung von Stahlbetonbauwerken. Journal of the Deutscher Ausschuss für Stahlbeton, Vol. 510, Beuth Verlag, Berlin, Germany
[27] Gehlen, Ch. et al. (2011), Kapitel XIV Lebensdauerbemessung, In: Bergmeister, K., Fingerloos, F., Wörner J.-D. (Eds.), Beton-Kalender 2011, Teil 2, Kraftwerke, Faserbeton, Ernst & Sohn, Berlin, Germany, pp. 231–278

EXPANDING KNOWLEDGE AND RESOURCES FOR MODERN CONCRETE PROFESSIONALS: INNOVATION, SUSTAINABILITY, AND RESILIENCE

MICHAEL J. SCHNEIDER

American Concrete Institute
38800 Country Club Dr. Farmington Hills, Michigan 48331 USA
www.concrete.org

Baker Concrete Construction, Inc.
900 N. Garver Rd. Monroe, Ohio 45050 USA
schneiderm@bakerconcrete.com / www.bakerconcrete.com

Key words: Cement, Climate Change, Concrete, Construction, Contractor, Design, Disaster-Protection, Engineer, Engineering, Excellence, Innovation, Jobsite Safety, Materials, Professor, Resilience, Resilient, Safety, Student, Sustainability

Abstract. Now more than ever, concrete design and construction projects must integrate innovative techniques and technologies to keep pace with ever-evolving economic, environmental, and aesthetic demands. Structures must be designed to protect against disasters and be resilient against climate change. Jobsite safety remains paramount. This presentation will highlight the many demands facing professionals in the concrete design, construction, and materials industry, and include examples of sustainability, innovation, and excellence. Also included will be American Concrete Institute initiatives to expand knowledge and resources to support modern engineers, contractors, researchers, and students.

1 INTRODUCTION

About the American Concrete Institute – Founded in 1904 and headquartered in Farmington Hills, Michigan, USA, the American Concrete Institute is a leading authority and resource worldwide for the development and distribution of consensus-based standards, technical resources, educational & training programs, certification programs, and proven expertise for individuals and organizations involved in concrete design, construction, and materials, who share a commitment to pursuing the best use of concrete. ACI has over 101 chapters, 93 student chapters, and nearly 20,000 members spanning over 120 countries. In recent years, the Institute has dedicated its resources to understanding and advancing the use of concrete in sustainable and resilient development through committees, articles, research, publications, partnerships, and events.

About Baker Concrete Construction, Inc. – Founded in 1968, Baker Concrete Construction, Inc., is one of the USA's leading concrete construction firms and specializes in all types of cast-in-place concrete construction. In addition to an industry-leading commitment to safety, both on and off the job, Baker Concrete Construction has earned a reputation for excellence through finely-honed skills, fierce determination, and a commitment to high performance. Baker believes that success is driven by the commitment of its workforce to live "Incident and Injury Free" (IIF) – a culture not exclusively about rules and procedures, but about each employee examining his or her own relationship to safety. Baker Concrete Construction is ranked first in the 2015 Top 20 Concrete Specialty Contractors category in *Engineering News-Record*, and has been ranked in the top three annually since 1989.

2 SUSTAINABILITY

Sustainable development is defined by the Brundtland Commission as "development that meets the need of the present without compromising the ability of future generations to meet their own needs." Resources have been developed both by the American Concrete Institute and Baker Concrete Construction on the topic of sustainability and sustainable development.

2.1 Sustainability at the American Concrete Institute

The American Concrete Institute's first position statement on sustainability, approved in 2005, stated that the Institute shall: 1) encourage the development of sustainable structures through the application of environmentally friendly and sustainable concrete design, materials, and construction; 2) position concrete to compete effectively; and 3) raise the level of awareness and seek support for increased sustainability inside and outside the concrete industry.

In 2008, the American Concrete Institute began hosting its annual Concrete Sustainability Forum. This annual event includes global experts sharing insight on: 1) the need to work more diligently to clarify our industry's environmental responsibility to society; 2) disseminating the significance of sustainability among members of the concrete sector, to

collect scientific data related to the environmental impacts of concrete, and to develop indicators and simple tools for the evaluation of those impacts; and 3) to host a forum on sustainability in concrete featuring representatives from the world's diverse concrete organizations and innovators.

In 2010, ACI's Board of Direction updated the position statement. It states the American Concrete Institute's intent to: 1) support the consideration of economic, social, and environmental balance for sustainability criteria in concrete design, materials, and construction; 2) identify and, as appropriate, remove barriers to the adoption of more sustainable concrete practices, technologies, standards, specifications, etc.; and 3) raise the level of awareness and seek support for increased sustainability practices and designs within the concrete industry and beyond.

Also in 2010, ACI formed a new technical committee to develop and report information on the sustainability of concrete (ACI Committee 130: Sustainability of Concrete). This technical committee subsequently formed seven subcommittees to strengthen, broaden, and institutionalize its efforts. In tandem, several ACI committees are working on specific areas of sustainability and resilience, which they have been doing since the mid-1900s, and have published state-of-the-art reports guiding industry practice.

(1) ACI Technical Committee Documents

The term "technical committee document" refers to all ACI technical committee works, whether published or under development, such as codes, specifications, reports, and guides. All technical committee documents are developed by ACI technical committees in accordance with the ACI Technical Committee Manual, and approved by the ACI Technical Activities Committee. ACI has several documents currently available on topics relating to sustainability, including:

- Removal and Reuse of Hardened Concrete (ACI 555R-01);
- Guide to Thermal Properties of Concrete and Masonry Systems (ACI 122R-14);
- Use of Fly Ash in Concrete (ACI 232.2R-03);
- Report on High-Volume Fly Ash Concrete for Structural Applications (ACI 232.3R-14);
- Slag Cement in Concrete and Mortar (ACI 233R-03);
- Guide to the Use of Silica Fume in Concrete (ACI 234R-06);
- Concrete Repair Guide (ACI 546R-14);
- Guide to Durable Concrete (ACI 201.2R-08); and

- Specification for Pervious Concrete Pavements (ACI 522.1-13), among others.

Additional ACI technical committee documents are under development on the topics of insulating concrete forms, concrete wind turbine towers, alternative cementitious materials, and more.

(2) Educational programs

The term "educational programs" refers to all ACI educational committee works, whether published or under development, and include seminars, webinars, and courses through the ACI University. Educational programs are practice-oriented and are intended to raise the competence level of concrete producers, contractors, technicians, engineers, and others within the concrete industry. ACI has several educational programs currently available on topics relating to sustainability, including:

- Concrete Sustainability Basics;
- Concrete Sustainability – Incorporating Environmental, Social, and Economic Aspects;
- Green Cements;
- High-Volume Fly Ash Concrete for Structural Applications
- Sustainability of Concrete Pavement; and
- The Art of Thermal Mass Modeling for Energy Conservation in Buildings; among others.

(3) Symposium publications

ACI “symposium publications” include a collection of manuscripts authored by an ACI technical committee or by individuals. Manuscripts are selected and reviewed by the sponsoring ACI committee in accordance with the policies established in the ACI Technical Committee Manual. ACI has several symposium publications currently available on topics relating to sustainability, including:

- Recycling Concrete and Other Materials for Sustainable Development (SP 219);
- Thirteenth International Conference on Advances in Concrete Technology and Sustainability Issues (SP 303);
- Sustainable Performance of Concrete Bridges and Elements Subjected to Aggressive Environments: Monitoring, Evaluation & Rehabilitation (SP 304); and
- Concrete: The Sustainable Materials Choice (SP 269); among others.

(4) U.S. Green Concrete Council publications

To meet the need for credible technical resources on concrete sustainability, the American Concrete Institute formed the U.S. Green Concrete Council, a subsidiary of the Institute, to develop two publications: "The Sustainable Concrete Guide – Strategies and Examples" (English and Spanish) and "The Sustainable Concrete Guide – Applications" (English). Unveiled in 2010, these publications set a new standard within ACI for timely publication of industry-critical resources, and over 10,000 copies have been distributed.

(5) Concrete Construction Sustainability and Resilience Assessor

The ACI Certification Programs Committee, with the guidance of the ACI technical committee on concrete sustainability, is researching the development of a program to certify individuals as Concrete Construction Sustainability and Resilience Assessors. The ACI-certified assessors would be responsible for identifying opportunities during concrete design and construction to support environmental objectives. A program launch date has not yet been established.

2.2 Sustainability at Baker Concrete Construction, Inc.

As stewards of resources and environment, Baker Concrete Construction strives to ensure a solid future for current and future generations of people, communities, the nation, and the world through a balanced pursuit of the following:

- Social and people-related sustainability – working with integrity to enhance the quality of life for all;
- Environmental stewardship – working in a responsible and ethical manner to improve the built environment, seeking to rectify the practices of the past, and setting new industry standards through innovation and continuous improvement;
- Economic sustainability – ensuring long-term financial stability through social and environmental initiatives.

Baker Concrete Construction contributes to sustainability by focusing on three complementary strategies:

1. Offering a selection of sustainable concrete construction products and services to customers;
2. Pursing its own every-day sustainability program on jobsites, in construction trailers, and in its offices; and
3. Working closely with suppliers and subcontractors to align their processes with Baker's own.

In addition, Baker Concrete Construction encourages special "Acts of Green" initiatives by each project, each function, and by individual co-workers. These Acts often originate from the Baker Safety, Sustainability, Quality and Productivity (SSQP) continuous improvement program.

> Baker's Safety, Sustainability, Quality and Productivity continuous improvement program generates many ideas that are implemented. Biggest successes have been with co-worker safety, but Baker has also improved quality, productivity, and social sustainability impact. Select impacts that have come from the program include:
>
> **Jobsite offerings that promote sustainability include:**
>
> - Support local charities: Toys for Tots, Make-a-Wish, food banks, building community playgrounds, etc. Giving is part of culture; becoming part of local communities when traveling to remote jobsites;
> - Improvement in products that we buy;
> - Promote buying local: labor, services, products;
> - By example, filled a need for 800 workers for steel mill project and hired 80% local co-workers while installing approximately 400,000 yd^3 of concrete in less than one year;
> - Promote cleaner project sites;
> - Encourage a range of strengths (e.g.: 56, 91 days);
> - Encourage zero discharge sites; separate dumpsters for steel and recycle concrete on modernization projects. When recycling is not practical, reuse concrete as fill or rip rap;
> - Encourage paperless projects and processes; several recent nuclear projects included over 3,000,000 pages of records. Baker invested in enterprise content management software and processed most pages electronically and with electronic work flows. Shredded and recycled paper that was used;
> - Increase efficiency of labor and materials;
> - Optimize aggregates; review mix designs to assure that they are not gap graded and workable – enhancing the quality of work;
> - Optimize mix designs: reduce CO_2 in concrete; routinely use 30% fly ash mixes and have used 50% fly ash mixes for mass concrete:
> - Implement storm water pollution protection plans on projects;

- Avoid use of toxic materials;
- Recycle water on jobsites/batch plant;
- Recycle: waste on jobsites, use recycled products;
- Reduce dust (collection shrouds, socks, fans, etc.);
- Reduce wood use though proper formwork selection, make-up processes, and proper use of form oils;
- Energy-saving lighting with motion detectors in permanent facilities
- Reduce fuel-consumption (study, alternative fuels, reduce engine running time); use bio-diesel to fuel compressors and generators on a several projects; no idling equipment and vehicles on jobsites;
- Reduce noise;
- Reduce waste; and encourage use of bio-degradable materials for products that must be landfilled; and
- Reduce water use.

General sustainability initiatives that promote sustainability include:

- Health insurance, flu shots, wellness programs part of "Incident and Injury Free" (IIF) culture;
- The Safety, Sustainability, Quality and Productivity continuous improvement program includes sustainability discussions. This contributes to better awareness of the impact on communities;
- All co-workers receive "Incident and Injury Free" indoctrination that encourages behavior based approach to safety;
- Wellness includes coaching regarding co-workers well-being and daily stretch & flex and encouragement; and
- Baker University offers a wide range of classes that enhance the lives of our co-workers. These classes go beyond technical skills needed to perform work and support co-worker growth with languages, math skills, etc.

Business development offerings that promote sustainability include:

- Polishing damaged slabs as opposed to removing and replacing;

- Offer restoration as an alternative to new construction; Baker works on many modernization projects;
- Participate on brownfield re-development site and practice site reclamation;
- Participate on many LEED-certified projects; and
- Provide design assist services and Building Information Modeling support to make projects more constructible and consuming fewer resources.

3 JOBSITE SAFETY

Paramount to all aspects of sustainable construction is the strict accordance to published safety guidelines. Hard hat, eye protection, safety vest, long-sleeved shirt, long pants, boots, and ear protection are minimum safety equipment for concrete work, and dust masks should be worn when necessary. Since fresh portland cement concrete is highly alkaline and can cause skin irritation and burns, it is important for all to comply with these additional precautions to avoid injury:

1. Keep cement products off skin — experienced concrete craftsmen protect their skin with boots, gloves, clothing, and knee pads. Skin injury may result from clothing that is wet from cement mixtures;
2. Don't let skin rub against cement products — Many cement products are abrasive. Rubbing increases the chances of serious injury. Keep concrete out of cuffs and boots;
3. Wash skin promptly after contact with cement products;
4. Keep cement and cement products out of eyes — Concrete workers should wear safety glasses or goggles. If any cement or cement mixtures get into the eye, flush immediately and repeatedly with water and consult a physician promptly; and
5. Keep products out of the reach of children.

3.1 Safety Resources from the American Concrete Institute

The American Concrete Institute works to disseminate consensus-based information through publications and educational products. Several Institute publications include content on jobsite safety, including:

- *Concrete Fundamentals*;
- *The Contractor's Guide to Quality Concrete Construction* (published jointly with the American Society of Concrete Contractors); and

- *Guide for Responsibility in Concrete Construction* (ACI 132R-14).

3.2 Jobsite Safety at Baker Concrete Construction, Inc.

To be the preeminent concrete contractor through a commitment to delivering unparalleled safety, quality, and value and caring for employees, clients, and the environment, Baker has developed several guiding principles that prioritize jobsite safety. These principles are broader than jobsite safety, and include:

- Promoting an "Incident and Injury-Free" lifestyle;
- Promoting and demonstrate a commitment to sustainable construction;
- Striving for performance excellence in all areas;
- Promoting honesty and integrity;
- Leading by example and working toward continuous improvement through innovation;
- Being positive contributors to the concrete industry;
- Encouraging frequent and open communication;
- Being professional at all times;
- Delivering on promises; and
- Respecting individuals while operating as a team.

4 RESILIENCE

Resilience is defined by the United Nations International Strategy for Disaster Reduction as the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. As further stated by the UNISDR, economic loss risk continues to increase across all regions – and seriously threatens the economies of low-income countries. Development with a renewed focus on resilience can offer opportunities for mitigating the impact of these events.

Resources are in development and have been developed both by the American Concrete Institute and Baker Concrete Construction to aid in creating resilient buildings, infrastructure, and communities.

4.1 Resilience and Disaster Protection at the American Concrete Institute

ACI Committee 133: Disaster Reconnaissance – This committee is working to report on the effects of major disasters on concrete construction worldwide. It aims to build institutional and individual member capabilities in disaster reconnaissance, and to leverage reconnaissance programs by other organizations, with special emphasis on concrete construction. Following the magnitude 7.8 earthquake earthquake in Nepal in April 2015 that caused more than 8,500 casualties and left over 22,000 people injured, ACI Committee 133 activitated a team to research the performance of low- and high-rise reinforced concrete buildings in the region. Thousands of buildings were destroyed and many more rendered unsafe. The team catalogued their findings for use by ACI and the government of Nepal.

ACI Committee 216: Fire Resistance and Fire Protection of Structures (joint ACI-TMS committee) – This committee is working to develop and report information on the fire resistance and protection of concrete and masonry structures, while ensuring that ACI's "Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies (ACI 216.1)" remains up to date.

ACI Committee 341: Earthquake-Resistant Concrete Bridges – This committee is working to develop and report information on bridges to resist earthquakes. It aims to publish a new document on recommendations for design of earthquake-resistant reinforced concrete bridge pier walls; complete bridge seismic isolation guide suitable for publication; develop a new document on performance-based seismic design of bridges; update ACI's seismic retrofit document; and continue to develop content for seismic design of bridge columns based on drift.

ACI Committee 377: Performance-Based Structural Integrity & Resilience of Concrete Structures – This committee is working to develop and report information on performance-based structural integrity and resilience of concrete structures. It is working to examine the current ACI 318 integrity requirements; identify collapse resisting mechanisms in load redistribution in case of initial damage; determine how detailing can enhance structural integrity and resilience; and propose approaches and methods for functional and disaster-resilient design of structural components and systems.

5 THE ACI EXCELLENCE IN CONCRETE CONSTRUCTION AWARDS

New for 2015 and occurring annually hereafter, the ACI Excellence in Concrete Construction Awards provide a platform to recognize concrete projects at the forefront of innovation and technology, and showcase projects that inspire excellence in concrete design, construction, and sustainability.

5.1 Excellence Award

In 2015, the highest award was presented to the Museum of European and Mediterranean Civilizations located in Marseille, France. As an icon of urban rejuvenation located on the

banks of the 2,600-year-old harbor at Marseille, France, the 3-exhibition story building houses the first French National museum outside of Paris. The technical performances of ultra-high performance fiber-reinforced concrete (UHPFRC) were uniquely applied for the first time at such a scale for a building structure in order to widen exhibition spaces, minimize material consumption, and provide shelter while allowing natural light to filter through.

5.2 First Place, Second Place, and Honorable Mentions

Additional global projects recognized in 2015 include:

Low-Rise Buildings – 1st Place: MuCEM: Museum of European and Mediterranean Civilizations in Marseille, France; 2nd Place: Louisiana Sports Hall of Fame and Northwest Louisiana History Museum in Natchitoches, LA, USA.

High-Rise Buildings – 1st Place: Al Hamra Business Tower in Kuwait City, Kuwait; Honorable Mention: Tower One of World Trade Center New York City, NY, USA; Honorable Mention: Adobe Corporate Campus Phase 1 in Lehi, UT, USA.

Infrastructure – 1st Place: Cable-stayed Foot Bridge in Celakovice, Czech Republic; 2nd Place: Interstate 5 Willamette River Bridge Project in Eugene, OR, USA.

Decorative Concrete – 1st Place: Jean Bouin Stadium in Paris, France; 2nd Place: Downtown Doral Park Pavilion in Doral, FL, USA.

Repair & Restoration – 1st Place: Mission Bridge Seismic Retrofit in Abbotsford, BC, Canada.

6 CONCLUSIONS

As concrete design and construction projects continue to integrate innovative techniques and technologies in keeping pace with ever-evolving economic, environmental, and aesthetic demands, the American Concrete Institute and Baker Concrete Construction are advancing the industry. Providing guidance to protect against disasters, be resilient against climate change, ensure safe jobsites, practice sustainable design and construction, and showcase truly excellent concrete construction, ACI and Baker are continually expanding knowledge and resources to support modern engineers, contractors, researchers, and students. And, as each of us act locally, collaborate, and maintain a global perspective, we will accelerate the concrete industry's conttribution to ensuring a safe, sustainable, and resilient future.

On behalf of my 2,500 Baker Concrete Construction co-workers and 40,000 fellow ACI committee leaders, committee members, members, chapter members, and students who are championing sustainability, resilience, and technical excellence across the globe, I look forward to continuing this sustainability journey together.

6 REFERENCES

American Concrete Institute. About, Committees, Technical Documents, etc. Retrieved January 4, 2016, from https://www.concrete.org/

Baker Concrete Construction, Inc., Who We Are, What We Do, History. Retrieved January 4, 2016, from http://www.bakerconcrete.com/

Sustainable Development Concept and Action. Retrieved January 11, 2016, from http://www.unece.org/oes/nutshell/2004-2005/focus_sustainable_development.html

Sakai, K., and Buffenbarger, J.K., "Concrete Sustainability Forum VII," Concrete International, V. 37, No. 3, Mar. 2015, pp. 55-58.

Global Assessment Report on Disaster Risk Reduction: Revealing Risk, Redefining Development. (2011). Retrieved January 11, 2016, from http://www.preventionweb.net/english/hyogo/gar/2011/en/home/preface.html

American Concrete Institute Excellence in Concrete Construction Awards. Retrieved January 4, 2016, from http://www.aciexcellence.org/

RECYCLING OF CONSTRUCTION AND DEMOLITION WASTE
AN OVERVIEW OF RILEM ACHIEVEMENTS AND STATE OF THE ART IN THE EU

JOHAN VYNCKE, JEROEN VRIJDERS

Director Research & Innovation, BBRI
President of RILEM

Deputy Head Laboratory Sustainable Development
Belgian Building Research Institute (BBRI)
www.bbri.be
e-mail: johan.vyncke@bbri.be, jeroen.vrijders@bbri.be

Key words: Sustainable Construction, Construction & Demolition Waste, Recycling, Circular Economy, Standards, Quality Control

Abstract. Technical research work on recycling started in RILEM back in 1981 in the TC 37-DRC chaired by Torben Hansen. The initial theoretical work on Demolition and Recycling of Concrete was quickly followed by industry driven actions as the interest in the topic was growing in practice. TC 121-DRG undertook under the leadership of Erik Lauritzen to come up with Guidelines for Demolition and Reuse of concrete in 1989.

Environmental legislation in Europe has been putting the topic of Construction and Demolition waste high on the agenda in recent year especially under impetus of northern Europe where now up to 90% of all the C&D waste is being recycled as part of a focus on sustainable construction and circular economy. Most recently in its communication on 'Resource Efficiency Opportunities in the Building Sector' COM (2014)445 the European commission focusses on the establishment of a common European approach to assess the environmental performance of buildings throughout their lifecycle, taking into account the use of resources such as energy, materials and water. The Commission announces in this context to support projects in H2020, COSME and Life+ related to research, innovation and demonstration showcasing how collaboration between public authorities and the private sector can create viable markets with recycled materials.

In the endeavor to fully implement a circular economy approach in the construction sector quality control and traceability of the origin of demolition waste is of utmost importance.

1 INTRODUCTION

The construction industry has to support a world of continuing population growth and social and economic development by providing homes, schools, offices, shops, hospitals,

airports, bridges, roads and infrastructures of all kind whilst improving the quality of life both in towns and on the countryside. At the same time, construction must respect the increasing and widespread social interest in environmental protection, preservation and restoration. So the construction sector has an important role to play with respect to economic, social and environmental issues and as such it has a central and crucial role to play in the development of our societies, our welfare and our environment.

The broad 'Construction' sector is generally interpreted to embrace all the activities that contribute to the creation, operation and maintenance of the built environment. It thus includes not only the design and construction of housing, other buildings and infrastructure works, but indeed also their operation, maintenance, repair, refurbishment and ultimate demolition and recycling. All associated activities related to the extraction and supply of construction materials, products, systems and services are of course also included. Construction thus defined is a major economic sector worldwide. As an example in Europe it represents a turnover of over 1000 billion Euros and it accounts for well over 10% of European GDP while employing directly and indirectly some 12 million people. From the above it is evident that the importance of the construction industry for the three elements of sustainable development, namely economic growth, social progress and effective protection of the environment, cannot be disregarded. Sustainable means lasting and enduring, therefore, sustainable development is economic development that lasts. Sustainable construction is obviously of great importance in Europe considering that according to different sources at present broadly speaking:

- 30% of all traffic is construction related,
- 40% of the energy consumption in Europe is construction related,
- 50% of material resources taken from nature are construction related,
- over 30% and up to 50% of national waste production comes from the construction sector.

This paper reviews in the perspective of sustainable construction some past and present technical evolutions with respect to recycling of construction & demolition waste in Europe this with a specific focus on the situation in Belgium especially in the densely populated Region of Flanders. Specific problems are indeed to be addressed especially in densely populated and congested areas. While striving to a circular economy, it can indeed hardly be accepted to dump valuable materials that have a potential for recycling or reuse on one side while extracting and transporting (over long distances) virgin materials on the other side. This is especially true for concrete and masonry waste materials.

2 SOME HISTORY ON RILEM'S INVOLVEMENT

Considered to be a "classic" in the sustainability movement, "The Limits to Growth" issued in 1972 by the Club of Rome http://www.clubofrome.org was the first study to question the viability of continued growth in the human ecological footprint. The report broke new ground as the first global study commissioned by an independent body rather than a government or the UN and inspired many research teams to explore in their field of work the contributions they could deliver to implement changes in the existing linear consumption

model in use at that point in time. Obviously this study of the Club of Rome got also the attention of researchers active in the context of RILEM. RILEM is the Union of Laboratories and Experts in Construction Materials, Systems and Structures. It endeavors especially to advance scientific knowledge related to the use of concrete, masonry, wood, asphalt, and other construction materials, and to encourage transfer and application of this knowledge world-wide. The essential work of RILEM is done in Technical Comities (TC's) which are set up in a Bottom-Up approach, i.e. the corporate members and individual members bring forward the proposals for action. Those are then evaluated on their merits by a technical advisory committee who also provides in monitoring of the progress of the TC's. Work within RILEM on recycling of construction and demolition waste started back in 1981 in the TC 37-DRC chaired by Torben Hansen. The initial theoretical work on Demolition and Recycling of Concrete was quickly followed by industry driven actions as the interest in the topic was growing in practice. TC 121-DRG under the leadership of Erik Lauritzen came up with Guidelines for Demolition and Reuse of concrete in 1989. A conference was held in Denmark in 1993 and a State of the art Report, and later also a RILEM recommendation were issued as final work of this TC. Further work in RILEM was taken forward amongst others in the TC's 165-SRM "Sustainable Raw Materials - construction and demolition waste" chaired by Charles Hendriks and 198-URM "Use of Recycled Materials" chaired by Charles Hendriks and Enric Vázquez. Today RILEM work on recycling concrete and masonry is still continuing and will be addressed later in this paper.

3 DEVELOPMENTS IN BELGIUM AS A CASE STUDY

Although there has been extensive research and several demonstration projects in Belgium and abroad, the high end reuse of recycled aggregates in concrete is at present still quite limited. Several barriers were identified: a lack of practical knowledge and experience, a standardization framework that does not allow for much recycling and the need for a specific quality assurance scheme. However, an evolution is ongoing in this domain. In this section different recent new developments are described, with focus on two main axes: practical experiences and support of the professionals on the one hand, and development of standards and new quality assurance approaches on the other.

3.1 Early developments

At the end of the 1970s, the first Belgian research on recycling of construction and demolition waste (C&D Waste) was executed, in order to develop the whole recycling process for the so-called stony fraction: from demolition techniques over crushing, sieving and sorting processes to the identification of applications for recycled materials. Besides the limited „ad hoc" experiences of recycling of rubble of the Second World War in Belgium and Germany, large scale application of C&D Waste as construction material did not really exist. In the following years, pioneering work of the BBRI was transferred from research to real practical applications. When a larger alternative to the Zandvliet lock in the Antwerp harbor was needed in 1982, it was decided to use recycled aggregates for the concrete for the construction of the new lock [1]. The recycled aggregates were in fact produced from the demolition waste of the old lock's embankment walls demolition. This approach allowed for the first real

industrial scale recycling plant to be set up in Belgium in 1986 and for the recycling of 200,000 tons of concrete aggregate in the concrete of the new Berendrecht lock. This knowledge was later on also applied in other exemplary projects like BBRIs Recycled House and the Centre for Sustainable Construction CeDuBo.

3.2 Role of the government

One of the main barriers for expansion of the sector in the 1990s was the lack of technical prescriptions. Thanks to a collective initiative, i.e. the set-up of a working group of the Flemish ministry for infrastructure LIN - „Hergebruik van Afvalstoffen" (Reuse of waste materials), several specific instructions for government example projects were drafted, allowing the use of secondary aggregates in road construction applications. This resulted in the uptake of technical prescriptions for recycled aggregates in the Standard Specifications for Road Constructions (SB250) in the Flemish region by 1996.

Also in the Walloon region, initiatives were supported by the government in order to start up the recycling industry. With the support of the Walloon government, the organisation TraDeCoWall was founded in 1991 in order to start recycling C&D Waste, to identify practical and reliable solutions for the management of waste originating from building and demolition sites and to develop valorisation options. This initiative was later on also supported by the publication of Walloon technical specifications for public road works in which recycling was permitted in some areas.

Besides the technical part, also the aspects of environmental protection were covered by authority initiatives. Following the Waste Decree of 1994, the OVAM was responsible for the definition of the Strategic Waste Management Plan in 1995, in which the ambition of a 75% recycling rate of C&D Waste in Flanders by the year 2000 was defined. In 1997, the first version of VLAREA regulation was published. The VLAREA regulates the administrative and chemical requirements (leaching, ...) for C&D Waste in order to be allowed for reuse in or as –amongst others- building materials. The VLAREA also implied a quality control and certification scheme for recycled aggregates, and was in this field the first legislation in Europe. In those days, the "COPRO" certification scheme emerged and allowed for the marketing of certified recycled aggregates.

Back in 1993, high grade applications such as recycled concrete with recycled aggregates were heavily debated. The already mentioned LIN working group even prepared technical specifications for "recycled concrete", but notwithstanding the earlier positive demonstrations by BBRI, the market and government bodies were still reluctant to allow such implementations in general practice. At the time this specifications which were based on the RILEM recommendations were regretfully not approved.

3.3 Ongoing actions

By now, anno 2016, the recycling of construction & demolition waste in Belgium can be considered as a 'grown up', well-developed economic activity in an established market. However despite many efforts, only an estimated amount of 1% of the available recycled

aggregate (which equals about 200,000 tons on 18 million tons each year) is currently not being down-cycled but used as aggregate for structural concrete. Several barriers to a wider application of recycled aggregate concrete were identified. There is still a lack of wide spread experience in the use of recycled aggregates in concrete. Therefore, on standardisation level, there is a reluctance to open up the Belgian concrete standards for wide application of recycled aggregates. And without an adapted Belgian standard, also quality assurance and certification, which is based on the Belgian concrete standard, is a difficult issue to tackle in everyday practical projects. However, an evolution is ongoing: on the one hand, more and more construction projects are realized using recycled aggregate concrete. This leads to more knowledge on the performance of concrete with recycled aggregates in real circumstances, but also gives more insight in the practical attention points during the execution process, which are not always described in standards or quality assurance manuals, but are a large surplus for more confident application. On the other hand, the new European standard EN 206 on concrete, published in 2013, contains an informative annex E on the application of recycled aggregates in concrete. This has led to the discussion on Belgian level to adapt the normative framework in order to allow for more use of recycled aggregates in concrete. Since 2012, Belgium has a concrete standard that allows the use of recycled concrete aggregates and specific types of slags in structural concrete: NBN B15-001:2012 [2]. Replacement up to 20% (in volume) of the coarse fraction is allowed in concrete meant for interior applications (X0 and XC1 according to EN 206-1). Other application domains are allowed, on condition that 'specific suitability is proven'. In order to expand this application domain, additional data and research results are needed. Three initiatives on Belgian level in order to anticipate on these evolutions and to stimulate the use of recycled aggregates in concrete and the uptake of recycled concrete aggregate in the standards and the Belgian quality assurance system have therefor been undertaken:

- The compilation of existing knowledge and experience in a Technical & Practical guidance document
- Research and developments in the field of standardisation
- Elaboration of a specific quality assurance scheme for recycled aggregate concrete

3.4 Practical guidance report

An important barrier for the use of recycled aggregate concrete remains the lack of practical experience and well documented knowledge. Therefor in 2013, a new pilot project campaign was started, in order to have a new set of demonstration projects that are well documented and can be monitored for several years, in order to assess the real life durability performance. On the other hand as mentioned above, several research projects took place in the 1990s and 2000s, that have led to a considerable body of scientific results on the use of recycled aggregates in concrete [3,4,5]. Both the practical experiences and the research results are now bundled in a BBRI Technical Report [6,7]. This report is meant as a practical guidance document, complimentary to the standards and existing certification schemes, allowing parties in practice to make arrangements on the use of recycled aggregates in concrete for buildings or road works. It describes the whole production chain, from demolition to the production of qualitative aggregates and concrete, as well as the actual placement on site. In each of the steps, a technical description is given on relevant criteria &

information, and practical recommendations are given to achieve the desired requirements & criteria. An important perquisite for qualitative concrete, is the use of high quality aggregates. Two important aspects to obtain qualitative recycled aggregates are the sourcing on the one hand (demolition of road structures, prefab concrete, … with high compression strength and avoiding contaminations like plaster, wood, plastics, …) and the production process on the other hand (applying the correct crushing technique, crushing twice in order to retain only the best concrete aggregate, …). The most suitable indicators for the quality of the aggregate are density and water absorption. The report summarizes the influence the use of recycled aggregate can have on the concrete properties, such as workability, compression strength, creep and shrinkage, durability. Distinction is made between lower replacement ratios (< 30%) and higher replacement ratios (>30%). This allows the designers to make well-thought choices on the applications where they want to use recycled aggregates in concrete, and gives concrete producers insights in the technological aspects of concrete production. This last element is further elaborated in more practical guidelines on how to take into account the water absorption behavior of the recycled aggregates in the mixing of the concrete (pre-saturation, mixing protocol, storage of aggregates, calculation of effective water/cement-ratio, …). The third chapter gives more information on the execution process. This includes the attention points like workability and slump loss, time of setting & finishing,… but also gives guidance on the quality assurance process and the extra testing required when using recycled aggregates in specific applications that fall outside of the current standard framework. The final part of the technical report gives recommendations and aids decision makers to align the different phases in the process: quality and production of aggregates, choice for the correct concrete applications and replacement levels, quality control scheme and execution aspects.

3.5 Standardization and research

As mentioned before, the Belgian standard NBN B15-001 allows for the use or recycled aggregates in concrete since 2012. 20% (volume) of the coarse fraction can be replaced for concrete in interior applications. Some specific elements have to be taken into account:

- The required quality of the concrete aggregate is well defined and the requirements are more severe than those for 'regular concrete aggregate' used in road base constructions
    - $d \geq 4$ mm, $D \geq 10$ mm and the fines content should be below 1.5%. Thus, only coarse and well-graded aggregate can be used
    - $\rho rd \geq 2200$ kg/m³: only pure, uncontaminated concrete aggregate is allowed
    - The variation on the declared water absorption on 24h is limited to ± 2%, in order to avoid fluctuations
    - Other requirements are LA_{35}, FI_{20}, A_{40}, $SS_{0.2}$ but should not be difficult to obtain if the requirements stated above are fulfilled.
- One is allowed to use recycled aggregates up to 20% in other application domains (higher compression strength classes, other environments) on condition that the specificity of use is demonstrated for the intended use and the intended concrete composition. This means the concrete producer has to demonstrate that the concrete composition with recycled aggregates has the required compression strength, durability and fresh concrete properties. Unfortunately, the standard does not

specify the way this aptitude for use should be demonstrated.

- As the actual moisture content and the effective water absorption behavior of the recycled aggregates in the concrete are hard to determine, a safety factor is applied in the calculation of the effective W/C-ratio. The WA_{24} of the recycled aggregates should be lowered with 4%, assuming this to be a safe maximum. BBRI has recently started research to further investigate and refine these requirements, together with BRRC and CRIC. The first step in the research consisted of the characterization of the recycled concrete aggregates available on the market today, in order to assess the quality improvement needed to be in line with the normative requirements. 9 concrete aggregate types fulfilling the "d ≥ 4 mm, D ≥ 10 mm"-requirement were collected and their properties were determined. The first results show that:
    - The required composition (large amount of concrete & unbound aggregates) is obtained for the selected sources
    - Most of the aggregates contain too much fines (< 63 μm). Either the quality of the fines should be checked, either more attention should go to the production process and the circumstances (wet or dry weather has an influence on the fines content)
    - The water absorption (24h) varies between 2.9% and 6.6% from source to source. The lowest water absorption is obtained from aggregate produced from specifically selected road pavement concrete, the higher values are linked to crushers that accept a broader range of C&D waste
    - Chemical agents like chlorides, sulphates, binding altering substances, … are present in very low doses for recycled concrete aggregates
    - There is no link between the frost resistance of the aggregates and their water absorption. However, aggregates with a water absorption rate (24h) below 5%, appear to have a better frost resistance.

In the next phase of the research, several aggregates will be used to make concrete, in order to investigate the concrete quality, with a specific focus on the influence on the concrete characteristics due to the variance in the different aggregates: e.g. will the higher water absorption of some aggregate types have influence on the frost resistance, the carbonation resistance, … or will the concrete using aggregates with more fines be more difficult to obtain a certain workability.

3.6 Quality assurance & certification

Quality assurance plays an important role in the Belgian construction sector. Most public clients require the "BENOR label" as proof that the concrete delivered on site is conform to the Belgian concrete standard. A specific technical prescription document exists for this third party certification. However, this scheme is not developed for concrete using recycled aggregates. A working group is now developing these specific requirements, with special attention for the following aspects. First of all, the quality of the recycled aggregates should be guaranteed & certified as well. In addition to the requirements of NBN B15-001, the maximum diameter of the aggregates is limited to 20mm. This is done to avoid

carbonation tests on the concrete level. Also specific requirements are imposed on the storage and processing of the recycled aggregates, in order to avoid contamination with other fractions, and in order to guarantee a controlled humidity environment (to take into account in the mixing process). A distinction is made between concrete types and families. There are the 'basic' or standard concrete types on the one hand, requiring the same quality control aspects as conventional concrete without recycled aggregates, expanded with specific Initial Type Testing tests for each concrete composition in terms of compression strength and workability. On the other hand, the application domain where durability is an issue, more tests are required in the initial phase, specifically on carbonation resistance and frost-thaw resistance of the concrete with recycled aggregate.

4 FURTHER WORK

4.1 RILEM / fib collaboration

Recently a new RILEM TC on the "Structural behavior and innovation of recycled aggregate concrete" was approved. The terms of reference of this TC point to collecting case studies regarding environmental design of concrete and concrete structures. Background research will be studied and carried out as well. The proposed TC members are from academics, universities, national labs, engineers, research students and collaboration with fib is targeted. Indeed a Memorandum of Cooperation (MoC) was signed recently at the RILEM general council in Melbourne between RILEM and fib, the main aim is to develop further synergy in the field of concrete and especially to set up joint committees. It is nice to see that the TC on "structural behaviour and innovation of Recycled Aggregate Concrete" RAC chaired by Jianzhuang XIAO will be one of the first committees putting this RILEM-fib MoC in practise.

4.2 EC Initiatives

Environmental legislation in Europe has also been putting the topic of Construction and Demolition waste again high on the agenda especially under impetus of northern Europe where now up to 90% of all the C&D waste is being recycled as part of a focus on sustainable construction. Most recently in its communication on 'Resource Efficiency Opportunities in the Building Sector' COM (2014)445 the commission focusses on the establishment of a common European approach to assess the environmental performance of buildings throughout their lifecycle, taking into account the use of resources such as energy, materials and water. The Commission announces in this context to support projects in H2020, COSME and Life+ related to research, innovation and demonstration showcasing how collaboration between public authorities and the private sector can create viable markets with recycled materials.

5 TOWARDS A CIRCULAR ECONOMY

A circular economy approach is based on maintaining the value of the materials and the energy used in products in the value chain for as long as possible, and on minimizing production of waste and consumption of resources. It therefore promotes competitiveness, innovation, a high level of protection for human beings and the environment, and brings major economic benefits, thus contributing to growth and job creation. A circular economy

model foresees the application of systemic approaches and interventions at several levels, e.g.

- new methods for the production and use of materials in order to reduce the quantity of materials produced and the amount of energy consumed, as well as
- new methods for the lengthening of the use phase of products the, redesign of products for easier maintenance, repair, upgrading, remanufacturing or dismantling, and recycling (i.e. eco-design); reducing the use of materials which are hazardous or difficult to recycle; the development of markets for secondary raw materials;
- incentivising and supporting waste reduction and high-quality separation by consumers; incentivising separation, collection systems that minimise the costs of recycling;
- improving cross-sectoral cooperation and facilitating clustering of activities to prevent by-products from becoming wastes (industrial symbiosis); and
- the development of new business models (e.g. renting or sharing versus buying).

The building and construction sector can contribute to this process as an important player. The construction industry is an ideal field for the use of recycled materials. This is because in this industry large quantities of materials are consumed, and even in cases where such materials are not environmentally inert it might be possible, by means of various substances or processes, to permanently immobilize hazardous components, however due attention is then also to be given to the reuse of such immobilize materials. The characteristics of new products can be equal to or even better than those which are conventionally produced. Cooperation with waste owners and the planning of processes in which by-products are formed is of great importance in order to produce good-quality construction products. The present legislation permits such an approach: materials are not discriminated against, regardless of their origin or denomination; what matters are simply their characteristics, their potential uses, and their environmental footprint. In 2013, a new and additional essential requirement (No. 7) was introduced in the revised version of the Construction Products Regulation, which promotes the efficient and sustainable use of resources. Also, the Waste Framework Directive 2008/98/ES introduced a new waste management hierarchy, where reuse and recycling are the priorities. The big challenge for the building and construction sector is therefore how to find the most realistic and balanced option for the utilization of recycled waste into new innovative products, in terms of both the nature and quantity of the waste, taking into account the location of potential end users, the current market demand for such products, their environmental impacts, the costs of recycling processes, and, in particular, the feasibility of applications for standard civil engineering technology, so that new materials can be produced, transported, installed and recycled again using existing civil engineering machinery and technology. The higher added value of a new product or environmental technology is always welcome, but it is not an absolute priority. It is also important that the final product is not harmful to the environment, and that the used solutions are robust and can be reused also in a next life cycle.

Other potential areas where the construction sector could become a role model in the circular economy approach are, for example: energy and material efficient innovative buildings which are easy to build, use, maintain, dismantle and recycle, which produce rather than use energy and water, new business models based on the renting and sharing of systems without

jeopardizing consumers' interests in terms of costs, protection, information etc., improvement and implementation of green public procurement principles, improving information about the sustainability of construction products based on LCA assessment (Environmental Product Declaration), life cycle thinking in building design (e.g. design for de-construction), awareness raising about de-construction and redesign among users and decision-makers to ensure that construction products are recycled at their end of life, improved techniques for selective demolishing, improvement of health and safety in the construction sector…. A lot of these issues will require as well an appropriate processing techniques as a good traceability of the life cycles of the materials used.

6 TRACEBILITY

Crucial for a circular economy approach to demolition waste will clearly be the level of quality control which can economically be installed. Tracking of construction and demolition waste and consequently the quality of the whole recycling process has long been a bottleneck in the industry. Together with relevant stakeholders such as demolition contractors, transportation firms, recycling companies, environmental agencies and researchers the Flemish Confederation of Construction Contractors has taken the initiative to put a demolition management organization into practice: TRACIMAT. Tracimat aims to promote a selective demolition process and to trace the origin of the demolition waste delivered to a recycling plant. This can guarantee the quality of the demolition waste delivered for further processing and recycling. The whole tracing starts with the preparation of a strict demolition planning prepared by an expert. This expert should always be a neutral party independent of the demolition contractor. Such an approach clearly has great potential not only with respect to guaranteeing the environmental quality of the waste delivered on site but with respect to its technical qualities. It is expected that this approach will give a further boost to the recycling of C&D waste and implementing circular economy aspects in the construction sector.

7 CONCLUSIONS

The paper gives an overview of general consideration with respect to recycling as well as current initiatives and projects in Belgium, leading to a well-developed framework for the application of recycled aggregates in concrete. The documentation and investigation in practical experiences and large scale projects is complemented by work on procedures and standards that keep evolving towards a more broadened application domain for recycled aggregates in concrete. Both technical aspects together (standards & practical experience) combined with a well-controlled management system are believed to be essential to lead to a higher confidence level and a wider use of recycled aggregates in the concrete sector.

REFERENCES

[1] Vyncke, J. and Rousseau, E., ‘Recycling of construction and demolition waste in Belgium: actual situation and future evolution’, in Lauritzen E.K.(ed.) ‘Demolition and reuse of concrete – proceedings of the third international RILEM symposium’, RILEM, London, 1994.

[2] NBN, 'NBN B15-001 - Beton - Specificatie, eigenschappen, vervaardiging en conformiteit - Nationale aanvulling bij NBN EN 206-1 : 2001.', 2012
[3] De Pauw, P, et al., 'Shrinkage and creep of concrete with recycled materials as coarse aggregates.', in SUSTAINABLE CONSTRUCTION: USE OF RECYCLED CONCRETE AGGREGATE-PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM HELD AT DEPARTMENT OF TRADE AND INDUSTRY CONFERENCE CENTRE, LONDON, UK, 11-12 NOVEMBER 1998. 1998.
[4] Desmyter, J., Van Dessel J., and Blockmans S., 'The use of recycled concrete and masonry aggregates in concrete: improving the quality and purity of the aggregates.' in Proceedings of the International Symposium "Exploiting wastes in concrete". 1999.
[5] Boehme, L., Vrijders J., and Van Gysel A., 'Assessment of recycled concrete aggregates in concrete C20/25 & C25/30.' in Concrete structures fir sustainable community (2012): 71-74.
[6] Vrijders, J. and Desmyter. J., 'Recycling in Belgium: an overview of the present situation in Belgium from the recycling industry and research about CDW', in Vazquez E. (ed.), 'Progress of Recycling in the Built Environment: Final Report of the RILEM Technical Committee 217-PRE', RILEM, Netherlands, 2013, 37-41
[7] Vrijders, J. et.al., 'Putting recycled concrete into practice: lessons learned from Belgian pilot & demonstration projects', in the Proceedings of the RILEM conference III PROGRESS OF RECYCLING IN THE BUILT ENVIRONMENT - Recycle'15, 2015 (in review)

SUSTAINABILITY EVALUATION OF THE CONCRETE STRUCTURES

ANTONIO AGUADO[1], JAIME C. GÁLVEZ[2], DAVID FERNÁNDEZ-ORDÓÑEZ[3], ALBERT DE LA FUENTE[1]

[1] E.T.S Ingenieros de Caminos, Canales y Puertos. Technical University of Catalonia
[2] E.T.S Ingenieros de Caminos, Canales y Puertos. Technical University of Madrid
[3] E.T.S Ingenieros de Ingeniería Civil. Technical University of Madrid

Key words: Assessment, sustainability, concrete, multi-criteria methods, MIVES

Abstract. Sustainability is a new and settled concept in advanced societies, even though the term is sometimes inappropriately used, which may represents a threat. For this reason it is suitable to supply methods of measuring sustainability. Given that the sustainability concept involves distinct requirements and criteria, it seems reasonable to use multi-criteria methods in the decision making process. This work shows a brief review of such methods applied to concrete structures. The MIVES method is applied in this work for assessing the sustainability of the concrete structures. Three examples are proposed to show the capacity of the method. One of them is based on the general application of the Spanish Structural Code for Concrete Structures (EHE-08), and the other two assess the sustainability of reinforced concrete columns by adopting distinct type of concrete and building procedures.

1 INTRODUCTION

Sustainability approach, if implicit in the history of human development, has had a remarkable boom in the last three decades after the definition of the term within the framework of the United Nations (Bruntland Report, 1987).

The scope of sustainability, with its three pillars (economy, environment and social), covers the activities of the humanity and in its various forms (goods, services, etc.). Obviously, it is included the construction sector. In this sector, concrete as a structural material is one of the most used (Sakai, (2009), Ahmad and Saker (2014)) and one of the cheapest.

However, from the environmental point of view, the concrete, mainly by the contribution of cement, it is one of largest producers of CO_2 emissions into the atmosphere. The global production is approximately 5-6% of the total CO_2. Distinct actions have been developed for reducing this contribution of CO_2 (Metha, 2009): a) optimization of structural design, by incorporating an innovative engineering that reduce dimensions of elements, b) selection of more advanced ages as contractual age (56 or 91 days) to minimize the amount of cement, as it is already done in dams, c) advances in the binders that will reduce the content of clinker.

From the social point of view, the perception of the sustainability will be different, depending on the situation of the observer, both from a standpoint of social position, and depending on the general circumstances of the country. Thus, in a developing country, a new cement factory creates new jobs, but under the view of a developed country the same fact can be received as negative for the environment.

As a summary, from the point of view of sustainability, there are advantages and disadvantages in the use of concrete as the building material, both in construction in-situ and precast elements. Given that, the assessment of the sustainability of each alternative proposed by the construction sector seems a promising way for the decision making process.

In concrete structures, once fulfilled the functional requirements and safety, progress in the pillars of sustainability measures is uneven. From the economic point of view, historically there are numerous methods and the level of development is high. Latest environmental methods are incorporated, whether of general type: referring to several as more specific type (ACV, and others). The lowest level of progress, at the level of measures, occurs in the social pillar, although there are jobs in that direction.

This is usually done in a disaggregated way without integrating the set in an indicator for measuring sustainability. To address the issue jointly, the multi-criteria methods can be a reasonably approach to measure the indicators, variables or attributes.

The main objective of the present work is to highlight the importance of measuring the sustainability, as a tool for comparing alternatives. In addition, some examples are presented for showing the possibilities of the multi-criteria methods in the assessment of the sustainability.

2 CURRENT SITUATION AND TRENDS

Nobody disputes that the world changes quickly, exponential somewhat, and that the social, environmental and economic changes of the past 25 years, following the report of UN (1987), have led to a change of paradigm in decision-making at all levels and, of course, also in the sector of the construction, in relation to the project construction and the operation of our infrastructure. The concept of sustainability has become an aspect to consider that it can even influence the construction of the infrastructure.

The new paradigm in decision making process includes the incorporation of the point of view of the actors involved and affected by new construction or infrastructure. In this sense not only the promoter (public or private) and the technician decide, but also rather the opinion of society and its benefit come a growing weight.

When designing a structure, apart from the classical requirements, usually used: safety, durability, functionality, etc., it should be considered the requirements of sustainability: economic, environmental and social aspects. This process represents a disaggregated approach for measuring the sides of a polyhedron, which each face is every one of these requirements. However, it is possible to move forward and consider a joint assessment that represents the volume of the polyhedron (each of those requirements is a side).

Some improvements have been done in distinct directions, as evidenced Jato *et al.* (2014), showing by the increasing number of published papers in international journals focused on this topic. The direction of action may be different; on the one hand, the measure of the classical parameters, such as safety, durability, economic aspects, and even environmental and social parameters. On the other hand, the attempt for integrating measures of each plane into some set value, demonstrating, in any case, the need to measure to place the structure in its context and move forward.

The way to do these advances, in a multi-criteria approach, includes the incorporation of new requirements, since the methodology used in one of them. For example, from the

economic point of view is often to work on cost/benefit issues and intends to assess the economic value of the social and environmental aspects. This way faces great difficulties and disagreements among experts.

An additional way, in areas with less experience, is to start the evaluation with the use of checklists, regarding, for example, to social or environmental aspects. In such approach the models type BREAM, GBC, LEED and others may be a reference. It is also possible to perform more complex models, from the point of view of environmental such as Life Cycle Assessment (LCA) or other associated calculations, but in practice, they are difficult to apply to the standard type projects. There are steps of integration of similar methods at various levels, for example integrate Life Cycle Cost (LCC) and ACL in civil structures by means of Analytic Hierarchy Process (AHP), Kim *et al.* (2013).

There are distinct integration methods in the sector of the construction such as the MCDM multi-criteria methods: ANP, DEA/ELECTRE, TOPSIS, AHP, PROMÉTHÉE and other (Jato *et al*, 2014), although each of them is only used in one geographical framework or habit of work determined. The approach is based on the treatment of problems with homogeneous alternatives, i.e. of the same type.

These advances are also shown by the regulations. An example is series of European standards that are developed by the CEN/TC 350 (see Figure 1), used in Europe for assessing the sustainability building construction. This Committee discusses the environmental efficiency of the buildings, the various aspects on the analysis of the life cycle of the buildings and the problems at the level of the products. The AEN CTN 198 "Sustainability in construction" Committee (Tenorio and Vega, 2011) follows the CEN/TC 350 regulations and proposals in Spain. In general, while the concept is clear, in practice there is a certain imbalance that shows a bias towards environmental issues, confusing a part to the whole, when the analysis must be global, integrated manner with other sustainability requirements.

With considered bias, not surprising that the concrete is now penalized by the high value of CO_2 emissions and its moderated recyclability. In addition to this bias, different studies do not defined properly the boundaries of the system by not including relevant aspects of transportation.

3 MIVES METHOD

The above exposed shows the convenience to find multi-criteria methods (MCDM) that allow incorporate heterogeneous and, to the same time, flexible alternatives for measure the sustainability. These should be versatile for adapting to the different situations of projects (Basic projects or projects construction very elaborate) and to the different complexities of the structure (simple or very complex). The integrated model of value for sustainable assessments (MIVES) satisfactorily meets this challenge.

MIVES is a multi-criteria method that began with a research project[1] in 2002, led by Prof. Antonio Aguado, in coordination with UPC, UPV and TECNALIA. Then, other universities (UaC, UIC and UPM) were incorporated to the project. As a result, since 2005, the year in which the first PhD thesis of this line was defended, a total of 16 additional PhD

[1] *Quantification of the value of a constructive project evaluation of sustainability-oriented integrated model. Application to the industrial construction*. MAT2002-04310-C03-01. UPC, LABEIN, ETSII BILBAO. November 2002–October 2005. Lead by Prof. Antonio Aguado.

theses have been presented, in four Spanish universities. In addition, a significant number of papers and communications to congresses have been made.

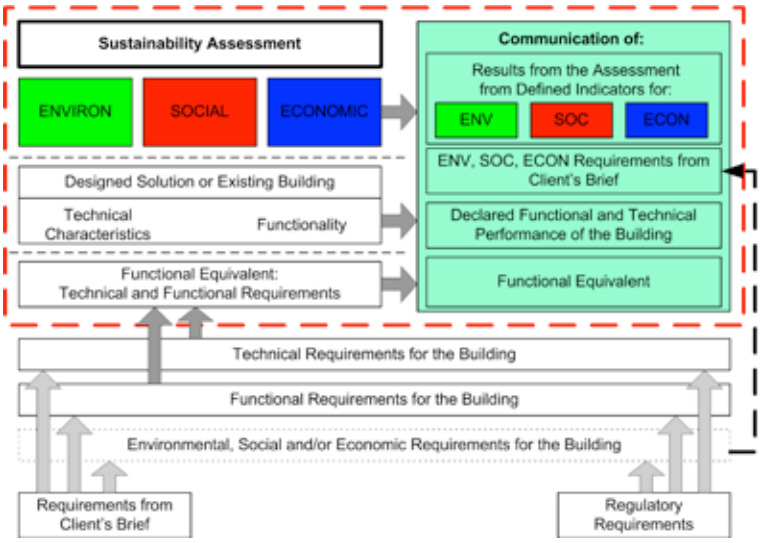

Figure 1: Approach to the sustainability proposed by the CEN/TC 350 Committee.

The MIVES method responds to a classical structure of tree structured, usually in three levels (requirements, criteria and indicators), as shown in Figure 2. The sustainability requirements are economy, environmental and social aspects. The involved requirements and criteria, allow structuring the decision and easy the communication to third parties. The indicators allow measuring both variables and attributes.

In the evaluation is conversely as described in Figure 2. For the evaluation of each indicator a function of value previously established and agreed is used. It is a sigmoid of four parameters shape function; details may be consulted in Alarcón *et al.* (2011). The result of the measured indicator (V_{Ik}) (using variables or attributes), enters the abscissa (see Figure 2) and, by using the value function the value of the indicator is obtained (values from 0 to 1).

The value of a generic criterion (V_{Cj}) is supplied by Equation 1. The Equation 1 shows the addition from K = 1 to n (where n is the number of indicators that there are in the criterion) of the product of the value of each indicator group (V_{Ik}), by the weight associated with the same (w_{Ik}).

$$V_{Cj} = \sum_{k=1}^{n} w_{Ik} * V_{Ik} \qquad \text{[Eq.1]}$$

Same approach is used in the assessment of the requirements, obtaining the value of a requested generic (V_{Ri}) in the Equation 2, which expresses the sum from j = 1 to i (being i the number of criteria that are in the requirement) of the products of the value of each criterion of

the Group (J_{cv}), by the weight associated with the same (w_{Cj}).

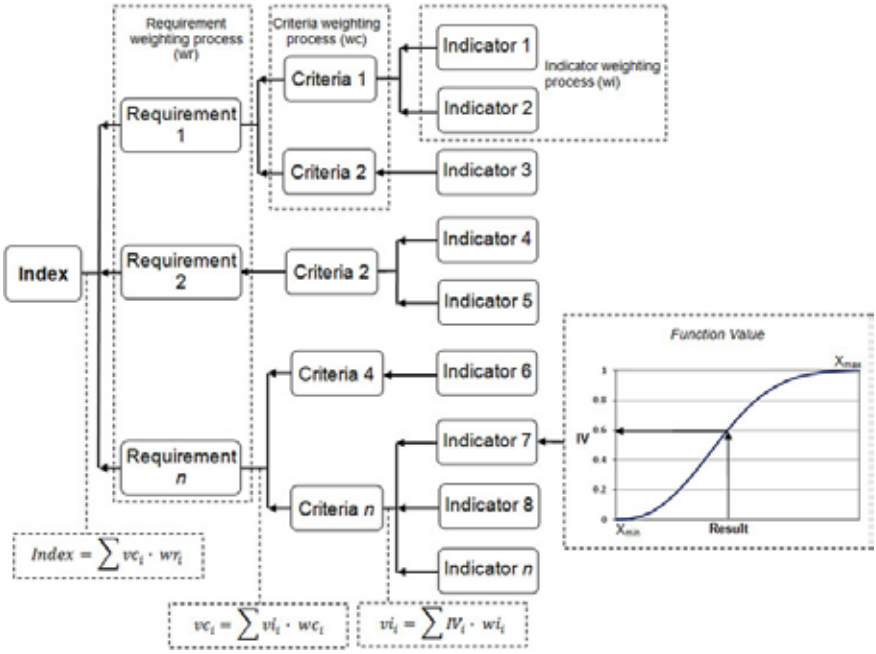

Figure 2: Structure of a generic decision tree.

$$V_{Ri} = \sum_{j=1}^{l} w_{Cj} * V_{Cj} \quad \text{[Eq.2]}$$

Finally, the rate of sustainability of a building (SI) is obtained by the sum of the dimensionless values of each of the requirements (V_{Ri}) multiplied by the weight corresponding to each of them (w_{Ri}) as shown in equation [3]. The subscript i represents the number of established requirements, which is 3 (economic, social and environmental) for sustainability studies.

$$SI = \sum_{i=1}^{j} w_{Ri} * V_{Ri} \quad \text{[Eq.3]}$$

The assessment of the indicators can be obtained deterministically or with probability approaches. The method allows a separation of components, for example, in the case of a building: structure, façade, foundations, facilities, etc., performing the assessment of the sustainability based on the contribution of each component of the building. For the assignation of weights, it can be used distinct methods. MIVES usually adopts directly assignation or AHP, in both cases, previously agreed, before studying alternatives.

The versatility shown by the MIVES method allows facing problems of decisions from different points of view, even with high plurality. The MIVES Method may evaluate highly technical aspects of construction, the social perception of a company, the selection of sites, the ranking of the staff of University departments, or prioritization of investments. The result of the sustainability index (SI) is a dimensionless value.

The above previously shown can directly apply when homogeneous alternatives are being evaluated. Nevertheless, in complex problems with heterogeneous alternatives, a phase called homogenization that fit the perception of the decision-maker between these heterogeneous alternatives is required (Pardo y Aguado, 2016).

4 CONSIDERATIONS ON A PRACTICAL USE OF THE METHOD

The method leads to good results if the decision tree is correctly built. It is of the highest importance that the decision taking party takes part in the definition of requirements and weights. Every theoretical development must be made without any alternative solutions to be independent when choosing indicators.

With respect to indicators it is advisable that only relevant ones should be considered. We propose that only indicators that have a relevance of more than 5% should be considered. Also only indicators that take into account differences for the alternatives that are under study should be considered.

The method does not need to consider many indicators but just the principal indicators that are relevant for the comparison. With this procedure we can save time in the calculation and higher accuracy because otherwise principal indicators may be shadowed by a large quantity of less important indicators.

Value functions of each indicator must be defined before the alternatives are discussed. Better results are obtained if are defined by consensus of experts with the help of seminars.

Of course, when we compare alternative solutions, limits of the system have to be homogeneous and consequently have to introduce associated transportations to resources movements like aggregates, cement and other products. It is also a key factor to consider decision taking party for each aspect like for example the selection of a typology for a construction decision may be different if we only consider promoting agency, contractor, end user or just a citizen. The decision is not a generic one but has to take into account the point of view of the final decision party and also economic, social and environmental aspects when the decision is taken.

Decision tree has to incorporate all aspects to be considered. If we try to measure resilience of a solution or the survival against unknown changes (like climate change) this concept has to be included explicitly in the tree.

On the other hand, it is important to state at the early stages which are boundary conditions that the alternatives that will be studied have to comply with. If some of the boundary conditions are not fulfilled, then the alternative cannot be tested. Also if all boundary conditions are fulfilled then what it has to be evaluated are the increments over the base value. For example, it protection time against fire as a starting point is 120 minutes and one of the alternatives guarantees 150 minutes, does these supplementary 30 minutes have to be considered? In this same direction are other aspects related with service life of a structure that

has to be stablished previously and if all alternatives comply then, should increments have a value?

A decision tree can be defined to evaluate which alternative solution is better to make better a process or production from the sustainability point of view. For example, the ones already said in point 1 by Metha (2009) or Sakai (2009). Also other aspects related with them in a decision tree or in a general point of view. We see then that when we include a decision branch for the use of resources in environment part of the tree we are also considering design aspects that reduce the use of resources (aggregates, etc.). Other example can be when considering different types of binding components, that can reduce the amount of clinker (Josa *et al*. 2005 and Josa *et al*. 2007) it is also taken into account in emissions branch (i.e. CO_2) within the environmental branch

5 EXAMPLES

To make evident the use of the method we describe some examples of it application that cover several aspects in decision taking:

- Sustainability Contribution Index for Structures (ICES) used in Spanish Normative EHE08
- Sustainability evaluation of precast products made of different materials like concrete or steel
- Selection of building process taking into account sustainability

Sustainability Contribution Index for Structures (ICES)

Current Spanish Normative on structural concrete (EHE-08) (M.F., 2008) includes Annex 13 (not mandatory) with the title Indice de contribución de la estructura a la sostenibilidad (Contribution index of the structure to sustainability). It has been in international normalization for structures that at this level a sustainability index is included. ICES evaluation is done after structural design is developed and after the comply to structural and functional requirements. In that 1st version it was done under the environmental aspect only. It also included other aspects from the social point of view and indirectly from the economic point of view.

With this development as are explained by Aguado *et al.,* (2012) one could obtain the ISMA or Environmental Sustainability index for the later incorporation of social aspects, as for equation 4.

$$ICES = a + b \times ISMA \qquad [Eq.4]$$

Where: a is a social contribution coefficient, that considers several factors in this aspect and b is a coefficient for the extension of service life of the structure.

The decision tree for this example is described in Figure 3. We can see that the different branches considered in the ISMA decision tree includes measurements as previously described (Metha, (2009), Sakai (2009)). In the same figure the different weights considered for each branch can be seen and also that the decision tree is not large to make every aspect

decisive. The tree is designed so that homogeneous solutions, that are built with different processes, can be evaluated (in situ or with precast elements). In both solutions also different transport distances can be considered for materials to take into account emissions and costs.

After the publication of the structural concrete normative the same idea has been implemented in the structural steel normative (EAE-10) and in the composite structures normative. Also in the revision of the not published structural code also is considered the same model with a slightly more precise different approach.

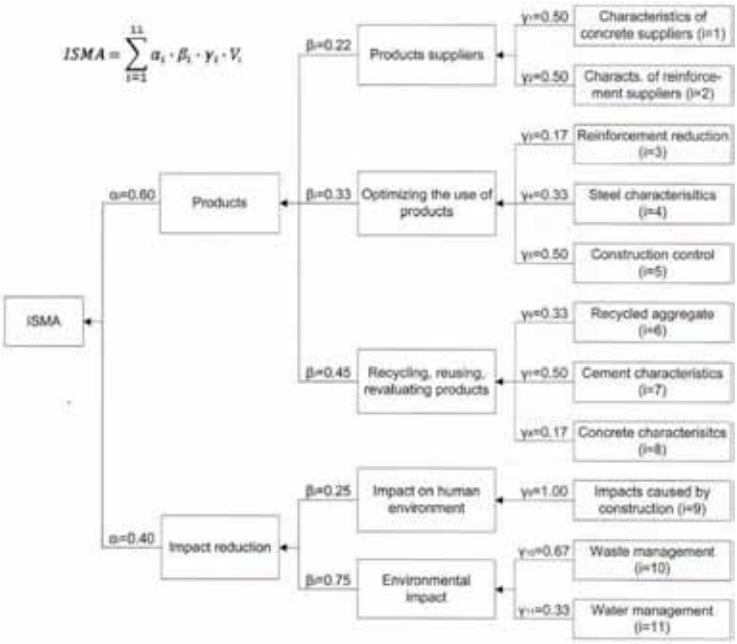

Figure 3: *Decision Tree for EHE-08 (Sources: M.F. (2008) y Aguado et al. (2011))*

Sustainability evaluation of precast products made of different materials

Other problem that can be studied with this method is the sustainability assessment of precast elements it is different solutions with constructive differences or different materials (concrete, steel, plastics, etc.). For these solutions an example of the evaluation of the sustainability of sewerage pipes with different alternative solutions (Viñolas (2011), de la Fuente *et al,*. (2016)). There are also other examples for the evaluation of sustainability of wind turbines (de la Fuente *et al.,* 2016).

In Table 1 are presented different solutions of pipes with the following names: HM: Unreinforced concrete R class, HA: Reinforced concrete, class IV, PP: Structural Polypropilene, class SN8, PVC: Compact Vynil Polycloride, class SN, PVC: Compact Vynil Polycloride, Class 10.

In Table 2 it can be reviewed the decision tree with the considered assigned weights. In the table it has been considered the three columns of sustainability, incorporated for this example. In this case the additional functionality has been incorporated in the decision tree.

Alternativa	Diámetro ext.	Diámetro int.	Espesor	Peso (kg/m)
HM 400 mm	520 mm	400 mm	60 mm	240,00
HA 800 mm	1000 mm	800 mm	100 mm	705,00
HA 1200 mm	1480 mm	1200 mm	140 mm	1395,00
HA 2000 mm	2430 mm	2000 mm	215 mm	3650,00
PP 450 mm	450 mm	400 mm	50 mm	8,32
PVC 800 mm	800 mm	748 mm	26 mm	87,87
PE 1200 mm	1200 mm	1030 mm	85 mm	67,50
PRFV 2000 mm	2047 mm	1958 mm	44,5 mm	383,66

Table 1: Geometrical data of the alternatives.

Requirements	Criteria	Indicators
Functional (11,11%)	Pipe Dysfunctions (33,3%)	Pipe surface degradation (100%)
	joints Dysfunctions (33,33%)	Risks in the connections between tubes; (100%)
	Added Capacity (33,33%)	Added mechanical capacity; (100%)
Economic (33,33%)	Costs (80%)	Cost production + transport + erection: (100%)
	Time (20%)	Construction time (100%)
Environmental (33,33%)	Production and transportation; (20%)	Emissions de CO_2; (100%)
	Used resources (60%)	Raw material consumption in construction; (33,33%)
		Percentage of recycled water; (33,33%)
		Energy required; (33,33%)
	Environmental corrective measures (20%)	Environmental sensibility of the production plant; (100%)
Social (22,22%)	Third party affections (75%)	Repair and affection time; (33,33%)
		Pollution of water; (33,33%)
		Reliability to possible breakage from external agents; (33,33%)

Table 2.- Decision tree for sewerage pipes made of different materials.

Results arising from this study are presented in Figure 4, in which results from 3 different scenarios are presented (A: favourable conditions, B: Intermediate conditions, C: Unfavourable conditions). They are associated to some of the environmental indicators (% of recycled water, sensibility to environment in production plant). We can observe that, for small diameters (400mm) the solution with structured polypropylene, class SN 8 (PP) is the solution that obtains the best result while for larger diameters reinforced concrete solutions obtain the best results and are clearly the best for large diameters (2000mm).

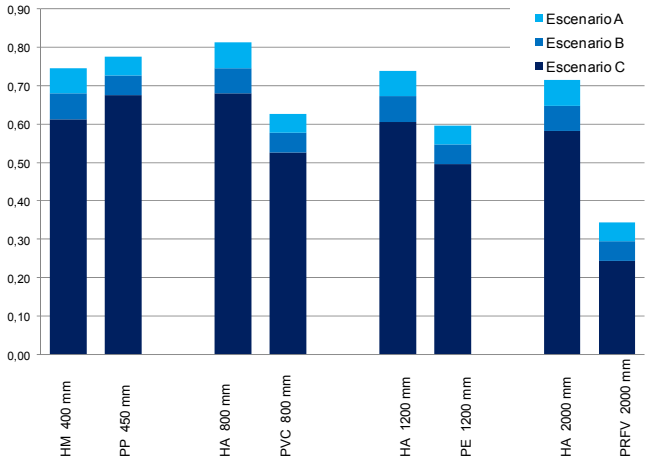

Figure 4.-*Sustainability Index results for sewerage pipes.*

Selection of building process taking into account sustainability

Other example is for the evaluation of sustainability in different process of construction solutions. To show this solution an example is now described. The example is based on the comparison of different solutions of building columns with the following parameters: characteristic strength of concrete (hormigón (HA-25, HA-50 y HA-75), compacting of concrete (Self compacting, vibrated), geometry of the cross section (rectangular, circular). More information can be found in (Duran (2011) y Pons y de la Fuente (2014)).

For the sake of comparison the forces resisted are the same in all cases and also steel is B500SD (characteristic yield stress f_{yk} of 500 N/mm^2 and Young Modulus E_S of 200.000 N/mm^2). In Table 3 it is shown different combinations from the study and the dimensions of the columns.

To make the different alternative solutions comparable regarding concrete specific and not generic corresponding to the different components used in each type of concrete depending on the compaction system and strength as it is shown in Table 4. In this table it can be checked how aggregates differ and also the fines content. Other data with relation to formwork, costs and other variables can be found in Duran (2011) y Pons y de la Fuente (2014).

The defined decision tree in this evaluation and the weights adopted are presented in Table 5. Both decision tree and weights were decided in a seminar with an expert committee. They considered which indicators were fundamental to decide the alternatives.

Type f_{ck}	Compacting system	Section	Dimensions (cm)	A_c (mm^2)	A_s (mm^2)	Ref.
C25	Vibration	Rectangular	40x40	158743	1257	C25/V/S
		Circular	50	195331	1018	C25/V/C
	Self Compacting	Rectangular	40x40	158743	1257	C25/SC/S
		Circular	50	195331	1018	C25/SC/C
C50	Vibration	Rectangular	30x30	88743	1257	C50/V/S
		Circular	35	96211	792	C50/V/C
	Self Compacting	Rectangular	30x30	88743	1257	C50/SC/S
		Circular	35	96211	792	C50/SC/C
C75	Vibration	Rectangular	25x25	61243	1257	C75/V/S
		Circular	30	70685	679	C75/V/C
	Self Compacting	Rectangular	25x25	61243	1257	C75/SC/S
		Circular	30	70685	679	C75/SC/C

Table 3.- Alternatives considered in the example.

MATERIALS		HA-25		HA-50		HA-75	
		B	AC	B	AC	B	AC
Cement	CEM I (kg)	262	300	450	450	500	500
Aditions	Filler (kg)	-	100	-	-	-	-
	Nano silica (kg)	-	-	-	-	10	10
Aggregates (kg)		1851	1725	1803	1803	1705	1705
Water (kg)		145	175	180	195	190	215
a/c		0.55	0.58	0.4	0.43	0.38	0.43
Pozzolith (ligno)	% spc	0.7	0.9	0.3	0.8	0.3	0.8
	(kg)	1.8	2.7	1.4	3.6	1.5	4.0
Glenium (PCE)	% spc	0.3	1.5	0.7	1.3	0.7	1.3
	(kg)	0.8	4.5	3.2	5.9	3.5	6.5

Table 4.- Components for each type of concrete

Requirements	Criteria	Indicators
R1. Economic (50%)	C1. Construction costs (67%)	I1. Building costs (85%)
		I2. Non acceptance costs (15%)
	C2. Efficiency (33%)	I3. Maintenance (60%)
		I4. Habitability (40%)
R2. Environmental (33%)	C3. Emissions (67%)	I5. CO_2 Emissions (100%)
	C4.Resources consumption (33%)	I6. Concrete consumption (90%)
		I7. Steel consumption (10%)
R3. Social (17%)	C5. Negative effects on the producer industry (80%)	I8. Workers' inconveniences (20%)
		I9. Workers' safety (80%)
	C6. Effects to third party (20%)	I10. Environment nuisances (100%)

Table 5.- Decision Tree and considered weights

The results of the Sustainability Index (SI) of each one of the alternatives are presented in Table 6. It can be observed that are all with a minimum value of 0,558 (corresponding to C25, C25, vibrated and square cross-section) and a maximum value of 0,852 (corresponding to C75, self-compacting and circular) because in a way to the reduced use of raw materials and to the increment of usable space in the building. This corresponds to the higher strengths used in high-rise buildings.

Ref.	SI	Ref.	SI	Ref.	SI
C25/V/S	0.608	C50/V/S	0.662	C75/V/S	0.707
C25/V/C	0,558	C50/V/C	0.716	C75/V/C	0.794
C25/SC/S	0.623	C50/SC/S	0.717	C75/SC/S	0.771
C25/SC/C	0,564	C50/SC/C	0.768	C75/SC/C	0.852

Table 6. Result of Sustainability Index (SI)

On the other hand it can be checked that in general the alternatives that use self compacting concrete result in higher SI values that the ones that use vibrated concrete. This corresponds in a way to aspects that have to do with non-quality costs, for voids in the base of the columns due to its compaction difficulties.

Lastly square columns result in higher values when concrete strengths are low (C25). When concrete strength is higher (C50 and C75), circular alternatives allow better results for sustainability due mainly to construction costs.

6 CONCLUSIONS

We can extract the following conclusions from the examples explained above:

- Sustainability as a concept is a well-established idea in our society and it is slowly being considered in the construction sector where it is difficult to produce changes. Evaluation methods are a necessary tool that will allow producing advances in the process.
- MIVES method is a very flexible tool to evaluate sustainability in structures from different points of view and different levels. It allows studying and evaluating in situ or precast solutions if they are efficient to solve a certain problem.
- Each decision requires a specific decision tree because if only a general is adopted it will not evaluate detailed aspects. This is shown in the examples described, each one on a different aspect.

ACKNOWLEDGEMENT

The authors thank Prof. Dr. Sakai the trust for the assignment of this keynote speech at the International Conference on Concrete Sustainability (ICCS16). Also the members of the UPC team thank the al Ministerio de Economía y Competitividad for the award of the investigation project Gestión y seguridad en infraestructuras hidráulicas (BIA2013-49106-C2-1-R)

REFERENCES

Aguado, A., del Caño, A., de la Cruz, P., Gómez, and Josa, A. (2012) Sustainability assessment of concrete structures. The EHE approach. *Journal of Construction*

Engineering and Management. ASCE. Vol. 138 (2): 268-276. (2012). 10.1061/(ASCE) CO.1943-7862.0000419

Ahmad, S. I., & Saker, M. A. (2014). Perspectives on Sustainable Materials and Practice in the Concrete Industry of Bangladesh. In *World Environmental and Water Resources Congress 2014@ sWater Without Borders* (pp. 2014-2022). ASCE.

de la Fuente, A., Armengou, J., Pons, O. and Aguado, A. (2016) Multicriterio decision making model for assessing the sustainability index of wind-turbine system: Application to a new precast concrete alternative. *Journal of Civil Engineering and Management*. 10.3846/13923730.2015.1023347

de la Fuente, A., Pons, O., Josa A. and Aguado A. (2016) Multicriteria-decision making in the sustainability assessment of sewerage pipe systems. *Journal of Cleaner Production* 112 (2016) 4762-4770. 10.1016/j.jclepro. 2015.07.002

de la Fuente, A., Armengou, J., Pons, O. and Aguado A. (2016) Multicriterio decision making model for assessing the sustainability index of wind-turbine system: Application to a new precast concrete alternative. *Journal of Civil Engineering and Management.* DOI: 10.3846/13923730.2015.1023347

Henry, M. and Kato. ,Y. (2011) An assessment framework based on social perspectives and Analytic Hierarchy Process: A case study on sustainability in the Japanese concrete industry. *Journal of Engineering and Technology Management*, Vol 28, nº 4. Oct-Nov. pp.: 300-316. 10.1016 / j.jengtecman.2011.06.006

Henry, M. and Kato, Y. (2012). "Perspectives on Sustainable Practice and Materials in the Japanese Concrete Industry." *Journal of Materials Civil Engineering*, 275-288. 10.1061/(ASCE)MT.1943-5533.0000388.

Henry, M. and Kato, Y. (2014). Sustainable concrete in Asia: Approaches and barriers considering regional context. *Constructions and Building Materials*, 399-404. 10.1016/j.conbuildmat.2013.12.074

Jato-Espino, D., Castillo-López, E., Rodríguez-Hernández, J. and Canteras-Jordana, J.C. (2014) A review of application of multi-criteria decision making methods in construction. *Automation in Construction*, 2014, 45, 151-162. 10.1016/j.autcon. 2014. 05.013

Josa, A., Aguado, A., Heino, A., Byars E. and Cardim, A. (2005) Comparative analysis of available life cycle inventories of cement in the EU. *Cement and Concrete Research*, Vol. 34, nº 8, 2004. pp. 1013-1020 10.1016/j.cemconres.2003. 12.020

Josa, A., Aguado, A., Cardim, A. and Byars. E. (2007) Comparative analysis of the life cycle impact assessment of available cement inventories in the EU. *Cement and Concrete Research*, Vol. 37, nº 5, 2007. pp. 781-788 10.1016/j.cemconres. 2007.02.004

Kim, S., Choi, M., Mha, H. and Joung, J. (2013) Environmental impact assessment and ecofriendly decision-making in civil structures, *Journal of Environmental Management*. 126 (2013) 105-112. 10.1016/j.jenvman.2013.03.045

Malhotra, V. M. (1999) Making Concrete Greener with Fly Ash, *Concrete International*, V. 21, No. 5, May, pp. 61-66.

Mehta, P. K. (1999) Concrete Technology for Sustainable Development, *Concrete International*, V. 21, No. 11, Nov. 1999, pp. 47-53.

Mehta, P. K. (2009) Global Concrete Industry Sustainability, Tools for moving forward to cut carbon emissions, *Concrete International, ACI*, pp.: 45-48, February

Ministerio de Fomento (2008) EHE-08 Instrucción de Hormigón Estructural. Comisión permanente del Hormigón

Pardo-Bosch F. and Aguado, A. (2016) Investment priorities for the management of hydraulic structures. *Structure and Infrastructure Engineering*. Vol. 11, No. 10, 1338-1351. doi: 10.1080/15732479.2014.964267

Pons, O. and de la Fuente, A. (2013) Integrated sustainability assessment method applied to structural concrete columns. *Construction and Building Materials*, v 49, p 882-893. doi:10.1016/j.conbuildmat.2013.09.009

Sakai, K. (2009) The rol of the concrete sector concerning sustainability. 16ο Συνέδριο Σκυροδέματος, ΤΕΕ, ΕΤΕΚ, 21-23/10/ 2009, Πάφος, Κύπρος

Sakai, K. (2009) Towards environmental revolution in concrete technologies, Proceedings of the 11th Annual International fib Symposium, Concrete: 21st. Century Superhero, London, 2009.

United Nations (1987): Report of the World Commisision on Environment and Development Our Common Future. UN General Assembly Resolutions 42/187.

TECHNICAL SESSIONS

Sustainability of Bridge Structures. Indicator System

R. Valdivieso[1], D. Fernández-Ordóñez[*1],
[1] Universidad Politécnica de Madrid, Madrid, Spain

The impacts on ecosystem services due to human activity are now a fact: the loss of biodiversity, the climate change, desertification, health and illness, the broad social and economic differences, … coupled with an increasingly committed society required to give an immediate response to the new challenges today in short and long terms.

The amount of waste generated by the construction industry and the resources consumed (energy, raw materials) in the life cycle (construction, operating, maintaining, deconstruction) contribute to the enhancement of human ecological footprint.

There are new sustainability goals in civil engineering projects. The techniques to reach these goals in construction sector have been analyzed and a methodologic frame of sustainable management have been proposed.

In the recent years, there have been different attempts to respond to the need of more sustainable infrastructure projects from different perspectives or through the creation of certain instruments. One of these instruments is the Sustainability Assessment Methods, which have been already implemented on buildings, but are still taking their first steps in its implementation to the infrastructure project scale.

An indicator system is proposed in this project for assessing sustainability in railway infrastructure projects from early stages (previous analysis of alternatives) to allow classification of the different alternatives according to the impact on the environment, society and economy, and thus to select the most sustainable alternative. After developing an extensive study of the state of knowledge on sustainable construction worldwide and, according to exiting initiatives, it the sustainability assessment of railway infrastructure projects is proposed using a set of criteria and indicators.

In order to elaborate this proposal, a through comparative analysis has been undertaken about the tools and methods more widely used at the present, which are LEED for Neighbourhood Development, BREEAM for Communities and MIVES. Also other tools have been revised, with lower or more local uptake, which pose interesting or complementary approaches.

The indicator system is also applied to a case study, Spanish bridges of railway infrastructure, through a multi-criteria analysis, to identify existing constraints to the implementation of sustainability criteria from early stages considering the project life cycle. The indicator valuation in later stages and their possible application in the comparison between projects will be taking into account the interest of controlling and monitoring.

REFERENCES

[1] A. Tillman & C. Llatas “Life Cycle Assessment (LCA) of Building”

]2] European Union Directive on the Energy Performance of Buildings (EPBD2002/91/EC)

[3] European Thematic Network on Practical Recommendations for Sustainable Construction (PRESCO): http://www.etn-presco.net/

Bond-Slip Behaviours between Deformed Steel Bar and 100% Recycled Coarse Aggregate (RCA) Concrete Using Pull-Out and Beam Tests

Hyun-Do Yun*, Seok-Joon Jang*, Sun-Woo Kim† and Wan-Shin Park†

* Department of Architectural Engineering, Chungnam National University (CNU)
Daejeon, 305764, South Korea
e-mail: wiseroad@cnu.ac.kr; suk-joon@nate.com, web page: http://www.cnu.ac.kr

† Department of Construction Engineering Education, Chungnam National University (CNU)
Daejeon, 305764, South Korea
Email: sw.kim@cnu.ac.kr; salshin@cnu.ac.kr - Web page: http://www.cnu.ac.kr

ABSTRACT

This paper presents the experimental results of an investigation dealing with flexural and pull-out bond behaviors of deformed steel bars in recycled aggregate concretes (RACs) manufactured using equivalent mix proportions with 100% recycled coarse aggregate (RCA) replacement percentage. To investigate the impact of the embedment length ($4d_b$ and $8d_b$) of deformed bar on the bond-slip behavior of 21 MPa RAC, a series of beam tests in accordance with RILEM recommendation were conducted. For deformed bar's embedment length of $4d_b$, pull-out and beam tests were conducted to examine the effect test method on the bond responses between deformed bar and RCA. From these tests, it was observed that the bond-slip behavior and bond strength between RCA concrete and natural coarse aggregate (NCA) concrete were comparable and the replacement levels of RAC with water absorption ratio of 1.59 % had no significant effect on the bond performance of deformed steel bars in the RACs. It was found that the ultimate bond stresses in the pull-out specimens agreed with the values obtained from beam tests with embedment length of $4d_b$. It is concluded that provisions in the ACI 318 Code for development length and lap splice of steel bars in NAC concrete members can be applied for the RAC with recycled coarse aggregate satisfying the requirements specified in Korean industrial standard KS F 2573.

REFERENCES

[1] Xiao, J., & Falkner, H. (2007). Bond behaviour between recycled aggregate concrete and steel rebars. *Construction and Building Materials*, *21*(2), 395-401.

[2] Kim, S. W., Yun, H. D., Park, W. S., & Jang, Y. I. (2015). Bond strength prediction for deformed steel rebar embedded in recycled coarse aggregate concrete. *Materials & Design*, *83*, 257-269.

This work was supported by the Human Resource Training Program for Regional Innovation and Creativity through the Ministry of Education and National Research Foundation of Korea (NRF-2014H1C1A1066970)

Carbonation and recycling potential of novel MgO cements ICCS16

C. Unluer*

* School of Civil & Environmental Engineering
Nanyang Technological University
Singapore 639798
e-mail: ucise@ntu.edu.sg, web page:
http://www.cee.ntu.edu.sg/aboutus/FacultyDir/Pages/ccunluer.aspx

ABSTRACT

Mineral CO_2 sequestration, combining alkaline earth metals with CO_2 to form stable carbonates, is a safe and rapid approach for reducing industrial CO_2 emissions. Reactive magnesia (MgO) cements have received significant attention in the technical press due to their technical and sustainability credentials over Portland cement (PC) including: (i) lower manufacturing temperatures (~700 vs. 1450°C), (ii) ability to sequester significant quantities of CO_2 becoming carbon neutral and leading to high strengths, (iii) significant durability advantages, (iv) lower sensitivity to impurities and capability of blending with large quantities of industrial by-products and (v) complete recyclability at the end of use. The use of MgO as a binder in concrete mixes was observed to have special advantages in terms of mechanical and durability performance and CO_2 sequestration potential over PC and PC-MgO blends. This work focuses on a closed loop cycle including the carbonation and recycling of reactive MgO within construction products. The results highlight the parameters that influence the capacity of MgO to absorb CO_2 and gain strength within construction products and potential to be recycled at the end of use, thereby reducing the overall impact of the construction industry. Microstructural analyses including scanning electron microscopy (SEM), X-ray diffraction (XRD) and thermogravimetry/differential thermal analysis (TG/DTA) are used in addition to porosity and compressive strength (CS) testing to understand the performance mechanisms. XRD, acid digestion and TG/DTA are utilized to quantify the amount of CO_2 sequestered with the goal of achieving 100% carbonation through careful mix design, leading to a range of carbon-neutral products with high strengths. As a result of this work, MgO was fully carbonated in concrete mixes, recycled and reused in the production of new construction products.

Case study for Combination of Architectural and Structural Design for a Sustainable and Aesthetic Façade for a Multilevel Car park

By- Ajit Bhate*

*Managing Director- Precast India Infrastructures Pvt. Ltd.
58B, CDSA Campus, Pune Paud Road, Bavdhan, Pune 411021, Maharashtra, India
Email: ajitbhate@precastindia.co.in, webpage: http://www.precastindia.co.in/

Abstract

This Case study highlights use of decorative semi structural concrete elements for enhancing the Aesthetical and functional aspects of a normally mundane Multilevel Car Park by preserving the use of concrete elements instead of conventional glass or composite aluminium facade materials.

This building of one basement plus ten floors, measuring around half a million square feet, parking around 1300 cars is located in Pune, India and constructed as a combination of cast in situ concrete and prefabricated structural concrete elements, and later on treated with an envelope of concrete façade elements, includes the combination of a unique methodology of prefabricating concrete façade elements to be fixed on spandrels specially designed and integrated with the precast structural elements, in a simple but effective manner, requiring the use of sustainable construction materials, and ascertains the creation of additional values of sustainability ratings for the building.

The case study explains evolution of the design and integration of concrete façade elements, structurally and aesthetically, with the main structure, and deals with production, transport and installation techniques, as also to the calculation of values for certification of the entire building in sustainable criterias of LEED ratings, and deciphers the achievement of safety standards of the building necessary as an additional aspect by annulling use of additional steel grills or meshes, which would have been needed in local conditions and norms.

Being a ground level person as a Managing Director of a Concrete Precast Company and also MD of a Construction Company, this paper proves the economic viability and excellent balance achieved by the façade yet adding substantial value to the Aesthetic and Sustainable qualities of the entire structure, while highlighting the conceptual evolution, architectural and structural design, trial mock ups, production, transport, and installation details during execution stages.

Contributing to sustainability of concrete by using steel fibres from recycled tyres in water retaining structures

A. Pérez Caldentey*†, J. Giménez Vila*, J.M. Ortolano González*, Fernando Rodríguez García*, Giancarlo Groli†

* FHECOR Consulting Engineers
Barquillo, 23, 2º
28004 Madrid, Spain
e-mail: apc@fhecor.es; jgv@fhecor.es; jmog@fhecor.es web page: http://www.fhecor.es

† Universidad Politécnica de Madrid
Profesor Aranguren S/N
Ciudad Universitaria, 28040 Madrid, Spain
Email: apc@he-upm.com - Web page: http://he-upm.com

ABSTRACT

Within the framework of European FP7 project, Anagennisi (Rebirth/Renaissance) [1], focused on the recycling of all components of end-of-life tyres into concrete (www.Anagennisi.org), FHECOR Consulting Engineers, one of the 16 partners of the project, has been analysing the potential for the use of recycled steel fibres (RSF) for cracking control in the design of water retaining structures (WRS).

In WRS made from concrete, the reinforcement is determined from considerations pertaining to crack width, whose allowable value ranges from 0,2 mm to 0,1 mm. In traditional RC design, this means that the amount of reinforcement needed for Ultimate Limit State needs to be doubled or tripled in order to effectively control crack opening to admissible values.

Due to the fact that steel ratios for this type of structures are low, steel fibres are very effective in controlling crack widths. If these fibres come from recycled end-of-life tyres, concrete structures become more sustainable as well as less expensive. There is already experimental evidence ([1],[3]) that (RSF) are effective in controlling crack widths for reinforced concrete structures with small reinforcement ratios. They will be even more effective if these ratios can be further reduced.

In the proposed paper a parametric study will be carried out, studying the influence of the shape of the constitutive law of RSFRC in tension, the cross section height and the reinforcement ratio on the construction cost and Life Cycle Analysis (LCA) of typical water retaining structures.

REFERENCES

[1] K. Pilakoutas, S. Raffoul, P. Papastergiou, R. Garcia, M. Guadagnini, and I. Hajirasouliha "Innovative reuse of all tyre components in concrete: the Anagennisi project", in Proc. of the International Conference on Sustainable Structural Concrete 2015, La Plata, Argentina, September 15-18, (2015).

[2] G. Groli. "Crack width control in RC elements with recycled steel fibres and applications to integral structures: theoretical and experimental study.", *PhD Thesis*, Polytechnic University of Madrid, pp. 138, (2014).

[3] G. Groli, A. Caldentey and A. Giraldo Soto "Cracking performance of SCC reinforced with recycled fibres – an experimental study", *Structural Concrete* ,Vol. **15**, Issue 2, pp. 136–153, (2014).

Feasibility Study on the Utilization of Alkali-treated Ground Municipal Solid Waste Incineration Bottom Ash as Cement Replacement

Yiquan Liu* and En-Hua Yang†

* Energy Research Institute @NTU (ERI@N), Interdisciplinary Graduate School, Nanyang Technological University
50 Nanyang Avenue, Singapore 639798
e-mail: liuy0102@e.ntu.edu.sg, web page: http://erian.ntu.edu.sg

† School of Civil and Environmental Engineering, Nanyang Technological University
50 Nanyang Avenue, Singapore 639798
Email: ehyang@ntu.edu.sg - Web page: http://www.cee.ntu.edu.sg/

ABSTRACT

As municipal solid waste incineration bottom ash (IBA) contains metallic aluminium, crack and expansion issue could happen due to hydrogen gas generation when IBA is used in cement matrix. In this paper, ground IBA powder was first pre-treated with alkaline solution under certain conditions to remove metallic aluminium, and after that the treated IBA was used as cement replacement in cement mortar. The alkali treatment effects on metallic aluminium removal, chemical composition of IBA and compressive strength of cement-IBA mortar were evaluated. The results showed that metallic aluminium in IBA could be completely removed by treatment with sodium hydroxide solution, and the alkali treatment did not change the major components of IBA though some aluminium compounds changed. From the compressive strength of cement-IBA mortar, it showed that some pozzolanic property of IBA could sacrifice when IBA is treated with alkaline solution. However, the strength activity index value of cement-IBA mortar using IBA treated with sodium hydroxide solution under low temperature and low PH can still reach more than 80%, which is meaningful for practical application. In general, this paper revealed a viable way to treat IBA to be suitable for cement replacement.

Ladle furnace slags of low and high alumina in masonry mortars

I. Vegas[*†], T. Herrero[†], D. García[†], A. Santamaría[††], J.T. San-José[††], J.J. González[††]

[†]TECNALIA Research & Innovation
c/Geldo, Edificio 700 - Parque Tecnológico de Bizkaia, 48160 Derio (Vizcaya), Spain
Edificio C1, Campus Norte UPC
Email: inigo.vegas@tecnalia.com Web page: http://www.tecnalia.com

[††]University of the Basque Country. Dep. of Mining, Metallurgical and Materials Science
Alameda Urquijo, s/n. 48013 Bilbao (Vizcaya), Spain
web page: http://www.ehu.eus/es/

ABSTRACT

An important by-product from steelmaking industry is the ladle furnace (white or basic) slag, produced in the secondary or basic refining of steel. This manufacturing process yields two types of basic slag that are either low or high in alumina, depending on the saturation method.

Among other properties, in previous works, have been analyzed their instabilities, mineralogy, hydraulic reactivity and their application in construction sector by their addition in Portland cement matrixes (pastes and masonry mortars). Present research will be focused on the characterization of pastes and masonry mortars (non-structural) containing such by-product as a partial substitution of binders (cement) and fine aggregates.

This investigation will be emphasized on the reactivity of certain compounds at outdoor temperatures such as calcium aluminates, free calcium oxide and free magnesium oxide. In line with this experimental work, different techniques will be used: DRX, TGA, chemical analyses, volumetric stability and a series of controlled hydration reactions. Hence, this research work focuses on the study of such slag in itself and its performance in cement matrixes.

In order to do this, different properties will be studied: mechanical behaviour under compression and flexural loads and durability issues, under weathering ageing, mainly referred to efflorescence and wetting-drying ageing cycles.

Interesting results were achieved by the replacement of 10% and 20% in cement by weight. The white slags with a high content of alumina showed a better physical-chemical performance than mortar designs incorporating high content of silica slag.

Present research concludes that the ladle furnace basic slag can induce slight hydraulic reactivity and that a partial cement replacement, by it lower than 20% by weight, does not negatively affect the mechanical performance and durability in cement masonry mortars.

Keywords: Cement; Durability; Ladle Furnace Slag; Masonry Mortar; Pastes; Shrinkage;

REFERENCES

[1] J.M. Manso, A. Rodríguez, A. Aragón, J.J. González, "The durability of masonry mortars made with ladle furnace slag", Construction and Building Materials, vol. 25, pp. 3508–3519, (2011).

[2] J. Papayianni, E. Anastasiou, "Effect of granulometry on cementitious properties of ladle furnace slag", Cement and Concrete Composites vol. 34, pp. 400-407 (2012).

[3] T. Herrero, "Estudio del efecto de la hidratación de la escoria blanca de acería de HEA: aplicación en pastas y morteros de cemento". Ph.D. Thesis, University of the Basque Country (UPV/EHU), 2015.

Large infrastructure economic, social and environmental Sustainability assessment. An approach to the Canal de Navarra Irrigation Area case

Jose E. Arizón Fanlo*, David Fernández-Ordóñez Hernández[1] and Jose A. Alfaro Tanco[2]

* Aguacanal, Concessionaire of the Canal de Navarra Irrigation Area 1st Phase
Pol. Industrial Mutilva Baja, calle E, nº 11, 1ºA, 31192 Mutilva Baja (Navarra), Spain
e-mail: jearizon@aguacanal.es, web page: http://www.aguacanal.es

[1] Technical School of Civil Engineers
Universidad Politécnica de Madrid
Alfonso XII 3 y 5, 28014 Madrid, Spain
e-mail: david.fernandez-ordoñez@upm.es, web page: http://www.upm.es

[2] School of Economics and Business
Universidad de Navarra
Campus Universitario, 31080 Pamplona (Navarra), Spain
e-mail: jalfaro@unav.es, web page: http://www.unav.es

ABSTRACT

Beyond the functionality of a large public work, its aesthetics or the short term construction costs, time is the infallible judge for the rightness or wrongness of the Public Administration that decided to implement it. And the criteria by which time measures the goodness of things are sometimes very different from those used to make a political decision on launching a public work.

A large infrastructure construction involves the spending of many public resources, it affects a significant part of the population, and generally implies large variations on environmental conditions before and after its existence. To pass the aforementioned time test, it should be able to maintain the balance between the positive and negative long-term impacts it produces. It must be sustainable.

The 2008 global economic crisis has clearly shown, particularly in developed countries, that economic, social and environmental infrastructure sustainability have not been sufficiently weighted as decisive criteria for determining its construction. If public authorities had reliable and transparent tools for making an objective assessment -on initial planning phases- of economic, social and environmental sustainability of large infrastructures, society would be closer to ensure satisfying the needs of the present without compromising the ability of future generations to meet their own needs.

The paper tackles the issue of assessing the real impact of a 23.000 ha irrigation infrastructure in northern Spain, from the three economic, social and environmental points of view, five years after construction completion, and comparing the short-term achieved results to those expected at the planning phase.

REFERENCES

[1] Alarcón, D.B. Modelo integrado de valor para estructuras sostenibles. Universitat Politècnica de Catalunya, Escola Tècnica Superior d`Enginyers de Camins, Canals y Ports. Barcelona, 2005.

[2] Fernández, G. Propuesta de modelo para la evaluación de la sostenibilidad en la dirección integrada de proyectos de ingeniería civil. Universidad Politécnica de Madrid, Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos. Madrid, 2010.

Self-healing performance of magnesia-based pellets in concrete

Rami Alghamri [1] and Abir Al-Tabbaa [2]

[1] PhD candidate, Department of Engineering, University of Cambridge, Cambridge, UK – e-mail: rja75@cam.ac.uk

[2] Professor of Civil & Environmental Engineering, University of Cambridge, Cambridge, UK – e-mail: aa22@cam.ac.uk

ABSTRACT

Concrete is the most widely used building material all over the world. However, it is liable to cracking, a phenomenon that hampers the material's structural integrity and durability. Thus, maintenance and repair work is very essential and indispensable. The conventional repair methods increase the life-cycle cost of concrete, have a significant environmental impact, and need long time and intensive labour. Therefore, development of concrete with sufficient healing capability is inspired by different materials in our nature such as the damaged skins of animals that can autonomously heal themselves. Concrete composite has a certain healing capability but it is very limited and uncertain in most circumstances. Different approaches have been developed to improve the healing capability of concrete such as adhesive polymers in hollow fibre glasses or microcapsules, bacteria in porous particles, and mineral admixtures directly incorporated in the cement based materials. This study presents the potential of using magnesium oxide (MgO) based pellets to improve crack self-healing capability of concrete. Commercial hard burnt MgO pellets were used in this work. Pellets were enclosed in a film coating layer of polyvinyl alcohol (PVA) based material to sequester the core materials until the crack time. The coated pellets were replaced the fine lightweight aggregates by 10% in mortar concrete mix. Two more mortar mixes were prepared; control and another mix including 10% of uncoated MgO pellets. The self-healing efficacy was verified through three-point flexural strength and monitoring cracks closure using optical microscope images. The results indicate that the coated MgO pellets presented 14.6% and 18.5% strength regain at 30 and 120 days respectively. In contrast, the control samples and the samples contained uncoated pellets didn't exceed at best 9% strength recovery at both ages. Moreover, the microscopic investigation showed complete cracks closure for concrete samples contained the coated pellets compared to partial closure for the pristine samples and those contained uncoated pellets.

Key words: Self-healing, concrete, pellet, magnesium oxide, film coating

Study of Concrete Modification Effect with Recycled Aggregate Treated by Carbonation

Takeshi Iyoda*, Nobuhiro Matsuda†

* Shibaura Institute of Technology (SIT)
Department of Civil Engineering, Associate Professor
3-7-5, Toyosu, Koto-ku, Tokyo, Japan
e-mail: iyoda@sic.shibaura-it.ac.jp, web page:http://www.db.shibaura-it.ac.jp/~iyoda/

† Tokyo Techno
3343, Onoji-machi, Macida city, Tokyo, Japan
Email: n-matsuda@tokyo-techno.co.jp

ABSTRACT

Ready-mixed concrete in Japan, if that were not used in the field, concrete that would remain back to the ready-mixed concrete plants is increasing year by year. In Tokyo, in order to reduce the return concrete, it has been taken also measures such as providing a penalty in return concrete, however it can't be easily reduced. Therefore, it is desired the technique for reusing of these concretes. By separating all materials from return concrete, the aggregate is realized a method of utilizing the recovered aggregate. However, in case of that time has elapsed from the mixing on initial ready-mixed concrete, it is difficult to separate them.

In this study, these return concretes are once hardened, it was investigated how to reuse as an aggregate by crushing. However, since the mortar is attached to the surrounding aggregate, the quality of the produced aggregates are not good. Therefore, even lower performance as recycled aggregate, it is difficult to use as aggregate for concrete. However, if it added a high degree of crushing and grinding, in the fact, that energy and cost is also high, the environmental impact is significant. So, in this study, after the rough grinding, a mortar of aggregate was modified by carbonation.

As a result, it was possible to increase the density and water absorption as compared to the original rough milled aggregate. Therefore, to produce a concrete with modified aggregate was significantly improved effect on the concrete strength and the drying shrinkage. By using this technique, it is possible to improve the processing problems of the return concrete. In addition, it is possible to contribute to the reduction of global warming gases by adsorption of carbon dioxide gas. Incidentally, carbon dioxide is considered to be generated from a number of industries and the techniques that lead to environmental reduction technology in society as a whole world.

Sustainability Dimension of an Elevated Corridor over a Greenfield

Shishir Bansal[*], S K Singh[†], P K Sharma[†]

[*] Research Scholar, Environmental Engineering Department, DTU
A 304, Lake View Apartments; G17, Sunder Vihar
New Delhi 110087, India
e-mail: bansal.shishir@gmail.com, Mobile : +91 98101 73245

[†] Professor and Head, Environmental Engineering Department,
Delhi Technological University (DTU), Delhi 110042, India
Email: sksinghdce@gmail.com

[†] Executive Engineer, FPD F123,
Public Works Department (PWD), Delhi 110001, India
Email: pksharma1606@yahoo.co.in

ABSTRACT

Background: Govt. of Delhi has planned express corridors, which are fully elevated for a long distance, say 3 to 5 KMs within the city and intermittently connected by Ramps with Traffic at Grade for better usage. One such corridor was constructed From Sarai Kale Khan (in East Delhi) to Nehru Stadium (in South Delhi) during Common wealth Games, but some of its pre-conceived ramps could not be constructed due to scarcity of time and are being built up now in next phase. One such ramp under advance stage of completion is crossing Silver Oak Park near Jangpura in South Delhi.

Main Features: Silver Oak Park is a green field area, triangular in shape and developed in an area of about 45000 sqm with large numbers of Oak trees. As per the previous planning of the corridor done in 2007, it was crossing the Silver Oak Park at one corner so that the sanctity of the park is not lost. But, subsequently, when the construction was taken up in 2013, it was realised that Delhi Metro Rail Corporation (DMRC) has placed their underground Jangpura station building at the same location. It was not possible to take the ramp above the station building due to foundation issues. Spanning over the entire station building would have made a very long span, requiring a special structure at a high cost and additional time in planning and implementation. Thus, the economical solution was the shifting of the corridor towards the midst of the Silver Oak Park.

Shifting of the alignment resulted in twin issues that were environmentally related and making the project unsustainable. Firstly, the cutting and removal of trees causing heavy depletion of green belt and secondly, getting the park divided into two parts thus loosing its oneness character.

Various options were exercised to reduce the depletion of green belt. Out of possible 3 alignments, one having removal of minimum trees was chosen. Also it was decided to transplant the trees to the possible extent instead of just cutting and loosing them. Further ten times the trees lost were again planted to make up the loss to the extent possible.

For the second problem, it was decided that instead of filled up ramp, it is constructed on stilts. Further, the green area beneath the elevated ramp was stepped down after excavating and removal of the earth and the entire area landscaped. Thus, the movement across the park on either side of the ramp with full headroom will be allowed. The columns will be given artistic touch by making murals so that it becomes part of overall landscape and the oneness character of silver Oak Park is also retained.

Results: Once the construction of corridor is complete and opened to traffic, it will be a part of overall scheme of Silver Oak Park with attractive landscaping and murals. Thus, the overall Environment, greenery and social and economical factors are taken care of while modifying the scheme and implementing at site.

Conclusions: If some issues are observed in the implementation of a planned corridor due to delay for any reason, then all efforts are required to be put in to find the most sustainable solution to the problem without losing the basic character and functionality of the Project.

REFERENCES

[1] Bansal Shishir, Singh S K and Gupta Vinay, "Barapullah Elevated Road Project: Past, Present and Future", ING-IABSE Seminar on Elevated Transport Corridors, Mysore, June 26-27, 2014.

Sustainability Evaluation of a New Type Concrete Bridge Structure - Butterfly Web Bridge -

Ken-ichi Kata*, Akio Kasuga* and Koji. Sakai†

* Sumitomo Mitsui Construction Co., Ltd.
2-1-6, Tsukuda, Chuo-ku, Tokyo 104-0051, Japan
e-mail: k-kata@smcon.co.jp, akasuga@smcon.co.jp
web page: http://www.smcon.co.jp

† Japan Sustainability Institute
1-25 Kita-21 Higashi-19, Higashi-ku, Sapporo, 065-0021, Japan
e-mail: sakai@jsi-ks.jp, web page: http://www.jsi-ks.jp/

ABSTRACT

It is important to reduce the superstructure weight in an earthquake country like Japan. Therefore, corrugated steel web bridges have been applied in many projects. However, the maintenance cost is relatively high to keep the durability of the structure during their design life time.

In order to solve such probrems, a new type of bridge called “Butterfly Web Bridge” was developed in Japan. In a butterfly web bridge, the butterfly-shaped web forms a structure that exhibits behavior similar to a double Warren truss. The 80MPa concrete is used for the butterfly web which has a precast plate with a thickness of 150 mm. As butterfly web is a concrete material, reinforcement provided by prestressing tendons is needed on the tension side. Moreover, the 150mm plate has no re-bars but is reinforced by steel fibers.

Three butterfly web bridges were constructed in an express way. Takubogawa Bridge and Akutagawa Bridge are continuous one box-gider type having 87.5m and 75.0m maximum span length respactively. Mukogawa Bridge is a two box-gider extradosed bridge type having 100.0m maximum span length. These bridges are constructed by cantilever erection method. The butterfly web is prefabricated in a concrete factory and its weight is 3 tons.

This new type of structure enables the reduction of the amount of materials such as concrete, re-bars, prestressing steels. Therefore, it reduces the dead load of the superstructure by 10% compared with an ordinary box girder, and also the size of substructure. From the calculation of CO_2 emissions of the above three bridges considering the amount of materials with the reference [4], it was found that this type of bridge could enable the CO_2 emission reduction of approximately 10%.

REFERENCES

[1] K. Ashizuka, K. Miyamoto, K. Kata and A. Kasuga, “Construction of a Butterfly Web Bridge”, Proceeding of *fib* Symposium 2012, Stockholm, pp. 545-548
[2] Y. Kaminaga, K. Ashizuka, A. Takahashi, T. Yamamoto, Y. Hashi and K. Kawano, “Design and Construction of Butterfly web Bridge -Akutagawa Bridge-”, Proceeding of IABSE Conference Nara 2015, IA-23
[3] K. Mizuno, J. Samizo, M. Fukuda and A. Kasuga, “Design and Construction of the Mukogawa Bridge”, Proceeding of *fib* Symposium 2015, Copenhagen
[4] “Recommendation on Environmental Performance Verification for Concrete Structures (Draft)” , JSCE Concrete Library No. 125, 2005. (Japanese)

THE OPTIMIZATION OF RAILWAY CONCRETE SLEEPERS FOR INCREASING THE DURABILITY AND SUSTAINABILITY

Szabolcs Attila Köllő*, Gavril Köllő* and Attila Puskás†

*Technical University of Cluj-Napoca
72-74 Observatorului str., 400363 Cluj-Napoca, Romania
e-mail: kszabolcsattila@yahoo.com, web page: http://constructii.utcluj.ro

†Technical University of Cluj-Napoca
25 Bariţiu str.,room 123, 400027, Cluj-Napoca, Romania
Email: attila.puskas@dst.utcluj.ro - Web page: http://users.utcluj.ro/~puskas/

ABSTRACT

Railway transport represents a cost effective, energy efficient and sustainable communication technology. In the last 40 years in the railway transport the demand for high speed trains increased, but in some countries the rail freight also entered in a new era, exposing the superstructures of railway tracks to higher technical requirements. Simultaneously, an approach change has occurred in terms of perception of superstructures since initially the aspects of construction works and the safe transport were considered a priority, bringing the importance of maintenance to a secondary role, but nowadays the economical, safety and environmental protection factors are taken into account for the whole life cycle of the structures.

Economic conditions include the developments of the construction and maintenance costs. In addition to reducing investment and construction costs it is important to obtain more sustainable solutions. Railway companies undertake even the higher construction costs, if the maintenance costs will be substantially reduced over the serviceability life time.
Therefore it is necessary the optimization of concrete railway sleepers which enables the reducing of the energy and use of material in short time, decreasing the costs of production of these elements, but in long term increase the sleepers` durability against the variable load cases and environmental influences. In this process the connection between the wheels of rolling stock materials, the rails and the sleepers has an essential role.

In this article the authors are studying the possibilities of the optimizations of railway concrete sleepers` geometry in terms of the effect of the sleepers on the rails, considering the ballast layer properties according to specific local conditions unchanged during the studies.
For the calculations the authors used the ballasted track superstructures calculating model, which is based on the method of Zimmermann. This application transforms the transversely sleepered track represented theoretical by a discrete supported beam to an equivalent longitudinally sleepered track represented by a fictive, continuously supported beam on an elastic foundation. Using the above mentioned calculation model, the authors analysed the appearing bending moments in the rail beams depending on the variation of geometrical characteristics of sleepers, which determine the rigidity of these structural elements.
During the study the dimensions of the sleepers currently used by European Railway Companies have been considered as benchmark sizes, with distances between of 600 mm. The study is aiming to establish the sleepers with the optimal dimensions for the given load bearing capacity of the rail under the maximum axle load of 250kN, achieving also the necessary stiffness of the elements with reduced material consumption, if possible.
In case of sleepers of the same length, the steady increase in height of the sleeper`s cross section increases linearly the rail's load bearing capacity. A similar trend also seems to be outlined in the case of the same height but different length sleepers. The differences between the load bearing capacities of rails are higher when the sleepers in different length and height domains are studied.

REFERENCES

[1] N. F. Doyle, *Railway track design*, Canberra: Australian government publishing service; 1980.

[2] C. Esveld, Modern Railway track, 2nd Edition, MRT-Productions; 2001.

THERMAL MASS IMPROVEMENT OF LIGHTWEIGHT CONCRETE WITH MODIFIED AGGREGATES

Araceli Gálvez[*], Siska L.A. Valcke[†]

[*] Acciona Infraestructuras. Dirección de Innovación Tecnológica.
C/Valportillo II, 8. 28108 Alcobendas, Madrid (SPAIN)
e-mail: araceli.galvez.moreno@acciona.com, www.acciona.com

† TNO
Van Mourik Broekmanweg 6, 2628 XE Delft, The Netherlands
e-mail: siska.valcke@tno.nl, www.tno.com

ABSTRACT

The increased use of lightweight materials in construction is causing decreased thermal inertia of the materials used and therefore the need for an extra effort to achieve good thermal energy efficiency.
The object of this research is to obtain an extra supply of thermal inertia in building materials by the addition of phase change materials (PCM) by means of the aggregates. So, the incorporation not interfere with the mechanical, physical or chemical properties of the materials and also this incorporation is simple because is part of the same dosage process of aggregates.
All this research is enclosed in a FP7 UE Project called Adaptiwall (Multifunctional lightweight wall panel based on adaptive insulation and nanomaterials for energy efficient buildings) and the specific objective of this task is to achieve a lightweight concrete buffer with the same thermal properties than a traditional concrete.
Vacuum impregnated technique [1],[2] was used to incorporate the PCM in the porosity of lightweight aggregates and different commercial aggregates like expanded clay, perlite, sepiolite, pumice and vermiculite were used.
After the aggregates characterization, concrete specimens were produced and mechanical and thermal tests were carried out to analyse the influence of the PCM in the concrete structure.
Specific thermal test were carried out to concrete sample of 20x20x5 cm with different dosages. Comparisons with traditional concrete (δ = 2300 kg/m^3) show that the increase of the thermal mass of lightweight concrete with PCM has the double energy storage capacity then traditional concrete. Other parameters as thermal conductivity, thermal delay and thermal decrement were studied in the tested cases.

REFERENCES

[1] Dong Zhang, Zongjin Lib, Jianmin Zhoua, Keru Wua. Development of thermal energy storage concrete. Cement and Concrete Research 34 (2004) 927–934.
[2] Dong Zhang a,*, Jianming Zhou a, Keru Wu a, Zongjin Li. Granular phase changing composites for thermal energy storage. Solar Energy 78 (2005) 471–480.

WOOD-CONCRETE COMPOSITE FLOOR SYSTEM IN REHABILITATION

.

Martínez Juan, B.*; Irles Más, R [**]**

[*] Ingeniero de Caminos, Profesor Asociado
e-mail: bernardo.martinez@ua.es,
[**] Ingeniero de Caminos, Catedrático de Universidad
e-mail: r.irles@ua.es

Departamento de Ingeniería Civil. web page: http://www.ua.dic.es
Universidad de Alicante. Carr. San Vicente del Raspeig, s/n, 03690
Sant Vicent del Raspeig, Alicante

ABSTRACT

The rehabilitation of the constructed heritage is one of the important aspects in sustainability criteria nowadays contemplated in construction area. The present communication focuses on the rehabilitation of ancient floors made of wood by means of the demolition of his not structural elements and restructuring to a wood-concrete composites (WCC) systems (concrete of new contribution and wood respecting the preexisting one) due connected for his joint work, which turns out to be much more efficient on having replaced filling material with structural material.

This technology has already some accomplishments in the last decades, having developed diverse specific connection devices, more or less satisfactory, and several investigation works in various countries.

In the communication there is exposed part of the initial results, already available, of the investigation program for the doctoral thesis development of the first author, nowadays in process, that includes some conclusions of realized tests, full scale, with ordinary and light concretes about a new system of original connection, the planning of some additional tests, the adjustment of an analysis procedure for design, as well as the execution rehabilitation works of a floor terrace in a manor which original construction dates back of the 20s of the 20th century, realized successfully by means of this procedure.

Automatic design of building construction processes by simulated annealing. A measure to improve sustainability, time, financial and computational costs

Manuel Buitrago*, Jose M Adam[†1],

Pedro A. Calderón[†2], Juan J. Moragues[†3]

Instituto de Ciencia y Tecnología del Hormigón (ICITECH)
Universidad Politécnica de Valencia
Camino de Vera s/n Edificio 4N, 46022 Valencia, Spain
* e-mail: mabuimo1@upv.es
[†1] e-mail: joadmar@upv.es
[†2] e-mail: pcaldero@upv.es
[†3] e-mail: jmorague@cst.upv.es

ABSTRACT

Economizing building construction processes by using successive levels of shoring, involves two strategies: 1) reducing the time spent in each of the construction operations, and 2) attempting to recover most of the components used as soon as possible. Through these two strategies, more efficient building construction processes can been achieved.

Since safety must be taken into account in the construction process, it is necessary to have a calculation method. Accordingly, a computer tool which calculates and verifies building construction processes by a simplified procedure [1] was developed. This simplified procedure is able to consider the usual construction system types: Shoring/Striking (SS), Shoring/Reshoring/Striking (SRS) and Shoring/Clearing/Striking (SCS) for slabs, waffle slabs and girderless hollow floor slabs. It also takes into account the different possible boundary conditions: end, corner and internal spans. In addition, in this work different values of the number of successive levels of shoring were considered, from a floor to four successive levels.

The main novelty of this work lies in its automatic optimum design of building construction processes, which was created by using Simulated Annealing (SA) [2] heuristic algorithm. This tool can improve four of the most important points involved in construction: sustainability, safety, time and financial cost. After applying this strategy to a real case, it was found that SA performed an intelligent search of the optimal solution. The optimal solution was achieved while reducing up to 42% of the cost of the shoring system compared to the real construction process, in shorter construction time, meeting all the usual requirements for the construction of buildings and using fewer materials.

REFERENCES

[1] PA Calderón, YA Alvarado and JM Adam, “A new simplified procedure to estimate loads on slabs and shoring during the construction of multistorey buildings”, *Engineering Structures*, Vol. **33**, pp. 1565–1575, (2011).

[2] S Kirkpatrick, CD Gelatt and MP Vecchi, "Optimization by simulated annealing", Science Vol. **220**, pp. 671-680, (1983).

Fabrication, performance and environmental safety of fired bricks from lake silt and sewage sludge

JIA Lutao*，MEI Hao*，ZHANG Ping*，CUI Qiang†, ZHANG Yamei*，ZHANG Peigen*, SUN Zhengming*

*School of Materials Science and Engineering, Jiangsu Key Laboratory of Construction Materials
Southeast University
Nanjing, 211189,China
e-mail: ymzhang@seu.edu.cn

†Wuxi Guolian Environment & Energy Group Co. ,Ltd.
Wuxi,214131,China

ABSTRACT

Lake silt, cinder and sewage sludge were used as raw materials to prepare fired brick samples using the vacuum plastic extruder in laboratory. Physical and chemical properties, including plasticity index, oxide composition and mineral composition of raw materials and the linear drying shrinkage, water absorption, bulk density, compressive strength, thermal conductivity and freeze-thaw resistance of the fired brick samples were investigated. Results showed that the linear drying shrinkage, water absorption and compressive strength of fired brick samples made from 85% lake silt, 10% cinder and 5% sewage sludge were 5.35%, 16.5% and 20.5 MPa, respectively. Leaching test showed that heavy metals in bricks were immobilized effectively during the sintering process. Gas produced during sintering process was collected and analyzed. The results demonstrated that the toxic equivalent quantity of PCDDs/PCDFs was much less than the value specified in standard for pollution control of the municipal solid waste incineration. This study reveals that it is an effective way to comprehensively use lake silt, cinder and sewage sludge as raw material to produce bricks.

REFERENCES

[1]. C. Le, Y. Zha, Y. Li, D. Sun, H. Lu, B. Yin, Eutrophication of lake waters in China: cost, causes, and control, Environmental management, 45 (2010) 662-668.

[2]. W. Jinglu, H. Chengmin, Z. Haiao, G.H. Schleser, R. Battarbee, Sedimentary evidence for recent eutrophication in the northern basin of Lake Taihu, China: human impacts on a large shallow lake, Journal of Paleolimnology, 38 (2007) 13-23.

[3]. Q. Zhou, Y. Zhu, Potential pollution and recommended critical levels of phosphorus in Y.M. ZHANG，L.T. JIA，H. MEI，P. ZHANG，Q. CUI, P.G. ZHANG, Z.M.SUN 9 paddy soils of the southern Lake Tai area, China, Geoderma, 115 (2003) 45-54.

[4]. R.-Y. Li, H. Yang, Z.-G. Zhou, J.-J. LÜ, X.-H. Shao, F. Jin, Fractionation of Heavy Metals in Sediments from Dianchi Lake, China, Pedosphere, 17 (2007) 265-272.

[5]. H. Niu, W. Deng, Q. Wu, X. Chen, Potential toxic risk of heavy metals from sediment of the Pearl River in South China, Journal of Environmental Sciences, 21 (2009) 1053-1058.

[6]. G. Shen, Y. Lu, M. Wang, Y. Sun, Status and fuzzy comprehensive assessment of combined heavy metal and organo-chlorine pesticide pollution in the Taihu Lake region of China, Journal of environmental management, 76 (2005) 355-362.

[7]. S. Li, An approach to accelerating innovative development of the lake science in China, Bull Chinese Acad Sci, 21 (2006) 399-405.

[8]. W. Liu, R. Qiu, Water eutrophication in China and the combating strategies, Journal of Chemical Technology & Biotechnology, 82 (2007) 781-786.

[9]. D. Fytili, A. Zabaniotou, Utilization of sewage sludge in EU application of old and new methods—A review, Renewable and Sustainable Energy Reviews, 12 (2008) 116-140.

SHOTCRETE REINFORCED WITH RECYCLED FIBERS FROM SECONDARY WASTE OF END OF LIFE TIRES

SONIA SERNA[*], PEDRO SERNA[*], MARIA J. PELUFO[*], VICTOR ORERO[*], AND AITOR LLANO[*]

[*] Instituto de Ciencia y Tecnología del Hormigón (ICITECH)
Universitat Politècnica de València
Camino de Vera s/n, 46021 València, Spain
e-mail: pserna@cst.upv.es,

Key words: End-of-life tyres, recycled fiber, mechanical behaviour, shotcrete.

ABSTRACT

The main objective of this research work is to study the possibility of obtaining a functional, sustainable, and less expensive concrete by using in its production metallic fibers produced from tyres that are no longer in use. In addition, the work includes the identification of any benefits originated by the use of these recycled fibers in pavements and shotcrete.

This research analyzes concretes produced with recycled fibers from different sources - cars and trucks - and obtained through different methods. The concretes' mechanical characteristics and their spraying possibilities are studied in the laboratory prior to production for spraying in a construction site and analyzing the existing differences.

The spraying conditions are studied for dry and a wet process, and the technological difficulties in the process of introducing the fibers in the concrete mixer and during projection are discussed.

Regarding the flexural strength, the use and the quantity of different types of fibers do not introduce significant changes in the first crack strength. However, these parameters do introduce changes in the results of residual strength depending on type and amount of fibers fibers. There have been differences observed between results obtained in specimens made by pouring and those made by spraying. Energy absorption results obtained are promising.

The difficulty of fiber-reinforced concrete spraying process is also considered adequate.

A case of study for embedding RFID tags in precast concrete

R. Alonso-Calvo[1], M. Garcia-Remesal[1], D. Fernández-Ordóñez[1]
[1] *Universidad Politécnica de Madrid, Madrid, Spain*
{raul.alonso},{miguel.garcia.remesal},{david.fernandez-ordonez}@upm.es

In recent years several studies have demonstrated that radio-frequency identification (RFID) tags are very useful when combined with building information models (BIM) systems. Moreover, RFID labelling could be used for improving traceability in precast, transport of pieces and quality assurance for idenifying unitary building pieces and its location following BIM definition.

RFID tags, like other identification techniques in construction, such as labels and barcodes, are usually located in the surface of BIM items, even in concrete pieces and precast. Therefore, integrity of the RFID tags is tested out by the ruggedness of the harsh construction industry environment. Durability of piece identification is very important during transport and assembly phases. But achieving a long term labelling for the whole life of a piece could contribute to traceability from the BIM system and its sustainability.

In this paper, authors present a laboratoy study where different types of RFID tags have been embeded into concrete and at diferent depths from the concrete surface. The study measures the response of RFID tags and the effects of concrete materials to RF magnetic waves. Different measures of the communication with tags at different stages of the concrete curation have been done.

The study demonstrates the availability of achieving long term electronic labelling for concrete pieces by embedding RFID tags into the concrete items. Because concrete acts as a shield for RFID tags during tranportation and building stages of BIM pieces improving the durability of piece labelling. Additionally RFID technology data security and privacy of information stored in RFID Tags

REFERENCES

[1] Resource Management in Civil Construction Using RFID Technologies. Changyoon Kim, Yeonjong Ju, Hyoungkwan Kim and Jung-Hoon Kim. Pages 105-108 (2009 Proceedings of the 26th ISARC, Austin TX, U.S.A.)

[2] RFID-Assisted Lifecycle Management of Building Components Using BIM

Data. Ali Motamedi and Amin Hammad. 26th International Symposium on Automation and Robotics in Construction (ISARC 2009)

[3] Application of BIM and RFID in Public Housing Projects. CICID 10th Anniversary Conference
. Ada Fung. May 2011

[4] BIM and RFID Integration: A Pilot Study. Pavan Meadati. Second International Conference on Construction in Developing Countries (ICCIDC–II). August 3-5, 2010, Cairo, Egypt

An Experimental Study on Precast Concrete Beam-to-Column Connection Using Interlocking Bars

Vera A. Noorhidana*, and John P. Forth†

* Institute for Resilient Infrastructure, University of Leeds, Civil Engineering, Woodhouse Lane, LS2 9JT, Leeds, UK
e-mail: cnvan@leeds.ac.uk, web page: http:// www.engineering.leeds.ac.uk

† Institute for Resilient Infrastructure, University of Leeds, Civil Engineering, Woodhouse Lane, LS2 9JT, Leeds, UK
e-mail: j.p.forth@leeds.ac.uk, web page: http:// www.engineering.leeds.ac.uk

ABSTRACT

Precast concrete system, besides meet the rules of the green construction, also offers some advantages in terms of the speed and cost of construction. On the other hand, the beam-to-column connection still face the problem regarding the behaviour of the connection and the difficulties of implementation due to the complicated detail or a high degree of the precision, which lead to be uneconomical.

There have been many studies on the connection of precast concrete beam-to-column connection. These connections have used either welding, bolts, and/or cast-in-place (CIP) concrete. Each type of connection has advantages and disadvantages. The performance of the weld connection is determined by the quality of welding in the connection and this will need skilled labour on site. Bolted connections need a high degree of precision when locating the channels before casting the precast concrete elements. CIP concrete connection, even though it create more monolithic connection, it requires additional formwork on site until the concrete gains the strength, which extend the overall time construction.

The new type connection presented in this paper was designed to avoid the negative aspects mentioned above, such as avoiding the use of welding, bolts, and CIP concrete connection. The connection here uses a U-beam and corbel to minimize the use of formwork, and the interlocking bars to connect the precast column and precast beam which act as the flexural reinforcement to withstand the hogging and sagging moment subjected during testing. The test specimens represented an exterior beam-column joint of a multi-storey building. The length of the beam and column was bounded by the contra-flexure points resulted from computer analysis. The beam-column joint was designed according the strong column-weak beam principle. The load was imposed on the beam tip. The static-monotonic loading was applied to the first specimen (P1), while a quasi-static loading was applied on the second specimen (P2). Tip deflection and cracks were monitored during the tests.

The result, flexural cracks occurred at the plastic hinges in the beam of both specimens. P1 has no significant cracks in the joint, while P2 has 'X' cracks but still acceptable. The precast columns of both P1 and P2 were free from cracks. Therefore, the development length of the interlocking bars, i.e. 800 mm from the column face, is sufficient to generate enough bond strength between the reinforcing bars and concrete, so that the interlocking bars can develop their tensile strength through to yield. It can be concluded that this new connection design meets the strong column-weak beam principle.

REFERENCES

[1] H. K. Choi, Y. C. Choi, and C. S. Choi, "Development and Testing of Precast Concrete Beam-to-Column Connections." *Engineering Structures,* Vol.56**,** pp.1820-1835, 2013.

[2] O. Ertas, S. Ozden, and T. Ozturan, "Ductile Connections in Precast Concrete Moment Resisting Frames." *PCI Journal***,** pp.2-12, 2006.

Cement based facades for mid-rise commercial sustainable and resilient buildings

Gonzalo Barluenga *, Oluwateniola Ladipo †, Georg Reichard †, Roberto T Leon +

* Department of Architecture, University of Alcala
Calle Santa Ursula, 8. Alcala de Henares. 28801-Madrid, Spain
e-mail: gonzalo.barluenga@uah.es, web page: http://www.uah.es

† Department of Building Construction, Virginia Tech
Bishop-Favrao Hall, Blacksburg, VA 24061
e-mails: tladipo@vt.edu, reichard@vt.edu, web page: http://www.bc.vt.edu

+ Via Department of Civil and Environmental Engineering, Virginia Tech
200 Patton Hall, Blacksburg, VA 24061
e-mail: rleon@vt.edu, web page: http://www.cee.vt.edu

ABSTRACT

The social, economic, and environmental impacts associated with natural hazards can threaten the sustainability of the building environment. Architects and engineers must consider the reconstruction impacts associated with unknown future extreme events that may occur during a building's lifetime jointly with initial construction impacts in order to design resilient and sustainable buildings. The design selection must therefore balance multiple competing interests.

Due to its external location on the building, the enclosure is the constructive system most exposed to natural hazards, as wind or flood, and has a main role on the global building performance regarding energy efficiency and vapour and air interchange. Hence, sustainability and resilience of buildings depend on the short and long term performance of the enclosure.

To evaluate the most common cement based facades (CBF) solutions for mid-rise office buildings, a study of the functional performance level, sustainability and resilience against coastal and seismic hazards was carried out with data and examples taken from a literature review. CBF were categorized considering the materials, the reinforcement and application (cast in place, prefabricated, multi-layered, etc.), self-weight, functional/control layers' placement and interdependences with the structure. This work was part of a NSF Project RSB: Performance-based Decision Support System for Resilient and Sustainable Multi-Hazard Building Design (Award number 1455466).

Then, CBF solutions were evaluated regarding their performance level (baseline, over-code and high performance) during normal operational conditions and amid climatic hazards. Sustainability analysis took into account the manufacturing and construction impacts, the operational costs in normal conditions, durability aspects and the end of life conditions. Resilience assessment considered the effect of multiple coastal and seismic hazards, expected damages and recovery measures. A vulnerability analysis of the CBF types' expected damages, levels of damage regarding the baseline performance of functional layers and functionality loss was carried out. The recovery considered the inspections and tests required to evaluate damage, the repair and replacement measures required and the time until baseline operational performance is reached. The conclusions highlighted the advantages of the different CBF types and the weaknesses that should be addressed to improve sustainability and resilience that could help early building design decisions.

Development of Environment-Friendly Blended Cement and Application of the Cement to a Building Construction Project

Mamoru YAMADA*, Noboru URUSHIZAKI† and Yuji KAWABATA†

*Obayashi Corporation Technical Division

2-15-2, Kounan, Minato-ku, Tokyo, JAPAN

E-mail: yamada.mamoru@obayashi.co.jp, web page: http://www.obayashi.co.jp/

†Obayashi Corporation Environmental Division

2-15-2, Kounan, Minato-ku, Tokyo, JAPAN

ABSTRACT

Authors present a newly developed environment-friendly blended cement which meets Japanese Industrial Standards (JIS) and provide some information about a construction project using the said cement.

Carbon dioxide (CO_2) emission from production of an ordinary concrete is estimated at 300 kg per one cubic meter. To contribute in achieving a sustainable society, Obayashi Corporation has been developing an environment-friendly concrete called “Clean Crete” which contains large amount of industrial by-products such as ground granulated blast-furnace slag (GGBS), fly ash and silica fume as supplementary cementing materials (SCMs) instead of using cement [1][2]. Using Clean Crete can reduce CO_2 emission during the production of concrete to 20-40%. Clean Crete, however, has been used only Obayashi Corporation for about 20 construction projects, approximately 45,000 m^3 so far because of difficulty with SCMs procurement at ready-mixed concrete producers.

Therefore, in order to distribute the environment-friendly concrete widely in the entire Japanese construction industry, authors developed the blended cement for Clean Crete which satisfies specifications of JIS. The blended cement which contains GGBS, having an upper limit prescribed in JIS, can reduce CO_2 emission to 40% of ordinary Portland cement and can be readily used by many ready-mixed concrete producers anywhere in Japan.

REFERENCES

[1] N.Takeda, “Low-Carbon High-Flowable Concrete "CLEAN CRETE"”, ACI Concrete Sustainability Forum IV, (2011)

[2] T.Kobayashi et al., “Study on the basic properties of low carbon concrete with high amount of admixture”, *Proceedings of ICCS13 (CD-ROM)*, (2013).

Durability Of Concrete Exposed To Sea Water At Early Age: Floating Dock Method For Construction Of Caissons

J. Vera-Agullo[*], R. Lample[*], N. Silva[†], U. Mueller[†] And K. Malaga[†]

[*] ACCIONA Infraestructuras S.A.
Centro Tecnológico
Valportillo Segunda nº8, 28108 Madrid, Spain
e-mail: jose.vera.agullo@acciona.com, www.acciona-infraestructuras.es

[†] Swedish Cement and Concrete Research Institute (CBI)
Brinellgatan 4. SE-504 62 Boras
email: nelson.silva@cbi.se, http://www.cbi.se/

ABSTRACT

ACCIONA Infrastructure, a Spanish contractor, uses the caisson method for the construction of breakwater structures. One of its floating docks, Kugira, is one of the largest of its kind in the world and it can produce concrete caissons measuring 70 m long by 36 m wide and 35 m high. Concrete caissons made in floating docks are gradually immersed in sea water as they are built; thus, the set concrete is exposed to sea water at a very early stage, within 18 to 48 hours after casting in sliding formwork.

In order to study the durability of slag concrete using this construction method, the properties of concrete exposed to sea water at a very young age have been tested. Specimens were exposed to artificial sea water by the ponding method at different ages (16h, 1, 2, 3, 7 and 28 days) for a period of 6, 18 and 36 (analysis pending) months.

The following properties were measured and compared with unexposed specimens: compressive strength, water and oxygen permeability, pore size distribution, migration coefficient DNT492 and chloride profiles. After 6 and 18 months ponding, lower chloride contents were measured for the specimens exposed to sea water after 28 days curing compared to those exposed at early ages. However, this difference significantly decreases within a small depth from the exposed surface. Also the migration coefficient DNT492 decreases significantly with the increase of the age of the concrete. With regards to water and oxygen permeability, no significant differences were found.

In this paper, a summary of all these works is presented.

REFERENCES

[1] Caballero, J., Polder, R.B., Leegwater, G.A. and Fraaij, A.L.A. Chloride penetration into cementitious mortar at early age. Heron (2012) 57:185-196.

[2] Hong, K., Hooton, R.D. Effects of cyclic chloride exposure on penetration of concrete cover. Cement and Concrete Research (1999) 29:1379–1386.

[3] Tang, L., Boubitsas, D. and Utgenannt, P., Chloride ingress in concrete exposed to marine environment – Field data up to 20 years exposure. CBI Report (2014).

[4] Tang, L. and Nilsson, L-O., Chloride binding capacity and binding isotherms of OPC pastes and mortars. Cement and Concrete Research (1993) 23:247-253.

Eco-mechanical analysis of two lightweight fiber-reinforced cement-based composites

Alessandro P. Fantilli[(1)], Andrea Gorino[(2)] and Bernardino Chiaia[(2)]

[(1), (2)] Department of Structural and Geotechnical Engineering (DISEG)
Politecnico di Torino
Corso Duca degli Abruzzi 24, 10126 Torino, Italy
[(1)] corresponding author: e-mail: alessandro.fantilli@polito.it, web page: http://www.polito.it

ABSTRACT

The mechanical and environmental performances of two different lightweight concretes are compared in the paper. As an optimal compromise between structural and environmental requirements needs to be reached in building materials, to tailor such cement-based composites the so-called eco-mechanical approach is adopted [1].

The first mixture is a traditional lightweight concrete, containing industrial aggregates made with expanded clay (to reduce the weight) and polymeric fibers (to reach a ductile failure) in place of the traditional stone aggregates and steel rebars, respectively [2]. The second mixture is an innovative lightweight cement-based composite, in which recycled rubber from end-of-life tires partially replaces the aggregates [3]. Also in this concrete, polymeric fibers have been used as reinforcement.

Concerning the mechanical properties, the results of two experimental campaigns, both performed on materials (i.e., uniaxial compression tests on cylinders) and on a full-scale structures (i.e., plates in three point bending), are taken into consideration. In particular, the plates have been used to retrofit the sidewalks of a famous bridge in Italy [4]. On the other hand, the carbon footprint, the embodied energy, and the amount of water used to manufacture the two types of concretes, define the environmental impact [1].

If the eco-mechanical analysis is performed at the material level, considering only the compressive strength, the traditional lightweight concrete shows the best performances. Conversely, the plates made with fiber-reinforced rubber concrete behave better than those made with traditional lightweight composite.

As a result, the above-mentioned differences suggest the necessity of a proper definition of the scale (i.e., material or structural) where the eco-mechanical analysis needs to be performed.

REFERENCES

[1] B. Chiaia, A.P. Fantilli, A. Guerini, G. Volpatti, D. Zampini, "Eco-mechanical index for structural concrete", *Construction and Building Materials*, Vol. **67**, pp. 386–392, (2014).

[2] A.P. Fantilli, A. Gorino, B. Chiaia, "Precast plates made with lightweight fiber-reinforced concrete", *Proceedings of the FRC 2014 Joint ACI-fib International Workshop*, pp. 224–234, (2015).

[3] A.P. Fantilli, A. Gorino, B. Chiaia, "Concrete plates made with fiber-reinforced concrete containing end-of-life rubber", *Proceedings of the Eleventh International Symposium on Brittle Matrix Composites* (2015).

[4] A.P. Fantilli, A.D. Cavallo, G. Pistone, "Fiber-reinforced lightweight concrete slabs for the maintenance of the Soleri Viaduct", *Engineering Structures*, Vol. **99**, pp. 184–191, (2015).

Innovative precast concrete structural floor as a part of a HVAC System. The real application experience in a building.

Felipe Pich-Aguilera Baurier*, Pau Casaldàliga† and Ute Muencheberg†

* Picharchitects
c/Ávila 138 4º 1a
, 08018 Barcelona, Spain
e-mail: felipe@picharchitects.com, web page: http://www.picharchitects.com

† Picharchitects
c/Ávila 138 4º 1a
, 08018 Barcelona, Spain
e-mail: p.casaldaliga@picharchitects.com, ute@picharchitects.com web page:
http://www.picharchitects.com

This abstract summarizes the environmental behavior of a precast concrete floor that is located in a new construction building (Barcelona; Leitat Technology Centre. 2014). This concrete structural floor has been designed by Picharchitects.

The building (Leitat Technology Centre with a total floor area 4.800sqm and 5.2M€ of construction cost), will be used for research spaces and laboratories in the areas Biotech, Nanotech and new technologies. The presence of the building tries to connect, with the existing building, creating, abstractly, continuity in the skin texture of the traditional city. Moreover the building was designed with independent components that can be built industrially as well as assembled on site in order to get a very flexible building for future uses, even its deconstruction.

About the construction system is important to notice that the architecture has been designed to act as an interface between the weather conditions outside and inside, not as a watertight barrier, but as a membrane that filters and shares the conditions of the environment. The metal structure acts as an integrated beam lattice, which support the floors composed of a single span that embraces from facade to façade. The front has an enclosure that efficiently meets all physical requirements of the building - structure, filtering natural light, privacy and service-provider.

Going further the structural system and its relationship with the HVAC (Heating, Ventilation and Air Conditioning System) of the building is important the specify: It's a system that uses the thermal mass in precast hollowcore concrete floors to provide low energy heating and cooling. This system is integrated with the structure of a building. The last part of the ductwork system for the supply air consists of hollow core concrete slabs instead of traditional steel ducts. It uses the thermal storage capacity of the building´s structural mass to regulate the internal temperatures. The effectiveness of the building's thermal mass is enhanced by passing supply air through the slab before it enters the room. The slabs work as heat exchangers between the supply air and the rooms. The floor-ceiling slabs serve many purposes: Besides from being the structural floor it conveys fresh air into the building and it serves also as an energy store.

These planks of the system heat the room in two ways:

Radiation: The concrete planks act as lukewarm radiators. They cover the whole ceiling, and has a capable of heating the whole room. In summer, they act as cooling radiators.

Air feed: The slabs are kept at around room temperature by passing air slowly through them. Some of this air is vented into the room to provide heating and cooling and ventilation. Stale air is sucked out of the room into the slabs

We could highlight that the technological research on the field of concrete has to provide important advances on the environmental behavior of our buildings. Future buildings will be excellent test field in order to guarantee the functionality of these solutions.

Lessons Learned from a Life-Cycle Assessment of North American Precast Concrete

Dean Frank* and Emily Lorenz†

* Precast/Prestressed Concrete Institute
200 W. Adams St. Suite 2100
Chicago, Illinois 60606, USA
e-mail: dfrank@pci.org, web page: http://www.pci.org

† independent consultant
1333 W. Greenleaf Ave.
Chicago, Illinois 60626, USA
Email: emilyblorenz@gmail.com - Web page: http://www.sevgen.com

ABSTRACT

Sustainability is a concept that we all strive for in our building designs. This presentation will explain topics related to sustainability, including life-cycle assessment, environmental product declarations, and environmental impacts. The presenter will discuss the importance of considering a full set of environmental impacts during design. Finally, examples of design choices based on various life cycles will be compared. A case study of an LCA performed by North American precast concrete manufacturers will be used to illustrate key points in the presentation.

Reducing energy needs in residential buildings in the Spanish climate through an innovative daily storage based solution

Servando Álvarez*, Jose Antonio Tenorio[1] Rafael Salmerón[2]

[*] Grupo de Termotecnia, Escuela de Ingenieros
Camino de los descubrimientos S/N
41092 Seville, Spain
e-mail: salvarez@us.es, web page: http://www.etsi.us.es/

[1] Institute of Construction Science Eduardo Torroja (CSIC)
Gran Capitán s/n, 08034 Madrid, Spain
e-mail: tenorio@ietcc.csic.es, web page: http://www.ietcc.csic.es/

[2] Grupo de Termotecnia, Escuela de Ingenieros
Camino de los descubrimientos S/N
41092 Seville, Spain
e-mail: rsalmeron@us.es, web page: http://www.etsi.us.es/

ABSTRACT

The framework of the research presented in the paper is a project oriented to promote the use of concrete solutions in buildings based on maximizing the benefits of its thermal inertia for both heating and cooling periods.

The constructive solution developed has to configurations, one for summer (cooling mode) and another for winter (heating mode). In the cooling mode, the constructive solution is similar to a ventilated facade that is formed by a thermally insulated outer layer of concrete, an intermediate air layer and an inner layer of concrete. The inner layer is cooled at night by forced ventilation using an outdoor - outdoor scheme. The heating mode is reached by the addition of a crystal layer in front of the outer of concrete, creating an attached solar space.

The aim of this paper is to show the results about the potential of special concrete walls as solutions to reduce energy demand in residential buildings by heat storage and thermal offset in Spanish Mediterranean climates.

In summer, the concrete building facades are used as heat sinks. The aim is to cool the inner layer of concrete moving outdoor air through the air layer during night taking advantage of the low nigh-time air temperatures. The cool stored is released to the interior spaces when the maximum peak load of the space takes place.

In winter, the inner layer of concrete is heated moving hot air coming from the attached solar space created by adding an external glass to the solution. The heat stored is released to the interior space during evening and early night hours when heating is typically required.

With the aim of select a proper design of the innovative element, the influence of thickness of the inner layer, the inner and outer air chamber, the absorption capacity of the outer layer, the air velocity in the inner space and the thermal lag wrapped in the cooling or heating periods that have been analyzed.

The simulations show that the use of this element is very satisfactory to reduce energy demand in residential buildings in the Spanish climate. The experiments have taken place during 2014. We have obtained important conclusions in the design and possible results with these solutions in real buildings.

M. C. Pacheco*, M. J. Arévalo†, A. Macías††, P. Serna†††

* Ornamental Stone, Products and Construction Works Department (INTROMAC)
Campus Universitario, s/n, 10071 Cáceres, Spain.
e-mail: cpacheco@intromac.com

† Department of Organic and Inorganic Chemistry
Technologic School, University of Extremadura
Avda. de la Universidad s/n, 10004 Cáceres, Spain
e-mail: arevalo@unex.es

†† Mechanic, Energetic and Materials Department
School of Industrial Engineerings, University of Extremadura
Avda. de Elvas s/n, 06071 Badajoz, Spain
email: amacgar@unex.es

††† Institute of Concrete Science and Technology (ICITECH)
Universitat Politècnica de València (UPV)
Camino de Vera / 46022, València, Spain
email: pserna@cst.upv.es

ABSTRACT

Currently there is an increasing awareness about environment and sustainable development because of the high consumption of natural resources and pollution. The demand for concrete is expected to reach 18 billion tons and as a consequence a considerable amount of natural resources will be required for producing construction materials. The utilization of industrial and agricultural waste components, as whole or partial replacement of conventional aggregates, contributes to energy saving and conservation of natural resources. It also solves disposal problem of wastes and helps environmental protection, making concrete industry more environmentally friendly and sustainable. The use of industrial or agricultural waste as aggregate can provide an alternative to conventional methods for the production of lightweight concrete.

Cork is a light, renewable and biodegradable material with a cellular structure. It has a low bulk density (< 300 K/m^3) and viscoelastic behaviour. Its tensile strength is 1,1 MPa and is compressive strength 12,5 MPa. Moreover cork shows low thermal conductivity and good sound absorption. This material, in a granular shape, has been incorporated in concrete as lightweight aggregate improving its density and thermal conductivity, although a reduction of concrete's mechanical properties has been observed. However, there is not any evidence of granulated refuse cork being included as aggregate in concrete production.

This communication constitutes an exploratory study about the use of refuse cork as aggregate in concrete mixtures by partially replacing natural aggregates. Granulated refuse with size between 3.2 to 5 mm has been employed for partially replace natural aggregates in different dosages in concrete specimens and masonry units. Different properties such as hardened density, compressive strength, thermal conductivity and resistance to thermal shock of the casted specimens have been evaluated. Concrete and concrete blocks obtained from natural aggregates have been used as reference. Hardened density, compressive strength and thermal conductivity present a decrease for an increase of the refuse cork dosage, and therefore, this organic aggregate allows making concrete lighter and less thermal conductor.

RETROFITTING WITH AN IAB CONCEPT: A SUSTAINABLE SOLUTION

M. MUNOZ [*], F. ARINEZ[†], R. YADAV[*], M. IULIANO[*] AND B. BRISEGHELLA[*]

[*] University of Fuzhou, College of Civil Engineering
Fujian Province, China
e-mail: miguel.munozma@gmail.com

[†] Universidad Politician de Madrid
E.T.S.I. Caminos, Canales y Puertos
Departamento de Mecánica de Medios Continuos y Teoría de Estructuras
email: faf@he-upm.com

Key words: Integral Abutment Bridges, Bearings, Expansion joints, Retrofitting, Sustainability

Abstract. Integral abutment bridges [IAB] represent an alternative structural solution often better than conventional solutions for bridges with span lengths less than 60 meters. The benefits of this typology, compared to simply supported bridges ("conventional bridge" as used in this paper) are reduction of inspection and maintenance costs due to the absence of expansion joints and bearings; reduction of the failure risk under seismic loads and an improvement in terms of flood water management. The purpose of this work is to evaluate the benefits of retrofitting an existing bridge, converting it into an integral abutment bridge. This procedure will produce more sustainable bridges. This work also presents some methods to assess sustainability in civil constructions to compare the advantages of retrofitting a simply supported bridge. A practical example is provided.

Study of the use of different chemical admixtures in mortars manufactured with recycled sand from CDW

C. Cingolani†, A.I. Torres Gómez*, J. R. Jiménez*, V. Corinaldesi†, E.F. Ledesma*

* Construction Engineering Area. University of Córdoba, Ed. Leonardo Da Vinci, Campus de Rabanales, Ctra. N-IV, km-396, CP 14014, Córdoba, Spain
e-mail: jrjimenez@uco.es

† Università Politecnica delle Marche
Dipartimento SIMAU
Via Brecce Bianche 12, 60131 Ancona, Italy
e-mail: v.corinaldesi@univpm.it

ABSTRACT

Construction and demolition waste (CDW) properly treated and processed in recycling plants can be transformed into recycled aggregates (RA). According to the European Directive 2008/98 / EC, the member states must reach a minimum recycling rate of 70% by 2020. To date, there are numerous investigations of using the coarse fraction of RA in different applications, such as roads and concrete production. However, the use of recycled fine aggregate fraction in concrete manufacture hasn't been widely studied. The incorporation of fine RA decreases the mechanical strength and durability of concrete. The use of chemical admixtures could improve properties of concrete made with the fine fraction of the recycled concrete aggregates [1]. An alternative would be the use of it on the manufacture of mortars for masonry. Recent studies demonstrate the feasibility of replacing up to 50% of natural sand by recycled sand in mortar production, although a higher w/c ratio is needed for achieving the same fresh consistency as a result of the increased absorption of recycled aggregates [2].
In this work, the effects of different chemical admixtures on the properties of mortars made with recycled aggregates from CDW were analyzed: two types of air entraining, a retarder and a superplasticizing admixtures were used. Fresh and hardened mortar properties were studied using two different cement types: CEM II / BL 32.5N and CEM IV / B (V) 32.5N. A 1:6 volumetric cement-to-aggregate ratio was adopted. The results obtained for the mixtures made with recycled sand were compared with the reference mortar based on natural sand. The grading curve of the recycled sand was similar to Faury curve. Both sands used were characterized by the same particle size distribution with a maximum particle size of 4 mm. The w/c ratio was varied case by case in order to ensure a fresh consistency of 175 ± 10mm. The use of chemical admixtures in general decreased the w/c ratio, in particular the use of superplasticizer improved the mechanical strength, but decreased the setting time. Durability properties related to drying shrinkage and capillary water absorption were improved with the incorporation of admixtures.

REFERENCES

[1] Cartuxo, F., de Brito, J., Evangelista, L., Jiménez, J. R., & Ledesma, E. F. "Rheological behaviour of concrete made with fine recycled concrete aggregates–Influence of the superplasticizer." *Constr Build Mat,* Vol. 89, pp. 36-47, (2015).

[2] Ledesma, E. F., Jiménez, J. R., Ayuso, J., Fernández, J. M., & de Brito, J. "Maximum feasible use of recycled sand from construction and demolition waste for eco-mortar production–Part-I: ceramic masonry waste." *J. Clean Prod*, Vol.87, pp. 692-706, (2015).

Sustainability Features of an Elevated Road Corridor under Construction in an Urban Environment

Shishir Bansal[*] and S K Singh[†]

[*] Research Scholar, Environmental Engineering Department, DTU
A 304, Lake View Apartments; G17, Sunder Vihar
New Delhi 110087, India
e-mail: bansal.shishir@gmail.com, Mobile : +91 98101 73245

[†] Professor and Head, Environmental Engineering Department,
Delhi Technological University (DTU), Delhi 110042, India
Email: sksinghdce@gmail.com

ABSTRACT

Background: In the new millennium, Delhi, the capital city of India has experienced a phenomenal growth in vehicular population resulting in choking of the city roads all over Delhi. In order to reduce the travelling time between distinct far ends, express corridors have been planned by Govt. of Delhi. One such corridor is South-East Delhi corridor popularly called as Elevated Road Project over Barapullah Nallah. This is conceived in three phases having nodal locations as Mayur Vihar in East Delhi and Aurobindo Marg in South Delhi with intermediate locations as Sarai Kale Khan and Jawahar Lal Nehru Stadium. An Elevated road, 4 Kms long connecting Sarai Kale Khan and Jawahar Lal Nehru Stadium has already been completed and fully functional in 1st Phase. Work from Nehru Stadium to Aurobindo Marg is at advance stage of construction in 2nd Phase, while the 3rd Phase, which consists of the last link between Sarai Kale Khan and Mayur Vihar to complete the Southeast link has just started with target to complete the whole Project in September 2017. This Paper covers sustainability features of the 2nd Phase of the project.

Main Features: In order to complete the construction in minimum time period, the precast segmental construction technique with pre-stressing couplers for making fully continuous three/four spans has been adopted for a better riding comforts. One of the challenging tasks was to align the corridor through a cluster of services like water mains and High Tension Electric Cables, which could not be dislocated and the corridor was negotiated successfully with in-depth planning for laying the foundations. Second important issues were to maintain the ecology of Silver Oak Park, which had a threat of getting it divided into two parts in order to accommodate a loop passing over it. The part has been saved with proper planning landscaping and saved from getting it divided. Thirdly, the corridor passes over the Sewa Nagar Railway tracks and disallowing the piers in the Railway land forced to designers to provide the 100 m curved span to be constructed with Cantilever Construction technique. Simultaneously, Delhi Metro had also planned a tunnel beneath the Barapullah Corridor crossing it obliquely which put a challenge to the designers to workout a tailor made structure with non-standard spans to accommodate the tunnels. The Field Engineers from both the departments coordinated their construction activities for successful implementation of tunnels as wells as elevated corridor over each other.

Results: The difficulties observed in planning during the construction ahs been well planned and the project is being implemented with minimum dislocation of underground services as well as minimum uprooting of trees falling in the alignment. Use of high strength concrete is expected to result into an acceptable performance of the structure. Fully pre-stressed superstructure has been designed for no tension condition, anywhere, leading to enhanced performance of the structure.

Conclusions: Since the alignment of the corridor was over a drain (Nallah), and other Engineering measures for environmental related issues like use of fly ash, high strength concrete for reducing carbon footprints etc., the project is graded as an Environmentally Sustainable Project.

REFERENCES

[1] Bansal Shishir, Singh S K and Gupta Vinay, "Barapullah Elevated Road Project: Past, Present and Future", ING-IABSE Seminar on Elevated Transport Corridors, Mysore, June 26-27, 2014.

[2] Bansal Shishir, Singh S K and Gupta Vinay, "An Elevated Road over Barapullah Nallah in New Delhi", 4th International FIB Congress 2014, Mumbai, India, Feb 10 to 14, 2014.

Sustainable TBM Tunnels for Tomorrow

Silvino Pompeu-Santos*

* SPS Consulting
Lisbon, Portugal
e-mail: pompeusantos@sapo.pt,
web page: http://www.sps-consulting.pt

Topic: Construction Aspects

- Construction Technologies

ABSTRACT

Tunnels are becoming increasingly used in building infrastructure around the world, for railway and roadway transportation systems, because of both environmental and economic reasons. The TBM ("Tunnel Boring Machine") technique is the most common, nowadays, allowing for a significant reduction of the environmental impact, cost and time of construction. However, the TBM technique still faces important challenges.

In the case of soft soil (e.g., mud) in seismic areas the construction of tunnels with the conventional TBM technique can be unreliable, because, as the connections between precast segments are weak, the strength and the ductility of the tunnel are low then there is the risk of sinking or collapsing.

Furthermore, in the case of long TBM tunnels, for safety reasons, instead of a single tunnel, two separated tunnels are generally adopted each one for a direction of traffic, as well as complex systems of safety galleries for the rescue of users. When these rescue galleries are not possible to build (e.g., underwater tunnels) a third tunnel is in general also adopted. In addition to failing to ensure the necessary reliability, these solutions are obviously very expensive.

To meet these challenges, three innovative concepts have recently been developed, which are the new trends for sustainable tunnels in the future. The TISB ("Tunnel of Improved Seismic Behaviour") concept enables reliable execution of tunnels built with the TBM technique, in soft soil and seismic areas, allowing the tunnel be provided with the adequate resistance and ductility without significantly increasing the cost. The TMG ("Tunnel Multi Gallery") and the TMF ("Tunnel Multi Floor") concepts, respectively for rail and road TBM tunnels, allow a single tube tunnel provide the capabilities usually offered by conventional solutions with two or three tunnels and adopt advanced means for rescue of users, dramatically improving the safety during operation, while significantly reducing costs.

In the paper the description and justification of the three concepts is presented, as well as their application to specific cases.

REFERENCES

[1] S. Pompeu-Santos, "The TMG and TMF Concepts: The Right Approach for Large Tunnel Crossings", *WTC2013- Underground, the Way to the Future,* Geneva, Switzerland (2013)

[2] S. Pompeu-Santos, "Optimised TBM Tunnel Solution for the Fehmarnbelt Fixed Link", *fib Symposium Concrete- Innovation and Design*, Copenhagen, Denmark (2015)

Sustainable Technology for PC Grout Infill

T. Matsuka*, K. Sakai†, S. Tanabe††, R. Kudo††, F. Seki* and T. Urano*

* National Institute of Technology, Kumamoto College
Dept. of Architecture and Civil Engineering
2627 Hirayamashin-Machi, Yatsushiro, Kumamoto, Japan
e-mail: matsuka@kumamoto-nct.ac.jp - Web page: http://www.kumamoto-nct.ac.jp

† Japan Sustainability Institute (JSI)
1-25 Higashi-19 Kita-21, Higashi-ku, Sapporo, Japan
Email: sakai@jsi-ks.jp - Web page: http://www.jsi-ks.jp

†† Hazama Ando Corporation
General Contractors, Architects & Engineers
6-1-20, Akasaka, minato-ku, Tokyo, Japan
Email: tanabe.shigeo@ad-hzm.co.jp - Web page: http://www.ad-hzm.co.jp/

ABSTRACT

In the prestressed concrete (PC) member of post-tension system, after the casting and curing of concrete, the PC tendons in the sheath tube prearranged in the member are tensioned and anchored, and then the sheath tube is grouted. PC grouting is conducted to protect PC tendon from corrosion by keeping it in alkaline environment and to ensure the bond of the tendon and surrounding concrete. As the infill of PC grout influences greatly the serviceability and mechanical performances of a PC structure, it is significant to assure the infill performance. In addition, the enhancement of the efficiency in the grouting execution is required.

There are two types of PC grout which is high viscosity type and ultra-low visicosity type. The high viscosity type grout has an exellent materials segregation resistance. The high viscosity type of PC grout needs high pressure in the grouting execution. Therefore, it takes longer time than ultra-low viscosity type of grout. In addition, sometimes PC grout gets blocked in the sheath tube. On the other hand, the ultra-low viscosity type of PC grout can be executed efficiently with the low pressure and the risk to get blocked is low. However, there is a possibility that the void in the down slope area of the sheath tube is formed due to 'flow ahead phenomenon.'

In this study, the effect of the execution methods on the infill performance of super-low viscosity type of PC grout was examined in the following three cases : (1) general method ; (2) vacum suction method from the end of the sheath tube ; (3) vacum suction method from the end part and intermediate parts of the sheath tube.

The test results showed (1) regardless of the execution methods, the ultra-low viscosity type of PC grout causes the flow-ahead phenomenon, (2) the vacum suction only from the end part of the sheath tube makes a large void in the vicinity of the starting point of the down slope, and (3) the vacume suction from the end and intermeadiate parts of the sheath tube makes the infilling of PC grout 100%.

The super-low viscosity PC grout infilling technology with vacum suction from the end and intermadiate parts of the sheath tube makes the efficient and reliable grouting possible. It can be said that this is a sustainable technology to ensure the long-term safety and serviciability of a PC structure.

The Effectiveness of Thermal Mass in Insulated Walls in Moderate Climates

Martha G. VanGeem*

*Self-employed, Consulting Engineer, PE, LEED AP BD+C, FACI
808 S. School St., Mount Prospect, IL 60056, USA
Email: martha.vangeem@gmail.com - Web page: http://www.vangeemconsulting.com

ABSTRACT

Concrete masonry assemblies have many attributes, including being a versatile material choice for energy efficiency in building envelopes and providing thermal mass. Recently completed simulations of realistic single-family houses shows that thermal mass walls outperform wood-framed walls whether the insulation is on the inside or outside of the thermal mass in the moderate climates defined by ASHRAE 90.1. These climates include cities such as Madrid, Paris, London, Istanbul, Cape Town, Shanghai, Sydney, Buenos Aires, and Mexico City, Washington DC, Memphis, and Los Angeles.

The results show that the house with concrete masonry walls with insulation on the exterior uses 5 to 35% less heating, ventilating and air-conditioning (HVAC) energy than the same house with wood-framed walls. The results also show that the house with concrete masonry walls with insulation on the interior uses 3 to 23% less HVAC energy than the house with wood-framed walls.

EnergyPlus simulations were performed on 607 walls in 15 climate zones (CZ), and for a typical one- and two-story house for an analysis period of one year. Most of the walls were constructed of concrete masonry units (CMU) of different unit weights, various grout spacings in the CMU cores, and different amounts of insulation on the inside, outside, and in the cores of the CMU. The windows in the homes were equally distributed on all four cardinal directions and were 15% of the conditioned floor area, which is 2200 sq. ft. for the two-story house. The windows and energy criteria other than insulation in opaque walls meet the 2012 International Energy Conservation Code (IECC) for each CZ. The research held all factors, other than the opaque sections of the exterior walls, equal for each climate zone for simulations.

Note that results would most likely be even more favorable had passive solar techniques been employed, such as shifting more windows to the south side of the house and allowing a larger range in thermostat set points (they are quite narrow in this study). But even in typical houses, the results are favorable.

TRC multilayer precast façade panel: structural behaviour in freezing-thawing condition

I. G. Colombo[1], M. Colombo[2], and M. di Prisco[3]

Politecnico di Milano, Milano, Italy, [1] isabellagiorgia.colombo@polimi.it
[2] matteo.colombo@polimi.it [3] marco.diprisco@polimi.it

In Europe about 40% of the total energy consumption is due to residential and commercial buildings; in particular, the 70% of this energy is used for heating. To significantly reduce this consumption, it is necessary to energy retrofit existing buildings, because of their large impact on the phenomenon.

In this perspective, in the framework of the European EASEE project, a multi-layer prefabricated façade panel is proposed (maximum dimension 1.50 x 3.30 m^2). The panel is characterized by an internal EPS layer, 100 mm thick, used to transfer the shear, and by two external layers made of textile reinforced concrete (TRC), 10 mm thick. The main advantages of the solution are: the low impact on occupant life, the possibility to obtain the desired finishing and the good durability. This latter aspect is particularly important, especially considering a residual expected building life of at least 30 years. Durability deals both with winter and summer conditions. In this paper the behaviour of the adopted sandwich solution when subjected to freezing and thawing cycles is investigated, while further investigations concerning the effect of sun radiation are still in progress.

The paper presents an experimental investigation carried out at Politecnico di Milano in order to study the mechanical behaviour of both TRC and sandwich solution when exposed to an increasing number of freezing and thawing cycles (up to 500, +4/-18°C) considering both un-cracked and pre-cracked initial conditions. The experimental results are used to calibrate an "ad-hoc" design approach able to take into account the freezing-thawing effect. The results showed a negligible effect on both initial stiffness and maximum bearing capacity of the solution, and a not negligible reduction of the ductility.

(a)

(b)

Figure 1: (a) test façade and (b) specimen tested after 500 cycles

Corresponding author: Isabella Giorgia Colombo

ALKALI-SILICA RESISTANCE OF COAL BOTTOM ASH MORTARS

Cristina Argiz*, Esperanza Menéndez†† and Amparo Moragues†

*† E.T.S. Ingenieros de Caminos, Canales y Puertos. Universidad Politécnica de Madrid
Profesor Aranguren, s/n, Ciudad Universitaria, 28040 Madrid, Spain
Email: cg.argiz@upm.es - Web page: http://www.upm.es

†† Instituto de Ciencias de la Construcción Eduardo Torroja (CSIC)
Serrano Galvache, 4, 28033 Madrid, Spain
Email: emm@ietcc.csic.es - Web page: http://www.ietcc.csic.es

ABSTRACT

It is well-known the efficiency of the fly ash as cement constituent thanks to many studies carried out in the past. However, its small amount produced currently leads to a more limited use. In these days, coal bottom ash is dumped in many cases as a waste generating an environmental problem. This paper contributes to improve the knowledge about this material and check its viability in order to be used mixed with fly ash or alone as a new Portland cement constituent.

In order to check the durability of ground coal bottom ash when is part of a Portland cement, some alkali-silica reaction tests were performed. These test methods provide a means of assessing the potential alkali reactivity of mortars made using blended hydraulic cements.

Blended cements with coal bottom ash, coal fly ash or a mix of them presented a better resistance against alkali-silica reaction with regard to the reference mortars without any addition.

Summing up, it can be highlighted that coal bottom ash could be used in common Portland cements alone or mixed in an optimized percentage with fly ash.

REFERENCES

[1] M. Cheriaf, J. C. Rocha and J. Pera, "Pozzolanic properties of pulverized coal combustion bottom ash", *Cem. Concr. Res.*, Vol. **29**, pp. 1387-1391, (1999).

[2] C. Argiz, E. Menéndez and M.A. Sanjuán, "Effect of mixes made of coal bottom ash and fly ash on the mechanical strength and porosity of Portland cement", *Mater. Construcc.*, Vol. **309**, pp. 49-64, (2013).

[3] C. Argiz, E. Menéndez, A. Moragues and M.A. Sanjuán, "Recent advances in coal bottom ash use as a new common Portland cement constituent", *Structural Engineering International*, Vol. **4/2014**, pp. 503-508, (2014).

[4] C. Argiz, E. Menéndez, A. Moragues and M.A. Sanjuán, "Fly ash characteristics of Spanish coal-fired power plants", *Afinidad*, Vol. **72**, October-November, (2015).

Concrete cracking in marine micro-climates

P. Castro-Borges*, A. A. Torres-Acosta†, M.G. Balancán-Zapata* and J.A. Cabrera-Madrid*

*Centro de Investigación y de Estudios Avanzados del IPN Unidad Mérida,
Antigua Carretera a Progreso, Km 6, 97310, Mérida, Yucatán México
e-mail: pcastro@mda.cinvestav.mx, web page: http://www.mda.cinvestav.mx

†Universidad Marista de Querétaro,
Marte No. 2, Col. Centro, 76000, Querétaro, Querétaro,México.
Permanent affiliation: Instituto Mexicano del Transporte,
Carretera Querétaro-Galindo Km 12 + 000, 76700 Sanfandila, Querétaro, México

ABSTRACT

The mechanism of corrosion-induced concrete cover cracking is very important for durability forecasting of reinforced concrete structures. Accelerated corrosion tests have provided very useful information on corrosion propagation and residual life stages, but tests and data from natural environments are required to validate and corroborate previous findings. Concrete cylinders with different water/cement (w/c) ratios, exposed at three natural sites, 50 m, 100 m and 780 m from the seashore (three micro-climates), in the Port of Progreso, Yucatán, México, were used to measure corrosion parameters such as time-to corrosion initiation, apparent corrosion rate, surface crack propagation, rebar radius loss to generate concrete cover cracking, and rebar pit depth due to natural corrosion. A slight but clear correlation between data of concrete cracking from the three micro-climates was found. The w/c ratio of concrete was the most important parameter to in the durability performance of concrete in such tropical environment. Empirical correlations between natural and accelerated corrosion tests were also obtained to corroborate data available in the literature regarding residual life of corroding reinforced concrete structures.

Keywords: concrete cracking, corrosion initiation, corrosion propagation, micro-climates, marine environment

Corrosion crack pattern at early ages due to pressure rust layer in reinforced concrete

David Galé *, Ángela M.Bazán and Jaime C. Gálvez

Department of Civil Engineering: Construction, School of Civil Engineering, Technical University of Madrid
C/ Profesor Aranguren s/n, 28040 Madrid, Spain
Email:, web page:

ABSTRACT

This paper studies the mechanical effects of rust layer by accelerated corrosion test with the goal of completing cracking models, which do not take into account the penetration process of corrosion products into the porous network. There is no enough research focused on the initial stage of the propagation of the rust products in the porous structure of the surrounding concrete. The numerical and analytical modeling of the cover cracking due to corrosion of concrete usually assume that the pressure of the rust products of the rebar on concrete is delayed due to their penetration in the porous network. The assessment of this delayed time is based on empirical data. The aim of this work is to study in depth the penetration of the rust products in the porous network combined with the assessment of the strain and stresses of the concrete, near to the rebars. Two distinct concretes have been tested, one is a convectional concrete, and the other one includes silica fume. The former has a closer and narrower porous network. Faster growing of the pressure should be expected in the silica fume concrete that surrounds the rebar than in conventional concrete at early stages of the rebar corrosion. The penetration of rust layer in the concrete was measured by using SEM microscopy and strain gauges. The results have shown that the growth of corrosion layer occurs at early ages. Furthermore, the pore structure characteristic appeared to be a significantly contributing factor in the process of corrosion. A good relationship between the production and penetration of the rust products in the network porous and the delaying of the cracking pressure in concrete has been observed.

REFERENCES

[1] S. Guzmán, J.C. Gálvez, and J.M. Sancho, “Modelling of corrosion-induced cover cracking in reinforced concrete by an embedded cohesive crack finite element”, *Engineering Fracture Mechanics,* **93**: 92-107, 2012.

[2] S. Guzmán, J.C. Gálvez, y J.M. Sancho, “Cover cracking of reinforced concrete due to rebar corrosion induced by chloride penetration”, *Cement and Concrete Research*, **41**: 893-902 2011.

[3] Zhao, Yuxi, Yingyao Wu, and Weiliang Jin. "Distribution of millscale on corroded steel bars and penetration of steel corrosion products in concrete."Corrosion Science 66 (2013): 160-168.

[4] Koleva, D. A., et al. "Microstructural analysis of plain and reinforced mortars under chloride-induced deterioration." Cement and concrete research 37.4 (2007): 604-617.

[5] Su, Ray Kai Leung, and Yanlong Zhang. "A double-cylinder model incorporating confinement effects for the analysis of corrosion-caused cover cracking in reinforced concrete structures." Corrosion Science 99 (2015): 205-218.

[6] Zhao, Yuxi, et al. "Composition and expansion coefficient of rust based on X-ray diffraction and thermal analysis." Corrosion Science 53.5 (2011): 1646-1658.

[7] Yüzer, Nabi, Fevziye Aköz, and Nihat Kabay. "Prediction of time to crack initiation in reinforced concrete exposed to chloride." Construction and Building Materials 22.6 (2008): 1100-1107.

[8] Zhao, Yuxi, Jiang Yu, and Weiliang Jin. "Damage analysis and cracking model of reinforced concrete structures with rebar corrosion." Corrosion Science 53.10 (2011): 3388-3397.

Durability of Sustainable Ternary Blended Concrete Containing Blast Furnace Slag and Limestone Filler

Álvaro Fernández*, M. Cruz Alonso, José L. García Calvo, Mercedes Sánchez

Institute for Construction Sciences Eduardo Torroja (IETcc)
Serrano Galvache 4, 28033 Madrid, Spain
Email: alvaroferperez@ietcc.csic.es, mcalonso@ietcc.csic.es, jolgac@ietcc.csic.es, mercesanc@ietcc.csic.es, - Web page: http://www.ietcc.csic.es

ABSTRACT

The partial replacement of Ordinary Portland Cement (OPC) by mineral additions is one of the main ways to increase the sustainability in the construction industry as it reduces the OPC production and consequently, the generation of greenhouse gases. Furthermore, replacement of OPC by mineral additions gives added-value to industrial byproducts. In this context, ternary blends, composed by OPC plus two mineral additions (Blast furnace Slag (BFS), Fly Ash (FA), Silica Fume (SF) or Limestone Filler (LF) are those more commonly used), emerge as a sustainable measure from ecological, technically and economically points of view. There are studies on ternary and quaternary blends dealing with characterisation of the microstructure evolution in relation to hydration changes introduced by blend mineral additions respect to OPC and with the mechanical properties of the cementitious material. However, the durability related aspects are not widely considered.

In the present paper, the physic-mechanical and durability properties of a concrete designed according to sustainable parameters (30%BFS+6%LF) were studied, and compared to those measured in a reference concrete (100% OPC). In both concretes different parameters were evaluated: the evolution in compressive strength (28 and 90 days of curing), the pore structure (28 days), the resistance respect carbonation risk (after 28 and 90 days) during 1 and 2 years of exposure considering two natural environments (Madrid atmosphere sheltered from rain (≅50%RH) and inside laboratory atmosphere <45%RH), and the resistance to natural chloride penetration (28 and 90 days of curing) after 12 and 18 months of exposure in a ponding test.

The ternary concrete is able to achieve similar mechanical properties, or even higher at advanced ages of curing, aided by a higher refinement of the pore structure and a lower total porosity promoted by the mineral additions both at early and at long hydration ages. At short ages the small particle size of LF contributes to increase the density and accelerates the OPC hydration; at longer curing ages, the hydration of BFS contributes to fill and refine the pore structure. This pores size refinement allows lower water capillary absorption coefficient in the ternary concrete than in plain OPC one, thus increasing the ternary concrete resistance against aggressive fluids penetration. Furthermore, the carbonation resistance of ternary concretes show that the carbonation rate is not significantly increased, regardless of the curing time and the environment exposure and in spite of the reduction in OPC content (<36%) with the subsequent portlandite decrease. After 2 years the next carbonated depth were measured: 4.82 and 4.56 mm in OPC concrete, and 6.60 and 5.57 mm in ternary concrete, for Madrid and laboratory atmosphere, respectively. In the case of chloride ingress, higher resistance in the ternary blend is found showing a clear decrease in the Cl^- content at the different penetration depths considered. The pore refinement and the higher binding capacity of ternary blend are responsible for this beneficial effect. All these aspects contribute to the enhancement in mechanical properties, to better control the penetration of aggressive agents that finally extend the initiation period in service life performance, increasing in this way the sustainability of the concrete structure.

Acknowledgements: Authors acknowledge to MINECO Spanish Ministry the financial support (project BIA2011-22760).

Effect of Phase Change Material on Temperature Shifting in Concrete Panels

Piti Sukontasukkul*

* King Mongkut's University of Technology North Bangkok
Department of Civil Engineering
1518 Pracharath I Rd., Bangsue, Bangkok 10800,Thailand
e-mail: piti.kmutnb@gmail.com, web page: http://kmutnb.academia.edu/PitiSukontasukkul

ABSTRACT

This paper describes the experimental results on effect of phase change material (PCM) on the thermal behavior of concrete panels. The investigation was carried out on two types of cementitious materials: normal concrete and geopolymer concrete. The PCM is impregnated into lightweight aggregates and incorporated into concrete during the mixing process. The experiments were conducted using a temperature chamber constructed at KMUTNB. Three thermocouples were installed inside the panel to monitor real time temperature change. During the experiment, the heat is supplied to the panel until the mid-plate temperature reaches the 65oC and then ceased. Experimental results indicated that the existence of phase change material does have markedly effect on the temperature movement inside the panel before and after the peak. For example, prior to the peak, more heat is required to drive the temperature inside the PCM panels to hit the target temperature of 65oC than the non-PCM panels. Also after the peak, the heat tended to remain inside the PCM panels longer than the non-PCM panels.

For any further request, please contact:

King Mongkut's University of Technology North Bangkok
Science and Technology Research Institute (STRI)
1518 Pracharath I Rd., Bangsue, Bangkok 10800,Thailand
Tel: +66 02 555 2000 ext. 1506
Fax: +66 02 587 4337
E-mail: piti.kmutnb@gmail.com

Replacement of Steel with GFRP as Internal Reinforcement for Corrosion-Free Reinforced Concrete Structures

Shamim A. Sheikh[*], Zahra Kharal[+] and Arsalan Tavassoli[**]

[*]Department of Civil Engineering, University of Toronto, Toronto, Canada
sheikh@ecf.utoronto.ca

[+]Department of Civil Engineering, University of Toronto, Toronto, Canada
Zahra.kharal@mail.utoronto.ca

[**]Department of Civil Engineering, University of Toronto, Toronto, Canada
arsalan.tavassoli@mail.utoronto.ca

ABSTRACT

The corrosion of steel in reinforced concrete structures has cost a significant amount of resources globally over the past few decades. In 2010, the total annual cost of corrosion was estimated at US $2.2 trillion which amounted to about 3% of the world's GDP. Obviously, an alternative is needed to build sustainable infrastructure. Glass fibre reinforcement polymer (GFRP) bars present a feasible and cost effective solution to the steel corrosion problem. Despite many advantages of GFRP, most designers are still reluctant to use GFRP as the main reinforcement in concrete members due to its different behavior than steel.

The aim of this paper is to let engineers gain a better understanding of the overall behaviour of GFRP as internal reinforcement so that they have better confidence in using it as a sustainable material. Significant outcomes from an extensive experimental program underway at the University of Toronto will be presented. The part of the program to be discussed in this paper involved testing of 40 GFRP reinforced beams, 60 GFRP direct tension specimens and 20 GFRP confined columns in which the behavior of GFRP-reinforced concrete in flexure, shear, tension and compression was investigated. A new tension-stiffening model was developed that significantly improved the prediction of deflection and stiffness in GFRP-reinforced concrete beams. Another significant conclusion drawn from this research is that GFRP spirals not only can be used efficiently as primary lateral reinforcement in columns but also confine the concrete core in a column more effectively than steel spirals. GFRP bars were also found to resist about 700 MPa compression which is about 60% of their tensile capacity.

Seeking a More Sustainable Structural Concrete by using a Combination of Polyolefin-based fibres and Steel Fibres

M.G. Alberti*, A. Enfedaque* and J.C. Gálvez*

* Departamento de Ingeniería Civil: Construcción, E.T.S de Ingenieros de Caminos, Canales y Puertos, Universidad Politécnica de Madrid. C / Profesor Aranguren, s/n, 28040, Madrid.
e-mail: jaime.galvez@upm.es

ABSTRACT

From the development of steel reinforced concrete (RC), this material has steered towards its supremacy in construction, playing a key-role in our modern societies. The good mechanical performance of steel combined with concrete is widely known. However, steel is rapidly subjected to corrosion when in nature and its durability in the concrete matrix have concerned engineers and industry alike. In recent years, the efforts of plastic industry have allowed the production of a new generation of polyolefin-based macro-fibres that are inert in alkaline environment and provide concrete with structural capacities that enable to reduce or substitute the steel reinforcement. Polyolefin fibres have good tensile properties, abrasion resistance and excellent resistance to chemicals what added to the low cost placed them as an alternative to the conventional reinforcement carried out using steel bars or fibres. Polyolefin Fibre-Reinforced Concrete (PFRC) has considerable residual tensile strengths [1] and both scientists and industry have found significant advances, especially due to the lower cost of the material and the lack of corrosion of the fibres when exposed to hazardous environments.

PFRC has multiple sustainability benefits that justified new research in practice and end-of-life cycles, showing reduced impacts compared with the use of steel [2]. The lower weights needed to reach similar strengths than those found using steel fibres reduce the costs of transportation and the carbon footprint. Derived from the production methods, significant decreases of the carbon emissions were found if compared with those from the production of steel. Plastic fibres are directly mixed with concrete and the handling of this type of fibres is safer and lighter. Consequently, PFRC produces saves from time consuming operations such as the preparation and placing of the wire mesh. The continuous production induces a reduction of labour costs to about half of those using steel [3]. Thus, PFRC has become an appealing solution showing some additional advantages if the complete life cycle is considered [2]. Beyond cost and environmental benefits, some mechanical issues of PFRC should be considered to achieve a more sustainable concrete. The control of the cracking processes are directly related with durability of RC. For the initial crack openings, related to Service Limit States (SLS), the crack width is associated with the penetration of water and other components that can both deteriorate concrete and accelerate the corrosion of the steel reinforcement.

The intention of this study is to discuss the influencing parameters of the behaviour of PFRC and in particular the possible benefits in terms of sustainability. The mechanical properties and fracture behaviour of PFRC has been assessed to sustain the proposed substitution of steel-bar reinforcement. Furthermore, with the aim of producing a high-performance concrete in terms of sustainability, the crack openings at SLS have been improved by combining a small amount of 35mm-long steel-hooked fibres with a medium amount of 60mm-long polyolefin fibres. The latter provides an efficient use of the materials, as well as a better mechanical behaviour in both service and failure states and therefore assures an improved durability for the concrete piece.

REFERENCES

[1] M. G. Alberti, A. Enfedaque and J. C. Gálvez, “On the mechanical properties and fracture behavior of polyolefin fiber-reinforced self-compacting concrete,” *Construction and Building Materials,* vol. Volume 55, pp. 274-288, 2014.

[2] S. Yin, T. R., M. Sheehan, M. Combe and T. Collister, “A life cycle assessment of recycled polypropylene fibre in concrete footpaths,” *Journal of Cleaner Production,* 2015.

[3] T. Ochi, S. Okubo and K. Fukui, “Development of recycled PET fiber and its application as concrete-reinforcing fiber,” *Cement and Concrete Composites,* vol. 29(6), pp. 448-455, 2007.

The damage of calcium sulfoanluminate (CSA) cement paste partially immersed in Na_2CO_3 solution

Zanqun Liu [1,*], Le Hou[1], Xiangling Li [1], Dehua Deng[1], Geert De Schutter 2

1 School of Civil Engineering, Central South University, Changsha, Hunan 410075, PR China

2 Magnel Laboratory for Concrete Research, Department of Structural Engineering, Ghent University, Ghent 9052, Belgium

Corresponding Author email: zanqun.liu@csu.edu.cn

Abstract: Currently, salt weathering of concrete is a topic being paid attention. However, if there exist chemical reactions between cement hydration products and salt solution, the salt weathering of concrete should be carefully defined, such as sulfate salt weathering of concrete. In the presented paper, the study was carried out on the calcium sulfoanluminate (CSA) cement paste partially exposed to Na_2CO_3 solution. The CSA cement paste specimen with the size of 40mm*10mm*160mm was immersed in the 10% Na_2CO_3 solution at 40^oC to accelerate the chemical reaction, after the chemical reaction finished, the paste specimen was partially immersed in 10% Na_2CO_3 solution again. As reference, the uncontaminated CSA paste specimen was also partially exposed to 10% Na_2CO_3 solution under the same exposure condition of 20 ^oC and 60% RH. The damage difference of two pastes was compared to offer further evidences of salt weathering of concrete.

The study will offer more results to disclosed the salt weathering o

Solving the Paradox of the use of HSC for Reducing Environmental Impact and Increasing Sustainability

Jéssika Pacheco[1], Lígia Doniak[2], Mariana Carvalho [3], Paulo Helene[*]

[1] PhD Engenharia
Visconde de Ouro Preto street, 201 – 01303-060. Sao Paulo. SP. Brazil
e-mail: jessika.pacheco@concretophd.com.br, web page: http://www.phd.eng.br/

[3] PhD Engenharia
e-mail: ligia.doniak@concretophd.com.br

[4] PhD Engenharia
e-mail: mariana.carvalho@concretophd.com.br

[*] Full Professor at Universidade de São Paulo. PhD Engenharia
e-mail: paulo.helene@concretophd.com.br

ABSTRACT

The concern about the depletion of natural resources and the environmental pollution is increasing in the construction sector. Paradoxically, the society and the main sustainability indexes in construction control organizations have given little importance to the concrete, which is the industrial product most widely used on the planet, to improve the life quality of society. Despite the concrete structures are rarely considered in established sustainability programs in construction, several studies have been developed in order to quantify and minimize their environmental impacts, which are related to the structural design and the physical and mechanical properties of the concrete. In this context, this article points out some concepts of environmental management and proposes, with significant examples, the observation of new and interesting sustainability criteria for the use of structural concrete, demonstrating the employment advantage of high strength concrete (HSC).

A STUDY ON THE CRACK DISTRIBUTION AND CHARACTERISTICS OF A CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

HJ JV RENSBURG[*†], KJ JENKINS[†]

[*] Aurecon South Africa (Pty) Ltd
Aurecon Centre, 1 Century City Drive, Waterford Precinct,
Century City, 7441, South Arica
e-mail: Henning.jvr@aurecongroup.com, www.aurecongroup.com

[†] University of Stellenbosch (US)
Institute for Transport Technology, University Stellenbosch
Private Bag X1, Matieland, 7602, South Africa
email: kjenkins@sun.ac.za, www.sun.ac.za

Key words: CRCP, Concrete, Pavements, Environment, Shrinkage, Cracks

Abstract: Rigid pavements are used throughout the continuously expanding infrastructure in South Africa because of their durability and their minimal maintenance requirements. As budgets for pavement construction decrease, with clients still wanting the same quality product, the need has arisen to develop more accurate models to better predict pavement performance during its lifetime.

Crack distributions in rigid pavements significantly affect the durability of the pavement, but little is known about the exact effect that material properties, loads and environmental factors play in the spacing of cracks. The design that is applied considers only single mix proportions and environmental conditions to deliver a final design life. But, mix proportions and environmental conditions do however vary during construction and during the pavement's life.

Various studies have been done on the performance of continuously reinforced concrete pavement (CRCP) and factors that influence it. Climatic conditions and the material properties of the concrete are the two most important factors affecting CRCP performance, with each site having its own micro environment (that changes hourly), and considerable variance in the material used in each concrete batch. It remains the case that even if a design is executed with averages in mind, temperature, wind, humidity and other governing factors change hourly and are different for each month of the year.

This paper focusses on the collection of actual material, climatic and crack spacing data throughout construction as well as a year after, and reports on actual observations. All of the collected data was then analysed by using a model setup by Associate Professor L.J.M. Houben of TU Delft, which calculates the induced and accrued stress at short time intervals throughout the life. The final output of this model is the predicted crack spacing for a given

environmental and material set.

CRCP crack spacing designs were similarly done with the actual materials used as well as the environmental conditions at time of construction and compared to the actual cracks observed on site as well as the crack distributions determined with Houben's model.

With better understanding of the uncertainty in design predictions, better confidence can be achieved in the final output of the design. In addition, with better confidence the safety factors built into designs could be reduced, bringing down cost of CRCP whilst delivering a good product to the client.

The most significant contribution of this paper would be to create an understanding that there might be a need for a "concrete construction embargo period" or extended and more advanced curing required.

REFERENCES

[1] Houben, L.J.M., Structural Design of Pavements – Part IV: Design of Concrete Pavements Lecture Notes CT4860, Faculty of Civil Engineering and Geosciences, TU Delft, (2006).
[2] Uno, P.J., Plastic Shrinkage Cracking and Evaporation Formulas. ACI Materials Journal, (1998).
[3] Perrie, B & Rossmann D. Concrete Road Construction, Cement & Concrete Institute, (2009)
[4] Carino, NJ., Clifton, JR., Prediction of Cracking in Reinforced Concrete Structures, NISTIR 5634, 1995

Practical Evaluation of Rapid Tests for Assessing the Chloride Resistance of Concretes containing Silica Fume

A.A. Ramezanianpour*, A. Pilvar† and H. Rajaie†

* Department of Civil & Environmental Engineering Amirkabir University of Technology, Tehran, Iran
e-mail: aaramce@aut.ac.ir

† Department of Civil & Environmental Engineering Amirkabir University of Technology, Tehran, Iran
Email: amir63p@aut.ac.ir, rajaieh@aut.ac.ir

ABSTRACT

The present study is an exploratory research that appraise and compare the performance of four rapid tests for assessing the chloride penetration of concrete; Rapid Chloride Permeability Test (RCPT), Rapid Chloride Migration Test (RCMT), Surface Electrical Resistivity (SR) and Modified Rapid Chloride Permeability Test (MRCPT). Due to the concern raised by some scholars about the effect that the conductivity of the pore solution impinges upon the results on some of these rapid tests, silica fume was used as supplementary cementitious material in portions of 7.5% and 15%. All four methods exhibited substantial reduction in the chloride permeability of concrete mixtures containing silica fume compared to the control mixture, at the ages of 28 and 90 days. The increase in performance caused by silica fume usage was significant for RCPT and SR methods, moderate for RCMT and marginal for MRCPT. The results show that the variation in the conductivity of the pore solution significantly alters the results of SR and RCPT tests, and marginally alters those of MRCPT.

Keywords: Concrete; Chloride permeability; conductivity; pore solution.

Calcium hydroxide curing for accelerated carbonation testing of high volume fly ash cementitious blends

Rui Reis*, Aires Camões*, Manuel Ribeiro† and Raphaele Malheiro*

* Centre for Territory, Environment and Construction (CTAC)
University of Minho
Campus de Azurém, Guimarães, Portugal
e-mail: ruicunhareis@gmail.com; aires@civil.uminho.pt; raphamalheiro@gmail.com - Web page: http://www.ctac.uminho.pt

† UIDM, ESTG, Polytechnic Institute of Viana do Castelo
4900-347, Viana do Castelo, Portugal
Email: ribeiro@estg.ipvc.pt - Web page: http://uidm.estg.ipvc.pt

ABSTRACT

During wet curing, the alkali concrete compounds, such as calcium hydroxide, can be leached out to the curing solution, due to the pH gradient between concrete and curing solution. In the presence of high volume fly ash cementitious blends, there is a decrease in concrete pH that may further magnify the problem. In this context it was carried out a research in mortars with an original composition of high volume fly ash and calcium hydroxide. These were exposed to water curing and water saturated with calcium hydroxide curing. The results show that the introduction of calcium hydroxide in the curing solution, provides a slightly enhancement of carbonation resistance. Based on the obtained results, the incorporation of calcium hydroxide in the initial composition seems to be useful to develop extra strength to carbonation of high volume of fly ash concrete.

Carbonation-resistant evaluation of the fly-ash concrete in consideration of the pozzolanic reaction

First Kenichi Imagawa*, Second Akio Koyama†

* Graduate School of Science and Technology,
Meiji Univ.
214-8571 kanagawa, Japan
e-mail: mosac.in.the.dark@gmail.com

†Dept. of Architecture Faculty of Science and Technology, Dr.Eng
Meiji Univ.
214-8571 kanagawa, Japan
e-mail: akoya@meiji.ac.jp

ABSTRACT

There are opinions that concretes which used fly-ash for as mixture materials are superior in durability compared with port-land cement plain concrete by characteristics such as the formation of elaborate structure and long-term strength development by the pozzolanic reaction. In contrast, when executes durable evaluations of fly-ash concretes by accelerated tests, there is particularly difficult to evaluate potential ability in carbonation resistance appropriately, because it is exposed to extremely severe from true environment before the progress of the pozzolanic reaction.
We thought that it was necessary to activate the pozzolanic reaction before accelerated carbonation tests so that the formation of elaborate structure by pozzolanic reaction if targeted the tests. Firstly, sealed the specimen side of test pieces, and took treatment of them in environment temperature 40 degrees Celsius. Thereafter, examined accelerated carbonation tests, compressive strength tests, and quantitative analysis of the Calcium hydroxide by the differential thermal analysis method.
As a result, it was revealed that the progress of the pozzolanic reaction depends on the temperature from compressive strength tests and quantitative analysis of the Calcium hydroxide, and incorporated the formation of elaborate structure by the pozzolanic reaction in the carbonation resistant, it became clear that approximately 20% evaluation level improved on the average. From this, it was not only expansion of the utilization of the industrial by-product to use fly-ash concrete, and the possibility that an aspect the improvement durability of the concrete could contribute to sustainability was suggested.

REFERENCES

[1] M. D. A. Thomas; J. D. Matthews, “Carbonation of fly ash concrete”, Magazine of Concrete Research, Vol. 44, pp. 217-228, 1992.

[2] S. Wada, and M. Abe, K. Yanagi, K. Fujita, “Experimental Study on Carbonation, Watertightness and Salt Interruption of Fly-Ash Concrete”, Proceedings of the Japan Concrete Institute Vol. 20 (2), pp.121-126, 1998.

CHANGES IN CHLORIDE PENETRATION PROPERTIES CAUSED BY REACTION BETWEEN SULFATE IONS AND CEMENT HYDRATES

YOSHITATA KATO[1], SATOKO NAOMACHI[2] AND EMA KATO[3]

1 Department of Civil Engineering, Faculty of Science and Technology
Tokyo University of Science
2641 Yamazaki, Noda-shi, Chiba, Japan
email: katoyosh@rs.tus.ac.jp, www.rs.tus.ac.jp/concrete/index.htm

2 Department of Civil Engineering, Graduate School of Science and Technology
Tokyo University of Science
2641 Yamazaki, Noda-shi, Chiba, Japan
email: j7614620@ed.tus.ac.jp

3 Structural Mechanics Group
Port and Airport Research Institute
3-1-1 Nagase,Yokosuka, Kanagawa, Japan
e-ail: katoh-e@pari.go.jp

Key words: Chloride binding, Sulfate ion, Friedel's salt, Kuzel's salt

Abstract. Many studies have focused only on the penetration of chloride ions. However, seawater contains various other ions such as sulfate and magnesium. Coexisting ions in seawater cause an electric effect and deterioration of hardened cement paste, which means that sulfate and magnesium ions react with CH or C-S-H, and generate gypsum dihydrate and brucite. Based on our previous research, chloride penetration was suppressed in all solutions compared with that of the NaCl solution. This is believed to be due to the chemical reaction between sulfate ions and cement hydrates. It is well known that when chloride ions from environmental solutions penetrate into concrete, some of them are captured by the cement hydrates; this is called chloride binding. It is considered that the chloride binding affects the chloride penetration, but there have been few studies on the influence of coexisting ions on chloride binding.

The present study examined the effect of sulfate ions on chloride ion penetration properties by conducting an immersion test. A reaction test was also conducted to understand the influence of sulfate ions on chloride binding. From the immersion test results, chloride penetration into the mortar was suppressed until the immersion period of 476 days, but was accelerated during the immersion period of 476 to 792 days. It is considered that the suppressive effect was due to the influence of the pores filled with gypsum dihydrate produced by the reaction between cement hydrates and sulfate ions, and the accelerative effect was due to the increment of free chloride ions in the pore solution, which can be presumed by the reduction of bound chloride amount caused by sulfate ions.

Changes in microstructure and pore structure of low-clinker cementitious materials during early stages of carbonation

M. BERTIN*[1], O. OMIKRINE-METALSSI[1], V. BAROGHEL-BOUNY[1] and M. SAILLIO[2]

[1] Université Paris-Est, MAST, FM2D, IFSTTAR, F-77447 Marne-la-Vallée, France

[2] Université Paris-Est, MAST, CPDM, IFSTTAR, F-77447 Marne-la-Vallée, France

Key words: Carbonation, drying, cement paste, slag, early age, pore structure

ABSTRACT

Carbonation is one of the main causes of reinforced concrete damage. It leads to decrease the pH of the concrete pore solution and to $CaCO_3$ formation from the reaction between CO_2 and cement hydrates. The mechanisms of carbonation are complex in low-clinker cementitious materials. At a given age, the hydration degree in low-clinker cementitious materials is reduced compared to CEM I materials which is due to the slower reaction of mineral additives and leads to the underdeveloped of microstructure. Therefore, the coupling between hydration, drying and carbonation at early age needs to be analysed, in order to understand and predict the durability of low-clinker cementitious materials. In this work, the coupled process leads to a faster drying of GGBS (Ground Granulated Blastfurnace Slag) cement paste at early age compared to the CEM I case. However, this trend changes when the GGBS reactions occur that are confirmed by the MIP results. Moreover, the carbonation depth is higher in the CEM I case due to a coarser pore structure as highlighted by MIP data.

Corresponding author: matthieu.bertin@ifsttar.fr

Chloride Diffusion in Alkali Activated Concrete

Olalekan O. Ojedokun* and Pal S. Mangat†

* Centre for Infrastructure Management, Materials & Engineering Research Institute, Sheffield Hallam University, Howard Street, Sheffield, S1 1WB, UK
e-mail: a5029351@my.shu.ac.uk and p.s.mangat@shu.ac.uk
web page: https://www.shu.ac.uk/

ABSTRACT

The corrosion resistance of steel reinforcement embedded in an alkali activated cementitious material (AACM) developed by Sheffield Hallam University (SHU) is being investigated. Two main initiators of corrosion, chloride diffusion and carbonation are being considered. This paper will present the results of chloride diffusion in the AACM concrete compositions under long term exposure (up to 180 days) by immersion in a 5% sodium chloride solution.

Different mix compositions of the AACM concrete (four grades of mixes) suitable for structural application have been selected, representing different concentrations of the alkali activator and different binder and aggregate ratios. Parallel investigations on control samples of normal concrete of similar strength have been conducted. The chloride diffusion profiles with depth have been obtained.

The results show a good correlation of chloride diffusion with Fick's second law of diffusion. A general reduction of chloride ion content within the AACM concrete matrix was observed compared to the control samples of normal concrete. Low liquid/binder ratio has a positive impact on strength, shrinkage and chloride diffusion of AACM concrete.

Coal bottom ash research program focused to evaluate a potential Portland cement constituent

Miguel A. Sanjuán*, Esperanza Menéndez†, Cristina Argiz†† and Amparo Moragues††

* Instituto Español del Cemento y sus Aplicaciones (IECA)
José Abascal, 53, 28003 Madrid, Spain
Email: masanjuan@ieca.es, web page: http://www.ieca.es

† Instituto de Ciencias de la Construcción Eduardo Torroja (CSIC)
Serrano Galvache, 4, 28033 Madrid, Spain
Email: emm@ietcc.csic.es - Web page: http://www.ietcc.csic.es

†† E.T.S. Ingenieros de Caminos, Canales y Puertos. Universidad Politécnica de Madrid
Profesor Aranguren, s/n, Ciudad Universitaria, 28040 Madrid, Spain
Email: cg.argiz@upm.es - Web page: http://www.upm.es

ABSTRACT

Coal bottom ash is a by-product of the coal combustion produced in electrical power stations. It is formed together with the coal fly ash in the same boiler. Then, I would be possible to find several similarities with regard to their chemical composition and mineralogical phases. However, the main characteristic recognised in these ashes is their quite different grain size. This fact could have an important effect on the chemical composition as well as on the mineralogical phases of both ashes. Therefore, the first step within this research program was to get a similar grain size, which was reached by bottom ash grinding. The second step was to compare both ashes from a mechanical, chemical, mineralogical and durable point of view. This comparison helped to evaluate the potential of the coal bottom ash as a Portland cement constituent. Finally, the third step was to check the viability of the ground coal bottom ash as a Portland cement constituent from a performance point of view.

The considered mechanical tests were 28-days compressive strength and flexure strength in order to classify the blended cement with regard to the strength. But also, 7, 14 and 90 days compressive and flexure strength were performed. Mechanical test results in ground coal bottom ash showed a good performance, which was similar to that of fly ash or even better.

Durability tests were planned taken into account those properties in which coal ashes do not improve significantly the blended cement performance: Natural carbonation, frost-thaw resistance, alkali-silica reaction and sulphate resistance.

Natural carbonation tests were developed according to the European standard EN 112011:2007 "Products and systems for the protection and repair of concrete structures -Test methods- Determination of carbonation depth in hardened concrete by the phenolphthalein method". Ground coal bottom ash mortars showed a worse carbonation resistance than the reference mortars without any addition. However, the carbonation resistance was the same in comparison to fly ash mortars.

Frost-thaw resistance tests after 28 and 42 cycles showed that ash mortars were lesser resistant than the reference mortars without any addition. Nevertheless, coal bottom ash mortars showed a better performance than coal fly ash mortars.

Finally, it can be highlighted that alkali-silica reaction and sulphate resistance were the only two durable properties considered in this research program in which a clear improvement was evidenced.

REFERENCES

[1] M. Cheriaf, J. C. Rocha and J. Pera, "Pozzolanic properties of pulverized coal combustion bottom ash", *Cem. Concr. Res.*, Vol. **29**, pp. 1387-1391, (1999).

[2] J. Khunthongkeaw, S. Tangtermsirikul and T. Leelawat, "A study on carbonation depth prediction for fly ash concrete", *Constr. Build. Mater.,* Vol. **20**, pp. 744–753, (2006).

Concrete as a radon barrier and its characterization

P. Linares*, C. Andrade† y D. Baza†

*Eduardo Torroja Institute for construction sciences (IETcc)
Spanish Research High Council
2 Serrano Galvache, St
Madrid, Spain
e-mail: plinares@ietcc.csic.es, web page: http://www.ietcc.csic.es/index.php/es/

ABSTRACT

Radon gas is a broadly known cause for lung cancer. Radon mainly enters buildings by convection though cracks and by diffusion though the buildings envelope material mass.

There are several ways of preventing this, such as sealing cracks or sub slab ventilation, among which we can outline using concrete as a radon barrier.

Concrete is a porous material which due to its diffusion coefficient generally allows an amount of gas to be diffunded though its pores. Radon diffusion coefficient can vary in concretes commonly used in buildings from 10^{-6} to 10^{-11} m^2/s. Because concrete is used in relatively quite thick layers to build building envelopes, around 30 cm, diffusion through its mass can be controlled.

However determination of radon diffusion coefficient in concrete is not a simple task. There is not a general standard which determines the test procedure, radon sources are not that inexpensive nor easy to acquire nor alpha radiation sensors to be able to detect radon gas.

Other tests or alternative parameters could be used, such as non radioactive gases diffusion coefficient tests or even permeability coefficients. All these parameters are dependant of materials porosity. There are already proposed generic correlations in scientific literature for both relationships.

This paper shows the results of a comprehensive research that has been carried out to analyse these generic correlations and to propose specific ones. A diffusion chamber has been designed. Two types of concrete mixes have been studied, with two different curing processes and three humidity contents. Each case has been tested to get oxygen diffusion and permeability coefficients, as well as some radon diffusion coefficients. The obtained oxygen diffusion coefficients with the designed diffusion chamber are similar to those presented in literature.

REFERENCES

[1] WORLD HEALTH ORGANIZATION. Handbook on indoor radon. A public health perspective [on line].

<http://whqlibdoc.who.int/publications/2009/9789241547673_eng.pdf>. [Consulta: 16-06-2015].

[2] GABER K. Influence of mix proportions and components on the diffusion coefficient and the permeability of concrete. Darmstadt Concrete 3 (1988) p. 39-48.

Corrosion protection evaluation of galvanized steel reinforced concrete for service life extension in chloride aggressive environments

Francisco Javier Luna Molina[*], María Cruz Alonso Alonso[*], Rocío Jarabo Centenero[*], Mercedes Sánchez Moreno[*] and Enrique Hernández Montes[†]

[*] Instituto de Ciencias de la Construcción Eduardo Torroja (IETcc)
Consejo Superior de Investigaciones Científicas (CSIC)
C/ Serrano Galvache, 4, 28033 Madrid, España
e-mail: j.luna@ietcc.csic.es, web page: http://www.ietcc.csic.es

[†] Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos (ETSICCP)
Universidad de Granada (UGR)
Calle Doctor Severo Ochoa, s/n, 18001 Granada, España

ABSTRACT

Durability loss of concrete structures is mainly questioned due to the risk of steel rebar corrosion in aggressive environments with further influence in the service life performance of the structure. Hot-dip galvanizing of the steel reinforcement is a competitive solution to enlarge the service life if risk of concrete carbonation exists or chlorides can reach the rebar level.

The identification of galvanized coating protection capacity is questioned and the quantification of the coating loss in aggressive environments has not been paid special attention.

In the present research, concrete with 100% ordinary Portland cement (OPC) and concrete with blend cement containing blast furnace slags and limestone filler (SL) have been used to fabricate specimens embedding galvanized rebars. After the chloride exposure of the samples, the galvanized coating thickness loss was theoretically estimated through corrosion rate measurements and the real coating thickness loss was identified by microscopic characterization.

The theoretical galvanized coating thickness loss was higher for the concrete including BFS (Figure 1) and the microscopic characterization confirmed this prevision. The study of the initial and residual thickness in several zones of the rebars showed that galvanized coating thickness loss is not significantly affected by the rebar zone. The Figure 2 shows this result for the case of SL concrete. For a similar age, a lower content of chlorides at the rebar level was found in the concrete made with blended cement, as consequence of the binding effect of BFS that retard the penetration of chlorides. Both phenomena affect the duration of the corrosion initiation period of service life.

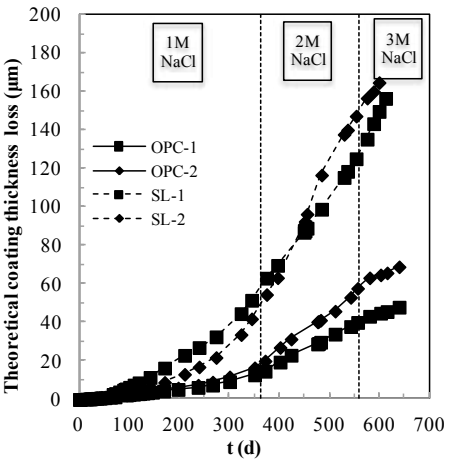

Figure 1: Evolution on time of the theoretical galvanized coating thickness loss

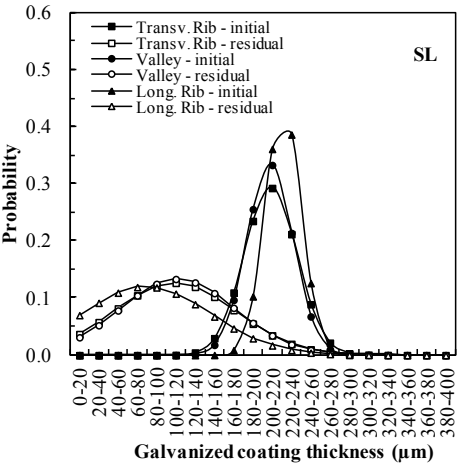

Figure 2: Comparison between the residual thickness of rebars for the SL case and the initial values

Eco-mechanical analysis of tyres-fiber-reinforced cement-based composites

Alessandro P. Fantilli[(1)], Raffaele Furnari[(2)] , Maurizio Guadagnini [(3)], Bernardino Chiaia[(2)]

[(1), (2)] Department of Structural and Geotechnical Engineering (DISEG)
Politecnico di Torino
Corso Duca degli Abruzzi 24, 10126 Torino, Italy
[(3)] Department of Civil and Structural Engineering
University of Sheffield
Sir Frederick Mappin Building, Mappin Street, Sheffield, UK, S1 3JD
[(1)] corresponding author: e-mail: alessandro.fantilli@polito.it, web page: http://www.polito.it

ABSTRACT

The disposal of waste tyres is a serious worldwide environmental problem. However, tyres consist of high-quality and high-strength raw materials, including steel, which can be effectively reused in several engineering applications. More specifically, some tyre-fiber-reinforced concrete (TFRC) mixtures are investigated in this paper. Through the so-called eco-mechanical analysis [1], the best TFCR, having the highest mechanical and environmental performances, is selected.

Concerning the structural behaviour, the results of a large experimental campaign, included in the programme of the European funded Anagennisi Project, are taken into consideration. Two amounts of macro fibers, i.e. 30 and 45 kg/m^3, used to reinforce slabs on grade and suspended slabs, respectively, have been realised with different contents of industrial and recycled fibres from tyre cords [2]. The mechanical performances of such composites have been measured by means of three-point bending tests perfomed in accordance with the British Standards [3]. Moreover, to evaluate the structural performances, the crack width of ideal RC ties, made with the TFRC mixtures, can be theoretically predicted by means of the block model introduced by Fantilli and Chiaia [4].

On the other hand, the carbon footprint, the embodied energy, and the amount of water used to manufacture the TFRC, define the Ecological index. [1]

As a result, recycled tyre-fibers can reduce the crack width during the serviceability stage of concrete structures, and therefore can substitute the manufactured fibres without penalising the structural performances. However, a small volume of tyres-fibers (0.5% in volume) combined with 0,1% in volume of industrial fibers, seems to provide the best combination. Infact, the synergetic effect of both the fibres enhances the concrete performances and, at the same time, ensures a low environmental impact.

REFERENCES

[1] B. Chiaia, A.P. Fantilli, A. Guerini, G. Volpatti, D. Zampini, “Eco-mechanical index for structural concrete”, *Construction and Building Materials*, Vol. **67**, pp. 386–392, (2014).

[2] Papastergiou P. et al., Technical Report, 5th series of SFRC prism tests for Twintec Ltd, United Kingdom (2015).

[3] BS EN 14651, 2005, Test method for metallic fibered concrete — Measuring the flexural tensile strength (limit of proportionality (LOP), residual), British Standard Institution, London, United Kingdom.

[4] B. Chiaia, A.P. Fantilli, “Golden Ratio in the Crack Pattern of Reinforced Concrete Structures”, *ASCE Journal of Engineering Mechanics*, V. **139**, pp. (2013).

Effectiveness of Various Shrinkage Prediction Models for Concrete Made of Crushed Clay Bricks as Coarse Aggregate

Syed I. Ahmad*† and S. Roy†

† Department of Civil Engineering
Bangladesh University of Engineering and Technology
Dhaka 1000, Bangladesh
e-mail: siahmad@ce.buet.ac.bd, web page: http://www.buet.ac.bd

ABSTRACT

Due to scarcity of natural stone, concrete made of crushed clay brick as coarse aggregate is extensively used in Bangladesh for construction of different types of structure from residential and commercial buildings to short span bridges. Previous studies have shown that properties of crushed clay brick aggregate concrete vary considerably from concrete of equivalent strength but made from natural stone aggregate [1,2] As shrinkage is influenced by many factors that include constituent materials, relative humidity and temperature, it is imperative to see the effectiveness of various widely used shrinkage prediction models for concrete made of crushed clay brick as coarse aggregate in a hot and humid climate in Bangladesh. For this, concrete having three different target strengths i.e. 17.2, 24 and 27.5 MPa are produced using crushed clay brick aggregate in the laboratory as per American Concrete Institute (ACI) mix design method. Test specimens are prepared from these three types of concrete as per ASTM C490 [3]. Shrinkage of these specimens is then measured as per ASTM C 157 [4] for up to 150 days. Laboratory measured data are then compared with prediction by three well known shrinkage prediction models i.e. ACI 209 model [5], CEB-FIP 90 model [6] and GL 2000 model [7]. Comparison of test and model prediction data shows that none of these models accurately predict the shrinkage of brick aggregate concrete. Using statistical tools, it is found that of these three, prediction by GL2000 is closest to the experimental data.

REFERENCES

[1] Akhtaruzzaman A.A, and Hasnat A., "Properties of concrete using crushed brick as aggregate", Concr.lnt .Des. Constr. 5(2), pp.58- 63 (1983).

[2] Ahmad, S.I. and Roy, S., "Creep Behavior and its prediction for normal strength concrete made from crushed clay bricks as coarse aggregate", J. Mater. Civ. Eng., 24(3), 308-314, (2012).

[3] ASTM, "Standard Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete", ASTM C 490, West Conshohocken, PA, (2000).

[4] ASTM, "Standard test method for length change of hydraulic cement mortar and concrete", ASTM C 157, West Conshohocken, PA, (2003).

[5] American Concrete Institute (ACI), "Prediction of creep, shrinkage and temperature effects in concrete structures." ACI 209R, Famington Hills, MI (1992).

[6] European Committee for Standardization. "Eurocode 2: Design of concrete structures—Part 1: General rules and rules for buildings." prEN 1992-1-1, Brussels, Belgium (2002).

[7] Gardner, N. J., and Lockman, M. J. "Design provision for drying shrinkage and creep for normal-strength concrete." ACI Mater. J., 98(2), 159–167 (2001).

Effect of incorporating Sugarcane Bagasse Ash (SCBA) in mortar to examine durability of sulfate attack

Alireza Joshaghani * and Ali Akbar Ramezanianpour †

* PhD Candidate, Civil Engineering
Zachry Department of Civil Engineering, Texas A&M University
College Station, Tx 77843-3136 USA
Email: joshaghani@tamu.edu

† Head of concrete technology and durability research center (CTDRC)
Department of Civil Engineering, Amirkabir University of Technology
Concrete Technology and Durability Research Center, No. 424, Hafez St., Tehran 15875-4413, Iran
Email: aaramce@aut.ac.ir - Web page: http://www.aut.ac.ir/ctdr/aaramce.htm

ABSTRACT

Utilization of various supplementary cementitious materials significantly influences fresh and hardened properties of mortar. Sugarcane bagasse ash is a by-product from sugar industries and can be used as supplementary cementitious material in concrete. In the present work an experimental research was carried out to investigate the influence of residual sugarcane bagasse ashes in the mechanical properties of mortar and durability. The aim of this study is to optimize the quality of sugarcane bagasse ash (BA) and to evaluate sulfate resistance of mortars containing bagasse ash (BA). In this study, the optimum temperature and duration of burning were determined. Then various experiments were carried out to get sulfate resistance of mortars containing 0, 10, 15, 20, 25 and 30% bagasse ash to examine durability. Tests included measuring concrete samples weight loss and compressive strength loss for 6 months, and length change of mortar prisms in sulfate solution. Moreover, since exposure conditions significantly affect the resistance of cements to sulfate attack, plain and blended cement mortar specimens were stored in three different conditions of exposure to Na2So4 and MgSo4, separately and simultaneously. Results show that mortar containing BA had higher compressive strength at various ages compared to control samples. In addition, results show that BA as an artificial pozzolanic material enhanced the durability of BA mortar, and reduced the detrimental effects of sulfate attack.

Keywords: Sugarcane Bagasse Ash; Mortar; Concrete; Sulfate Attach; Durability; Strength

EFFICIENCY OF CHLORIDE EXTRACTION FROM REINFORCED CONCRETE WITH INTERMITTENT APPLICATIONS

T.H.Y. NGUYEN[*1], H. YOKOTA[†2] AND K. HASHIMOTO[†3]

[*] Division of Engineering and Policy for Sustainable Environment, Graduate School of Engineering, Hokkaido University, Kita 13, Nishi 8, Kita-ku, Sapporo, 060-8628, Japan
[1]e-mail: haiyenvl06@gmail.com

[†] Division of Engineering and Policy for Sustainable Environment, Faculty of Engineering School, Hokkaido University, Kita 13, Nishi 8, Kita-ku, Sapporo, 060-8628, Japan
[2]email: yokota@eng.hokudai.ac.jp, http://www.eng.hokudai.ac.jp/labo/lifetime
[3]email: hashimoto.k@eng.hokudai.ac.jp, http://www.eng.hokudai.ac.jp/labo/lifetime

Key words: Chloride removal, electrochemical chloride extraction, desalinization, intermittent application

Abstract: *Electrochemical chloride extraction has been used as a rehabilitation method to prevent the degradation of chloride-contaminated reinforced concrete structures for many years. Although many studies have been conducted and many existing reinforced concrete structures have been rehabilitated, the extraction technique has generally used as a continuous application. Very few studies can be found regarding the electrochemical chloride extraction with intermittent applications. Therefore, its efficiency and advantage are still unclear. The purpose of this research is to compare the efficiencies of chloride extraction between continuous and various intermittent applications. The results indicate that although the total applied charge number is much lower in intermittent applications compared to continuous application. There is no significant difference in the final efficiency of chloride extraction in these cases, especially in the zone near the concrete-reinforcement interface. However, the much lower of total charge number had been spent to remove the approximate quantity of chloride ions in the intermittent applications compared to the continuous application may offer a great advantage. Consequently, the intermittent applications may cause less severe impacts on concrete and the bond strength between concrete and reinforcement, which have been the main sources of arguments about this method. It is concluded that the intermittent application has adequate to rehabilitate the performance and prolong the lifetime of structure.*

REFERENCES

[1] Houston, J.T., Atimtay, E. and Ferguson, P.M. Corrosion of Reinforcing Steel Embedded in Structural Concrete. *Research Report No. 112-1F*, Federal Highway Administration, Washington, DC, (1972).
[2] Clear, K.C., and Hay, R.E. Time-to-Corrosion of Reinforcing Steel in Concrete Slabe, V.1: Effect of Mix Design and Construction Parameters. *FHWA-RD-73-32*, Federal Highway Administration, Washington, DC, (1973).
[3] Bennett, J.E. Chloride Removal Implementation Guide. *Report No. SHRP-S-347*. SHRP, National Research Council, Washington D.C., (1993).

Evaluation of Mechanical Properties and Accelerated Chloride Ion Penetration (RCMT) in Alkali Activated Slag Concrete

A. A. Ramezanianpour*, F. Bahman zadeh†, A. Zolfagharnasab†, M. R. Pourebrahimi†, A. M. Ramezanianpour††

* Department of Civil and Environmental Engineering, Amirkabir University, Tehran, Iran
E-mail: aaramce@aut.ac.ir, web page: http://civil.aut.ac.ir/ra/index.html

† Department of Civil and Environmental Engineering, Amirkabir University, Tehran, Iran
E-mail: farnaz1991@aut.ac.ir
E-mail: arashzolfaghar@aut.ac.ir
E-mail: mrp@aut.ac.ir
†† Department of Civil Engineering, University of Tehran, Tehran, Iran
E-mail: ramezanian@ut.ac.ir

ABSTRACT

Cement is one of the main constituent in concrete that its production causes about 7% of CO2 world emission. Alkali activated compounds refer to inorganic materials that cement is not the main constituent in their mixes. In fact, alkali activated binder structure consists of two parts: source material and alkaline activator liquid. The alkaline activator used in this study was sodium silicate solution (wt. ratio: Na2O/SiO2 = 2.33) and 6 M potassium hydroxide and also, blast furnace slag is selected as a source material. For discovering the effect of each participant, 9 alkali activated concrete mix designs are utilized. In these mixes the influence of the amount of source material, solid part of alkaline activator, solid part of sodium silicate solution and also the ratio of water to binder is evaluated. In addition, one mix design for ordinary Portland cement (OPC) concrete is performed to compare with alkali activated slag (AAS) concretes characteristics.

In this research, the fresh concrete properties investigated by the means of slump loss test and compressive strength is measured at 1, 7, 28 and 90 days. Permeability of the concrete is determined by capillary water absorption test and the amount of chloride penetration in concrete is measured by rapid chloride migration test (RCMT) at the ages of 7, 28 and 90 days. Besides, electrical resistivity is measured to determine the effect of parameters on durability of AAS concretes. The results indicate that mechanical properties and durability of AAS concretes are mainly influenced by the amount of alkaline activators in a way that incorporating higher quantity of activators could bring about rapid hardening reactions at early ages and decelerate mechanical properties and durability development process.

REFERENCES

[1] Saud, A. O. "Performance of alkali-activated slag concrete." *The University of Sheffield, Sheffield* (2002).

[2] Bondar, Dali, C. J. Lynsdale, Neil B. Milestone, N. Hassani, and A. A. Ramezanianpour. "Effect of type, form, and dosage of activators on strength of alkali-activated natural pozzolans." *Cement and Concrete Composites* Vol. **33**, no. 2, pp 251-260, (2011).

Experimental study of concrete deterioration due to frost action

A. Marciniak*, M. Koniorczyk†

* Department of Building Physics and Building Materials
Lodz University of Technology
Al. Politechniki 6, 90-924 Łódź, Poland,
e-mail: alicja.marciniak@p.lodz.pl

† e-mail: marcin.koniorczyk@p.lodz.pl

ABSTRACT

The relationships between transport phenomena and durability of concrete is a main focus of research. The migration of contaminations can cause damage to the cement matrix and to the steel reinforcement. The permeability is an important factor influencing the concrete durability deterioration. The permeability coefficient can be used to compare the ability of concrete to resist the ingress of destructive substances.

This experimental study concerns the frost durability of an ordinary concrete without air-entraining admixtures, with two water to cement ratio (w/c equal to 0.5 and 0.4). The evolutions of some physical properties during repeating freeze-thaw cycles have been analyzed. The damage is characterized by the reduction of elastic modulus, as well as the permeability evolution due to frost action.

The changes of permeability, as well as compressive strength and the elastic modulus of concretes were investigated after 0, 50, 100 and 150 freeze-thaw cycles. Gas permeability tests were performed using Cembureau method, recommended by RILEM [1]. Intrinsic coefficient of permeability was determined using values of apparent gas permeability measured at three pressures: 0.2, 0.25 and 0.3MPa.

Finally the interaction of frost action with permeability and mechanical properties is discussed. First results indicate that the reduction in the mechanical resistance is accompanied by an increase in the intrinsic permeability of the concrete.

REFERENCES

[1] T.C. RILEM, Reccomendations of TC 116-PCD, “Tests for gas permeability of concrete. B. Measurement of the gas permeability of concrete by the RILEM-Cembureau method”, *Materials and Structures*, Vol. **32**, pp. 174–179, (1999).

First approach to thermochromic mortars: compatibility between thermochromic pigments and cement

G. Perez*[†], A. Guerrero[†] and A. Pons[#]

[†] Institute of Construction Science Eduardo Torroja (IETcc)
Spanish National Research Council – CSIC
Serrano Galvache 4, 28033 Madrid, Spain
E-mail: gperezaq@ietcc.csic.es, aguerrero@ietcc.csic.es

[#] Institute of Optics (IO)
Spanish National Research Council – CSIC
Serrano 144, 28006 Madrid, Spain
Email: alicia.pons@csic.es

ABSTRACT

Construction materials with reversible thermochromic behaviour are of significant interest to improve energetic efficiency in buildings and to reduce the environmental problem of the heat island effect associated to urban development.

Thermochromic materials are characterized by a change of their colour for a critical temperature value (T_c). These materials are especially interesting for building envelopes when the change is from a light colour at temperatures beyond T_c, to a dark colour at temperatures below T_c. With this behaviour it is expected that the solar reflectance would be high when the ambient temperature is high, thus reducing over-heating of the building during summer. On the contrary, when the weather is cold, the material would show a low solar reflectance and absorption of solar radiation would help warming the building in winter. Consequently, using reversible thermochromic materials in the building envelope would help to meet the demand of a thermally comfortable indoor environment, with the subsequent improvement in energy efficiency, and also would reduce environmental impact of urban construction.

This type of solutions have already been considered for thermochromic coatings in cold roofs [1]. In order to apply the same strategy to facades, the development of a reversible thermochromic mortar would be necessary. As a first approach to this target, the compatibility between pigments and cement based materials must be addressed. Several reversible thermochromic commercial products have been considered in this work, both in powder form and in aqueous solution. Microencapsulated pigments have been studied to increase their resistance to the highly alkaline environment and to the mechanically demanding mixing and casting procedures usual in cement-based materials. Moreover, two different cements have been used: an ordinary white Portland cement and an eco-efficient belite cement synthesized from fly ashes through a hydrothermal process, which shows a light cream color [2].

Cement paste specimens have been prepared with the two cements and with different amounts of pigments. The integrity of the microcapsules upon preparation and hydration of the specimens has been analyzed through scanning electron microscopy, while the stability of the thermochromic behaviour of the pigments within the cement matrix has been analyzed through measurements of solar reflectance at different temperatures. The results assess the compatibility of certain commercial reversible thermochromic pigments with cement based materials. Moreover, some requeriments for the mixing and casting procedures of cement paste specimens have been identified that will be useful for the development of reversible thermochromic mortars.

REFERENCES

[1] T. Karlessi, M. Santamouris, K. Apostolakis, A. Synnefa, I. Livada, "Development and testing of thermochromic coatings for buildings and urban structures", *Solar Energy*, Vol. **83**, pp. 538–551 (2009).

[2] A. Guerrero, S. Goñi, A. Macias, "Durability of new fly ash-belite cement mortars in sulphated and choride medium", *Cem. Conc. Res.*, Vol. **30**, pp. 1231-1238 (2000).

Formation of Air Pores in Concrete due to the addition of Tire Crumb Rubber

Adrian Zimmermann, Frank Röser, Eduardus A. B. Koenders

Institute of Construction and Building Materials (WIB)
Technische Universität Darmstadt
Franziska-Braun-Straße 3, 64287 Darmstadt, Germany
e-mail: zimmermann@wib.tu-darmstadt.de, web page: www.wib.tu-darmstadt.de

ABSTRACT

As a particular advantage of using tire crumb rubber in concrete an increase of the freeze-thaw resistance has been identified. In this context the present work focuses on the formation of air pores in concrete due to crumb rubber addition. Initially theoretical models are established and discussed. The subsequent experimental program includes an extensive microscopic analysis of the pore structure, air void content and pore size distribution. Specimens were made with five different particle sizes of crumb rubber up to 600 µm and in each case with five different crumb rubber contents up to 32 kg/m^3. Main result is that air bubbles attach themselves – due to the hydrophobicity of tire rubber – at the surface of rubber particles during the mixing process. Some of them separate from rubber particles and form spherical air voids in the cement paste. This model provides a basis to predict the air content and air pore distribution based on the particle size and content of crumb rubber.

Fundamental study on sorption characteristic of radionuclide ion in cement and blast furnace slag based samples

ICCS16

K. Hashimoto*, N. Taguchi† and H. Yokota††

* Faculty of Engineering, Hokkaido University
N13 W8 Kita-ku, 0608628 Sapporo, Japan
e-mail: hashimoto.k@eng.hokudai.ac.jp

†Graduate School of Engineering, Hokkaido University
N13 W8 Kita-ku, 0608628 Sapporo, Japan
Email: ntaguchi@eng.hokudai.ac.jp

††Faculty of Engineering, Hokkaido University
N13 W8 Kita-ku, 0608628 Sapporo, Japan
e-mail: yokota@eng.hokudai.ac.jp

ABSTRACT

Structures made of cement based materials deteriorate by various factors. Calcium (Ca) is a main component of cement matrices which is hardened with hydration process of cement. When water percolates into the cement hardened body under saturated conditions, the hydration products dissolve into pore solution and Ca ion leaches out from the hardened body, which makes its permeability become low. Since this phenomenon proceeds very slowly, it is not regarded as important deterioration in normal structures. In the context of radioactive waste management, however, long-term durability is one of the crucial aspects. The lifetime should be over thousands of years for the cement products used for the nuclear waste encapsulation and disposal facilities [1]. In radioactive waste processing structures, however, long-term durability is required, since the radioactive isotopes are hazardous for over thousands of years in extreme cases due to their half-life period if released into the environment. In the above-mentioned case, it is necessary to consider deterioration due to Ca leaching. The long-term durability of the cement products for nuclear waste applications is currently studied using the experimental leaching techniques [2][3]. In this study, simulated nuclear waste was tested in dissolution alteration and the behavior of radioactive nuclides was investigated. The results showed the improvement of dissolution deterioration resistance by replacement of Strontium (Sr) ion with Ca ion under NO_3 ion coexistence, but revealed that the phenomenon described above does not occur under Cl ion coexistence. Using the test results with simulated nuclear waste forms containing Cesium (Cs) and Sr, the solid-liquid equilibrium model focusing on Ca amount in solid phase and Ca, Sr and Cs ion in liquid phase were proposed.

REFERENCES

[1] Ojovan, MI, Lee, WE, *An Introduction to Nuclear Waste Immobilisation,* Elsevier, Oxford, 2005.

[2] Carde, C, Francois, R, Torrenti, J, 1996. Leaching of Both Calcium Hydroxide and C-S-H from Cement Paste: Modelling the Mechanical Behvaiour, *Cement and Concrete Research*, 26: pp.1257-1268

GEOPOLYMERISATION ACTIVITY OF EIFEL TUFF

OLIVER VOGT, NEVEN UKRAINCZYK, FRANK RÖSER, ENNO STEINDLBERGER, EDUARDUS A.B. KOENDERS

Institute of Construction and Building Materials (WIB)
Technische Universität Darmstadt
Franziska-Braun-Straße 3, 64287 Darmstadt, Germany
e-mail: ukrainczyk@wib.tu-darmstadt.de, vogt@wib.tu-darmstadt.de, web page: www.wib.tu-darmstadt.de

KEY WORDS: volcanic tuff, microstructure, geopolymers, alkali activated binders, sustainability.

SUMMARY. Alkali activated binders could significantly reduce the CO_2 emissions associated with the manufacturing of conventional cement, as they are made solely from industrial by-products and/or natural alumino-silicates. Alkali activation of volcanic tuff from the Eifel volcanic area known as Rhenish Trass is investigated here. Apart from silicate and aluminate content that exhibits good pozzolanic reactivity, the use of the Tuff in alkali activated binders is further motivated by its alkali content. Geopolymer paste mixtures were mixed with different amounts of sodium silicate and sodium hydroxide activation solutions to investigate the effect in molar ratios of Si/Al (2.8, 3.1, 3.4, 3.6) and SiO_2/Na_2O (8.6, 6.9, 5.7, 5.2, 4.1, 3.6) on mechanical strength and rheology. Best results were obtained by using waterglass activator mixes with Si/Al=3.4, with an optimal SiO_2/Na_2O ratio of 5.2. Workability of the mixes with waterglass increased with Si/Al ratio. Geopolymerisation reaction indicated an increase in amount of non-evaporable water and an increase in amount of amorphous and zeolite (Analcime and Phillipsit) phases. The results indicate a potential on utilisation of natural Eifel Tuff as a novel raw material for alkali activated binders.

Improvement of Freezing and Thawing Durability on Scaling of Eco-cement Extremely Dry Concrete under Deicing Agent Condition

A. UENO*, M. ISHIDA†, K. UJI†† and K. OHNO†††

* Department of Civil & Environmental Engineering
Tokyo Metropolitan University
1-1 Minamiosawa, Hachioji, Tokyo, 192-0397, Japan
e-mail: eagle@tmu.ac.jp, web page: http://www.tmu.ac.jp

†Central Research Laboratory
TAIHEIYO CEMENT CORPORATION
2-4-2 Osaku, Sakura, Chiba, 285-8655, Japan
Email: Masao_Ishida@taiheiyo-cement.co.jp, web page: http://www.taiheiyo-cement.co.jp

†† Department of Civil & Environmental Engineering
Tokyo Metropolitan University
1-1 Minamiosawa, Hachioji, Tokyo, 192-0397, Japan
e-mail: k.uji@tmu.ac.jp, web page: http://www.tmu.ac.jp

††† Department of Civil & Environmental Engineering
Tokyo Metropolitan University
1-1 Minamiosawa, Hachioji, Tokyo, 192-0397, Japan
e-mail: ohno@tmu.ac.jp, web page: http://www.tmu.ac.jp

ABSTRACT

Eco-cement is developed for long-term use of landfill areas near large cities and natural resource conservation during cement production in Japan. It mainly consists of incinerated ash from combustible city wastes as raw material, which is burnt in a rotary kiln to produce clinker similar to ordinary portland cement. Therefore, it is expected to enhance the sustainability of concrete production compared to its ordinary portland cement counterpart. This study addresses the mechanical properties of eco-cement-based extremely dry concrete for roller compacted concrete pavement (RCCP) and its freezing and thawing durability. Despite its adequate mechanical properties for pavement use, the material shows a relatively high decrease in mass compared to ordinary portland cement mixture during freezing and thawing tests in the presence of a deicing agent. Therefore, ground granulated blast-furnace slag and limestone powders with higher specific surface areas than both cements are added to improve the scaling behavior under deicing conditions. These mineral admixtures enhance the scaling property of the eco-cement-based extremely dry concrete in the presence of a deicing agent. Moreover, CO_2 emission and utilized waste mass are estimated in units of volume of concrete mixtures to evaluate environmental performances.

REFERENCES

[1] A. Ueno, M. Ishida, K. Ohno, and K. Uji, “Properties of Extremely Dry Concrete made with Ecocement and Recycled Coarse Aggregate”, Proc. of Third Int. Conf. on Sustainable Construction Materials and Technologies. e55 (2013).

[2] A. Ueno, M. Ishida, K. Uji, and K.Ohno, “Freezing and thawing properties of extremely dry concrete with eco-cement”, *Proc. of the Seventh International Conference on Concrete under Severe Conditions - Environment and Loading*, pp. 866-875, (2013).

[3] M. Kagaya, Y. Nishihara and, Y. Shirokado, “Experimantal study on air-entraining characteristics and freezing and thawing resistance of extremely stiff consistency concrete”, Concrete research and Technology, vol.20, No.3, pp.21-31, (2009)

Influence of C_3A Content on Chloride Transport in Concrete

K. Y. Ann[*], M. J. Kim[†1] and H. S. Jung[†2]

[*]Department of Civil and Environmental Engineering,
Hanyang University, Ansan 426-791, South Korea
e-mail: kyann@hanyang.ac.kr

[†1]Department of Civil and Environmental Engineering,
Hanyang University, Ansan 426-791, South Korea
-mail: manta209@hanyang.ac.kr

[†2]1 Ihwa-gil, Yangseong-myeon, Anseong-si, Gyeonggi-do, South Korea, 17503
-mail: hsnsj97@seilcon.com

ABSTRACT

As the C_3A content in cement matrix has been intuitively thought as an inhibitive nature, which can remove mobile chlorides from the pore solution, no hard evidence on binding capacity with respect to the corrosion resistance has been clearly identified. The present study presents a detailed experimental study on the influence of C_3A content on chloride transport. The C_3A content of specimens ranged 6.0, 10.5, 13.7 and 16.9% by modifying oxide compositions of cement, in particular Al_2O_3 and CaO. The water soluble chloride concentration, regarded as free chloride which has corrosiveness in the pore solution, was measured from boiling the extracted dust concrete sample in water. Moreover, the pore structure of concrete and penetration of chloride ions were determined by Mercury Intrusion Porosimetry and profiling test respectively. As a result, the chloride binding capacity was not affected by C_3A content, except for a very high range of C_3A. For chloride transport, the apparent diffusion coefficient of chloride ions was not influenced by C_3A. However, it was observed that an increase in the C_3A content resulted in an increase in the surface chloride concentration, leading to increased chloride ingresses at a given duration of exposure to a salt solution. Substantially, the benefit of increased chloride binding capacity in the corrosion resistance may be offset by the increase in surface chloride concentration.

Influence of carbonation on the chloride migration coefficient from non-steady-state migration test in fly ash concrete

Raphaele Malheiro*, Gustavo Camacho*, Aires Camões*, Gibson Meira†, Rui M. Ferreira††, Maria T. Amorim* and Rui Reis*

* Centre for Territory, Environment and Construction (CTAC)
University of Minho
Campus de Azurém, Guimarães, Portugal
e-mail: raphamalheiro@gmail.com; aires@civil.uminho.pt; mtamorim@det.uminho.pt; ruicunhareis@gmail.com; gustavo92@live.com.pt, web page: http://www.ctac.uminho.pt

† Federal Institute of Education, Science and Technology of Paraíba (IFPB)
João Pessoa, Brazil
e-mail: gibsonmeira@yahoo.com, web page: http://www.ifpb.edu.br

††Technical Research Centre of Finland (VTT)
Espoo, Finland
e-mail: miguel.ferreira@vtt.fi, web page: http://www.vtt.fi

ABSTRACT

The incorporation of fly ash (FA) in cementitious matrices have been frequently used in order to make the matrix more resistant to the action of chlorides. On the other hand, it is known that $Ca(OH)_2$ existing in the matrix is partially consumed by the pozzolanic reactions, which facilitates the advancement of carbonation. Given that the chloride ingress and carbonation are the two main causes of degradation in reinforced concrete, we speculate about the behaviour of the FA concrete when the structure is submitted to the chlorides and the carbonation at the same time.

This work intends to study the influence of carbonation on the chloride migration coefficient in FA concrete. For this, specimens with 0% and 40% replacement of cement CEM I 42.5 R for FA were molded with water/binder 0.55 and 0.50 respectively. After 90 days of curing period, half of samples were subjected to carbonation chamber (20ºC ,55%RH and 4%CO_2) for 1, 2 and 3 months. The other half were protected with plastic sheet during the same period. Non-steady-state migration test, according NT BUILD 492, was performed in specimens with and without exposure to carbon dioxide environment.

The results show that, for this conditions, regardless FA presence, the carbonation has a direct influence on chloride migration coefficient, increasing it. For FA concrete samples this effect is more evident. In these cases, the carbonated samples studied showed a coefficient until two times higher than noncarbonated ones.

The action of densification of pores caused by carbonation, and consequent reduction in matrix permeability, can be responsible for the decrease of chloride penetration in concrete subjected to combined action.

Influence of Electric Conduction of Steel Bars on Electrochemical Measurement of Reinforced Concrete Structure

Nozomu Someya*[1], Yoshitaka Kato[2] and Ema Kato[3]

*[1] Department of Civil Engineering, Graduate School of Science and Technology
Tokyo University of Science
2641 Yamazaki, Noda-shi, Chiba, Japan
e-mail: j7613701@ed.tus.ac.jp, web page: http://www.rs.tus.ac.jp/concrete/index.htm

[2] Department of Civil Engineering, Faculty of Science and Technology
Tokyo University of Science
2641 Yamazaki, Noda-shi, Chiba, Japan
e-mail: katoyosh@rs.tus.ac.jp

3 Structural Mechanics Group
Port and Airport Research Institute
3-1-1 Nagase,Yokosuka, Kanagawa, Japan
e-mail: katoh-e@pari.go.jp

ABSTRACT

In this study, the effect of electrical conductivity on corrosion progress of steel bar in concrete structures was examined by electrochemical measurement. The corrosion of steel bar is known to easily occur around the intersection part of steel bars. In that part, the non-corroded steel bar acts as the localized cathode while the corroded part of steel bar acts as anode. Consequently, it is thought that the corrosion current density concentrates in that part by connecting with non-corroded and corroded steel bars. However, there are a huge amount of intersection part in a structure, therefore, it is difficult to measure the electrochemical property of individual intersection parts because of the electrochemical intervention of each intersection and steel bar. To clarify the effect of electrical conductivity on the corrosion progress of steel bar in concrete structures, the electrochemical property of the connecting with non-corroded and corroded steel bar in the concrete was experimentally investigated.

Two types of test specimen were prepared in this study; the parallel-bar specimen in which corroded steel bar and non-corroded steel bar were arranged in parallel and the cross-bar specimen in which corroded steel bar and non-corroded steel bar were arranged in cross. To clarify the effect of electrical conductivity on corrosion progress of steel bar in concrete, the half-cell potential, the corrosion current density and the impedance spectroscopy were measured.

It was found that the half-cell potential of non-corroded steel bar shifted to a less inert range when the non-corroded steel bar connected with the corroded steel bar. Although the half-cell potential of non-corroded steel bar should be within the range of inertness, the half-cell potential of non-corroded bar was changed to be −400 mV. The corrosion current density of non-corroded steel bar was increased by connecting with the corroded steel bar. The impedance spectroscopy of non-corroded steel bar was decreased by connecting with the corroded steel bar.

Influence of High Temperature History on Chloride Penetration of Concrete Using Waste-Derived Aggregate

Yuko Ogawa*, Akihiro Fujiyama†, Ryoichi Sato††, Kenji Kawai††† and Hiroshi Ooishi††††

*,†, ††and ††† Department of Civil and Environmental Engineering
Hiroshima University
1-4-1, Kagamiyama, Higashi-Hiroshima, 739-8527, Japan
E-mail: * ogaway@hiroshima-u.ac.jp, † m153545@hiroshima-u.ac.jp,
†† sator@hiroshima-u.ac.jp, †††kkawai@hiroshima-u.ac.jp

†††† Bureau of Finance and Equipment
Ministry of Defense, Government of Japan
5-1, Honmura-cho, Ichigaya, Shinjuku-ku, Tokyo, 162-8801, Japan
E-mail: ooishihir01@mod.go.jp

ABSTRACT

Waste materials have been desired to be utilized as concrete materials in construction fields to preserve the environment. Molten slag fine aggregate (MS) produced from municipal waste was reported to be effective in enhancing the resistance to chloride ion (Cl^-) penetration probably owing to its latent hydraulicity [1]. Porous ceramic coarse and fine aggregates derived from roof tile waste (PCCA, PCFA) were also reported to be effective as an internal curing agent in reducing autogenous shrinkage and developing compressive strength of concrete [2][3]. On the other hand, although it is well known that high temperature history can affect properties of concrete, few investigations on the influence on resistance against Cl^- penetration have been carried out.

The present study aims at investigating the effect of high temperature history simulating a temperature generated in mass concrete structure on resistance to Cl^- penetration into concrete using the waste-derived aggregates. Six types of concretes were prepared. Portland blast-furnace slag cement type B was used and water to cement ratio of all concretes was 40% to enhance durability under severe chloride environment. Unit water content was 165 kg/m^3 and sand-total aggregate ratio was 45.0vol.%. The MS, PCCA and PCFA were used and their replacement ratios were 30vol.%, 12vol.% and 15vol.%, respectively. Specimens were sealed after casting and stored in a room where the temperature history, whose maximum temperature was 70^{o}C, was controlled. Specimens stored at 20^{o}C were also prepared to make clear the temperature effect. Specimens were submerged at the age of 28 days in sodium chloride solution at a concentration of 10mass% for 182 days.

As a result, apparent diffusion coefficients of Cl^- (D_{ap}) for all concrete subjected to high temperature history were larger than that for concrete cured at 20^{o}C. Besides, MS was observed to be effective in decreasing the D_{ap}, especially when concrete was subjected to high temperature history. In addition, the distributions of Cl^- in concrete at the age of 100 years were calculated by using the D_{ap} and the depth from the surface at which the concentration of Cl^- reached the threshold value for corrosion initiation were evaluated. The depths of concrete using waste-derived aggregates were at least 10% smaller than that of concrete without waste-derived aggregate. This fact shows that waste-derived aggregate can improve the resistance to Cl^- penetration into concrete if they are used appropriately.

REFERENCES

[1] K. Kawamura, Y. Ogawa, M. M. Macharia, K. Nakarai and R. Sato, "Properties of concrete containing a molten slag as fine aggregate", *Proc. of ICCS2013*, pp. 252-259, (2013).

[2] M. Suzuki, M. S. Meddah and R. Sato, "Long-term shrinkage and stress in ultra high strength concrete using porous ceramic waste for internal curing", *Proc. of the Int. RILEM Symp. on Use of Superabsorbent Polymers and Other New Additives in Concrete*, pp. 263-272, (2010).

[3] R. Sato, A. Shigematsu, T. Nukushina and M. Kimura, "Improvement of Properties of Portland Blast Furnace Cement Type B Concrete by Internal Curing Using Ceramic Roof Material Waste", *J. of Mater. in Civil Eng.*, ASCE, Vol. 23, Issue 6, pp. 777-782, (2011).

Long-term effects of the hardening temperature and relative humidity on the microstructure and properties of mortars with active additions

J.M. Ortega*, R.M. Tremiño*, I. Sánchez* and M.A. Climent*

* Departamento de Ingeniería Civil
Universidad de Alicante
Carretera San Vicente del Raspeig s/n, 03690 San Vicente del Raspeig, Alicante, Spain
e-mail: jm.ortega@ua.es, web page: http://www.ua.es

ABSTRACT

In recent years the use of active additions on cement, like ground granulated blast-furnace slag and fly ash, has become very popular because they have many environmental benefits [1, 2]. The main advantages are the reduction of CO_2 emissions and the lower energy consumption during the cement production, as well as the use of an industrial waste. The use of these wastes also means an economical benefit for the cement industry.

Many studies show that in laboratory conditions this kind of materials has good service properties, even better than Portland cement [3]. However, real structures are usually hardened in different conditions depending on their geographical location. These different environmental conditions may influence the development of the microstructure and the service properties of slag and fly ash cement mortars.

In this work, the behaviour of mortars made with an ordinary Portland cement and with cements which incorporate slag and fly ash, was tested. These mortars were exposed to different temperature and relative humidity conditions during their hardening. The development of the microstructure of mortars and the changes of their service properties were studied at different hardening ages until 5 years.

The mortars made with slag and fly ash cements have shown a good behaviour compared with ordinary Portland cement mortars. The temperature and relative humidity have an influence on microstructure and properties of all cement types studied. As a preliminary conclusion, cements with slag and fly ash hardened under non-optimal conditions can have good service properties at high hardening ages, even better than Portland cement.

REFERENCES

[1] L. Bertolini, M. Carsana, D. Cassago, A.Q. Cruzio and M. Collepardi, "MSWI ashes as mineral additions in concrete", *Cem. Concr. Res.*, Vol. **34**, pp. 1899-1906, (2004).

[2] V. Corinaldesi and G. Moriconi, "Influence of mineral additions on the performance of 100% recycled aggregate concrete", *Constr. Build. Mater.*, Vol. **23**, pp. 2869-2876, (2009).

[3] J. Bijen, "Benefits of slag and fly ash", *Constr. Build. Mater.*, Vol. **10**, pp. 309-314, (1996).

Mechanical properties and durability of mortars containing nanosilica and rice husk ash

A.A. Ramezanianpour[1], M Zahedi[2], A.M. Ramezanianpour[3]

[1]Professor of Amirkabir University of Technology,
[2]Master from Amirkabir university of Technology
[3]Assistant professor of Tehran University
Email: aaramce@aut.ac.ir

Abstract

Reactive materials such as nanosilica and rice husk ash when incorporated in mortars and concrete mixtures improve the mechanical properties and enhance their durability.
In the present investigation, the effect of nanosilica hydrosols and rice husk ash on the compressive strength, chloride ion permeability, capillary absorption, and electrical resistivity of single and binary blended mortars was investigated. Results showed that the addition of nanosilica improved mortar performance, while rice husk ash did not have a significant influence and mainly attributed to lower strength and durability for binary blended mortars, compared to single mixes containing nanosilica at early ages. However, binary mixtures displayed the best performance regarding the mechanical properties and durability at longer ages.

Keywords : Nanosilica, rice husk ash, mortar, mechanical properties, durability, sustainability

Mechanical properties of concrete reinforced with recycled steel fibres

Giuseppe Centonze*, Marianovella Leone*, Francesco Micelli* and Maria Antonietta Aiello*

* Department of Engineering for Innovation
University of Salento
Via per Monteroni, 73100 Lecce, Italy
e-mail: giuseppe.centonze@unisalento.it

ABSTRACT

According to recent data [1], every year approximately 2.5 million tonnes of used tyres (about 250 million units) are either recycled or recovered in Europe. Generally, end of life tyre (ELT) enters a waste management system based on product/material recycling and/or energy recovery. The application of ELTs in civil engineering (such as foundation for roads and railways, draining material, erosion barriers, etc.) in 2013 was 11% of ELTs sent to material recovery. However, the most important material recovery is represented by recycling of rubber granulates and powder (82%).

In this context, the experimental work herein discussed is part of a wider scientific investigation on the application of steel fibres recycled from ELTs as discontinuous reinforcement in concrete matrix. As a matter of fact, the main role of the steel fibres within the matrix is to control the crack opening and propagation, increasing the overall ductility of concrete elements [2, 3]. As soon as the cracks widen out, the toughness increases and the cracking process is modified from brittle to ductile, allowing the material to redistribute the stresses. This cracking control also improve the durability of the material.

On the basis of previous research studies [4, 5] and also considering the available literature [6, 7] the main issue of the proposed research is to extend the characterization of the recycled steel fibres and to develop the study of their structural behaviour when applied for a new eco-friendly concrete. Using these recycled steel fibres in concrete production could ensure a surplus value in terms of environmental and ecological benefits and consequently a significant reduction in landfilling of ELTs. Fresh and hardened properties of concrete reinforced with recycled steel fibres are discussed as well as the post-cracking behaviour properties. The obtained results evidenced the good behaviour of the proposed material when compared with concrete reinforced with industrial steel fibres.

REFERENCES

[1] ETRMA, “Annual report 2013/2014”, European Tyre & Rubber Manufacturers’ Association;

[2] CNR-DT 204/2006, “Guide for the design and construction of fiber-reinforced concrete structures”, Italian National Research Council, Italy, (2007);

[3] FIB “fib Model Code for concrete structures 2010”, (2013);

[4] Aiello M.A., Leuzzi F., Centonze G., Maffezzoli A., “Use of steel fibres recovered from waste tyres as reinforcement in concrete: pull-out behavior, compressive and flexural strength”, Waste Management, 29, 1960-1970, (2009);

[5] Centonze G., Leone M., Aiello M.A., (2012), “Steel fibers from waste tires as reinforcement in concrete: A mechanical characterization”, Construction and Building Materials, 36, 46-57;

[6] Zamanzadeh Z., Lourenço L., Barros J., “Recycled steel fibre reinforced concrete failing in bending and in shear”, Construction and Building Materials, 85, (2015);

[7] Graeff A, Pilakoutas K, Neocleous K. Peres M.V.N.N, Fatigue resistance and cracking mechanism of concrete pavements reinforced with recycled steel fibres recovered from post-consumer tyres, Engineering Structures, 45, pp 385-395, (2012);

Modified expanded clay lightweight concretes for thin-walled floating structures

Andrey Mishoutin[*], Sergii Kroviakov[*], Nikolay Mishoutin[†] and Vladimir Bogutsky[*]

Odessa State Academy of Civil Engineering and Architecture,
4 Didrihsona st., Odessa, 65029, Ukraine
[†]Mykolayiv National Agrarian University
9 Paryzka Komuna Str. Mykolayiv, 54020, Ukraine
e-mail: skrovyakov@ukr.net, web page: http://ogasa.org.ua

ABSTRACT

Reinforced concrete shipbuilding is developing in many countries around the world. Floating docks, marinas, hotels and houses are built of concrete. More often, heavy concrete shipbuilding is used for floating concrete structures. Using expanded clay lightweight concretes reduces the weight of the construction. At reducing the weight load lifting of the floating structure is increased. The use of lightweight concrete improves people's occupation and equipment on a reinforced concrete vessel.

Properties of shipbuilding expanded clay lightweight concretes were studied. Methods of experiment planning were used. The following factors of composition were varied: the amount of sulphate Portland cement; the concentration of the hydrophobic additive in the processing of gravel, the amount of waterproofing additives; the amount of superplasticizer; the amount of fiber. The experiment was conducted on a 5-factorial optimal plan. All tested lightweight aggregate mixture had the same high mobility.

It is found that the hydrophobic treatment gravel increased slightly compressive strength of expanded clay lightweight concrete. Maximum strength modified concrete saturated with water is more than 40 MPa. Fiber increases the tensile strength of the concrete. For the construction of floating structures the most important indicator of quality is a watertight concrete. Concrete with the Portland cement content of 500 kg/m^3 when processing hydrophobization porous gravel has watertight not lower W6. When the amount of cement to 600 kg/m^3 concrete with hydrophobic additive and hydrophobization gravel are not watertight below W8. Such concrete can be used for outdoor structures.

We investigated the frost resistance of concrete. We found that the shipbuilding expanded clay lightweight concrete with cement content of 500 kg/m^3 or more have frost resistance not lower than F450. Due to hydrophobic lightweight aggregate increased the frost resistance by 50-100 cycles, due to the introduction of fiber - 50 cycles. Maximum frost resistance of modified expanded clay lightweight concrete is F600.

The average density of shipbuilding expanded clay lightweight concrete in water saturated state is 1745..1855 Kg/m^3. Such density corresponds to the requirements of industry standards. When using hydrophobised gravel concrete density is reduced to 20-30 kg/m^3, humidity of the concrete is also reduced. Expanded clay lightweight concrete on hydrophobized gravel has a lower thermal conductivity.

Optimal compositions of shipbuilding expanded clay lightweight concrete were chosen. The technology of application of the modified shipbuilding lightweight concrete and heavy concrete was developed.

REFERENCES

[1] Official site of Kherson State Plant "Pallada": http://pallada.ks.ua/

[2] An experiment in Ship Building: http://www.concreteships.org

[3] Evaluation of lightweight concrete performance in 55 to 80 year old ships / [R.D. Sturm, N. McAskill, R.G. Burg, D.R. Morgan] – AC ISP 189-7 on High-performance concrete: Research to Practice, 1999. – P. 101-120.

[4] Mishoutin A.V. Increased durability of concrete reinforced concrete marine floating and stationary structures / A.V. Mishoutin, N.V. Mishoutin. – Odessa: Even, 2011. – 292 p.

PERMEABILITY OF HYBRID CONCRETE FOR SUSTAINABLE BRIDGE DECK PAVEMENT

Kyong-Ku YUN*, Seung-Woo LEE† and Yoon-Ho CHO††

* Professor and Director, Center for Regional Construction Technology, Kangwon National University, S. Korea, 1 Kangdae-gil, Chuncheon, 200-701, Korea.
Email: kkyun@kangwon.ac.kr

† Professor, Gangneung-Wonju National University, 7, jukheon-gil, Gangneung, 210-702, Korea.
Email: swl@gwnu.ac.kr

†† Professor, Chungang University, 84 Heukseok-ro, Dongjak-gu, Seoul, 156-756, Korea,
Email: yhcho@cau.ac.kr

ABSTRACT

The purpose of this paper was to investigate the effect of latex and silica fume in hybrid concrete containing organic latex and inorganic silica fume. To obtain this goal, a series of rapid chloride permeability tests were performed according to ASTM C 1202 with the main experimental variables of latex contents (3, 5 and 7%) and silica fume contents (6, 7 and 8%).

The compressive strengths of hybrid concrete were measured to be between 38 and 44MPa at 28 days and 41 to 50 MPa at 56 days. The flexural strengths were measured to be between 5.9 and 7.5MPa at 28 days. The permeability of hybrid concretes is very low at all mixtures. The passed charges were less than 600 Coulombs at 56 days for all mixtures, which is categorized as a “very low” permeable material according to the criteria indicated at ASTM C 1202[2]. This “very low” category is obtained at a latex-modified concrete or internally-sealed concrete, which means that the hybrid concrete is well internally sealed by latex film and filled by finer silica fume. The rapid chloride permeability was not affected by air content nor spacing factor, even though all mixtures showed ‘very low’ permeability. This might be explained by that the structure of the paste of latex-modified concrete is such that the micro pores and voids normally occurring in Portland cement system are partially filled with the latex film that forms during curing.

KEY WORDS: long-life bridge pavement, sustainability, permeability, hybrid concrete

Plastic Moment Capacity Evaluation for Reinforced Concrete Frame Elements by Adopting the Proper Material Constitutive Laws

Andrei Faur*, Attila Puskas†

* Department of Structures, Faculty of Civil Engineering
Technical University of Cluj-Napoca
C-tin Daicoviciu Street, no. 15, 400020, Cluj-Napoca, Romania
e-mail: Andrei.Faur@dst.utcluj.ro - Web page: http://constructii.utcluj.ro

† Department of Structures, Faculty of Civil Engineering
Technical University of Cluj-Napoca
C-tin Daicoviciu Street, no. 15, 400020, Cluj-Napoca, Romania
e-mail: Attila.Puskas@dst.utcluj.ro - Web page: http://constructii.utcluj.ro

ABSTRACT

In nonlinear analysis performed on reinforced concrete frame structures, one primary concern is the proper evaluation of the idealized plastic moment capacity for the individual frame elements. The procedure for such calculation can be extremely difficult to perform, even if numerical models are used to construct the complete moment-curvature (M-ϕ) curves. If the location of the plastic curvature (i.e. the point on the idealized M-ϕ curve which separates the elastic and perfectly-plastic domains) is not essential for the analysis, significant simplifications to the mathematical models can be performed. These simplifications refer to the approximation of the plastic moment capacity as the ultimate moment capacity. For these reasons, the present paper presents a study and proposes an analytical method through which the plastic and the ultimate state of stress can be calculated with sufficient accuracy given that the material constitutive laws are properly adopted.

The need for a simplified procedure to find the plastic moment capacity arises from the difficulty to correctly estimate the cracking and yielding states of stress/deformation needed for the construction of the elastic domain (at least the Caltrans Seismic Design Criteria [1] requires the yielding moment to be known). On the other hand, the ultimate state, characterized by the ultimate curvature is more clearly defined as the state of deformation at which the extreme concrete fibre reaches the maximum compression deformation, or the extreme tension reinforcement reaches the maximum tension deformation [2],[3]. Both these compression/elongation limits are imposed by design standards (e.g. the Eurocode 2 Standard [4]) and are used to calculate the ultimate moment capacity. Therefore, it is more suitable for simplified design procedures to determine the plastic moment capacity by correcting the value of the bending moment corresponding to the ultimate curvature.

REFERENCES

[1] Caltrans, "Seismic Design Criteria Version 1.7," *Calif. Dep. Transp. Sacramento, CA, U.S.*, no. April, 2013.

[2] T. Paulay and M. J. N. Priestley, *Seismic Design of Reinforced Concrete and Masonry Buildings*. John Wiley and Sons, New Jork, USA, 1992.

[3] M. J. N. Priestley, G. M. Calvi, and M. J. Kowalsky, *Displacement-Based Seismic Design of Structures*. IUSS Press, Pavia, Italy, 2007.

[4] "Eurocode 2, 1991. Design of Concrete Structures, Part 1: General rules and rules for buildings, ENV 1992-1-1." .

Porosity and Resistivity Measurement of Accelerated Cured Geopolymer And Conventional Concrete

A. Noushini*, A. Castel

Centre for Infrastructure Engineering and Safety (CIES)
School of Civil and Environmental Engineering
University of New South Wales
Sydney, NSW 2052, Australia
* e-mail: a.noushini@unsw.edu.au

ABSTRACT

Over the last decades, geopolymer concrete (GPC) has emerged as a novel engineering material with the potential to become a substantial alternative to Portland cement (OPC) concrete in construction and building industry. The term 'geopolymer' was first introduced by Davidovits in 1979 to represent the inorganic polymers resulting from the reaction of materials containing aluminosilicate with an alkali solution to produce an inorganic polymer binder. The production of silico-aluminate based geopolymer requires source materials that are rich in silica and alumina content, such as fly ash, slag, metakaolin, etc.

Currently, accelerated curing is widely being used where high early-age strength is required; such as precast industry. Thermal curing is known as reaction accelerator which significantly increases the early-age strength of Portland cement based systems compared to the ambient curing [1]. However, thermal curing has shown [1] to have a detrimental effect on the long term strength of OPC based systems. The same authors have previously studied the possibility of using geopolymer concrete in order to overcome the negative impact of thermal curing on the long-term strength of OPC concrete. A wide range of thermal curing and their influence on short term and long term strength of GPC and OPC concrete has been comprehensively studied [1]. The results showed that geopolymer concrete can benefit from the thermal curing to develop very high early-age strength as well as maintaining its long-term compressive strength. A proper heat-cured GPC (e.g. cured at 75°C for 18-24 hours) can obtain the 28-day compressive strength of its counterpart standard-cured OPC concrete after only 24 hours and maintains this strength for the rest of its measured lifespan [1].

Although the above mentioned conclusion is very valuable, the pore structure of the resulting material is also to be investigated in order to have a better understanding of the long term performance of the thermal-cured GPCs compared to the Portland cement based systems.

This study is aimed to evaluate and compare the pore structure and resistivity of thermal cured fly ash based geopolymer and Portland cement concretes. A wide range of practical thermal curing regimes were applied to the test specimens and materials properties were measured. Test results shows that although thermal curing increases the early-age strength of the Portland cement system, it leads to a lower long-term strength and higher porosity compared to the standard moist cured specimens. On the contrary, geopolymer concrete can benefit from the thermal curing to develop very high early-age strength as well as maintaining its long-term compressive strength. Also, the porosity of properly heat-cured geopolymer concrete is much lower than its counterpart accelerated-cured Portland cement concrete and very close to that of the water cured Portland cement concrete.

REFERENCES

[1] A. Noushini, M. Babaee, and A. Castel, "Suitability of heat-cured low-calcium fly ash-based geopolymer concrete for precast applications," *Mag. Concr. Res.*, vol. 68, no. 4, pp. 163–177, Sep. 2016.

Pozzolanic materials obtained through a treatment methodology of landfills. Characterization of new cements and durability of concretes

F. Puertas[1]*, C. Varga[1], M.M. Alonso[1], M.A. Diaz-Bautista[2], S. Lizarraga[3]

*[1] Eduardo Torroja Institute for Construction Science (IETcc-CSIC),
28033 Madrid, Spain
Email: puertasf@ietcc.csic.es, web page: http://www.ietcc.csic.es
[2] Grupo Cementos Portland Valderrivas (GPCV), Spain
[3] *Cement International Technologies (CIT), Spain*

ABSTRACT

This study introduces a separation protocol or technology and verifies the suitability of reusing materials recovered from landfills as active additions in cement manufacture. A landfill located in Spain, nearby coal-fired power plant, was used to study the possible pozzolanicity of the wastes deposited there. Physical-mechanical trials were run to compare the performance of the laboratory cement (75 % OPC, 25 % fractions with lowest particle sizes, with and without unburnt carbon) to the results found for cement bearing conventional fly ash (CEM II A-V). The results obtained shown that the behaviour exhibited by these new cements was comparable to the performance in standardised cement.

Also the durability of concretes prepared with these new cements was established. The concretes were submitted to durability tests of chlorine penetration, sulphate attach and leaching process. In all cases, the new concretes exhibited a comparable behaviour to concrete prepared with OPC cement

This methodology can be applied in other landfills in the world.

[1] Corresponding author: puertasf@ietcc.csic.es Tel +34-1-3020440, Fax +34-1-3020700

Preliminary Assessment of Durability of a Low Carbon Concrete Made With Limestone Calcined Clay Portland Cement

Fernando Martirena*, Ernesto Díaz[ε], Jose Artiles*, Dayran Rocha*, Adrian Alujas* and Karen Scrivener[†]

[*] Centro de Investigación y Desarrollo de Estructuras y Materiales (CIDEM)
Universidad Central de las Villas, Cuba
Carretera Camajuani km 5, 40832, Santa Clara, Cuba
e-mail: f.martirena@enet.cu

[ε] Centro de Investigación y Desarrollo de la Construcción (CIDC)
Reparto Bahía. La Habana, Cuba
email: ernesto@ctdmc.co.cu

† Laboratoir de Materiaux de Construction (LMC)
Ecole Polytechnique Federal de Lausanne (EPFL)
Bureau MXG239, MX-G Ecublens, CH-1015, Lausanne, Switzerland
e-mail: karen.scrivener@epfl.ch

ABSTRACT

Through a collaborative research effort between the Ecole Polytechnique Federal de Lausanne and CIDEM a new kind of cementitious binder has been developed based on the synergy between calcined clays and limestone. Industrial trials carried out in Cuba during 2013-2015 have proven that the new cement is very effective even with clinker content as low as 50%. This paper presents preliminary results of a full program of assessment of durability of concrete cast with the new cement. Concrete elements have been cast and placed on an exposure site in the northern coast of Cuba. Cores have been taken, and have been tested for chloride ingress and migration, carbonation and air permeability. Concrete made with the cement containing calcined clays and limestone appears to have a more tortuous pore structure, and an increased chloride binding capacity due to the presence of alumina phases, which helps decreasing the movement of chloride ions through the matrix. For the same reason, and despite the low free lime content, this concrete shows a reduced carbonation compared to the one made with Portland cement, at age 15 month, placed on seashore in the hot and humid tropical zone. Air permeability measurements confirm the lower permeability of the concrete subject of study; this is very consistent with the results of chloride ingress and migration and carbonation.

REFERENCES

[1] CEMBUREAU, "World cement production by region Evolution 2001-2012", (2014).

[2] Scrivener, K. L. Options for the future of cement. Indian Concr. J. **88**, 11–19 (2014).

[3] CSI & WBCSD. Development of State of the Art-Techniques in Cement Manufacturing : Trying to Look Ahead (CSI / ECRA-Technology Papers) Final Draft (2009).

[4] Damtoft, J. S., Lukasik, J., Herfort, D., Sorrentino, D. & Gartner, E. M. Sustainable development and climate change initiatives. Cem. Concr. Res. **38**, 115–127 (2008).

[5] Gartner, E. Industrially interesting approaches to 'low-CO2' cements. Cem. Concr. Res. **34**, 1489–1498 (2004).

[6] Scrivener, K. L. & Kirkpatrick, R. J. Innovation in use and research on cementitious material. Cem. Concr. Res. **38**, 128–136 (2008).

[7] Tironi, A., Trezza, M. a., Scian, A. N. & Irassar, E. F. Assessment of pozzolanic activity of different calcined clays. Cem. Concr. Compos. **37**, 319–327 (2013).

[8] Sabir, B., Wild, S. & Bai, J. Metakaolin and calcined clays as pozzolans for concrete: A review. Cement and Concrete Composites **23**, 441–454 (2001).

[9] Alujas, A., Fernández, R., Quintana, R., Scrivener, K. L. & Martirena, F. Pozzolanic reactivity of low grade kaolinitic clays: Influence of calcination temperature and impact of calcination products in OPC hydration. Appl. Clay Sci.; Volume **108**, Pages 94-101 (2015).

[10] Fernandez, R., Martirena, F. & Scrivener, K. L. The origin of the pozzolanic activity of calcined clay minerals: A comparison between kaolinite, illite and montmorillonite. Cem. Concr. Res. **41**, 113–122 (2011).

[11] Antoni, M., Rossen, J., Martirena, F. & Scrivener, K. Cement substitution by a combination of metakaolin and limestone. Cem. Concr. Res. **42**, 1579–1589 (2012).

[12] Matschei, T., Lothenbach, B. & Glasser, F. P. The role of calcium carbonate in cement hydration. Cem. Concr. Res. **37**, 551–558 (2007).

[13] Vizcaíno-Andrés, L. et al. Industrial trial to produce a low clinker , low carbon cement. Mater. Construcción **65**, (2015).

[14] Bishnoi, S., Maity, S., Mallik, A., Joseph, S. & Krisnnan, S. Pilot scale manufacture of limestone calcined clay cement: the Indian experience. India **88**, 22–28 (2014).

[15] Samson, E., Marchand, J. & Snyder, K. A. Calculation of ionic diffusion coefficients on the basis of migration test results. Mater. Struct. **36**, 156–165 (2003).

[16] Snyder, K. A. The relationship between the formation factor and the diffusion coefficient of porous materials saturated with concentrated electrolytes : theoretical and experimental considerations. Concr. Sci. Eng. **3**, 216–224 (2001).

[17] Snyder, K. A., Feng, X., Keen, B. D. & Mason, T. O. Estimating the electrical conductivity of cement paste pore solutions from OH À , K + and Na + concentrations. **33**, 793–798 (2003).

[18] [Jacobs, F., Leemann, A., Teruzzi, T., Torrent, R. & Denarie, E. Specification and site control of the permeability of the cover concrete : The Swiss approach Dedicated to Professor Dr . Bernhard Elsener on the occasion of his 60th birthday. Mater. Corros. **63**, 1127–1133 (2012).

[19] Thomas, M. D. A., Hooton, R. D., Scott, A. & Zibara, H. The effect of supplementary cementitious materials on chloride binding in hardened cement paste. Cem. Concr. Res. **42**, 1–7 (2012).

[20] Balonis, M., Lothenbach, B., Le, G. & Glasser, F. P. Impact of chloride on the mineralogy of hydrated Portland cement systems. Cem. Concr. Res. **40**, 1009–1022 (2010).

[21] Andrade, C., Sanjuán, M. a. & Cheyrezy, M. Concrete carbonation tests in natural and accelerated conditions. Advances in Cement Research **15**, 171–180 (2003).

[22] 262/1:2913, S. Bauwesen Betonbau – Ergänzende Festlegungen. 1–52 (2013).

PREVENTING REINFORCEMENT CORROSION IN CRACKED CONCRETE BY SELF-REPAIR

K. VAN TITTELBOOM[*], B. VAN BELLEGHEM[*], J. DHAENE[†], L. VAN HOOREBEKE[†] AND N. DE BELIE[*]

[*] Magnel Laboratory for Concrete Research
Department of Structural Engineering, Ghent University
Technologiepark-Zwijnaarde 904, 9052 Ghent, Belgium
e-mail: kim.vantittelboom@ugent.be, bjorn.vanbelleghem@ugent.be, nele.debelie@ugent.be

[†] Centre for X-ray Tomography of Ghent University – Radiation Physics
Department of Physics and Astronomy, Ghent University
Proeftuinstraat 86, 9000 Ghent, Belgium
e-mail: jelle.dhaene@ugent.be, luc.vanhoorebeke@ugent.be

Key words: Self-healing, Polyurethane, Capsules, Chloride-induced corrosion, X-ray radiography

Abstract. Corrosion of steel reinforcement is one of the most detrimental attack mechanisms for reinforced concrete structures. The presence of cracks, which are inextricably linked to reinforced concrete, accelerates this attack mechanism. Within this study it was aimed to heal cracks by an autonomous mechanism which is triggered upon crack appearance. During an accelerated corrosion test on mortar samples with embedded reinforcement bars, it was shown that the presence of cracks indeed accelerates the onset of corrosion and that crack healing in both, the traditional, manual way and the proposed autonomous way delay the onset of corrosion. This difference in corrosion behavior was proven by visual evaluation of the rebar surface, by means of X-ray radiography and by gravimetrical measurements which were performed after the accelerated corrosion test was finished.

Pumpability of sustainable SCC mixtures

Ángel Rodríguez[*], Gonzalo Barluenga[†], Olga Río[+], E. Mercedes López[+], Irene Palomar[†], Khanh Nguyen[+]

[*] AITEMIN
Margarita Salas,14. Leganés. 28918-Madrid, Spain
e-mail: angel.rodriguez@aitemin.es, web page: http://www.aitemin.es

[†] Department of Architecture, University of Alcala
Calle Santa Ursula, 8. Alcala de Henares. 28801-Madrid, Spain
e-mail: gonzalo.barluenga@uah.es, Irene.palomar@uah.es, web page: http://www.uah.es

[+] Eduardo Torroja Institute for Construction Sciences, IETcc–CSIC
Calle Serrano Galvache, 4. 28033-Madrid, Spain
e-mail: rio@ietcc.csic.es, mercedes.lopez@ietcc.csic.es, khanh@ietcc.csic.es web page: http://www.ietcc.csic.es

ABSTRACT

Self- Compacting Concretes (SCC) are sustainable materials because they can replace large amounts of cement by the use of low embodied energy and CO_2 mineral additions, require less energy for on-site placement, reduce working risks and enlarge durability due to the reduction of intrinsic permeability.

An experimental program on SCC-type mixtures pumpability has been proposed to analyse the material behaviour during pumping, early ages and hardened performance. The main goal of this research is to identify the main parameters for pumping quality control related both to the pumping process and the effects of pumping on the material performance at early ages (24 hours after casting) and in the hardened state.

The program is structured in three stages. The first step includes the mixtures design, the definition of the main flow equations and a laboratory experimental study to identify the main parameters to be controlled during and after pumping. In a second stage, a real scale testing setup will be instrumented and several SCC samples will be pumped. In the last part of the investigation, laboratory and real scale test results will be compared and the main parameters under study will be evaluated.

The study is expected to generate the knowledge needed for the development of practical procedures and quality control tools applicable in construction sites, for assessing SCC pumpability efficiency and early age performance. The main conclusions will produce also practical recommendations for SCC pumping and application.

The research team involves a multidisciplinary group of researchers and engineers which covers mathematical and physic modelling, materials science, concrete and cement based materials, fluid dynamics and mechanical and civil engineering, jointly with materials manufacturers and construction companies. The study, SCC_Pump (BIA2013-48480-C2-2-R and BIA2013-48480-C2-1-R), has been funded by the Spanish Ministry of Economy and Competitiveness.

REFERENCES

[1] G. Barluenga, J. Puentes, I. Palomar and O. Río, "Early age drying shrinkage evaluation of self-compacting concretes and pastes with mineral additions". CONCREEP10. ASCE Proceedings, 2015.

[2] G. Barluenga, J. Puentes and I. Palomar, "Early age monitoring of self-compacting concrete with mineral additions", *Const. Build. Mat*., Vol. 77, pp. 66-73, (2015)

[3] O. Río and A. Rodríguez, "Tools for monitoring the main stages of the shotcreting process", RN Raikar Memorial Intern. Conf. and Dr. Suru Shah Symposium on Advances in Science & Technology of Concrete, ACI Proceedings, 2013.

Punching Shear Strength of Concrete Slabs Reinforced with Recycled Steel fibres from Waste Tyres

Marko Bartolac*, Domagoj Damjanović*, Joško Krolo* and Ana Baričević*

* University of Zagreb, Faculty of Civil Engineering
Fra Andrije Kačića Miošića 26, 10 000 Zagreb, Croatia
e-mail: mbartolac@grad.hr, web page: http://www.grad.unizg.hr

ABSTRACT

The increasing amount of waste tires around the world and their landfilling present a continuous problem to be solved. Currently, in some countries and unions of countries there are directives which prohibit landfilling and imply that constituent materials of waste tires must be recycled. So, the research community is continuously trying to find different ways to reuse these materials and solve this environmental problem. The main goals of these researches presume engineering, ecological and economical benefits of newly found applications of waste tires rubber, steel fibres and textile fibres. This paper presents the investigation on bearing behaviour of concrete flat slabs reinforced with sorted recycled steel fibres from waste tyres loaded with punching shear force.

The ultimate strength of flat slabs is very often governed by their punching shear capacity. This failure mode is rather brittle and can lead to progressive collapses of slab – column connections which can cause collapse of the entire structure. This capacity is traditionally increased by reinforcement in form of stirrups, shear studs or shear bands for example. In addition to these methods of strengthening against punching, industrial steel fibres have proved to be an effective alternative because of their positive effect on shear behaviour and deformation capacity of elements concerned.

The main goal of the presented research was to test the ability of sorted recycled steel fibres to perform in the same way as industrial steel fibres in flat slabs loaded in punching. Research included investigation of behaviour of reinforced concrete slabs made of several mixes including plain concrete, concrete with industrial steel fibres and concrete with industrial and sorted recycled steel fibres – hybrid fibres. A series of small-scale flat slabs were tested and results indicate that the use of hybrid fibres can improve the punching shear strength and deformation capacity of concrete slabs. Furthermore, slabs reinforced with hybrid fibres showed better general behaviour when compared to slabs reinforced only with industrial steel fibres.

REFERENCES

[1] D. Bjegović, A. Baričević, S. Lakušić, D. Damjanović, I. Duvnjak, "Positive Interaction of Industrial and Recycled Steel Fibres in Fibre Reinfoced Concrete", *Journal of Civil Engineering and Management*, Vol. **19**, pp. 50-60, (2013).

[2] A. Muttoni, "Punching Shear Strength of Reinforced Concrete Slabs without Transverse Reinforcement", *ACI Structural Journal*, **Vol**. 105, pp. 440-450, (2008).

[3] R. N. Swamy, S. A. R. Ali, "Punching Shear Behavior of Reinforced Slab-Column Connections Made with Steel Fiber Concrete", *ACI Journal*, **Vol.** 79, pp. 392-406, (1982).

[4] L. Nguyen-Minh, M. Rovnak, T. Tran-Quoc, "Punching Shear Capacity of Interior SFRC Slab-Column Connections", *Journal of Structural Engineering*, **Vol.** 138, pp. 613-624, (2012).

[5] J. Michels, D. Waldmann, S. Maas, A. Zürbes, "Steel fibers as only reinforcement for flat slab construction – Experimental investigation and design", *Contruction and Building materials*, **Vol.** 26, pp. 145-155, (2012).

Robust Design and Durability of CO2-Reduced RedCarb-Concrete with high Amount of Supplementary Cementitious Materials

C. Begemann*, L. Lohaus

Institute of Building Materials Science
Leibniz University of Hannover
Appelstraße 9 a, 30167 Hannover, Germany
e-mail: c.begemann@baustoff.uni-hannover.de, lohaus@baustoff.uni-hannover.de
web page: http://www.baustoff.uni-hannover.de

ABSTRACT

Due to the high amount of greenhouse gases and resources, caused by cement clinker production, concrete deemed to be CO_2-intensive. With respect to climate goals the CO_2-load of concrete has to be reduced. A highly promising approach represents the reduction of cement content by the use of locally available supplementary cementitious materials (SCM), like fly ash, granular ground blast furnace slag, natural puzzolanic materials or limestone powder. This leads to an easy adaptable and flexible strategy for any region, especially in upcoming and developing countries.

Considering the technical demands of the construction task, the reduction of cement content is limited to the required performance. Therefore the necessary cement content has to be determined with respect to the chosen SCM which can be evaluated by performance tests. Especially for the characterization of durability new performance-based test methods have to be chosen and to be included in the design process.

For optimizing the performance, particularly under a high substitution level of cement, the addition of water has to be limited for a proper w/b-ratio. Due to an increasing use of superplasticizer and a granular optimization of the concrete composition the water content can be used efficiently for the workability of concrete.

However, the resulting CO_2-reduced concrete compositions describe complex mixture systems which can react sensitively to variations in temperature and water content during the application period. To obtain a safe use of CO_2-reduced concrete the robustness of these concrete mixtures and their effect to concrete properties have to be considered in their application.

The current paper describes a new performance based design concept for CO_2 reduced so called RedCarb-concrete, which determines the binder composition (cement / SCM) by limiting the cement content to the required performance. Considering the local availability of raw materials, the concept is easily adaptable to different local conditions. For optimizing the concrete composition an increased amount of superplasticizer and a new method for an optimized water-efficiency is used and executed by quick and easily applicable mortar tests. Performance tests (workability, mechanical properties, durability) on mortar and concrete compositions are carried out for different cement to SCM combinations. The test results for each concrete property can be plotted as relation between performance and substitution level of cement. The resulting performance curves are helpful to choose an accurate cement substitution level for each application task. Considering the special importance of durability for CO_2-reduced concrete the current paper focuses on durability properties.

The resulting concrete compositions perform well, even under high substitution levels of cement up to 80 Vol %. Further test results considering the robustness against variations in water content and temperature of the CO_2-reduced concrete are described and first recommendations for achieving an adequate robustness are mentioned.

Steel Corrosion in Recycled Aggregate Concrete Containing Amino Acid

Takao Ueda*, Keisuke Aihara* and Tomihiro Iiboshi†

* Tokushima University
Department of Civil and Environmental Engineering
2-1 Minami-jyosanjima cho, Tokushima, Japan
e-mail: ueda@ce.tokushima-u.ac.jp

†NIKKEN KOGAKU co., ltd.
Shikoku Business Office
1-23 Minami-showa cho, Tokushima, Japan
Email: iiboshi@nikken-kogaku.co.jp

ABSTRACT

Recently, it has been reported that wave-dissipating concrete blocks containing Arginine, a kind of amino acid, could effectively form marine periphytic algae on the concrete surface in the actual seawater area, which would improve the living environment for fishes in the sea [1]. Such Arginine mixed concrete has mainly applied as plain concrete. However, the application of Arginine mixed concrete to reinforced concrete structures may be effective due to the high basic property of Arginine [2] which would enhance the protection performance of the concrete against the steel corrosion in concrete.

On the other hand, recycled aggregate concrete has been focused on due to the shortage of aggregates for concrete and the effective utilization of resources. So, this study experimentally investigated the possibility of the recycled aggregate reinforced concrete containing Arginine from the view point of the resistance performance against chloride induced corrosion of steel in concrete. In this study, immersion test of reinforced concrete specimens into salt water and chemical analysis of pore solution extracted from mortar specimens by high compression were carried out.

As a result, in the cases of recycled aggregate concrete, the improvement of the protection effect against steel corrosion was not so significant. However, the combination of the admixture of Arginine and fly ash as a substitute of the fine aggregate was most effective to improve the resistance performance against chloride penetration into concrete and consequent steel corrosion in concrete. Moreover, it was confirmed that the concentration of hydroxide ions in pore solution increased while that of chloride ions decreased with the dosage of Arginine, which would result in the enhancement of the protection performance against steel corrosion in concrete.

REFERENCES

[1] K. Sato, Y. Kozuki, H. Nishimura, C, Tara, T. Nishimura, Y. Mizuguchi, R. Yamanaka, T. Tabohashi, M. Fukuda and J. Haga, “Duration of amino acid in concrete for algae”, *Proc. of the Global Congress of ICM*, (2013).

[2] K. F. Khaled and S. R. Al-Mhyawi, “Electrochemical and density function theory investigations of L-Arginine as corrosion inhibitor for Steel in 3.5% NaCl”, Int. J. Electrochem. Sci., Vol. 8, pp. 4055-4072 (2013).

STUDY OF THE BEHAVIOR OF CONCRETE WITH RECYCLED POLYPROPILENE FIBERS

ITZIAR CARNÉ* AND PEDRO SERNA*

*Institute of Concrete Science and Technology (ICITECH)
Universitat Politècnica de València (UPV)
Camino de Vera / 46022, València, Spain
e-mail: itcargar@cam.upv.es; pserna@cst.upv.es

Key words: Plastic Shrinkage, Recycled polypropilene fibers, Concrete control, Fiber reinforced concrete

ABSTRACT

This study aims to characterize the behavior of concrete reinforced with recycled synthetic fibers produced from polypropilene waste materials. The fact that these fibers are made of polypropilene guarantees that they are compatible with the alkalinity of the concrete. The objective is to analyze the effectiveness of these fibers when used to control the cracking due to shrinkage in concrete.

The test program includes plastic shrinkage (ASTM C 1579) tests for determining the effect on controlling shrinkage. Seven different concrete mixes have been analyzed using several types of fibers and two different dosages for the recycled synthetic fibers.

The tests performed in this work show promising results in the reduction of plastic shrinkage cracking using the synthetic fibers from recycled waste materials. This study could yield in the introduction of a new type of environmentally friendly commercial fiber, since the plastic wastes represent a high percentage of the total amount of wastes.

Sustainability analysis of steel fibre reinforced concrete flat slabs

A. Blanco[†], A. de la Fuente*, and Antonio Aguado[+]

Department of Civil and Environmental Engineering
Universidad Politécnica de Cataluña
Jordi Girona 1-3, 08034 Barcelona, Spain

*e-mail: albert.de.la.fuente@upc.edu
[†]e-mail: ana.blanco@upc.edu
[+] e-mail:

ABSTRACT

Fibre reinforced concrete has been used in concrete structures without any additional reinforcement when the design is determined by transient load stages (e.g. precast segments for tunnels), in elements with favorable boundary conditions or structures subjected to low load levels (e.g. pavements or pipes) [1-3]. The material has been more recently applied as the primary reinforcement in elements subjected to higher load levels such as slabs [4-6]. As a result of the experience gained in this type of application the American Concrete Institute (ACI) has published a report on the design and construction of steel fiber reinforced concrete (SFRC) elevated slabs.

Despite these advances, in some cases fibers have not been used as primary reinforcement in concrete slabs due to economic reasons. However, in most cases the comparison of this solution with other alternatives such as traditional reinforcement has been made considering only direct material costs disregarding indirect costs, social and environmental factors. Considering the above, the aim of this study is to present a method to evaluate the sustainability of concrete slabs by means of the multi-criteria decision making approach for assessing sustainability MIVES [7-8].

REFERENCES

[1] A. de la Fuente, A. Blanco, P. Pujadas and A. Aguado. "Experiences in Barcelona with the use of fibers in segmental linings", *Tunn. Undergr. Sp. Tech*., Vol. 27, Issue 1, pp. 60–71, (2012).

[2] A. de la Fuente, R.C. Escariz, A.D. de Figueiredo and A. Aguado. "Design of macro synthetic fiber reinforced concrete pipes", *Constr. Build. Mater.*, Vol. **43**, pp. 523–532, (2013).

[3] B. Belletti, R. Cerioni, A. Meda and G. Plizzari. "Design aspects on steel fiber-reinforced concrete pavements". *J. Mater. Civ. Eng.*, Vol. **20**, Issue 9, pp. 599–607, (2008).

[4] C. Soranakom, B. Mobasher and X. Destrée. "Numerical simulation of FRC Round Panel Tests and Full-Scale Elevated Slabs", *ACI Special Publication*, Vol. **248**, pp. 31 – 40, (2007).

[5] A. Blanco, P. Pujadas, A. de la Fuente, S.H.P. Cavalaro and A. Aguado. "Assessment of the fibre orientation factor in SFRC slabs", *Composites Part B,* Vol. **68**, pp. 343–354, (2015).

[6] P. Pujadas, A. Blanco, S.H.P. Cavalaro, and A. Aguado. "Plastic fibres as the only reinforcement for flat suspended slabs: Experimental investigation and numerical simulation", *Constr. Build. Mater.*, Vol. **57**, pp. 92–104, (2014).

[7] G. Ormazabal, B. Viñolas and A. Aguado. "Enhancing Value in Crucial Decisions: Line 9 of the Barcelona Subway", *Manage. Eng. J.*, Vol. **24**, Issue 4, pp. 265–272, (2008).

[8] O. Pons and A. de la Fuente. "Integrated sustainability assessment method applied to structural concrete columns", *Constr. Build. Mater.*, Vol. 49, pp. 882–893, (2013).

The Influence of Metakaolin and Zeolithe on the Rehology, Engineering Properties, Durability and Transport phenomena of High Strength Self-Compacting Concrete at the early age
ICCS16

Kianoosh Samimi*[1], Siham Kamali Bernard [2], Ali Akbar Maghsoudi [3] and Mohammad Maghsoudi [4]

[1] Department of Civil and Mechanical Eng (LGCGM)., Institut National des Sciences Appliquées de Rennes, FRANCE.
Department of Civil Eng., Shahid Bahonar University of Kerman, IRAN.
Research and Development Service, Imen Rah Consulting Engineering Co., Tehran, IRAN.
(E-mail: samimi.kianoosh@yahoo.fr)

[2] Department of Civil and Environmental Eng., Institut National des Sciences Appliquées de Rennes, FRANCE.
(E-mail: siham.kamali- bernard@insa-rennes.fr)

[3, 4] Department of Civil Eng., Shahid Bahonar University of Kerman, IRAN.
(E-mail: maghsoudi_mohammad@yahoo.com, maghsoudi.a.a@uk.ac.ir)

ABSTRACT

The purpose of this article is to examine the effect of two types of pozzolan named as; metakaolin and zeolithe in high strength self-compacting concrete, HSSCC at the early age. For this aim, the rheological, engineering properties and transport phenomena of prepared mixtures are investigated. Five concrete mixtures are prepared with the same cement content type II (450 kg/m^3), constant W/C_m ratio of 0.4 and constant gravel to sand ratio of G/S = 1. A concrete mixture used as the control concrete (HSL) and in the other four formulations as HSM10, HSM15, HSZ10, HSZ15 metakaolin and zeolithe were usedespectively as an additive with two different replacement percentages of 10% and 15% by cement. The results indicated that the compressive strength of the concrete containing zeolithe is lower than the HSL in all ages up to 28 day. At 28 day, the compressive strength of HSM10 is higher than the HSL specimen. Whereas, from 1 day age, the compressive strength of HSM15 is higher than the HSL and HSM10. At early age, there is a close relationship between transport properties such as the migration of chloride ions in non-steady state, the electrical resistance, the capillary absorption and the profoundness of water penetration. Both pozzolan improves all the characters of transport properties in compare to control concrete. Also, with increasing the percentage of pozzolan this improvement is very considerable. In rapid chloride migration test [RCMT], by increasing age, with increasing hydration in all samples, the initial current creates derived from the primary voltage applied (30v) decreases. The study of this research shows that, taking into account the rheological and mechanical behavior, transport phenomena and also economic issues in general the use 10% of zeolithe and 15 % of metakaolin is affordable for all aspects.

Keywords: Capillary Absorption, Electrical Resistance, High Strength Self-Compacting Concrete, Metakaolin, Migration of Chloride Ions in Non-Steady State, Porosity, Penetration of the Water, Rheological and Engineering Properties, Zeolithe.

VARIOUS DURABILITY ASPECTS OF CEMENT PASTES AND CONCRETES WITH SUPPLEMENTARY CEMENTITIOUS MATERIALS

M. Saillio*, V. Baroghel-Bouny† and S. Pradelle†

* Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR), Laboratoire de Comportement Physico-chimique et Durabilité des Matériaux (CPDM)
Université-Paris-Est
14-20 Boulevard Newton, 77447 Marne-La-Vallée, France
e-mail: mickael.saillio@ifsttar.fr, web page: http://www.ifsttar.fr/

† Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR), Laboratoire de Formulation, Microstructure, Modélisation et Durabilité des matériaux de construction (FM²D)
Université-Paris-Est
14-20 Boulevard Newton, 77447 Marne-La-Vallée, France

ABSTRACT

The use of supplementary cementitious materials (SCMs) as a constituent for concrete receives considerable attention, due to the lower CO_2 emission of these materials compared to the production of classic Portland cement. Furthermore, concretes incorporating SCMs show some improved durability properties. SCMs are mainly pozzolanic materials (Fly Ash or Metakaolin) or alkali-activated materials such as ground granulated blast slag (GGBS).

In this paper, the durability of concretes and cement pastes, which incorporate SCMs as partial replacement of cement, has been investigated in comparison with the CEM-I material one. Here, studied binders are CEM I (OPC with clinker 97%), CEM I with Metakaolin (10% and 25% in replacement of cement), CEM I with fly ash (30%) and CEM I with GGBS (62% and 82%). Water porosity, chloride migration and diffusion, electrical resistivity and natural and accelerated carbonation tests have been performed, in particular in order to assess durability indicators. Coupled aggressions are also studied on these materials. For example, the materials are put in contact with chloride and sulphate solutions after partial carbonation. Apparent chloride diffusion coefficients, as well as chloride binding isotherms, are obtained by the profile method. In addition, some aspects of the microstructure and of the pore structure are investigated (for example by Mercury Intrusion Porosimetry), in order to better understand the results obtained relatively to durability indicators. Finally, the changes in the durability properties with the water curing time (from 7 days to more than 1 year) have been investigated.

The results show an evolution of the properties as a function of the cement replacement ratio by SCMs. Such a replacement improves the durability with regard to chloride penetration but decreases the resistance to carbonation (whatever the SCM type and content). In addition, since the portlandite quantity decreases in materials with SCMs, these materials are less resistant to carbonation for same exposure conditions (time and CO_2 concentration).

Keywords: Concrete, Supplementary Cementitious Materials, Durability indicators, Mercury Intrusion Porosimetry

REFERENCES

[1] M. Saillio, V. Baroghel-Bouny and F. Barberon, "Chloride binding in sound and carbonated cementitious materials with various types of binder", *Construction and Building Materials*, Vol. **68**, pp. 82–91, (2014).

[2] V. Baroghel-Bouny, K. Kinomura, M. Thiery and S. Moscardelli, "Easy assessment of durability indicators for service life prediction or quality control of concretes with high volumes of supplementary cementitious materials", *Cement and Concrete Composites*, Vol. **33**, pp. 832–847, (2011).

A Study on an Indicator for Environmental Impacts of Cement Industry

Kenji Kawai*, Seiichi Hoshino†, Hiroshi Hirao† and Satoshi Tanaka†

* Department of Civil and Environmental Engineering, Graduate School of Engineering,
Hiroshima University
1-4-1, Kagamiyama, Higashi-Hiroshima 739-8527 Japan
E-mail: kkawai@hiroshima-u.ac.jp, Web page: http://www.civil-hu.jp/concrete/

† Central Research Laboratory, Taiheiyo Cement Corporation
2-4-2, Osaku, Sakura 285-8655 Japan
E-mail: Seiichi_Hoshino@taiheiyo-cement.co.jp, Hiroshi_Hirao@taiheiyo-cement.co.jp,
Satoshi_Tanaka@taiheiyo-cement.co.jp,
Web page: http://www.taiheiyo-cement.co.jp/english/index.html

ABSTRACT

It is well known that a large amount of CO_2 is released in cement manufacturing due to decarbonation of limestone and fossil fuel combustion. In Japan, the CO_2 emission for the cement industry accounts for 3 to 4 % of the domestic total CO_2 emission. As a method for environmental impact reduction of cement, therefore, blended cement is often used nowadays. On the other hand, Japan is a very small island country that has limited general and industrial waste disposal sites. Effective utilization of resources and resource recycling as well as reduction of CO_2 emission are very important for creating a sustainable society at least in Japan. Although cement manufacturing has a heavy load on the environment in terms of CO_2 emission, it also significantly contributes to resource recycling in Japan. About 28.5 million tons of industrial wastes and by-products were recycled in cement manufacturing in 2012 as alternative raw materials and fuels. This value corresponds to about 10 % of domestic total reused amount. From this point of view, the use of blended cement instead of normal cement reduces the recycling of wastes in cement manufacturing. It can be said that the environmental impacts of cement manufacturing should be evaluated from the viewpoints of not only CO_2 emission but also resource recycling.

Based on the above background, an indicator appropriate to evaluate the environmental impacts of cement industry was investigated in this study. There are already many indicators for environmental impacts developed all over the world. In this study, however, a comparatively simplified evaluation method was discussed to easily calculate the environmental impacts.

As an indicator for resource recycling, recycling rates were focused on in this study. The industrial wastes and by-products recycled in cement manufacturing in Japan include blast furnace slag, coal ash, dirt and sludge, by-production gypsum, construction soil, ash (dust), nonferrous slag, wood chips, foundry sand, steel slag, waste plastic, waste oil, waste activated clay, reclaimed oil, used tire meat and bone meal, waste coal and so on, some of which are very difficult to be recycled in other industries than cement manufacturing. The recycling of those wastes was considered to increase the value of the indicator more than that of other wastes. The value of this indicator was compared to the value obtained from a conventional LCA method. Integration of the indicators of CO_2 emission and resource recycling was also discussed.

As a result, the values of the indicator for resource recycling are in good agreement with the values obtained from the conventional LCA method. For this indicator, the use of normal cement provided a higher value than the use of blended cement. It was suggested that the indicator for resource recycling which is calculated using recycling rates could be effective in the evaluation of environmental impacts of cement manufacturing.

REFERENCES

[1] S. Hoshino, K. Kawai, R. Kuga, O. Kubota, H. Hirao, S. Tanaka and T. Okamura, “Study of environmental indicator for material life cycle of cement in Japan”, *Proc. 14th Int. Congr. Chem. Cem.*, (2015).

Can a general structural code for both new and existing concrete structures enhance the way we approach sustainability for existing structures?

S L Matthews * and G Mancini †
** Building Research Establishment Ltd., Garston, Watford, WD25 9XX, UK*
Convenor fib Commission 3: Existing concrete structures
Email: matthewss@bre.co.uk; Web page: www.bre.co.uk; www.breglobal.com

† *Politecnico Di Torino, Department of Structural & Geotechnical Engineering Torino, Italy*
Deputy Convenor fib Commission 3: Existing concrete structures
Email: giuseppe.mancini@polito.it; Web page: www.polito.it

THEMES: Sustainability aspects of durability and the extension of use of concrete structures

ABSTRACT

Discussions have been underway in *fib* (*Fédération Internationale du Béton*) about advancing the *fib* Model Code for Concrete Structures 2010 (MC2010) and the desire to extend the current *fib* code provisions for matters relating to existing concrete structures. These diverse discussions include a recent (June 2015) *fib* international workshop on this topic held in The Hague, the Netherlands.

The debate has considered factors relevant to the preparation of a single merged general code that fully integrates the provisions for the design of new concrete structures and matters relating to existing concrete structures, including situations where new structural members are incorporated as parts of existing structures.

Such a general structural code would need to be able to deal effectively with both new and existing concrete structures and to follow an integrated life cycle perspective and service life design approach, which promotes a holistic treatment of defined performance requirements, incorporating consideration of structural safety, serviceability, durability and sustainability, establishing a link to wider issues such as the through-life management, cost, environmental and societal impacts of concrete structures.

Examples of the desired improvements include:

- Procedures for verifying what constitutes the most sustainable engineering solution, especially with regard to the particular cases found with existing structures.
- Refined mechanical response models, based on rational physical behaviours (i.e. to replace where possible those based on empirical relationships with limited validity) providing a consistent basis for both design and assessment.
- A wider systematic implementation of the Level of Approximation Approach used in *fib* MC2010.
- Improvements in the ease of use of the code.

Thus a general structural code would have integrated provisions for both the design of new structures and all the activities associated with the assessment, interventions and the through-life management of existing concrete structures.

The paper would overview these potential developments, with a particular focus being on the way we might approach the sustainability for existing structures, issues of durability and the extension of the use and service life of existing concrete structures. Examples of practice and benefits arising for existing structures would be given.

Engineering the Way for Sustainability
ICCS16

György L. Balázs*,

Salem G. Nehme*, Rita Nemes*, Arpad Ceh† and Katalin Kopecskó**

* Budapest Univ. of Technology and Economics (BME)
Fac. of Civil Eng., Dept. of Consturction Materials and Technologies, H-1521 Budapest
e-mail: balazs.gyorgy@epito.bme.hu, nehme.salem@epito.bme.hu, nemes.rita@epito.bme.hu

† University of Novi Sad, Faculty of Civil Engineering, Subotica,
e-mail: ceh@gf.uns.ac.rs

* Budapest Univ. of Technology and Economics (BME)
Fac. of Civil Eng., Dept. of Engineering Geology and Geotechnics,
e-mail: kopecsko.katalin@epito.bme.hu

ABSTRACT

Where are we going? How far can we go?

Engineers play an extraordinary role in understanding and in application of sustainability rules. We should be able to develop and show the most reasonable way to keep the right proportions of human needs and nature acceptance. Sustainability is considered as a necessary effort to find a reasonable balance among safety, serviceability, robustness, durability, environmental protection as well as social and economic needs.

Innovative solutions

We have to find innovative solutions from the point of view of structural engineering including new materials as well as new structural concepts that extend current practice for supporting sustainability.

Environmentally friendly materials

Future structural materials should follow optimal selection of material compositions and construction processes with wider use of blended and ternary cements and wider use of recycled aggregates as well as alternative binders. Use of slag and fly ash in blended cements is not only for environmental purposes but may have also advantageous like improved sulphate resistance, lower shrinkage, reduced probability of AAR etc. Wider acceptance of natural fibres as kind of tensile reinforcement is also of importance.

Durability, Service life, Service life extension

Increased durability (as well as increased service life and increased maintenance cycles) provide one of the best solutions to sustainability.

We are going towards a better acceptance and better understanding for sustainability as one of the key aspects in the material production as well as in the design, construction and use.

GREEN CONCRETE SPECIFICATION AND ENVIRONMENTAL DECLARATIONS OF CONCRETE

Donguk CHOI

Dept. of Architectural Engineering, Hankyong National University,
(17579) Anseong, Gyeonggi-do, South Korea
1) e-mail: choidu@hknu.ac.kr, www.choidu.com

Abstract

This technical paper introduces "Green Concrete Specification" and "Environmental Declarations of Concrete" that are results of recent work in the area of sustainability by Korea Concrete Institute (KCI). While the former is a technical specification to be launched in the near future, the latter is a draft standard at present. The key concept of the Green Concrete Specification includes the "environmental management and green construction plan" submitted by the contractor to the client at the beginning of concrete construction in the following four areas: reduction of GHG emission and energy consumption, effective use of resources, environmental management of construction site and neighborhood, and water management. Environmental Declarations of Concrete is introduced in two parts: introduction of concepts of the environmental labels and declarations, and excerpts from the aforesaid draft standard. Finally an effort for standardization on environmental labels and declarations of concrete and concrete structures at international level is briefly introduced.

Keywords: Green Specification, Environmental Labels, Environmental Declaration, Concrete, ISO

717: New route to synthesize biobased PCE superplasicizer

J. Zimmermann*, C. Fiuza#

*Sika Technology AG
Tüffenwies 16
8048 Zürich, Switzerland
e-mail: zimmermann.joerg@ch.sika.com

#Sika Services AG
In der Luberzen 25
8902 Urdorf, Switzerland
e-mail: fiuza.clara@ch.sika.com

ABSTRACT

The limited availability of fossil resources and the need to reduce CO2 emission accelerate the development of bio based polymers which possess a low carbon footprint. Beside natural polymers, particular the fast development of biomass conversion in bio refineries has extended the number of available base chemicals within the recent years.

Within concrete production, the use of natural polymers like carbohydrates, cellulose derivatives or lignosulfonate has a long history. However, all high performing polycarboxylate ether (PCE) based superplasticizers, are nowadays based on monomers derived from crude oil.
In this article a new route to synthesize biobased PCE superplasicizer is presented. Based on the used raw materials, this PCE superplasticizer contains more than 80% biobased carbon. Live cycle analysis (LCA) in comparison with conventional crude oil based PCE was done. It is shown that the global warming potential can be reduced by 9% and primary energy demand by 36% if biobased PCE are used.
Beside the clinker reduction, the use of biobased superplasticizer will further improve the sustainability of concrete in future.

Overview of Resource Conservation and Closed-loop Recycling in Concrete toward Sustainability

Takafumi Noguchi

Department of Architecture
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
e-mail: noguchi@bme.arch.t.u-tokyo.ac.jp, web page: http://bme.t.u-tokyo.ac.jp/modules/bme_en/index.html

ABSTRACT

Providing excellent performance as a structural material, concrete has long been deemed essential for modern civilization and recognized as a material that will continue to maintain and support the development of human society. The sheer amount of concrete in use and in stock compared with other building materials brings up the issue of the enormous amount of waste generated when concrete is disposed of. Besides, resources for good quality aggregate are beginning to be depleted at a high speed and limestone, which is an essential raw material for Portland cement, is not inexhaustible. Concrete has conventionally been regarded as being difficult to recycle. The construction industry has addressed these problems and carried out research and development regarding the recycling of concrete since the 1970s. The development history of concrete recycling is summarized in a paper from the viewpoints of the properties and the application of recycled aggregate concrete. The paper categorizes recycling technologies according to the quality of recycled concrete aggregate into several types including simple crushing techniques and advanced techniques, e.g. scrubbing with preheating. Advanced techniques avoid down cycling and recover recycled concrete aggregate, having the same quality as natural aggregate from waste concrete, forming a closed-loop in terms of the resource circulation of concrete materials. However the problems are remained in the energy-induced environmental impact and cost increase. The time has come when establishment of a new design concept for complete recycling of structural concrete is definitely necessary. The principle of complete recycling is that the concrete is subject to material design to reduce waste generation and facilitate resource circulation in a closed-loop system. Development technology based on such material design is regarded as proactive technology. The materials of concrete should be used as parts of concrete during the service life of concrete and remain usable after demolition as parts of similar or other products without quality deterioration, continuing circulation in various products as the media. The paper introduces a history of development of completely recyclable concrete, with which closed-loop circulation of component materials is realized like steel and aluminium. The paper also introduces the outline of "Guideline for Mix Design, Production and Construction Practice of Concrete with Recycled Concrete Aggregate" published by Architectural Institute of Japan in 2014. It shows standard specifications for the investigation of demolished reinforced concrete structures and the production and quality control of recycled aggregate, and recommendations for the appropriate application of recycled aggregate concrete according to the requirements for strength and service life of structures, and prescribes the mix proportioning, production technique, transportation method, execution technique, and quality control method for recycled aggregate concrete.

Resiliency: The Key to a Sustainable Future

Julie K. Buffenbarger, LafargeHolcim
1451 Snowberry Lane, Medina, Ohio, USA
e-mail: Julie.buffenbarger@lafarge.com, web page: http://www.lafarge-na.com

Worldwide population growth, urbanization, and global industrial production have driven increased consumption of resources (energy, water, materials, and land), political conflict, and climate change
These are all imminent challenges in coming decades, especially climate change. The increased frequency and severity of extreme weather events due to human-induced climate change have led to disaster scenarios resulting in catastrophic affects to physical and natural infrastructure, loss of community continuity, regional and global economic burden. Given the intensity of climate change, a call for resilience employing transformative innovations in urban planning, industrial technology, and environmental policy is necessary to sustain a growing, vibrant economy.

Society, generally understands that urban systems (buildings and infrastructure) represent enormous investments of materials, energy, and capital, resulting in significant environmental burdens and social consequences. In addition to designing buildings and infrastructure to minimum life safety provisions, adoption of fortification measures against climate-related, natural and manmade disasters must occur. Enhancing the robustness, durability, longevity, disaster resistance, and safety of structures is accomplishable with innovative materials and technology, sound construction practices, and employment of appropriate inspection and maintenance strategies. The safety, serviceability and extended service life minimizing the risk of failure for buildings and infrastructure are securable through sustainable and resilient design, construction and maintenance.

Sustainability of Concrete Structures in Changing World

Petr Hajek*

* Faculty of Civil Engineering, Department of Building Structures
Czech Technical University in Prague (CTU)
Thakurova 7, 166 29 Prague 6, Czech Republic
e-mail: petr.hajek@fsv.cvut.cz, web page: http://kps.fsv.cvut.cz

ABSTRACT

Concrete is used in construction of buildings, bridges, dams, roads, tunnels – basically every contemporary construction contains concrete. Cement production is associated with large energy consumption and high amount of CO_2 emissions. World cement production has been 12 times increased in the second half of the last century and thus the cement industry produces at present about 5 - 7% of global man-made CO_2 emissions. More over high amount of concrete use is associated with high transport needs and demands on production and demolition processes within the entire life cycle. This all has significant impact on the environment.

Current development of concrete, production technology and development of concrete constructions during last twenty years have lead to quality shift of technical parameters and also of related environmental impacts. New types of concrete have due to mix optimization significantly better characteristics from the perspective of strength, mechanical resistance, durability and resistance to extreme loads. Concrete gradually becomes building material with high potential for expectant environmental impact reduction. This needs better knowledge about technological processes and their impacts from wide variety of sustainability aspects within entire life cycle – from acquisition of materials, through production of concrete and concrete components, construction, use, up to demolition of concrete structure and recycling.

World is changing. We are faced to increasing frequency of natural disasters due to continuously increasing global environmental changes. Earthquakes, floods, storms, hurricanes, tornados, fires, tsunami, volcanic events, extreme dry weather etc. are more and more frequent. We are faced to increasing economical social problems incl. terrorism. The structures for sustainable future should be better prepared for the new conditions, more resilient.

New conceptual approach to design and evaluation of structures is an integrated life-cycle assessment, representing multi-parametric assessment of the structure within the whole life cycle. This approach integrates material, component, and structure design and considers selected relevant criterions from a wide range of criterions sorted in three basic groups of sustainability: environmental, economical and social. The paper presents conceptual approach for integrated life-cycle assessment of concrete structures based on general methods and tools for life-cycle assessment of structures and considering aspects of sustainability.

Already implemented realizations give clear signal that in the forthcoming era when designing and implementing concrete structures it will be necessary to take into account new requirements and criteria following from global aspects on sustainable development.

REFERENCES

[1] Hájek P, Fiala C., Kynčlová M.: Life Cycle Assessment of Concrete Structures – Step towards Evironmental Savings, Structural Concrete, fib, 2011, vol. 12, no. 1, p. 13-22. ISSN 1464-4177.

[2] Fib Bulletin 71 (2013) Integrated Life Cycle Assessment of Concrete Structures, State-of-the art report, ISBN 978-2-88394-111-3.

Swedish view on concrete & sustainability

Dr. Johan L Silfwerbrand
Professor in Structural Engineering & Bridges
Div. of Concrete Structures
Dept. of Civil & Architectural Engineering
KTH Royal Institute of Technology
SE-100 44 Stockholm
Sweden

E-mail: jsilfwer@kth.se

Abstract
Being the most frequently used man-maid construction material with a history of more than 2000 years, concrete may be defined as a sustainable material per se. Correctly designed, properly constructed, and suitably maintained, a concrete structure may reach a life-span that substantially exceeds 100 years. Durability is the bases for sustainability.
The importance of sustainability has increases successively during the last 20 years. In the concrete industry, the focus has been on substituting Portland cement – that roughly stands for 5 percent of the carbon dioxide emissions globally – with various byproducts as slag, fly ash, and silica fume. As organizer of the 2012 fib Symposium on "Concrete Structures for Sustainable Community" in Stockholm, Sweden, we could easily support this statement by just categorizing and counting the number of papers. However, there are many more aspects on sustainable concrete. The Swedish cement producer Cementa AB has a zero vision, i.e., there should be no CO_2 emissions in 2030. The goal will be reached by making the kiln more energy efficient, replacing fissile fuels by renewable fuels, taking the carbon uptake through carbonization into account, and by developing carbon capture and storage. We may develop new concrete mixes that either are lean with not more cement than necessary or high strength that will reduce the cross section and thus the dead load considerably.
In addition to all these measures on the material side, we must maximize the benefits of concrete during the serviceability state. The effects of energy storage capacity, brightness, and wear resistance make concrete buildings and concrete pavements competitive but by, e.g., increasing density, whiteness, and wear resistance we may save more energy for heating, cooling, illumination, and repaving. Finally, we must not forget concrete's opportunities concerning recycling.
The full paper will further discuss all these factors and summarize the Swedish research on some of the most important ones.

A Sustainability Assessment Approach Based On Life Cycle Assessment for Structural Retrofit of RC Members

Costantino Menna*, Loredana Napolano†, Domenico Asprone* and Andrea Prota*

* Department of Structures for engineering and Architecture
Univeristy of Naples Federico II
Via Claudio 21, 80125 Naples, Italy
e-mail: costantino.menna@unina.it, web page: http://dist.dip.unina.it/

† STRESS scarl, Sviluppo Tecnologie e Ricerca per l'Edilizia sismicamente Sicura ed ecoSostenibile,
Vico II San Nicola alla Dogana 9, 80133 Naples, Italy

ABSTRACT

Over the last decade, the rehabilitation/renovation of existing buildings has progressively attracted the attention of the scientific community and government institutions. However, only few studies have been conducted so far to investigate the environmental performance and potential benefits of these techniques applied to reinforced concrete (RC) structures. The environmental impacts associated with a structural retrofit operation can be successfully evaluated by means of a life-cycle assessment (LCA) based approach. Nevertheless, even though the LCA of a single building component or process can be effectively conducted according to processes/manufacturing data and methodological standards, on the other hand, a retrofitted building/structure is a system that is too complex to be assessed, with a long lifespan that involves multifaceted procedures, hypotheses, data collection, and interpretations. The goal of the present work is to shift the LCA application from single building components to retrofitted structures in order to orient the decision-making process (at the design stage) towards low-impact solutions.

To this aim, we provide a methodological framework to assess the environmental impacts of typical retrofit operations employed for RC members and referred to existing buildings. The study moves from the fact that the design approach for structural retrofit starts from specific requirements, often following technical national standards. As case study, three different retrofit options applied to RC columns are investigated: *i)* carbon fiber and *ii)* steel wire wrapping and *iii)* steel jacketing. The corresponding environmental performance is computed by means of a Life Cycle Assessment (LCA) approach; the main hypothesis for the LCA comparative study is that the different structural retrofit options are designed in order to guarantee the same structural performance in terms of resulting shear strength of the retrofitted RC column. In addition, the LCA analysis is conducted from "cradle to gate", i.e. including the following phases: the extraction and processing of raw materials, manufacturing, preparation of the substrate and the installation of the external reinforcement. The analysis revealed some important insights concerning the most impacting material for each technique as well as the environmental comparison between them. This preliminary assessment contributes to the definition of a methodological framework able to drive the construction community's users in the conduction of reliable environmental sustainability comparisons of a whole retrofitted building system at the design stage.

CARBON EMISSIONS CAPTURING IN CEMENT

VANESSA RHEINHEIMER* AND PAULO J.M. MONTEIRO†

* Berkeley Education Alliance for Research in Singapore Ltd 1 Create Way 11-01, 138602 Singapore
e-mail: vanessa.rheinheimer@bears-berkeley.sg
† University of California at Berkeley, Department of Civil and Environmental Engineering 725 Davis Hall, 94720 Berkeley CA, USA
e-mail: monteiro@ce.berkeley.edu

Key words: Carbon emissions, capturing, cement, concrete.

Abstract. The construction industry is constantly growing and demanding more materials to support its progress. Portland cement production is highly energy consuming and greenhouse gases emitting, and there are great efforts to minimize the environmental impact of the cement manufacturing.
Furthermore, the world's population is forecasted to reach 9 billion people by 2050, and with this comes a substantial need for infrastructure and urbanization and an enormous demand for cement: a consumption of 3859 million tonnes worldwide was observed in 2012, the highest in history and it is continuously increasing.
On the other hand, international agreements for the greenhouse gas emission reductions exert pressure on the industry by demanding the reduction of CO2 emissions by 80% prior to 2050, while the production is expected to double. Cement manufacturing produces approximately 2.4% of the global CO2 emissions from industrial and energy sources. This means that this process and material characteristics have to change significantly in the near future if these reductions are to be achieved.
There are efforts from the cement and concrete industry on finding alternatives not only to reduce the emission of CO2, but also to develop materials that can capture the CO2 from the environment during its production and service life, becoming carbon-zero or even carbon- negative.
Technologies being developed range from traditional clinker materials, to alternative cements and binders, and are reviewed in this paper.

Design for safety in construction work

M. Casanovas-Rubio*[a], J. Armengou[a] and G. Ramos[b]

[a] Universitat Internacional de Catalunya
Immaculada 22, 08017 Barcelona, Spain
e-mail: mcasanovas@uic.es, web page: http://www.uic.es

[b] Universitat Politècnica de Catalunya BarcelonaTech
Edificio B1, Campus Norte UPC
Gran Capitán s/n, 08034 Barcelona, Spain
Email: gonzalo.ramos@upc.edu - Web page: http://www.upc.edu

ABSTRACT

The concern for occupational health and safety in construction work is reflected in the many preventive measures taken. However, examples of the systematic assessment of project alternatives aimed at minimizing occupational hazards are rare.

This paper proposes a measure of occupational safety, the occupational risk index (ORI), that is based solely on the project design and resulting construction process, and is a function of the activities carried out and their specific occupational risks (probability of occurrence and most probable consequence). The proposal is illustrated with an example in which two alternatives, one precast and the other constructed in situ, are prioritized in terms of occupational safety, and certain aspects related to redesign are briefly addressed. The research is based on an analysis of the applicable legislation and interviews with experts on risk prevention.

With the ORI, occupational safety goes from having a passive influence (applications to projects that have already been designed) to an active one on the design concept itself. The ORI can thus be used as an indicator to feed multicriteria decision-analysis tools.

Development of Cementious-woodtip Compound Products for Resilience Measures in Disaster Situation Toward Sustainability

Masaki TAMURA*, Kyohei ARAKAWA*2 and Yumi OIWA*3

*1Environment Material Engineering Group, Department of Architecture,
Graduate School of Engineering, Kogakuin University,
1-24-2 Nishi-shinjuku, Shinjuku-ku, Tokyo, 163-8677, Japan
e-mail: masaki-t@cc.kogakuin.ac.jp, web page: http://www.ns.kogakuin.ac.jp/~dt40009/tamura/
*2 Sumitomo Ringyo Hometec, Co.,Ltd
*3 PanaHome Co.,Ltd.

ABSTRACT

Recently the urbanaized areas in Japan, a lot of concrete structures have been stocked and the performance conditions in a part of them have been deteriorating gradually.

On the other hand, the various effects of natural disasters such as big earthquake focusing on a city zone and the global warming phenomenon in whole urban and regional areas would be necessary to prospect the occurance in near future, and the various effective prenention measures are preparating to carry out immediately and strongly.

The important era against these situations is upcoming rapidly, and seeking to reconfirm the balances between resource conservation and building construction to be considered the resilience measures in disaster situation toward Sustainability.
Overview these conditions, the new methods for material production and building construction would be indispensable to present in Japan.

This study focused on the development of Cementious-woodtip Compound Products (CCP). The original woodtip materilals of CCP was using wasted wood materials released by the Great East Japan Earthquake 2011.

In the experiments, we prepared many types of CCP specimens applied for structural body and curtain wall panel to evaluate the relationship between mix proportions and fundamental properties. These mix proportions are different from content rates of water, particle size of woodtip and sand, and we conducted these experimental evaluations in detail on workability, strength and durability supposing to be applied for structural body and curtain wall.

As these resuls, it has been found that the mechanical strength was related between the particle size of woodtip and water cement ratio mainly, and the durability and fracture toughness were deeply effected there mixproportions.
Finally, It would be expected to increse the potential utilization of CCP by developing fundamental properties by optimizing the use ratio of woodtip compositions.

REFERENCES

[1] Masaki Tamura: Sustainability design by building resource stock utilization and activation on condition of resilience measures of disaster situation, Sustainability Workshop in Takamatsu (2014)

Doing more with less: topology optimization as a means for the design of sustainable concrete forms

Mark K. Donofrio*

* Assistant Professor of Structure and Design
School of Architecture and Allied Arts, University of Oregon
1206 University of Oregon
Eugene, Oregon 97403-1206, United States of America
e-mail: donofrio@uoregon.edu, web page: https://architecture.uoregon.edu/faculty/donofrio

ABSTRACT

Concrete is the single most widely used man-made material in the world. As such, it also carries the reputation of being the largest contributor to the rise in carbon dioxide (CO_2) and greenhouse gas emissions. The negative reputation that concrete carries is less a matter of it being inherently a 'bad material' and has more to do with the sheer abundance of its use, making it an easy target for criticism. No material is perfect. For instance, in order to achieve an equivalent performing structure in steel, one would consume upwards of twice the volume of energy, as well as cause more severe impacts on water and air pollution than to produce its concrete equivalent. There are clearly no simple answers in the search for more sustainable material usage within the building industry. The strides currently being made by chemists, material scientists and manufacturers to achieve more sustainable means of production and manufacturing of their respective materials is certainly a step in the right direction, but this alone will not solve all of the problems. It is up to the designers of the built environment, architects and engineers, to also seek more sustainable means of designing with these materials. What is needed is a design methodology that strives to do more with less.

This paper presents research exploring the potential of topology optimization as a means for the design of sustainable concrete structures. Topology optimization is a mathematical, gradient-based design procedure that can be used to determine the distribution of required material within a design domain based upon defined loads and boundary conditions while meeting a prescribed target objective, such as minimizing deflection. Topology optimization differs from other optimization techniques, such as shape optimization, as shape optimization methods typically operate on a fixed, predefined topology. Therefore, topology optimization is used to generate the initial form concepts and shape optimization can be used to fine-tune a chosen design topology. The concept of topology optimization has been utilized by the automotive and aerospace industry for almost thirty years now, since its early development, as problems associated with solutions meant to satisfy maximum stiffness with minimum weight are of the utmost importance.

The recent saturation of digital design tools and techniques within the architecture industry have led more and more architects to seek computationally driven, data-centric, methodologies to assist in the design process. Topology optimization is well suited as a methodology to assist in the development of form that is rooted in sound structural logic while striving for material efficiency. This paper presents case studies of recent architectural projects that utilize topology optimization for projects ranging from long-span roof structures to high-rise buildings. While not all the projects exclusively utilize reinforced concrete, these case studies are examined more for their potential in defining a methodology and workflow that seek material efficient forms through the use of topology optimization. In addition to these professional design case studies, case studies of student work from a course recently taught at the University of Oregon focuses more specifically on the issues associated with the design and production of concrete structures and highlights the opportunities of advanced manufacturing techniques as a means of realizing more sustainable concrete forms through the use of topology optimization.

REFERENCES

[1] Crow, James Mitchell. "The Concrete Conundrum." *Chemistry World* 5, no. 3 (2008): 62-66.
[2] Bendsøe, Martin P., and Sigmund, O. *Topology Optimization : Theory, Methods, and Applications*. Berlin; New York: Springer, 2003.

Durability behaviour of sustainable cements exposed under real environmental conditions of the Mediterranean area

I. Sánchez, M.P. Lopez, J.M. Ortega, M.A. Climent

Civil Engineering Department, Univerisity of Alicante.
EPS II, Campus San Vicente del Raspeig, 03690, San Vicente del Raspeig (Spain)
e-mail: isidro.sanchez@ua.es

ABSTRACT

The use of cements that contain mineral admixtures is a topic of great interest, mainly due to the contribution to the sustainability of the construction industry that these cements provide. In fact in the current instruction for structural concrete in Spain an index to calculate the contribution to the sustainability of a structure has been included. Among some other factors, one of most important ones is the use of cements containing additions to produce a more sustainable structure [1].

The use of this type of cements, under some conditions, improve the properties of concrete structures, both from the strength point of view, as from the durability point of view, and these aspects have been tested also under non optimal conditions [2, 3]. These studies were done under controlled and constant conditions, closer to the reality of the environment where most structures are hardened, but do not include the variation that occurs in real exposures.

In order to get a more realistic study of the behaviour of these materials in real environments several samples have been exposed in two different locations in the area of Alicante. One of them is placed close to the seaside, and the other one has been placed close to a very crowded highway. In this locations it has been studied the microstructural development of the materials, using mercury intrusion porosimetry, and some durability factors, such as capillary suction coefficient, chloride diffusion coefficients, carbonation rate, and corrosion potential and corrosion rate. The results show that under the studied conditions the studied cements give durability properties at least as good as the ordinary Portland cement does, in real conditions. This result is important because guarantees the durability of structures built with more sustainable materials.

REFERENCES

[1] "EHE-08 Instrucción de hormigón estructural". (2010) 4th Edition. Ministerio de Fomento. (Spain)

[2] J.M. Ortega, I. Sánchez, M.A. Climent. "Durability related transport properties of OPC and slag cement mortars hardened under different environmental conditions". Con. Build. Mat. 27 (2012), pp. 176–183

[3] J.M. Ortega, I. Sánchez, C. Antón, G. de Vera, M.A. Climent. "Influence of Environment on Durability of Fly Ash Cement Mortars". ACI Mat. J. 109 (6), (2012). pp 647-656

Lessons Learned from Implementing the North American Precast Concrete Sustainable Plant Program

Emily Lorenz* and Dean Frank†

* independent consultant
1333 W. Greenleaf Ave.
Chicago, Illinois 60626, USA
Email: emilyblorenz@gmail.com - Web page: http://www.sevgen.com

† Precast/Prestressed Concrete Institute
200 W. Adams St. Suite 2100
Chicago, Illinois 60606, USA
e-mail: dfrank@pci.org, web page: http://www.pci.org

ABSTRACT

As codes, standards and environmental mandates continue to drive green building; customers are increasingly requesting products made from environmentally friendly industrial and manufacturing processes. In response, the North American Precast Concrete Industry has launched a Sustainable Plant Program. The goal of the program is to position its members for success in this high growth market by helping them improve the environmental impact of their manufacturing facilities. To do so, some tracking is required to monitor progress and establish an industry average Environmental Product Declaration. This presentation will outline the requirements of the program, and will include examples lessons learned during implementation of the program.

Life Cycle Assessment of Protective Coatings for Concrete

Michel Donadio*, Ana Carmona†, Antonio Tebar† and Clara Fiuza†

* Sika Services AG, Tüffenwies 16, 8048 Zürich, Switzerland
e-mail: donadio.michel@ch.sika.com, web page: http://www.Sika.com

† Sika, S.A.U., Ctra de Fuencarral, 72, 28108 Madrid, Spain
Email: carmona.ana@es.sika.com – web page: www.sika.es

† Sika, S.A.U., Ctra de Fuencarral, 72, 28108 Madrid, Spain
Email: tebar.antonio@es.sika.com – web page: www.sika.es

† Sika Services AG, Tueffenwies 16, 8048 Zurich, Switzerland
Email: fiuza.clara@ch.sika.com – web page: www.sika.com

ABSTRACT

Concrete protection is generally carried out using protective coatings that in Europe should comply with EN 1504-2. Different types of coatings are available in the market, including water or solvent dispersed acrylic polymer based, or with other polymer bases such as polyurethane (PU).

Depending on the quality and exposure of a coating, recoating is generally required after some times. Based on experience, it is assumed that a good quality, water dispersed acrylic coating needs to be recoated approximately every 10 years, whilst a similar solvent dispersed acrylic or PU coating can last longer and extend the period before recoating is required to maintain the performance.

EN 1504-2 details the performance requirements that a protective coating must comply with, but it does not provide any information on the impact that the use of different types of coating materials may have on the sustainability aspects.

This paper presents a Life Cycle Assessment of several different protective coatings for concrete – all conforming with EN 1504-2 including a water dispersed acrylic and a newly developed water dispersed PU; a solvent dispersed acrylic normal and high performance grades, plus a solvent dispersed PU. This was carried out using a scenario of the application of these different coatings over 1000 m^2 each on a concrete structure and evaluated over a period of 60 years.

LCA is a standardized method to assess and compare the inputs, outputs and potential environmental impacts of products over their life cycle. By providing a quantitative assessment of the environmental performance, it enables the differentiation of products that may have similar performance, but greater differences concerning their environmental impact, where obviously the lower, the better.

The analysis shows that the quality of the coatings, their durability, frequency and quantity of inputs, as well as solvent content are keys to evaluate the environmental performance of the different protective coatings over a given structure's lifespan.

REFERENCES

[1] International Organisation for Standardisation (ISO). Environmental management – Life cycle assessment – Requirements and guidelines, ISO 14044:2006; ISO: Geneva, 2006.

[2] CEN/TC 350, Sustainability of construction works - Environmental product declarations - core rules for the product category of construction products, EN 15804:2012, 20112.

Life cycle assessment of reinforced concrete beams designed according to the MC 2010 and the Spanish EHE – 08 standard

Pujadas, P.*, de la Fuente, A.† and Almirall C.†

*Department of Civil and Environmental Engineering, Division of Structures, Materials and Construction Technology, School of Civil Engineering
Universidad Politécnica de Cataluña
Campus Norte UPC, 08034 Barcelona, Spain
e-mail: pablopujadas@upc.edu, web page: http://www.upc.com

ABSTRACT

The Model Code for Concrete Structures 2010 is a recommendation for the design of structural concrete, written with the intention of giving guidance for future codes [1]. As such, the results of the newest research and development work are used to generate recommendations for structural concrete at the level of the latest state of the art. Inevitably, some differences exist between the structural design approach proposed by the Model code and one proposed by other design standards such as the Spanish code (EHE-08).

Such differences on the design of concrete beams may result in different solutions, all of which ensure service during the whole expected lifetime with a maximum functional quality and safety, but with different environmental impacts. For this, the objective of the study is to carry out a comparative analysis of the environmental impact of concrete beams depending on the reference code used for its design

With this aim, a large number of simply supported beams cases were calculated according to the EHE and the Model Code standards varying basic parameters such the length span, beam geometry, ambient class, and design loads. Thus, not only a direct a cross-wise comparison of the environmental repercussion between both design codes is done but a complete environmental parametric study.

Thereby, this paper represents a meaningful contribution to provide a step towards the use of environmental structures approaches on standard codes and design recommendations.

REFERENCES

[1] Walraven, J. (2013). *fib Model Code for Concrete Structures 2010: mastering challenges and encountering new ones*. Structural Concrete, 14(1), 3-9.

Life Cycle Assessment of Waterproofing Solution for Concrete Basement

Ana Carmona[*], Clara Fiúza[†], Cristobal López[†]

[*] Sika, S.A.U.
Ctra de Fuencarral, 72, 28108 Madrid, Spain
Email: carmona.ana@es.sika.com – web page: www.sika.es

[†]Sika Services AG
Tueffenwies 16, 8048 Zurich, Switzerland
Email: fiuza.clara@ch.sika.com – web page: www.sika.com

[†]Sika, S.A.U.
Ctra de Fuencarral, 72, 28108 Madrid, Spain
E-mail: lopez.cristobal@es.sika.com – web page: www.sika.es

ABSTRACT

The use and durability of a concrete structure is mainly dominated by the watertightness of the structure: water ingress not only results in physical and chemical degradation of the structure, but also influences the living comfort due to high air humidity or seepages. An appropriate designed waterproofing system avoids all these negative effects during the entire life cycle, saves energy and costs for remedial works.

Taking all project requirements (ground conditions, degree of watertightness, type of application as well as durability) into consideration, the basic strategy for waterproofing of basement can be evaluated. In general there are three different strategies which can be designed as rigid and/or flexible waterproofing: integral, external or internal waterproofing systems.

The paper provides an overview of the three waterproofing strategies, with particular focus on external waterproofing systems. Within the external waterproofing systems strategy, three different systems available for the waterproofing of below ground concrete structures are analysed. It shows how specialised systems can help the designer and contractor, to the benefit of the customer. A case study is shown for the waterproofing of a below ground concrete structure in Spain, with the aim to analyse the environmental advantages of using such specialised sustainable solutions, to finally achieve a higher concrete durability and efficiency of buildings and construction. A Life Cycle Assessment (LCA) of the three external waterproofing solutions and materials based on real life practical experiences was performed, to evaluate and compare their potential environmental impacts. LCA is a standardized method to assess and compare the inputs, outputs and potential environmental impacts of products over their life cycle. By providing a quantitative assessment of the environmental performance, it enables the differentiation of products that may have similar performance, but greater differences concerning their environmental impact, where obviously the lower, the better. The analysis shows how the selection of the right waterproofing strategy improves the overall environmental performance.

NO_x Adsorption, Fire Resistance and CO_2 Sequestration of High Performance, High Durability Concrete Containing Activated Char

M. Di Tommaso* I. Bordonzotti**

* Istituto Meccanica dei Materiali SA (IMM SA) - Montagnola / Lugano – Switzerland e-mail: ditommaso@imm.ch, www.imm.ch
** ibotech SAGL – Morbio Inferiore – Switzerland

ABSTRACT

The scientific community made limited research to date on the use of bio-char in concrete. **C**urrent work assumes this material as inert/waste aggregate and defines the impact of its dosage on the properties of concrete[1]. **CO_2** sequestration by incorporation of a product generated by pyrolysis of biomass being the main target of current research. **H**owever, due to its nature, activated bio-char promises to be more than that, providing pollutants adsorbing properties[2] and improved fire resistance of concrete. **T**he scope of our research is that of determining a proprietary blend of suitable cementitious materials and activated bio-char that could provide: NO_x adsorbing properties and resistance to fire. **W**e compared properties of a C50/60 XF4, XC4, XD3, XA3 fire resisting (with PP fibers) concrete mix used for the construction of the viaducts of the high speed railway system in Switzerland. **A** reference C50/60 high performance mix has been cast with and without activated bio-char. **W**hen activated bio-char was used, PP fibers were omitted from the mix. **T**he following properties were compared: compressive and tensile strength, elastic modulus, freeze-thaw resistance, chloride diffusion, capillary permeability, sulphates resistance, accelerated carbonation and resistance to fire (spalling depth and temperature profiles). **R**esults have shown that the use of optimal dosages of activated bio-char in high performance concrete does not affect any of its mechanical and durability properties. **A**ll values obtained by the activated bio-char concrete fulfil the requirements of SN EN 206/1 and SIA 262/1 standards. **C**ompressive and tensile strength and elastic modulus resulted fully comparable with/without activated bio-char. **A**dditionally, the consequence of using activated bio-char is that concrete can became a potential long-term storage medium for NO_x pollutants while providing an improved resistance to fire even in the absence of PP fibers. **T**he reason why spalling depth during fire exposure was limited when bio-char was used as PP replacement is not yet clearly understood but a dissipation mechanism of internal vapour pore pressure promoted by the activated (high porous) bio-char may be possibly invoked. **A**ll tests conducted in this research have been carried out by an ISO/CEI 17025 laboratory (IMM SA) according to relevant Swiss / European standards with the exception of the NO_x adsorption test and fire resistance test carried our by accredited European laboratories (Tera Environment and EFECTIS Netherland respectively) according to *ad-hoc* developed procedures (for NO_x adsorption[2]) and testing recommendations/fire curves[3]. **B**io-char seems to offer therefore a greener/technically promising opportunity for the production of high strength, high durability concrete for road tunnels (where increased resistance to fire is mandatory for safety issues and pollutants' adsorbing properties are desirable for environmental issues) and for civil infrastructures in general where the yearly (extremely large) volumes of (activated bio-char) concrete may create long term sink structures for NO_x adsorption. **B**ecause of its nature of a product obtained from thermal cracking of biomass generated by fixing atmospheric CO_2, incorporation of bio-char allows also to exponentially increase the CO_2 sequestration potential of concrete which is by far the most widely used construction material.

[1] http://www.reeis.usda.gov/web/crisprojectpages/0230956-charcrete-carbon-sequestration-in-concrete.html

[2] M. Horgnies, I. Dubuois-Brugger and E.M. Gartner, "NO_x de-pollution by hardened concrete and the influence of activated charcoal additions", *Cement and concrete research*., 42 (2012) , pp. 1348–1355

[3] Swiss Federal Authority (AlpTransit): Guidelines on fire resisting concrete testing procedure, ed. 2012

Parametric Analyses on Sustainability Indicators for Design, Execution and Maintenance of Conference Structure

Hiroshi Yokota*[1], Shunichiro Goto[†2] and Koji Sakai[†3]

[*1] Faculty of engineering, Hokkaido University
Kita 13, Nishi 8, Kita-ku, 060-8628 Sapporo, Japan
e-mail: yokota@eng.hokudai.ac.jp, web page: http://www.eng.hokudai.ac.jp/labo/lifetime

[†2] Graduate School of Engineering, Hokkaido University
Kita 13, Nishi 8, Kita-ku, 060-8628 Sapporo, Japan
e-mail: gottu@eng.hokudai.ac.jp, web page: http://www.eng.hokudai.ac.jp/labo/lifetime

[†3] Japan Sustainability Institute
Kita 21, Higashi 19, Higashi-ku, 065-0021, Sapporo, Japan
Email: sakai@jsi-ks.jp - Web page: http://www.jsi-ks.jp

ABSTRACT

Sustainability is one of the key issues in a construction sector in the 21st century. Some design, execution, and maintenance codes recently have introduced the framework of the sustainability; for example, short but rather important specifications can be found in the Fib Model Code 2010. Sustainability is defined as a concept including environmental, economic, and social aspects. It is likely to be taken into account in concrete work from the viewpoints of resources and energy consumption, initial construction and/or lifecycle cost, durability, and environmental impact. During the lifecycle of a concrete structure, sustainability is generally considered with one or a few of these viewpoints, but it is not so easy to find the best solution among alternatives because no comprehensive sustainability indicator exists. For example, when the margin of safety is taken more, more resources and energy may be needed for construction and higher construction cost will be consequences. In other words, the sufficient balance among each sustainability indicator should be achieved.

This paper examines the sensitivity of design parameters such as safety factors for structural capacity on cost and CO_2 emission of reinforced concrete beams. The safety factor is related to the social aspect of sustainability, and the cost and the CO_2 emission are related to the economical and environmental aspects of sustainability, respectively. Dimensions of reinforced concrete beams, quantity of reinforcing bars, materials strengths, environmental conditions, and design working life are varied as parameters for design calculations as well as partial safety factors. For each set of those parameters, initial construction cost, life-cycle cost including expecting restoration cost, CO_2 emission are calculated. Finally a comprehensive sustainability indicator will be proposed. As a result, based on the parametric analyses, the safety factor does not have a considerable impact on the CO_2 emission and the cost. From this, it will be necessary to think about the degree of redundancy for structural capacity in terms of the comprehensive sustainability indicator from the viewpoint of sustainability.

REFERENCES

[1] K. Sakai and T. Noguchi, *The sustainable use of concrete*, CRC Press, 2012.

[2] Japan Society of Civil Engineers, *Recommendation of environmental performance verification for concrete structures [Draft]*, JSCE Guidelines for Concrete, No. 7, 2006.

Self – Compacting Concrete CO_2 uptake

Hubert Witkowski, Marcin Koniorczyk

Department of Building Physics and Building Materials
Technical University of Lodz
Al. Politechniki 6
90-924 Łódź, Poland
e-mail: eng.hubert.witkowski@gmail.com,
web page: http://kfb-lx.p.lodz.pl/index_eng.html

ABSTRACT

Develop of a new types of Self – Compacting Concrete (SCC) with a low binder content, referred as a Green SCC or ECO SCC, was a response for a growing demands associated with sustainable development. With a progress in concrete admixtures, a possibilities of reduction cement contribution raised. A lower cement content was to provide a lower carbon footprint.

A basic comparative analysis of CO_2e emission at cradle to gate stage of a GREEN SCC, regular SCC described in literature [1] with an exemplary SCC applied to actual construction project developed by Skanska S.A., shows that a cement content is not a major factor, but above all – a type of cement, what was described in [2]. However for a complete analysis of carbon footprint of material, according to ISO [3] requirement, a holistic approach to life cycle of material is needed. Therefore more attention is paid also to maintenance, demolish and storage phases, especially when sequestration of concrete is assumed. It has been already described [4], that when concrete is demolished to a concrete rumble, a carbonation process accelerates, as a larger surface is exposed for CO_2 uptake. In recent time this issue has become very current, as the limits of CO_2 emissions has begun to be an important problem.

The carbonation of three SCC mixtures after 56, 112 and 168 days in two types of sample form, described in [2] are presented in the paper. One type of form was a typical cubic sample and the other was a crushed concrete. A grain size of a crushed concrete was chosen to imitate a concrete rumble after a concrete demolish. Controlled conditions of 1% concentration of CO_2, 21°C temperature and 60% RH were kept in carbonation chamber in test period. After test in carbonation chamber samples were investigated with two test methods – a basic pH indicator and the Fourier Transformation Infrared Spectroscopy (FITR) test. A compare of result from different test method in three test period are discussed in paper.

REFERENCES

[1] Wcisło A., Kuniczuk, “Self – Compacting Concrete with low binder – the new beginning for Self – Compacting Concretes used in Poland”, 7th RILEM Conference on Self – Compacting Concrete, Paris (2013).

[2] Witkowski H., “Sustainability of Self – Compacting Concrete”, ACEE 1/2015, The Silesian University of Technology (2015).

[3] ISO/TS 14067 (2013); Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication.

[4] Lagerblad B., “Carbon dioxide uptake during life cycle – State of art”, CBI Report 2 (2005).

Strength development of concrete: balancing production requirements and ecological impact

Stijn Onghena*, Steffen Grünewald*,† and Geert de Schutter*

* Laboratory Magnel for Concrete Research
Ghent University
Technologiepark-Zwijnaarde 904, 9052 Ghent, Belgium
web page: http://www.ugent.be/ea/structural-engineering/en/

† Section Structural Design and Building Engineering
Delft University of Technology
Stevinweg 1, 2628 CN Delft, Netherlands
web page: http://www.citg.tudelft.nl/en/about-faculty/departments/structural-engineering/sections/sbe/

ABSTRACT

An effective production of concrete structures requires adequate control of strength development in order to realize the scheduled production cycles. Demoulding of elements can take place only when sufficient strength is gained and the production cycle has to be maintained with seasonal changes of temperature. The use of Portland cement promotes high early age strength, but comes with a relative high impact on the environment since decarbonation and a high energy demand characterize cement production. Supplementary cementitious materials have been widely applied to improve the sustainability of concrete but the rate of early age strength development often has to be compromised to some degree.

An experimental study was executed with the aim to maintain a similar strength level at early age but lowering the content of Portland clinker in concrete. Parameters of the study were the replacement level of Portland cement, the curing temperature and the use of accelerator. At a comparable workability level, specimens were produced of which the compressive and flexural strengths were determined at different ages after casting. The Dutch CUR tool 'Groen Beton 3.0' was used to determine the environmental costs of the mixtures. The results show that concrete can have a much lower impact on the environment without compromising on the production conditions. Quantifying the trade-off between the use of Portland Cement and other mixture components and adding heat in the process is important information in order to balance production requirements and the ecological impact of concrete structures.

For any further request, please contact:

Ghent University
To: Steffen Grünewald
Technologiepark-Zwijnaarde 904
9052 Ghent, Belgium
Tel: +31 6 10581314
E-mail: Steffen.Grunewald@ugent.be

Sustainability and Human Habitat

Miquel Bastons [†], Jaume Armengou*

[†] Faculty of Economics and Social Sciencies
Universitat Internacional de Catalunya
C/ Immaculada, 22, 08017 Barcelona
bastons@uic.es
* School of Architecture
Universitat Internacional de Catalunya
C/ Immaculada, 22, 08017 Barcelona
jarmengou@uic.es

ABSTRACT

The idea of sustainability calls into question the way the human being inhabits the earth. This article is a conceptual contribution on how to make the human habitat more sustainable. The organization of human space is today in crisis (Padovano, 1993). In the well-known lecture delivered in 1951, Martin Heidegger refers the housing problem to a more in-depth reflection on the meaning of human "dwelling". Animals do not have problems with the dwelling, humans do (see Dekkers, 2011; Swanton, 2010). Taken the Heidegger's conception of "dwelling" as starting point, a new form of understanding the organization of the human space is proposed. The crisis of human housing has to do with a crisis of human dwelling (Padovano, 1993). It will be shown that such crisis responds partly to the notion of space, which is understood as the organization of a "physical" space. The human space is seen as a "place" (locus) and its organization –the urbanization- is resolved in terms of "localization" (see for example, Guthey et al.), 2014.

Many challenges of the city organization come from reducing the organization of human space to the organization of physical space. One of them is given by the fact that physical space cannot be shared, can only be divided. This puts the organization of human life under the logic of competence (my place might not be occupied by others) and under the logic of cost-benefit calculation (Gibson, 2012). Another challenge is that physical space is finite. This leads to the conflict with the human aim to development and growth (Barry, 1997), and opens the typical dilemma in approaching sustainability, between "preservation" (Fergus and Rowney , 2005; Gibson, 2012) or "enhancement of human capabilities (Bañón et al. 2011; Raatzsch, 2012; ; Sen, 2013; Bansal, 2014).

The aim of this article is to propose a new view for the organization of human dwelling, which overcomes the physic-based conception of space. In doing so, the meaning of human "habitat" as "space for developing capabilities" will be recovered, and the implications for the organization of the human habitat considered. "Habitat" has to do with "habit" (habitus), which is the increase of human potential produced by acting (Aristotle, 1980). The human action is not only "consumer" of resources. Human life is a process of improvement of possibilities as well (MacIntyre, 1984; Interazi, 2014).

Habitat is not a physical space, is the "field of possibilities of action" which humans which humans give themselves. The human house is the city (polis). However, the city is above all a practical and social space constituted in a temporal process of learning and capabilities development (Ozolins, 2010). This habitat as capabilities-based space can be shared and its development is infinite so that a way is opened for overcoming the logic of competence and the conflict of sustainability with development.

REFERENCES

[1] Aristotle, *The Nicomachean Ethics*, trans. D. Ross, Oxford University Press, Oxford, New York, 1980.

[2] P. Bansal and M. R. DesJardine,. "Business sustainability: It is about time", *Strategic Organization*, vol. 12 (1), pp. 70–78, (2014).

[3] A. J. Bañón, M. Guillén, W. Michael, R. E. McNulty, "Rethinking the Concept of Sustainability", *Business and Society Review,* vol. 116 (2), pp. 171–191, (2011).

[4] B. Barry, "Sustainability and Intergenerational Justice", *Theoria,* vol. 89, pp. 43-64, (1997)

[5] W. Dekkers, "Dwelling, house and home: towards a home-led perspective on dementia care", *Medical Health Care and Philosophy*, vol. 14, pp. 291–300. (2011).

[6] A. H. T. Fergus and J. I. A. Rowney, "Sustainable Development: Lost Meaning and Opportunity?", *Journal of Business Ethics*, vol. 60, pp. 17-27, (2005).

[7] K. Gibson, "Stakeholders and Sustainability: An Evolving Theory", *Journal of Business Ethics*, vol. 109, pp. 15–25, (2012).

[8] G.T. Guthey, G. Whiteman and M. Elmes, "Place and Sense of Place: Implications for Organizational Studies of Sustainability", *Journal of Management Inquiry*, Vol. 23(3), pp. 254–265, (2014).

[9] M. Heidegger, "Bauen, Whonen, Denken", in *Chillida, Heidegger, Husserl. El concepto de espacio en la Filosofía y en la Plástica del s. XX*, Universidad del País Basco, Bilbao, 1992.

[10] A. Intezari and D. J. Pauleen, "Management Wisdom in Perspective: Are You Virtuous Enough to Succeed in Volatile Times?", *Journal of Business Ethics*, vol. 120, pp. 393–404, (2014).

[11] A. MacIntyre , *After Virtue*, University of Notre Dame Press, Notre Dame, 1984.

[12] J.T. Ozolins, "Popper's ThirdWorld: Moral habits, moral habitat and their maintenance", *Educational Philosophy and Theory, vol.* 42, (7), pp. 742-761, (2010).

[13] G. Padovano, *Verso il modern future. Nuove strategie per il territorio della complessità*, Alinea Editrice, Firence, 1993.

[14] R. Raatzsch, "On the Notion of Sustainability", *Inquiry: An Interdisciplinary Journal of Philosophy*, vol. 55 (4), pp. 361-385, (2012).

[15] A. Sen, "The Ends and Means of Sustainability", *Journal of Human Development and Capabilities: A Multi-Disciplinary Journal for People-Centered Development*, vol. 14 (1), pp. 6-20, (2011).

[16] C. Swanton, "Heideggerian Environmental Virtue Ethics", *Journal of Agricultural Environmental Ethics*, vol. 23, pp. 145–166, (2010).

Sustainability assessment of Indian blended cements in terms of energy and resource consumption

Aanchal Patel[1], Ravindra Gettu[1]*, Sanoop Prakasan[1], Vaibhav Rathi[2], Kriti Nagarath[2], Sivakumar Palaniappan[1] and Soumen Maity[2]

[1]Department of Civil Engineering, Indian Institute of Technology Madras
600036 Chennai, India
E-mails: aanchal.patel70@gmail.com, gettu@iitm.ac.in, sanoop.prakasan@gmail.com, sp@iitm.ac.in
- web page: http://www.iitm.ac.in

[2]Development Alternatives
B-32 TARA Crescent, Qutub Institutional Area
110016 New Delhi, India
Emails: vrathi@devalt.org, knagrath@devalt.org, smaity@devalt.org
- web page: http:// www.devalt.org

ABSTRACT

India is the second largest manufacturer of cement in the world with a production of about 280 million tonnes per year. This is expected to increase over the next few decades as the demand for new infrastructure and housing is far from being satisfied in the near future. Therefore, the Indian cement industry has relevance in both the local and global contexts due to the associated raw material imports, fuel needs and emissions. This work looks at typical cement production in different areas of the India, and uses generic process maps and plant data to assess the impact of blending cement with local supplementary cementitious materials (SCMs) on CO_2 emissions and energy requirement. Also, specific aspects that are critical to Indian conditions are highlighted.

In addition to assessing cements with fly ash and ground granulated blast furnace slag (GGBS), a newly proposed binder called limestone calcined clay cement or LC^3, having 50% clinker, 30% calcined China clay (with a typical kaolinite content of 50-60%), 15% crushed limestone and 5% gypsum has also been studied. The impacts are compared considering cradle-to-gate or ground-to-gate (more appropriate for products that rely heavily on mined resources) and gate-to-gate system boundaries, as applied to a typical cement plant location in South India. In addition to assessing the cements, typical concretes of 30 and 50 MPa design strengths are evaluated using mixture proportions obtained in the laboratory for the different binder systems.

The results confirm that the use of SCMs lead to substantial benefits in terms of energy consumption and CO_2 emissions. However, the use of GGBS at a dosage of 15% is not as beneficial as the incorporation of fly ash at 30%. This is attributed to energy required to process the slag, which is not treated as a waste product such as fly ash. The newly proposed LC^3 cement is seen to be considerably beneficial for the impact reduction, even though a conservative calcination energy value has been used. It is also evident that the benefits of substituting clinker with SCMs are significantly more in higher grade concretes.

REFERENCES

[1] L. Barcelo, J. Kline, G. Walenta, and E. Gartner, "Cement and carbon emissions", *Mater. Struct.*, V. **47**, pp. 1055-1065 (2014).

[2] K. Scrivener, "Options for the future of cement", *Indian Concr. J.*, V. **88**, No. 7, pp. 11-21 (2014).

[3] S. Bishnoi, S. Maity, A. Mallik, S. Joseph and S. Krishnan, "Pilot scale manufacture of limestone calcined clay cement: The Indian experience", *Indian Concr. J.*, V. **88**, No. 7, pp. 22-28 (2014).

[4] S.A. Miller, A. Horvath, P.J.M. Monteiro, and C.P. Ostertag, "Greenhouse gas emissions from concrete reduced by using mix proportions, geometric aspects, and age as design factors", *Environmental Research Letters*, 10, doi:10.1088/1748-9326/10/11/114017, 12 p. (2015).

The French National Project RECYBETON, to recycle concrete into concrete

De Larrard F.* and Colina H. †

* Scientific Director of National Project RECYBETON
& Scientific Director – Sustainable Construction and Partnerships of
Lafarge LCR (Research Center of Lafarge)
95 rue du Montmurier BP 70
38291 Saint Quentin Fallavier Cedex - France
Email: francois.delarrard@lafarge.com

† Director of National Project RECYBETON
& Research Director of
ATILH (French Technical Association for the Hydraulic Binders Industry)
7 place de la Défense
92974 Paris-la-Défense Cedex - France
Email: h.colina@atilh.fr

ABSTRACT

France is currently producing about 20 Mt/year of demolished concrete, most of this material being used in road sub-bases or embankments. However, this flow should increase in the near future, although less and less new roads are to be built. Another 20 Mt of mixed demolition materials, a good part of it being concrete or natural rock, is also available. Therefore there is a duty, both for the society and the planet, to make the best use of this demolished concrete, in order to preserve natural aggregate resources, which are increasingly difficult to obtain, and to eradicate waste material landfills.

Based on this reality, a national project was set in 2012, gathering 47 partners, among which representatives of all construction stakeholders. Partially funded by the French Ministry of Ecology, RECYBETON encompasses five fields of activities:

- Research on material processing.

- Research on recycled materials and structures.

- Research on sustainable development.

- Standards and regulations.

- Dissemination, among which demonstration sites.

The paper aims to present the main outputs of the project, which will produce various deliverables: a scientific book, a guide, a number of proposals to adapt standards and regulations, and, last but not least, five experimental constructions (demonstration sites) including a parking lot, two bridges, a public building and industrial constructions.

Use of recycled aggregates and sea water for sustainable concrete in marine environments

Miren Etxeberria*, Patricia Pardo†

* Department of Civil and Environmental Engineering, Polytechnic University of Catalonia BarcelonaTECH (UPC), Jordi Girona, 1-3, Campus Nord, Barcelona 08034, Spain

email: miren.etxeberria@upc.edu

† Department of Civil and Environmental Engineering, Polytechnic University of Catalonia BarcelonaTECH (UPC), Jordi Girona, 1-3, Campus Nord, Barcelona 08034, Spain

email: patricia.pardo@upc.edu

ABSTRACT

The generation of construction and demolition waste (C&DW) is of great environmental and economic concern. The development of new applications in which Recycled Mixed Aggregates (RMA) can be used leads to a reduction of landfill growth. Moreover, the use of seawater represents another advance in sustainability by reducing fresh water consumption, which can be a very limited resource in certain areas. Although seawater is not generally recommended for concrete production, especially in reinforced concretes, seawater can under certain conditions replace fresh water in the production of plain concretes.
This study intends to analyse the possibility of using RMA and seawater in the production of concrete to be used in port sites. The real scale production of dyke blocks was carried out in Barcelona's port and according to the obtained results, the concretes produced with a combined mixture of 50% coarse mixed aggregates and 50% of coarse steel aggregates achieved the most adequate properties for the purpose of dyke block manufacturing. The use of seawater instead of freshwater reduced the concrete's setting time as well as the porosity of the concretes produced, resulting in both the reduction of water penetration and the capillary water absorption capacity of the concretes. The use of seawater also increased concrete's compressive strength at early age.
Although the high availability of CEM I 42.5 SR restricted its employment for dyke production, the laboratory results of research work highlighted the beneficial effects of using type III cement, especially with regard to durability properties. The use of seawater improved the mechanical properties, reduced setting time and increased drying shrinkage. Moreover, our findings concluded that the cement type had a greater influence on the majority of properties rather than the type of aggregates employed. The use of seawater and cement with blast-furnace slag improved the performances of recycled aggregate concretes. The use of RMA and type III cement resulted in more durable concretes than those produced with natural aggregates and type I cement The use of seawater and cement with blast-furnace slag improved the performances of the RAC.

REFERENCES

[1] Miren Etxeberria, Jesus Manuel Fernandez, Jussara Limeira, Secondary aggregates and seawater employment for sustainable concrete dyke blocks production: Case study, Construction and Building Materials 113 (2016) 586–595

[2] Miren Etxeberria, Andreu Gonzalez-Corominas, Patricia Pardo, Influence of seawater and blast furnace cement employment on recycled aggregate concretes' properties, Construction and Building Materials 115 (2016) 496–505

Can artificial recycled fine aggregate truly represent fine aggregated from C&DW

A. Katz*, D. Kulisch

* National building Research Institute, Faculty of Civil and Environmental Engineering
Technion-Israel Institute of Technology,
Haifa, 32000, Israel
e-mail: akatz@technion.ac.il

ABSTRACT

Using construction and demolition waste (C&DW) as a source for aggregates draws attention lately due to the large quantities of C&DW accumulating in the modern world. The coarse fraction of this waste was studied extensively in the past as a source for coarse aggregates in the production of new concrete. It is quite acceptable that replacing 10-20% of the virgin coarse aggregate with recycled one will have a minor effect on the properties of the new concrete. However, using the fine fraction of C&DW to replace virgin aggregate is still in question and is restricted in the standards.

Studies on recycled aggregates usually use aggregated artificially manufactured in the lab from concrete produced under artificial conditions. The controlled conditions of concrete manufacturing enable understanding some of the impacts of the recycled aggregates but neglect the variability and complexity of the aggregates produced in real C&DW recycling plants.

The fine fraction of the waste is restricted for use in many standards in it has extensively studied in our laboratory. This paper presents part of the study aimed at comparing artificial aggregates produced from old concrete with known properties and old paste, both produced for this study, with aggregates obtained from two recycling plants. The results indicate that the properties of the aggregates and mortars prepared from these aggregates are different from the aggregates obtained in 'real life' showing that investigations on materials prepared from artificial sources are not enough for conclusions that can be implemented in standards.

Future Cements: Research Needs for Sustainability and Potential of LC3 Technology

Karen Scrivener*,

* Laboratory for Construction Materials, IMX
EPFL, Ecole Polytechnique Federale de Lausanne
Station 12, 1015 Lausanne, Switzerland
e-mail: Karen.scrivener@epfl.ch, web page: http://lmc.epfl.ch

ABSTRACT

Due to the enormous volumes produced the production of concrete accounts for around 5-10% of man-made CO_2 emissions. Consideration of possible routes to reduce this environmental impact indicates that the use of calcined clays in as supplementary cementitious materials in cement and concrete has by far the largest potential. This technology is being studied in a multi partner programme supported by the Swiss agency for Development and Cooperation

Influence of temperature on the rheology of pastes and selfcompacting mortars with sustainable binders

A. Pacios*, A. Köening† and F. Dehn†

* Department of Mechanical Engineering, ETSII
Universidad Politécnica de Madrid
c/ José Gutiérrez Abascal, 2, 28006 Madrid, Spain
e-mail: antonia.pacios@upm.es, web page: http://www.industriales.es

† Institute für Mineralogie, Kristallographie und Materialwissenschaft
Fakultät für Chemie und Mineralogie, Universität Leipzig
Scharnhorststraße 20, D-04275 Leipzig
e-mail: akoenig@uni-leipzig.de; fdehn@uni-leipzig.de - Web page: http://www.mfkw-leipzig.de

ABSTRACT

The use of ternary cements, is one of the strategies investigated to improve sustainability in construction. However, in construction sites, concrete and mortars with ternary cements and high dosages of admixtures show a high variability in rheological properties, especially with temperature changes. Supplementary materials have an effect in the hydration rate of ternary cements, and curing temperature has proved to be a key parameter in the rheological evolution since directly influences the hydration process. For small increments of admixtures, temperature is also a key parameter on the stability of the mixes.

A better understanding of the temperature influence on the rheological properties and stability of cement pastes and mortars is the main objective of this work. A series of pastes and mortars with different dosages of PCE HRWR superplastizier were tested using Viskomat rheometer. SP dosage was selected in agreement with the w/b ratio (0-1.25% for 0.4 w/b; and 2-3.5% for w/r of 0.3) so samples had a similar initial slump of 300 mm (±50mm). The temperatures studied were 5ºC, 10ºC, 20ºC and 37ºC for the mortars, and 20ºC and 37ºC for cement pastes. The three cement types were a Portland cement used as a reference (R1) and two blended cements prepared in the laboratory (SF2 has 64% of R1, 26% of slag and 10% of fly ash; SL1 has 64% of R1, 30% of slag and 6% of limestone).

To estimate the rheological parameters several rheological models were checked (power, modified Bingham, Herchel-Bulkley). Before accepting a model, the physical correspondence to the type of behavior that is trying to predict was checked. Power model gives the best fitting for all experimental results with pastes, and power and Herchel-Bulkley models for experimental results with mortars.

Conclusions show that mortars with higher values of viscosity (lower w/b ratio and higher SP dosage) are more sensitive to temperature for small increments of PCE; this is consistent for the two PCE tested. Increment in temperature is positive for the structural building-up for blended cements mortars, while for the reference mortar there is a strong loss of workability.

At 20 ºC, fluidity index of pastes with R1 cement are less sensitive to the increment of the SP dosage than blended cements. However, the influence of the type of admixture is larger for pastes with cement R1 that for blended cements at any w/b ratio. This temperature dependency is most pronounced for pastes with cement R1 and SF2.

REFERENCES

[1] A. Hallal; Kadri,; E.H. Ezziane; A. Kadri; H. Khelafi. "Combined effect of mineral admixtures with superplasticizers on the fluidity of the blended cement paste", *Construction and Building Materials*, 24, pp. 1418–1423, (2010).

[2] M. Nehdi; S. A. Marini. "Estimating time and temperature dependent yield stress of cement paste using oscillatory rheology and genetic algorithms", *Cement and Concrete Research*, 39, pp. 1007-1016, (2009).

Sustainability Applied to Prefabrication

D. Fernández-Ordóñez[1], A. De la Fuente[2]
[1] Universidad Politécnica de Madrid, Madrid, Spain
david.fernandez-ordonez@upm.es
[2] Universitat Polytecnica de Catalunya, Barcelona, Spain
albert.de.la.fuente@upc.edu

Prefabrication has evolved in depth and breadth from its beginnings, bringing many of the advantages of industrialisation to construction, while solving some of the problems that arose in the early years. Today prefabrication, compared to traditional construction methods, and concrete as a material, feature a number of beneficial characteristics.

Precast elements are factory made products. The only way to industrialise the construction industry is to shift work from temporary construction sites to modern permanent facilities. Factory production entails rational and efficient manufacturing processes, skilled workers, systematisation of repetitive tasks, and lower labour costs per m² as a result of automated production. Factory products are process-based and lean manufacturing principles are deployed. Automation is gradually being implemented in factories and is already in place in areas such as the preparation of reinforcing steel, mould assembly, concrete casting, and surface finishing on architectural concrete. And other stages in the process are sure to follow.

As prefabrication makes optimal use of materials, its potential for savings is much greater than in cast-in-situ construction. Structural performance and durability are also enhanced through design, modern manufacturing equipment and carefully planned working procedures. The environmental burden of prefabrication is mainly the burden caused by the raw materials of concrete (especially production of cement and steel). The environmental burden caused by raw materials is approximately three times larger than that caused by the production process of the elements, as indicated by the examples of environmental product declarations.

Also thermal inertia of heavy materials is well known for both in warm and cold climates. Most people have experienced the comfort of coming into a comparatively cool stone building on a hot day in a warm climate. In precast structures several systems have been developed using this characteristic.

As there is a Fib Bulletin under preparation in Commission 6 Prefabrication, by the Task Group 6.3 Sustainability, in which both authors are members, the conclusions of this document will be presented including a proposal for an evaluation model that can be applied to precast structures.

REFERENCES

[1] Fib (2003) Environmental issues in Prefabrication. Bulletin 21 FIB
[2] Fib (2004) Environmental Design. Bulletin 28. FIB
[3] Fib (2008) Environmental Design of Concrete Structures. Bulletin 47. FIB

Sustainability Assessment of Concrete with Recycled Concrete Aggregates ICCS16

D. García[*], A. Lisbona[*], J.S. Dolado[*], I. Vegas[*], J.T. San-José[†] And V. García[*]

[*] Sustainable Construction Unit, TECNALIA Research and Innovation,
48160 - Derio, Spain
e-mail: david.garcia@tecnalia.com - web page: http://www.tecnalia.com

[†] Dep. Mining, Metallurgical and Materials Science,
University of the Basque Country (UPV/EHU), 48013 – Bilbao, Spain
e-mail: josetomas.sanjose@ehu.eus - web page: http://www.ehu.eus/es/web/ingeniaritza-bilbao

ABSTRACT

Concrete is the most widely used construction material. It causes a substantial environmental impact, derived from CO_2 emission, mainly during Portland cement manufacture because of the calcination of the limestone and the fuel consumption. There are several strategies for reducing the amount of Portland cement, e.g. using alternative clinkers, like alkali-activated cements or belite cements, or partial replacement of Portland by secondary cementitious materials, like fly ash, natural pozzolans and/or limestone.

Aggregates, as the largest component of concrete, can also have a significant effect on the environmental cost of the concrete mixture. The choice of aggregate influences a wide range of sustainability attributes and as with most aspects of sustainability there are frequently tradeoffs between one choice and another. Aggregate materials of some kind are usually available locally and making best use of this can be preferable for reducing transport related energy use and carbon emissions as well as keeping expenditures in the local economy.

In many countries recycled concrete aggregates (RCA) have been proven to be practical for low-strength concretes and to a limited extent for some structural grade concrete. When structures made of concrete are demolished or renovated, concrete recycling is an increasingly common method of utilizing the rubble. Using RCA for new concrete reduces the demand for virgin aggregate conserving natural resources, while minimizing the waste stream by diverting demolished material from landfill. However each case should be individually evaluated and transport and recycling process (sorting, crushing and sieving) must be taken into account.

This paper presents a review of the general strategies for reducing concrete environmental impact and a real comparative LCA evaluation of two types of aggregate for precast concrete elements, one natural and one recycled.

A first approach: towards a sustainable civil engineering works with precast concrete solutions

Alejandro López Vidal

Asociación Nacional de la Industria del Prefabricado de Hormigón (ANDECE)
Paseo Castellana, 226, 28046 Madrid, Spain
e-mail: alopez@andece.org

ABSTRACT

Most of the achieved advances related to define standardized methodologies to quantify the contribution to "sustainabilize" the construction are linked to buildings rather than infrastructures, and much more in particular to housing. Global impact on housing are the widest and highest one, gathering the three sustainable axis: environmental (greenhouse gas emissions derived from heating or cooling to reach indoor comfort conditions), social (home is a basic need for families) and economic (it usually represents the main expense over the life of people).

Meanwhile civil engineering work has not evolved as long on this topic. Although we generally refer to greater constructions, sustainable impacts are more diffused and don´t have such a direct repercussion into the citizens and daily life.

For this reasons, there is no as many literature and investigation as in housing. It may implies a technical and promotional handicap to promote a higher use of precast concrete elements in a field governed by engineers that appreciate better their performance advantages.

This paper pretends to describe the strengths (and weaknesses) that precast concrete construction will have into the upcoming standards for civil engineering, in order to enhance their possibilities to reach a greater market share. Sustainable indicators on current draft standards will be assessed.

A Study into the Relationships between the Mechanical Properties of Recycled Aggregate Concrete

KHALIL N.[*], TOUMA A. [†], TOUMA T. [†], DAHER R. [††]

[*] Corresponding Author, Associate Professor, Department of Civil Engineering, University of Balamand, Tripoli- Lebanon.
e-mail: nariman.khalil@balamand.edu.lb

[†]A. Touma and T. Touma, Department of Civil Engineering
University of Balamand
Tripoli- Lebanon

[†] Civil Engineer, Dar El-Handasa, Beirut- Lebaonon
e-mail: rimah_daher@hotmail.com

ABSTRACT

The advances in construction industry have exhausted the available natural resources and placed high impact on the surrounding environment. This has encouraged the engineers to search for more innovative materials in design. The use of Recycled Concrete Aggregate (RCA) in new concrete offers a solution to such a problem of worldwide dimensions. That is to make construction more "green" and environmentally friendly and preserve resources; hence contribute to sustainability development.

In this paper, a detailed investigation is conducted to analyze the relationships between the mechanical properties of Recycled Aggregate Concrete (RAC). Five concrete mixes were designed to study the effect of different RCA content on concrete mechanical properties: concrete made entirely with natural aggregate as control mix and four types of concrete made with natural fine and recycled coarse aggregate (30%, 50%, 75% and 100% replacement of coarse recycled aggregate). The source of RAC in this study was from the concrete specimens tested in the laboratory. Based on the results of sixty specimens carried out; the relations between compressive strength, density, splitting tensile strength, flexural strength and elastic modulus are investigated and discussed in details. A comparison is made against the suggested equations in Codes of Practice and by other researchers. It is found that such relations could be different from that of conventional concrete and new equations need to be developed.

Key words: Recycled Aggregate Concrete; Recycled Concrete Aggregate; Mechanical Properties.

REFERENCES

[1] Hansen, T.C. *recycling of demolished concrete and masonry*. Taylor and Francis, Oxford shire, UK, (1992) 316.

[2] ACI221R-96. *Guide for use of normal weight and heavyweight aggregates in concrete*. (Re approved 2001).

[3] Katz, A. *Properties of concrete made with recycled aggregate from partially hydrated old concrete*. Cement and Concrete Research, (2003) 703-711.

[4] Xiao, J., Li, J.B. and Zhang, C. *On relationships between the mechanical properties of recycled aggregate concrete: An overview*. Materials and Structures (2006) 39.655-664.

[5] Etxeberria, M., Mari, A.R. and Vazquez, E. *Recycled aggregate concrete as structural material*. Materials and Structures, (2007) 40:529-541.

[6] Gonzalez, B. and Martinez, F. *Concrete with aggregates from demolition waste and silica fume*. Materials and mechanical properties, Building and Environment, (2008) 429-437.

[7] Florea, M. and Brouwers, H. *The influence of crushing method on recycled concrete properties*. Advances in Cement and Concrete Technology in Africa, (2009) 1041-1050.

[8] M. Malesev, M., Radonjanin, V. and Marinkovie, S. *Recycled concrete as aggregate for structural concrete production*. Sustainability (2010), www.mdpi.com, 1204-1225.

[9] Naguchi, T. *Sustainable recycling of concrete structures*. Indian Concrete Institute Journal, (2010) 41-53.

[10] Husain, A. and Assas, M. *Utilization of demolished concrete waste for new construction*. World Academy of Science, Engineering and Technology, (2013) 69-74.

[11] Belagraa, L. and Beddar, M. *Study of the mechanical performance of a recycled aggregate concrete with admixture addition*. Open Journal of Civil Engineering, http://www.scirp.org/journal/ojce, (2013).

[12] Jeong, H. *Processing and properties of recycled aggregate concrete.* http://hdl.handle.net/2142/26156, 2011, (2014).

[13] Cabral, A., Schalch, V., Dal Molin, D. and Ribeiro, J.L. *Mechanical properties modelling of recycled aggregate concrete*. Construction and Building Materials 24, ELSEVIER, (2010) 421-430.

[14] McNeil K. and Kang T. H.-K. *Recycled Concrete Aggregates: A Review*. International Journal of Concrete Structures and Materials, Vol. 7, No. 1, (2013) 61-69.

[15] Chehab, G. and Srour, I. *Recycling and reuse of construction materials*. Fourth Build it Green Conference, Beirut, Lebanon, (2013) 26-27.

[16] ACI Committee 318, "Building code requirements for structural concrete (ACI318-14) and Commentary", American Concrete Institute, Detroit.

[17] Yang, K.H. and Kim, Y.S. *An evaluation of slump loss for elapsed time and mechanical behavior of the recycled aggregate concrete mixed with blast-furnace slag*. Journal of the Architectural Institute of Korea, V.21, N0. 4, (2005) 117-124.

[18] Oluokun, F.A. *Prediction of concrete tensile strength from compressive strength: Evaluation of existing relations for normal weight concrete*. ACI Material Journal, V.88, No. 3, (1991) 302-309.

[19] Wardeh, G., Ghorbel, E. and Gomart, H. *Mix design and properties of recycled aggregates concretes: Applicability of Eurocode 2*. International Journal of Concrete Structures and Materials, V. 9, No. 1, (2015) 1-20.

[20] ASTM-C33, Standard Specification for Concrete Aggregates.

[21] Knaack, A. M. and Kurama, Y. C., *Design of concrete mixtures with recycled concrete aggregates*. ACI Material Journal, V. 110, No. 5, (2013) pp. 483-494.

[22] Khalil, N., Daher, R., Khattar, C. and Ghadie, M. *Recycled Concrete as Coarse Aggregate for Structural Concrete Production.* 13th Arab Structural Engineering Conference, University of Blida 1, ALGERIA, (2015).

[23] ACI Committee 211, *Standard practice for selecting proportions for normal, heavyweight and mass concrete (ACI 211.1-91)*, American Concrete Institute, Farmington Hills, MI, 1991, 38 pp.

[24] Yang, K., Chung, H. and Ashour, A. *Influence of type and replacement level of recycled aggregates on concrete properties.* ACI Material Journal, V. 105, No. 3, (2008) 289-296.

[25] Surya, M., Kanta Rao V. V. L. and Lakshmy, P. *Mechanical, durability and time-dependent properties of recycled aggregate concrete with fly ash*. ACI Materials Journal, V. 112, No. 5,(2015), pp.653-660.

[26] Guo, Z.H. and Shi, X.D. *Theory and analysis of reinforced concrete*. Tsinghua press, Beijing, (2003).

[27] Wardeh G., Ghorbel E., and Gomart H., "Mix design and properties of recycled aggregates concretes: Applicability of Eurocode 2", International Journal of Concrete Structures and Materials, V. 9, No. 1, pp 1-20, 2015.

[28] Li, X. *Recycling and reuse of waste concrete in china.* Part I. Material behavior of recycled aggregate concrete, Resources, Conversation and Recycling 53, ELSEVIER, (2008) 36-44.

A Study of the Sustainability Potential of Cement Reduced Concrete

Jack S. Moffatt*, Michael Haist and Harald S. Mueller

Institute for Concrete Structures and Building Materials (IMB)
Karlsruhe Institute of Technology (KIT)
Gotthard-Franz-Str. 3, 76131 Karlsruhe, Germany
e-mail: jack.moffatt@kit.edu, michael.haist@kit.edu, harald.mueller@kit.edu
www.imb.kit.edu

Key words: Cement-reduced concrete, green concrete, mix design, sustainability

ABSTRACT

Much focus within the sustainability debate has been placed on the building industry, as the production of building materials, the erection of structures and their use is a major source of environmental impact. The production of the concrete constituent material cement alone is responsible for a substantial share of global anthropogenic carbon dioxide emissions. The principle of sustainable structural engineering is that the energy and resources consumption and emissions due to the construction and operation of a structure must be minimized. Relating to concrete structures this principle can be applied by the use of the material in the most efficient way considering its strength and durability within the service life of the structure. Green concretes with reduced cement content may provide a feasible alternative for improving concrete sustainability independently of supplementary cementitious materials. For this purpose, cement-reduced, green concrete is developed by a design process centered on packing optimization of the granular mix constituents, nearly reducing the cement content by two thirds. The results indicate that the concretes developed with the presented concrete design algorithm have a high level of technical performance, but still show deficits in workability. As the sustainability of concrete is not only a function of absolute technical performance and environmental impact, the durability of these new concretes must also be thoroughly scrutinized.

APPLICABILITY OF BIOMASS PLANT WASTE TO THE DESIGN OF NEW CEMENT-BASED MATERIALS

José María Medina[◊], Isabel F. Sáez[◊], Moisés Frías[†], María Isabel Sánchez[†], César Medina*

*, ◊ Escuela Politécnica de Cáceres
Universidad de Extremadura, Unidad Asociada UEX-CSIC
Avenida de la Universidad, s/n, 10003, Cáceres (España)
E-mail: ingepisuerga@gmail.com/ isa.f.saez@gmail.com/ cmedinam@unex.es

† Instituto de Ciencias de la Construcción Eduardo Torroja
Consejo Superior de Investigaciones Científicas
C/ Serrano Galvache, 4, 28033, Madrid (España)
E-mail: mfrias@ietcc.csic.es/ srojas@ietcc.csic.es

ABSTRACT

Today's worldwide energy problem and the availability of vast amounts of biomass in certain countries have translated into an increase in the number of biomass plants designed to industrially transform agri-forest material into electric power, thereby reducing greenhouse gas emissions. This research analysed the viability of reusing the waste generated in biomass plants as raw material in the cement industry. In a preliminary stage, the waste was characterised chemically and mineralogically to determine its possible applicability to the design of new cement matrices. The physical and mechanical properties of the new cements were subsequently analysed and found to comply with the existing legislation.

Assessing the sustainability of precast concrete towers for wind turbines

A. de la Fuente*[†], C. Gómez del Pulgar[††], F. Pardo[†] and A. Aguado[†]

[†] Construction Engineering Department
Universidad Politécnica de Cataluña (UPC BarcelonaTECH)
Campus Norte UPC, 08034 Barcelona, Spain
Email: albert.de.la.fuente@upc.edu
Email: francesc.pardo@upc.edu
Email: antonio.aguado@upc.edu

[††] PACADAR, S.A.
Torre Espacio, Paseo de la Castellana, 259-D, 6a planta, 28046 Madrid, Spain
Email: celia.gomez@pacadar.com

ABSTRACT

Wind farms are an environmentally-friendly energy-production alternative which is growing in social acceptance. The growth of this is expected to be exponential, such that by 2020 there will be a total installed capacity of 1 million MW. In Spain, for instance, the current installed wind power capacity was already enough to meet up to 22% of the average annual electricity demand in 2013.

The most common three-bladed horizontal-axis wind turbine consists of a rotor, a nacelle and a tower used to support the electrical components and transfer the loads to the foundation. Towers are usually designed as a conical tube with varying diameter from the foundation to the top. Likewise, towers can be made up with different structural materials (generally steel and/or concrete) and, depending of the height and the power of the turbine, the optimal solution might be different. However, due to the economical competitiveness between the different existing alternatives, more variables should be considered to include environmental and social aspects that allow guaranteeing the most suitable solution in terms of global sustainability.

In this scientific contribution, a multi-criteria decision-making model based on the MIVES method is proposed for assessing the sustainability index of wind-turbine support systems. This model is designed to minimize the subjectivity of the decision and to facilitate the task of deciding which system is best for a given set of boundary conditions and economic, social and environmental requirements. Finally, the sustainability of a specific precast concrete support with heights up to 140 m is assessed by means of the proposed model. Likewise, the results derived from the same analysis applied to a steel support are compared with those obtained for the precast concrete alternative.

REFERENCES

[1] A. Aguado, A. del Caño, P. de la Cruz, P.J. Gómez and A. Josa. “Sustainability assessment of concrete structures within the Spanish structural concrete code”, *J Construct Eng M ASCE*, Vol. 138, pp. 268–276, (2012).

[2] B. Alarcón, A. Aguado, R. Manga, A. Josa. “A Value Function for Assessing Sustainability: Application to Industrial Buildings”, *Sustainability*, Vol. 3, pp. 35-50, (2011).

[3] O. Pons, A. de la Fuente. “Integrated sustainability assessment method applied to structural concrete columns”, *Construct Build Mater*, Vol. 49, pp. 882-893, (2013).

[4] T.L. Saaty. “How to make a decision: The analytic hierarchy process”, *Europe J of Operation Res*, Vol. 48, pp. 9-26, (1990).

Biomass and coal fly ash as cement replacement on mortar properties

E.R. Teixeira*, Aires Camões†, Fernando G. Branco†† and L.Tarelho†††

* C-Tac, Department of Civil Engineering, School of Engineering, University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal
E-mail: elisabeterodriguest@gmail.com

† C-Tac, Department of Civil Engineering, School of Engineering, University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal

†† INESC – Coimbra, Department of Civil Engineering, University of Coimbra, Rua Luís Reis Santos - Pólo II da Universidade, 3030 - 788 Coimbra Portugal// Faculty of Engineering – University Lúrio, Mozambique.

††† Centre for Environmental and Marine Studies, Department of Environment, University of Aveiro, 3810-193 Aveiro, Portugal

ABSTRACT

Concrete is one of the most used materials on building mainly by the fact of present several advantages [1,2]. However, concrete has a significant impact on environment, since it is necessary high content of natural recourses and energy flows to its production. Furthermore, it is known that to produce Portland cement, a significant emission of carbon dioxide is released to atmosphere, and this is related with the greenhouse gases and the global warming [1,3].

Nowadays, construction sector tries to implement several options to solve the issues related to concrete [4]. One of them is the use of supplementary cementitious materials, which offer a potential reduction in global CO_2 emissions [5], reduce the cost of concrete production, enhanced the workability and in some cases improve the durability of concrete [2].

Coal fly ashes are the most artificial pozzolana used in concrete production [2]. High fly ash volume concrete has been studied and used successfully in several applications with advantages in technical and environmental terms [1,5].

Countries, like Portugal, that are interest in the energy production using renewable sources, e.g. biomass, are now interested and lead with different issues. The use of biomass to produce energy by combustion increased in the last years [6]. The increase on its used led to a significant issue related with the increase of biomass fly ashes production that needs to be solved. Biomass fly ashes can be use as a pozzolanic material and some studies showed good results when they were incorporated in concrete [7].

Thereby, the main goal of this work was to study the effect of biomass fly ash (blended with coal fly ashes or alone) as cement replacement in the mortars properties. A group of sixteen formulations was set and three levels of cement replacement were studied 20, 40 and 60%wt. The workability of mixtures was measured by slump test. In terms of durability and quality of mortar were tested: the mechanical strength, water absorption, electric resistivity, water leaching and shrinkage.

Mortars with biomass fly ashes have lower slump value than the reference. It was observed a decrease on the slump value with the increased of cement substitution by biomass ashes. Mortars with 20% of cement substitution presents better results for all curing time, in terms of mechanical strength and water absorption. However, in the three percentages of substitution, and for all curing periods, the best results were found for mortars composed only by biomass fly ashes. It is known that shrinkage of mortar occurs at higher rate during the first 14 days [8], and this was observed for all formulations studied.

In short, this work showed that is possible to use biomass fly ashes as partial cement replacement with good results in terms of durability and quality of concrete. Its utilization at an industrial level of concrete production could decrease the energy and raw materials consumption related to cement production and allowed a more sustainable option on the ash management.

REFERENCES

[1] C. Meyer, "The greening of the concrete industry", *Cem Concr Compos*., Vol. **31**, pp. 601–605, (2009).

[2] N. Kabay, M.M. Tufekci, A.B. Kizilkanat and D. Oktay, "Properties of concrete with pumice powder and fly ash as cement replacement materials", *Constr Build Mater*., Vol. **85**, pp. 1–8, (2005).

[3] E. Benhelal, G. Zahedi, E. Shamsaei and A. Bahadori, "Global strategies and potentials to curb CO2 emissions in cement industry", *J Clean Prod*., Vol. **51**, pp. 142–161, (2013).

[4] S. Demis, J.G. Tapali and V.G. Papadakis, "An investigation of the effectiveness of the utilization of biomass ashes as pozzolanic materials", *Constr Build Mater*., Vol. **68**, pp. 291–300, (2014).

[5] K. Celik, C. Meral, A. Petek Gursel, P.K. Mehta, A. Horvath and P.J.M. Monteiro, "Mechanical properties, durability, and life-cycle assessment of self-consolidating concrete mixtures made with blended portland cements containing fly ash and limestone powder", *Cem Concr Compos*., Vol. **56**, pp. 59–72, (2015).

[6] L.A.C. Tarelho, E.R. Teixeira, D.F.R. Silva, R.C.E. Modolo and J.J.F. Silva, "Characteristics, management and applications of ashes from thermochemical conversion of biomass to energy", *World Bioenergy 2012*, Conf. Exhib. Biomass Energy, Jonkopin, (2012).

[7] R. Barbosa, N. Lapa, D. Dias and B. Mendes, "Concretes containing biomass ashes: Mechanical, chemical, and ecotoxic performances", *Constr Build Mater*., Vol. **56**, pp. 59–72, (2015).

[8] C.B. Cheah and M. Ramli, "Mechanical strength, durability and drying shrinkage of structural mortar containing HCWA as partial replacement of cement", *Constr Build Mater*., Vol. **30**, pp. 320–329, (2012).

CO_2 and H_2O diffusion of water- and clinker-reduced concretes

Sarah Steiner*, Anna-Louisa Müller and Tilo Proske

* Technische Universität Darmstadt
Institut für Massivbau
Franziska-Braun-Straße 3, 64287 Darmstadt, Germany
e-mail: steiner@massivbau.tu-darmstadt.de, web page: www.massivbau.to

ABSTRACT

The production of Portland cement clinker for concrete is associated with high environmental impacts. Therefore development of clinker reduced concretes is in force. Thereby a sufficient durability of the concrete, especially regarding carbonation, has to be guaranteed. The resistance of concrete against diffusion gases is considered as an important indicator of durability.

As part of this work the diffusion processes of CO_2 and water vapor of fully carbonated specimens were investigated. Water vapor diffusion and CO_2 diffusion coefficients of various water and clinker reduced concrete compositions were determined and analyzed. The studies on the diffusion were carried out at samples with different w/c-values and limestone contents at two different relative humidities. Based on the results, the validity of the existing correlations between CO_2 and water vapor diffusion were examined. In the present work, new correlations between CO_2 and H_2O diffusion coefficient are presented.

Design and Modeling of Nanostructured Sol-Gel Titania Cement System for Environmental Applications

E. Cerro-Prada[*†], **S. García-Salgado**[†], **F. Escolano and M.A. Quijano**[†]

[†] Civil Engineering Department (ETSIC)
Universidad Politécnica de Madrid (Technical University of Madrid)
Alfonso XII, 3, 28014 Madrid, Spain
Email: elena.cerro@upm.es

ABSTRACT

Incorporation of nanostructured chemically inert semiconductors with photocatalytic properties into cementitious materials is an important development in the field of heterogeneous photocatalytic pollution mitigation. In this study, the methylene blue (MB) photocatalytic degradation by titania (TiO2) blended cement pastes was used as a standard process to evaluate the internal factors that may influence the depollution performance. Titania nanoparticles were synthesized via low temperature sol-gel method and inserted in the cement paste matrix during the induction step of the hydration process. The chemical composition and microstructure of the TiO2 modified cement pastes were characterized and analyzed. The active photocatalytic sites related to the surface area of TiO2 are the key factor in determining the photocatalytic activity [1]. X-ray diffraction and thermal gravity analysis demonstrated that TiO2 was chemically stable in the hydrated cement matrix. The NOx removal ability decreased with the increase of curing age. This could be attributed to the cement hydration products which filled up capillary pores forming diffusion barriers to both reactants and photons. It was also proved that surface carbonation could reduce the photocatalytic pollution removal efficiency after the hydration of cement.

Mathematical models were developed to simulate the kinetics of photocatalytic degradation of methylene blue by titania nanoparticles inserted in cement matrix. Like in single dye degradation, some of the reactions present an unusual kinetic behavior, corresponding to the activation of the TiO2-mediator system. The kinetic constants of the models were estimated by minimizing the difference between the predicted and the experimental time courses. The ability of the models in representing the experimental results suggests that they could be used in design and simulation environmental applications.

REFERENCES

[1] E. Cerro-Prada et Al., "Sol-Gel TiO2 nanoparticles prompt photocatalytic cement for pollution degradation", *Proceedings of NICOM5*, Nanotechnology in Construction, Springer. 5th International Symposium on Nanotechnology in Construction, Chicago 24-26 May 2015.

Dosage of Economic Self-Compacting Concrete with Low and Medium Compressive Strength

Gemma P. Rodriguez de Sensale*, Iliana Rodriguez Viacava† and Rosana Rolfi†

* Instituto de la Construcción (IC)-Instituto de Ensayo de Materiales (IEM)
Universidad de la República
Julio Herrera y Reissig 565, 11300 Montevideo, Uruguay
e-mail: gemma@fing.edu.uy

† Instituto de la Construcción (IC)
Universidad de la República, Facultad de Arquitectura
Edil Hugo Prato, 11200 Montevideo, Uruguay
Email: rodriguez.iliana@gmail.com

ABSTRACT

The use of self-compacting concrete (SCC) has been widely accepted worldwide for the production of prefabricated elements. However, the situation is very different in other cases within the construction industry such asin ready-mixed concrete and in buildings made on-site, where a reduced use of SCC is evidenced, which is mostly reserved to processes exhibiting particular complexities (e.g. filling of parts with either special geometries or heavily reinforced, inaccessible areas and / or areas with inability to vibration, repair of existing structures, underground tunnels, etc.).

This is because mixtures usually exhibit high content of fines (450-600 kg/m3), which results in mixtures with higher contents of Portland cement and consequently high resistance values (40-70MPa), which are much higher than those strictly required in projects. Thus, the cost of the components that make up a SCC is comparatively high with respect to that of a conventional concrete of equal resistance. Study of SCC with mean values of compressive resistance within 20-30 MPa. (even 35MPa) range and reduced cost is of great interest, since such resistance range is the most widely used in the production of conventional concrete. Moreover, there is very little information on this subject in the scientific literature. SCC having these features could be very competitive with respect to traditional concrete, both technically and economically.

Therefore, the present paper has as its main objective to present a rational method for mix design of SCC with low and medium compression resistance and low cost, based on a physical path way while also bearing in mind environmental conditions. For this purpose all the different variables related to the available materials in a particular setting should be analyzed, the dosage itself (water / cement ratio, paste volumes) as well as the cost, which are analyzed in this work. These properties in fresh and hardened state as well as the SCC cost are studied employing the proposed mix design method. Statistical correlations are determined between the different variables and studied resulting properties. The results and costs obtained with SCC are compared with those in conventional concrete of same compressive strength showing the benefits of using SCC from technical, economic and ecological perspectives.

Durability of high volume fly ash concrete used in channel revetment

QI Bing *, GAO Jianming * and SHEN Yejiong *

* Jiangsu Key Laboratory of Construction Materials, School of Materials Science and Engineering, Southeast University, Nanjing 21189, China
E-mail: qibing5@126.com, jmgao@seu.edu.cn

ABSTRACT

This paper presents the results of a laboratory study on durability properties of high volume fly ash concrete that is suitable for channel revetment. Chloride ion permeability, carbonation, frost-resistance and microstructure variation of concrete were concemed. Two series of mixtures with two different water/binder ratios (0.55 and 0.58 by mass) were prepared by partial replacement of cement with fly ash. The replacing dosage of fly ash varies proportions from 30 % to 60 %. The experiment results demonstrated chloride diffusion coefficient of concrete decreases with the increasing volume of fly ash. However, the resistance to carbonation and freeze-thaw durability was adverse, especially when the content of fly ash was greater than 50 %.

REFERENCES

[1] B.K. Marsh and R.L. Day, "Pozzolanic and cementitious reactions of fly ash in blended cement pastes", Cement and Concrete Research, Vol. **18** , pp. 301-310, (1988).
[2] M. Ahmaruzzaman, "A review on the utilization of fly ash", Progress in Energy and Combustion Science, Vol. **36**, pp. 327-363, (2010).
[3] A. Oner,S. and Akyuz, "An experimental study on strength development of concrete containing fly ash and optimum usage of fly ash in concrete", Cement and Concrete Research, Vol. **35**, pp. 1165-1171,(2005).
[4] B.W. Langan and K. Weng, "Effect of silica fume and fly ash on heat of hydration of Portland cement", Cement and Concrete Research ,Vol. **32**, pp.1045-1051, (2002).
[5] A. Durán-Herrera and C.A. Juárez, "Evaluation of sustainable high-volume fly ash concretes", Cement and Concrete Composites ,Vol. **33**, pp.39-45,(2011).
[6] O. Kayali, and M.S. Ahmed, "Assessment of high volume replacement fly ash concrete–Concept of performance index", Construction and Building Materials Vol. **39**, pp.71-76 , (2013) .

Economical effect on ultra-high performance concrete by using of coarse aggregates

M. Schneider*, P. Druml* and Steiner, T.*

* Laboratory of Building Materials
Carinthia University of Applied Sciences
Halle T10, Europastrasse 3, 9524 Villach – St. Magdalen, Austria
e-mail: bau@fh-kaertnen.at, web page: http://www.fh-kaertnen.at

ABSTRACT

Ultra high performance concrete is generally mixed with a various number of fine aggregates and steel fibres respectively polypropylene fibres in the matrix for stress absorbing and fire resistance. All these ingredients based on the optimization of the grading curve. If we have this optimization the ultra-high performance concrete meets the target of compressive strength higher than 160 MPa. On a short view on the costs of mixing very fast it is observed, that the price is extremely high compared to other concretes with high strength. But the old question, why we need such concrete is obsolete. There are a lot of examples for realizing UHPC on maintenance of bridges, slender constructions and facades. That is why during a research program the reducing of costs is analysed from the view of sustainability. The information was fixed on variation of the binder and fine hydraulic activated slag [1]. The new option which will be presented is the possibility to change the matrix itself with coarse aggregates. We observed that the workability is not sufficient, that is why the maximum content is more or less 15 %. When we increase this amount, the production process has to be changed. One of the steps is use a pre-pact method. In the examination we considered the influence of coarse aggregates on the workability and sustainability because we reduce the content of cost intensive materials like cement, micro silica and quartzite fume.

In the second step of the examination the workability of pre-pact ultra high performance concrete elements is adapted to the pre-cast segment industry. It should be shown that the addition work for the pre-pact method is lower than the costs of the saved ingredients.

For any further request, please contact the first author:

Laboratory of Building Materials
Carinthia University of Applied Sciences
Europastrasse 3, 9524 Villach – St. Magdalen, Austria

Tel: +43 5 90500 1111
Fax: +43 5 90500 1110
E-mail: m.schneider@fh-kaernten.at

REFERENCES

[1] Randl, N., Steiner, T., Ofner, S., Baumgartner, E., Mészöly, T., "Development of UHPC mixtures from an ecological point of view", *Construction and Building Materials*, Vol 67, pp 373-378, (2014)

Effect of Internal Alkali Activation on Long-Term Pozzolanic Reaction of Fly Ash in Cement Paste

Phuong Trinh Bui*, Kazuki Ootaishi†, Yuko Ogawa††, Kenichiro Nakarai††† and Kenji Kawai††††

*, †, ††, †††, †††† Hiroshima University
1-4-1, Kagamiyama, Higashi-Hiroshima, 739-8527 Japan
e-mail: *d123252@hiroshima-u.ac.jp, †b120250@hiroshima-u.ac.jp, ††ogaway@hiroshima-u.ac.jp, †††nakarai@hiroshima-u.ac.jp, ††††kkawai@hiroshima-u.ac.jp

ABSTRACT

In recent years, alkali activation on fly ash particles has been suggested for accelerating their pozzolanic reaction, which enhances the durability of concrete [1, 2, 3]. However, the alkali activations become most effective when high temperature curing which has a limited use in practice, is applied [1, 2]. Alkali activation at normal temperature on fly ash cement paste from 1 month after casting has been investigated and it was found that the alkali activation was effective in accelerating the pozzolanic reaction at the age of 2 months [3]. Nevertheless, its effect on the long-term pozzolanic reaction of fly ash in the cement paste has not been reported yet. This study deals with the effects of internal alkali activation on the pozzolanic reaction of fly ash at the age of 12 months in the cement paste cured at normal temperature by examining the $Ca(OH)_2$ (CH) content, consumption of CH, and pore volume.

Cement pastes were prepared with a water to binder ratio of 30%. Fly ash replacement ratios were 0% (FA0) and 40% (FA40) by mass. A saturated $Ca(OH)_2$ solution was used for an internal alkali activation and water was used for a comparison. The internal activation was carried out by supplying the solution naturally through an installed syringe from the age of 1 month.

As a result, the injection of water or saturated $Ca(OH)_2$ solution increased the CH content in FA0 at the age of 12 months. It shows the cement hydration in FA0 at the age of 12 months was promoted by the internal activation from the age of 1 month. Meanwhile, the consumption of CH by the pozzolanic reaction in FA40 was calculated under each condition (with and without the injection of solution). It can be found that the consumptions of CH of samples with the injection of both water and saturated $Ca(OH)_2$ solution at the age of 12 months were larger than those without injection. It indicates that the pozzolanic reaction was accelerated at the age of 12 months by the internal activation from the age of 1 month. In addition to the increase in the consumption of CH, the internal activation from the age of 1 month reduced the total pore volume in FA0 and FA40. On the other hand, it decreased the volume ratio of 20-330 nm pores to the total pore in FA40, but not in FA0. Additionally, the injection of saturated $Ca(OH)_2$ solution from the age of 1 month was more effective in decreasing the CH content and the volume ratio of 20-330 nm pores to the total pore in FA40, and increasing the consumption of CH than the injection of water from the age of 1 month. It can be concluded that the internal activation from 1 month by using saturated $Ca(OH)_2$ solution accelerated the pozzolanic reaction of fly ash particles in the cement paste at the age of 12 months more than that by using water.

REFERENCES

[1] A. Katz, “Microscopic study of alkali-activated fly ash”, Cem. Concr. Res., Vol. 28, pp. 197-208, (1998).

[2] D. Li, Y. Chen, J. Shen, J. Su and X. Wu, “The influence of alkalinity on activation and microstructure of fly ash”, Cem. Concr. Res., Vol. 30, pp. 881-886, (2000).

[3] P.T. Bui, Y. Ogawa, K. Nakarai and K. Kawai, “A study on pozzolanic reaction of fly ash cement paste activated by an injection of alkali solution”, Constr. Build. Mater., Vol. 94, pp. 28-34, (2015).

Effects of Phase Change Material on Hydration Heat of Fly Ash and Blast-Furnace Slag Concrete

Seok-Joon Jang*, Gwon-Young Jeong * and Hyun-Do Yun*,

* Department of Architectural Engineering, Chungnam National University (CNU)
Daejeon, 305764, South Korea
e-mail: suk-joon@nate.com; wlqks123@naver.com; wiseroad@cnu.ac.kr
web page: http://www.cnu.ac.kr

ABSTRACT

Phase change material (PCM) can be applied to massive concrete structures as latent heat material for hydration heat reduction. This paper describes the effects of PCM on mechanical and hydration properties of concrete. Total four matrixes with conventional concrete, fly ash replacement ratio of 20% concrete and blast-furnace slag replacement ratio of 40% concrete were added PCM at a dosage rate of 11.4kg/m3. And properties such as drying shrinkage, compressive responses and hydration heat behavior were determined. Test results indicated that there are no significant effect of PCM add on compressive responses. On the other hand, the differences in the development rate of compressive strength were observed between Portland cement and other binder. It has found that matrixes with PCM were reduced of shrinkage values and hydration heat. Especially, mixtures with fly ash and blast-furnace slag more effective in those properties than conventional cement mixture. Based on test results, analytically study of mass concrete structure was conducted for field application of PCM concrete.

REFERENCES

[1] Langan, B. W., K. Weng, and M. A. Ward. "Effect of silica fume and fly ash on heat of hydration of Portland cement", Cement and Concrete Research, Vol. 32, No. 7, pp. 1045-1051, (2002).

[2] De Rojas, MI Sanchez, and M. Frías. "The pozzolanic activity of different materials, its influence on the hydration heat in mortars", Cement and Concrete Research Vol. 26, No. 2, pp. 203-213, (1996).

This work was supported by the Human Resource Training Program for Regional Innovation and Creativity through the Ministry of Education and National Research Foundation of Korea (NRF-2014H1C1A1066970)

Effects of pozzolanic addition and fibre treatment on mechanical performance of cement based composites reinforced with cellulose fibre nonwovens

Josep Claramunt[a]*, Lucia J Fernandez-Carrasco[b], Mònica Ardanuy[c]

[a]Departament d'Enginyeria Agroalimentària i Biotecnologia, Universitat Politècnica de Catalunya, 08860 Castelldefels, SPAIN; email: josep.claramunt@upc.edu;
[b]Departament de Construccions Arquitectòniques I, Universitat Politècnica de Catalunya, Barcelona 08028 SPAIN; email: lucia.fernandez@upc.edu
[c]Departament d'Enginyeria Tèxtil i Paperera, Universitat Politècnica de Catalunya, Terrassa 08222 SPAIN; email: monica.ardanuy@upc.edu

ABSTRACT

To improve the energy efficiency of the building sector it becomes necessary on the one hand to develop more environmentally-friendly and high performance building materials, and, on the other one, to develop new constructive solutions to reduce the energy consumption during the useful life of buildings.

Nowadays, the most used constructive solutions for building envelopes are the "ventilated façade" systems, which have continuity between the thermic and impermeable envelopes, avoiding thermal bridges and consequently avoiding the energy loss and the presence of water vapour condensations. This outer layer must meet certain requirements such as strength, flexibility, ductility, lightness, waterproofing, insulation and outdoor durability. Currently, the most common materials used for these envelopes are fibre-cements reinforced with synthetic short fibres made of polyvinyl alcohol (PVA fibres). In areas sheltered from the rain natural cellulose fibres can also be used as reinforcement. These fibres lead to materials with a good combination of strength, lightness, sustainability and low cost and constitute a very interesting biobased option to substitute other synthetic materials [1]. Concerning to the fibre form of the reinforcement in these composites, the most common one is cellulose pulps homogeneously dispersed on the matrix [2]. This form provides good results, with some restrictions such as maximum fibre content and limited deformability of the composite. Other researchers describe the use of other fibre forms and structures as unidirectional long fibres [3], woven fabrics [4], paper sheets [5] or nonvowens [6]. These fibre forms provide higher deformability and strength. Moreover, the use of textile preforms as nonwovens could bring the benefit such as fabric hand-ability and easier applicability on automatized process [7].

In this study composites made of Portland cement matrices with two types of pozzolanic additions (silica fume and metakaolin) combined with cellulose fibres in the form of nonwovens subjected to different treatments to improve their dimensional stability (wet/dry cycles in different conditions or plasma treatment) are analysed as potential materials for fibre-cement sheets for building envelopes with high strength and durability. The mechanical properties and durability are evaluated under direct tension tests after 28 days of curing in humidity chamber and after subjecting the sheets to accelerated aging.

REFERENCES

[1] H.Savastano, P.G. Warden and R.S.P.Coutts, "Mechanically pulped sisal as reinforcement in cementitious matrices", *Cem. Concr. Compos*., Vol. **25**, pp. 311–319, (2003).

[2] M. Ardanuy, J. Claramunt and R.D. Toledo Filho, "Cellulosic fiber reinforced cement-based composites: A review of recent research", *Const. Build. Mater*, Vol. **79**, pp. 115-128, (2015).

[3] F.A. Silva, R.D. Toledo Filho, J.D.A. Melo Filho and E.M.R. Fairbairn, "Physical and mechanical properties of durable sisal fiber–cement composites", *Const. Build. Mater*, Vol. **24**, pp. 777–785 (2010).

[4] M.E.A. Fidelis, F.A. Silva and R.D. Toledo Filho, “The influence of fiber treatment on the mechanical behavior of jute textile reinforced concrete”, *Key Engin. Mater*, Vol. **600**, pp. 469–474, (2014).

[5] B.J. Mohr, H. Nanko and K.E. Kurtis, “Aligned kraft pulp fiber sheets for reinforcing mortar”, *Cem. Concr. Compos*., Vol. **28**, pp. 161–172, (2006).

[6] J. Claramunt, L.J. Fernández Carrasco, and M. Ardanuy, “Mechanical behavior of flax nonwoven cement composites”, In Proocedings of SHCC3 Strain Hardening Cementitious Composites. Edited by E. Schlangen, M.G. Sierra Beltran, M. Lukovic and G. Ye., RILEM Publications, pp. 163-170 (2014).

[7] J. Claramunt, M. Ardanuy, L. Fernandez-Carrasco and H. Ventura, “Producto de material compuesto de aglomerante inorgánico y fibras vegetales, y método para su fabricación”, Patent Number Sol. P201430772 (2014).

EFFICIENCY FACTORS OF FLY ASH - A POWERFUL TOOL FOR MIX PROPORTIONING

SANTANU BHANJA
Professor, Department of Civil Engineering, National Institute of Technical Teachers' Training & Research, Kolkata, Block–FC, Sector–III, Salt Lake, West Bengal, 700106, India. e-mail: san244in@yahoo.com

ABSTRACT

With the objective of attaining sustainable construction a strong trend favoring the increased use of mineral admixtures, which are basically the waste products of industrial processes like fly ash, in concrete is emerging throughout the world. Fly ash has already proved its worth as an excellent cement replacement material. The physical and chemical properties of fly ash are widely variable and hence an idea about its cementitious properties can help in assessing the amount of ash to be replaced by one part of cement to achieve equivalent strength as that of control concrete. The cementing efficiency of a pozzolan is defined as the number of parts of cement that could be replaced by one part of the pozzolan without affecting the property under consideration (mainly strength). Efficiency of fly ash, being highly variable, should not be considered as an intrinsic or fundamental property of the material as it depends on a number of parameters like type of cement & fly ash, replacement level, age, w/cm, strength level etc, where cm is the cementitious material content. Quantification of the contribution of fly ash in concrete has been under study for many years. Statistical models developed by multiple regression analysis using compressive strengths determined over a wide range of w/cm values ranging from 0.3 to 0.6 and binder contents of 300, 375 and 450 kg/m^3 for predicting efficiency factors of fly ash have been presented in a previous publication of the author by [1]. The present paper is a continuation of the previous research and deals with further value addition to the previous reporting. In this paper the average values of the 28-day efficiency factors have been evaluated and their applicability on the mixture proportioning of fly ash concrete has been enumerated [2]. Nowadays guidelines or standards for mix proportioning of fly ash concrete are available in a host of countries including India. In the Indian Standard method to incorporate fly ash in concrete, the total binder content has been increased arbitrarily based on trial and skill of the designer [3]. This does not seem to be justified as the fly ash used can have a wide variation in properties which have not been taken into consideration. On the other hand if some guidelines are provided on the basis of the efficiency factor of fly ash, at least a good first hand estimate of the fly ash content equivalent to the cement replaced can be obtained. The proposed values of efficiency factors if used in mix proportioning of fly ash concrete can lead to proper quantification of the ash used without merely relying on the experience and discretion of the designer. It may be expected that the findings of the present work may serve as a useful guideline for judiciously applying the concept of efficiency factors to optimize the effect of fly ash in concrete and lead to improvement in the method of mix design of fly ash concretes. A simple numerical example enumerating how the proposed method can lead to improvement in the existing methodology has been presented.

REFERENCES

[1] Bhanja, Santanu, Pan, Samaresh, "Predictor Models for Evaluation of Efficiency Factors of Fly Ash in Concrete", First International Conference on Concrete Sustainability (ICCS13), Tokyo, Japan, 27-29 May 2013

[2] Bhanja, Santanu, Project Report Entitled — "Development of Modified Water-Cement Ratio Law for High Performance Concrete with Fly Ash", Department of Science & Technology, Government of India, New Delhi, India, 2012

[3] IS: 10262:2009, Indian Standard, "Concrete Mix Proportioning - Guidelines" (First Revision). Bureau of Indian Standards

Experimental study on Maintenance and Conservation for Traditional Architecture from the standpoint of Plaster Finishing Material

Kentaro OKA* and Masaki TAMURA†

* Construction Research Group, Environment Material Engineering Laboratory
Department of Architecture, Graduate School of Engineering, Kogakuin University,
1-24-2 Nishi-shinjuku, Shinjuku-ku, Tokyo, 163-8677, Japan
e-mail: dm15007@ns.kogakuin.ac.jp, web page: http://www.kogakuin.ac.jp/english/

†Construction Research Group, Environment Material Engineering Laboratory
Associate professor, Department of Architecture, Kogakuin University, Dr. Engineering
1-24-2 Nishi-shinjuku, Shinjuku-ku, Tokyo, 163-8677, Japan
e-mail: masaki-t@cc.kogakuin.ac.jp, web page: http://www.ns.kogakuin.ac.jp/~dt40009/tamura/

ABSTRACT

The traditional architecture and buildings in Japan, it has often been composing plaster mortar for surface finishing materials on the walls and ceilings regardless of structural types of masonry, wood, concrete. These plaster materials are called Shikkui in Japanese, and the chemical ingredient are almost constituted $Ca(OH)_2$ and its carbonized surface area. The Himeji castle of world heritage and The Gunkan Island (Battleship Island) of world heritage candidate in Japan are also has been used the plaster materials as interior or exterior finishing materials.

In general, these plaster materials are effected by curing reaction with carbon dioxide, and the strength of surface finishing materials has a tendency to increase for over a century. Finally, the covered conditions for structural body in such plaster materials would be capable to protect the architecture and building itself for a long time. [1]

However, some of these architecture and buildings have been placed in harsh environment and occurred natural disaster frequently. Actually, some cultural and historical architecture and buildings were damaged by the Great East Japan Earthquake 2011. There accidents have just caused the ceiling and wall pilling or collapse phenomenon, and it might have been relationship the loss of not only the architecture and building in itself but also traditional culture and historical value.

Therefore, this study focused on the fundamental properties on workability, strength and durability of plaster materials applied for ceiling. In this experiments, we prepared many types of plaster specimens to evaluate the relationship between mix proportions and fundamental properties. These mix proportions are different from content rates of water, plaster, sand and natural plant fiber, and we conducted these experimental evaluations in detail.

As these results in this study, it has been found that the mechanical strength of ceiling factor were related between plaster density and carbonated extend, and the durability and fracture toughness were effected there mix proportions. In additions, it would be expected to increse the potential fundamental properties and protect of authenticity by optimizing the use ratio of plaster materials,

REFERENCES

[1] S. Suzuki, M. Tamura and K Oka, "Maintenance and Conservation Strategy for Building and Constructed Assets from The Standpoint of Life Cycle Management, Part.3 Redundancy for concrete buildings by finishing plaster", Architectural Institute of Japan (Kinki) pp.1361-1362, (2014)

Fundamental study on the properties of mortar using Gehlenite clinker as fine aggregate

Hiromi Fujiwara*, Masanori Maruoka†, Masatoshi Nemoto†, Koki Yoshikawa† and Makoto Kobayakawa‡

* Professor for Design and Engineering for the Global Environment
Graduate school of Utsunomiya University
Yoto, 7-1-2, 321-8585 Tochigi, Japan
Email: fhiromi@cc.utsunomiya-u.ac.jp - Web page: http://www.utsunomiya-u.ac.jp/

† Design and Engineering for the Global Environment
Graduate school of Utsunomiya University
Yoto, 7-1-2, 321-8585 Tochigi, Japan
Email: mmaruoka@cc.utsunomiya-u.ac.jp - Web page: http://www.utsunomiya-u.ac.jp/

‡ Taiheiyo Cement Co. LTD
Osaku, Sakura, 285-8655 Chiba, Japan
Email: Makoto_Kobayakawa@taiheiyo-cement.co.jp - Web page: http://www.taiheiyo-cement.co.jp/

ABSTRACT

In recent years Japanese cement industry has been using a large amount of waste as the raw material for the production of cement. On the other hand, the future demand for cement in Japan is expected to decrease. Therefore, viewed in the effective utilization of waste, the development of new applications of the cement clinker is required.

In comparison with conventional clinker, for production of Gelignite clinker, the proportion of waste materials in the raw materials is very high.

However, performance of cement from it is not sufficient. In this study the possibility of using this Gelignite clinker as aggregate was investigated.

The various properties of mortar using Gehlenite clinker as fine aggregate were evaluated. As a result, compared to the mortar using a conventional fine aggregate, it is confirmed that compressive strength is high, amount of drying shrinkage is small, carbonation rate is low and self-healing performance is expected[1].

REFERENCES

[1] Self-healing properties and its use research Technical Committee of the cement-based material, *self-healing and use research expert committee report of the cement-based material*, pp. 36-37, 2008.

A High Performance Sustainable Grout

D. Hesselbarth*, C. Fiuza† and T. Moser†

* Sika Technology AG
Tüffenwies 16, 8048 Zürich, Switzerland
e-mail: hesselbarth.daniela@ch.sika.com, web page: http://www.sika.com

† Sika Services AG
In der Luberzen 25, 8902 Urdorf, Switzerland
e-mail: fiuza.clara@ch.sika.com, web page: http://www.sika.com

† Sika Technology AG
Tüffenwies 16, 8048 Zürich, Switzerland
e-mail: moser.thomas@ch.sika.com, web page: http://www.sika.com

ABSTRACT

Cement production is an energy-intensive process, responsible for a significant amount of the world's carbon dioxide emissions.[1] Mixtures with so-called supplementary cementitious materials (SCM) like pozzolanic materials (pulverized fly ash or natural pozzolanas), latent hydraulic products like ground granulated blast furnace slag and even inert materials like limestone are therefore used to reduce the CO_2 footprint. Such a clinker replacement with SCM may be able to partially overcome the problem of energy consumption in the cement production, however, the resulting binder often lacks in performance compared to ordinary Portland cement (OPC).[2]
In this paper, a high performance grout is presented in which part of the cement was replaced by a suitable combination of SCM to create a sustainable grout without compromising the performance. Characteristics, mechanical and physical properties are discussed. Additionally, the environmental performance is analyzed through a simplified life cycle assessment (LCA).

REFERENCES

[1] K.L. Scrivener, R.J. Kirkpatrick: Innovation in use and research on cementitious material, *Cement and Concrete Research*, 38 (2008), pp. 128-136.
[2] Tongsheng Zhang, Qijun Yu, Jiangxiong Wei, Pingping Zhang: A new gap-graded particle size distribution and resulting consequences on properties of blended cement, *Cement and Concrete Composites*, 33 (2011), pp. 543-550.

Impact of aluminates on silicates hydration

Pustovgar E.[1*], d'Espinose de Lacaillerie J.-B.[2], Palacios M.[1], Andreev A.[2], R. K. Mishra[1], Flatt R. J.[1*]

[1]Institute for Building Materials, ETH Zurich, 8093, Switzerland

[2]Soft Matter Science and Engineering laboratory, ESPCI ParisTech, PSL Research University, 75005 Paris, France

ABSTRACT

Replacement of clinker by suplementary cementitious materials (SCMs) is one of the most promising routes to decrease the carbon footprint and embodied energy of Portland cement. However, increasing amounts of alumina-rich SCMs leads to a delay of cement hydration and a decrease of early mechanical strength.

In this study, the passivation induced by aluminates on silicates hydration was investigated at the molecular level using Nuclear Magnetic Resonance (NMR). "In situ" ^{27}Al MAS NMR experiments allowed quantifying tricalcium silicate (C_3S) hydration in presence of different concentration of aluminates. Natural abundance of ^{27}Al is practically 100%, what provides a unique opportunity to realize this characterization in-situ and with a fast time-resolution thus under conditions precluding perturbation of the C-S-H structure due to the use of any drying technique. This study was complemented with isothermal calorimetry tests.

Results have shown that the delay of silicates hydration increases with the increase of aluminates concentration. Furthermore, the increase of aluminates promoted the formation of AFm phases that are converted into TAH at later time of hydration.

*corresponding author: flattr@ethz.ch

Influence of Physicochemical and Microstructural Properties of TiO_2 Cementitious materials on Hydroxyl Radicals Production and Photocatalytic Pollution Degradation

E. Jimenez-Relinque* and M. Castellote†

* Institute of Construction Eduardo Torroja (IETcc-CSIC)
Serrano Galvache, 4 28033 Madrid, Spain

† Institute of Construction Eduardo Torroja (IETcc-CSIC)
Serrano Galvache, 4 28033 Madrid, Spain

ABSTRACT

Environmental pollution problem on cities has led to the need developed for new environmentally friendly technologies and materials. In this context, the implementation of heterogeneous photocatalysis in the building industry may be a promising technology that can be used to address this challenge. Indeed, the incorporation of photocatalyst provides air decontamination, self-cleaning, self-sterilizing, and anti-fogging properties to construction materials. Among these materials, there is a growing interest in using cement-based materials (e.g. cement paste or mortar and concrete) as supports due to their strong binding property, porous structure and compatibility of their alkaline pH with TiO_2 [1].

In the last years, the large amount of literature about photocatalytic cementitious materials has predominantly dealt of individualized analysis of factors in design and manufacturing that affect efficiency issues. However, its influence of photocatalytic performance still lack systematic research and the effects in some cases showed contradictory results. Preliminary, the authors reported [1] the influence of parameters as cementitious matrix, surface roughness and microstructure. To complete that research, this work aims to study jointly: (1) TiO_2 addition effects on the characteristics of modified mortars, (2) assessment the physicochemical and microstructural properties of TiO_2 cementitious materials that influence on their photocatalytic performance, and (3) evaluate the contribution of hydroxyl radical (OH•, the main reactive oxygen specie in photocatalysis) on photocatalytic efficiency in function of parameters analyzed in the previous objective.

To achieve these objectives, the photocatalytic pollution degradation by TiO_2 blended cement pastes was evaluated using nitrogen oxides conversion and dyes discoloration as processes to evaluate the characteristic of TiO_2 cementitious materials that may influence the air depollution and self-cleaning performance respectively. Additionally, the production of OH• by photocatalytic cementitious materials was quantified by an adaptation of terephthalic acid as probe method for fluorescence spectrometry (TA-FL method) construction materials [2]. Results of the experimental program showed that parameters as chemical composition of cement and admixtures, available active surface and range pore size of material must be carefully selected to accomplish the requirements of efficiency. The different production of OH• and photocatalytic efficiency in function of chemical mixes composition have been explained on the basis of oxidation-reduction potentials and photoabsorption energy of the different constituents of cementitious matrix.

REFERENCES

[1] E. Jimenez-Relinque, J.R. Rodriguez-Garcia, A. Castillo and M. Castellote, "Characteristics and efficiency of photocatalytic cementitious materials: Type of binder, roughness and microstructure", *Cement and Concrete Research*, Vol. **71**, pp. 124-131, (2015).

[2] E. Jimenez-Relinque and M. Castellote, "Quantification of hydroxyl radicals on cementitious materials by fluorescence spectrophotometry as a method to assess the photocatalytic activity", *Cement and Concrete Research*, Vol. **74** (2015), pp. 108-115, (2015).

Material Properties and Application to Structure of Low Carbon High Performance Concrete Using Fly Ash and Blast Furnace Slag

Hisashi SAITO*, Atsushi SAITO† and Koji SAKAI††

* Sumitomo Osaka Cement Co., Ltd.
Cement Concrete Research Laboratory
558 Toyotomi-cho, Funabashi, Chiba, Japan 274-8601
e-mail: hisaitou@soc.co.jp, web page: http://www.soc.co.jp

† Hazama Ando Corporation
Technical Research Institute
515-1 Karima, Tsukuba, Ibaraki, Japan 305-0822
e-mail: atsushi.saito@ad-hzm.co.jp, web page: http://www.ad-hzm.co.jp

†† Japan Sustainability Institute
1-25 Kita-21 Higashi-19, Higashi-ku, Sapporo, Japan 065-0021
e-mail: sakai@jsi-ks.jp, web page: http://www.jsi-ks.jp

ABSTRACT

The optimum combinations of fly ash and blast furnace slag for low-carbon high performance concrete (LHC) were investigated, and it was found that the replacement ratio of cement with fly ash and blast furnace slag of 20% each was well-balanced in terms of "material properties" and "low carbon performance".
This paper describes the results of laboratory concrete tests and its onsite test practice. In the laboratory tests, the material properties of strength development, resistance to cracking, and durability were investigated. The environmental impacts were also calculated. In the onsite test practice, the production, transportation, placing, compaction and finishing of concrete were examined. The effects of concrete production seasons (spring, summer and winter) were also evaluated.
It was found from the laboratory tests that the strength development, resistance to cracking, durability except for carbonation and reduction of environmental impact of LHC were equal to or greater than that of concrete using ordinary portland cement. From the onsite tests, it was concluded that the SCM storage facility to produce LHC is not needed by using blast furnace slag cement type B in JIS instead of blast furnace slag as a SCM, the construction performance of LHC was the same as a general concrete, and LHC does not have any effect on its quality, but it should be noticed that in winter period the finishing time and strength development are delayed.

REFERENCES

[1] A. Saito, K. Sakai, Y. Suzuki and K. Fukudome, "Placement performance of low-carbon concrete using fly ash and ground granulated blast-furnace slag", *First International Conference on Concrete Sustainability*, pp.167-172, (2013).

[2] H. Saito, K. Sakai, Y. Suzuki and K. Fukudome, "Effect of cement type and expansive additive on resistance to cracking of low-carbon concrete using fly ash and ground granulated blast-furnace slag", *First International Conference on Concrete Sustainability*, pp.688-693, (2013).

Material Properties of Mineralized Foam and its Density Dependency – a Meta-study

Albrecht Gilka-Bötzow*, Marlon Zimmer and Eduardus A.B. Koenders*

* Institute of Construction and Building Materials (WIB)
Technische Universität Darmstadt
Franziska-Braun-Straße 3, 64287 Darmstadt, Germany
e-mail: gilka-boetzow@wib.tu-darmstadt.de, web page: www.wib.tu-darmstadt.de

ABSTRACT

The dependency of the material properties of mineralized foam, such as the compressive strength or thermal conductivity, is widely researched and generally known. However, most of the research conducted on this topic so far has been focusing on a very narrow range of densities. This has led to the fact that the current level of knowledge on the thermo-mechanical performance of this versatile material is very concentrated and, therefore, not providing an overall figure that is covering a wide range of densities. To extend this level of knowledge, a meta-study was conducted at the Institute of Construction and Building Materials of the TU Darmstadt consisting of literature data combined with results taken from own lab tests. Aim of this study was to get a full picture of the interdependencies between various thermo-mechanical parameters of the hardened mineralized foam, while covering a wide range of densities. The final result showed a consistent trend, where literature data and the lab test results turned out to be very complimentary.

REFERENCES

[1] Kearsley, E.P., Wainwright, P.J.: Ash content for optimum strength of foamed concrete. In: Cem. Concr. Res. 32 (2002) pp. 241–246

[2] Ramamurthy, K., Kunhanandan Nambiar, E.K., Indu Siva Ranjani, G.: A classification of studies on properties of foam concrete. In: Cem. Concr. Compos. 31 (2009) pp. 388–396

[3] Gilka-Bötzow, A., Röser, F., Koenders, E.A.B.: Mineral Foam in Energy Active Buildings. International Conference on the Regeneration and Conservation of Concrete Structures, Nagasaki, Japan (2015)

Mechanical Behaviour of Concrete using Recycled Granulated Steel

U. M. T. Quadir*, K. Islam#, A. H. M. M. Billah† and M. S. Alam†

* North South University
Bashundhara R/A, Dhaka-1229, Bangladesh.
E-mail: upal.quadir@northsouth.edu, Web page: http://www.northsouth.edu/faculty-members/seas/ceed-faculty-members/upal-mohammad-towfiqul-quadir

Military Institute of Science and Technology
Mirpur Cantonment, Mirpur, Dhaka-1216, Bangladesh.
E-mail: kamrul1@ualberta.edu, Web page: http://ce.mist.ac.bd/employees/kamrul-islam/

† The University of British Columbia
3333 University Way, Kelowna, BC V1V 1V7, Canada.
Email: shahria.alam@ubc.ca - Web page: https://people.ok.ubc.ca/shaalam/

ABSTRACT

Recycled granulated steel (RGS) is a by-product produced in the steel re-rolling mills. Steel re-rolling mills are generating significant volume of granulated steel each year. The use of RGS is new in the area of concrete research. This paper describes the influence of RGS on the fresh and hardened properties of concrete, and compared those properties with the control concrete specimens containing natural aggregates. RGS was introduced as a replacement to fine aggregates (up to 60% by weight). All the tests were conducted as per ASTM standards in compression and flexure under quasi-static loading condition. The results of the mechanical properties were presented in terms of stress-strain curves, modulus of elasticity, Poisson's ratio, and fracture toughness. The study shows that both fresh and hardened properties of the RGS concrete were quite similar to the control concrete. However, with the increase of RGS (i.e., from 30% up to 60%), slump value increases compared to the control concrete. The compressive strength, flexural strength and flexural toughness increase up to 10%, 30%, and 38%, respectively with the increase of RGS in the concrete mixtures compared to those of control concrete. Finally, this paper indicates the possible use of RGS in concrete as a replacement of fine aggregate to produce new generation concrete.

REFERENCES

[1] M.S. Alam, E. Slater, and A. H. M. M., Billah, Green concrete made with RCA and FRP scrap aggregate: fresh and hardened properties, Journal of materials in civil engineering, **Vol** 25(12), (2013).
[2] S.B. Huda and M.S. Alam, Mechanical behavior of three generations of 100% repeated recycled coarse aggregate concrete, Construction and building materials, **Vol** 65, pp. 574-582, (2014).

Mechanical properties of fiber reinforced cementitious composites with high amounts of fly ash as cement replacement

Antroula V. Georgiou* and Stavroula J. Pantazopoulou†

Civil and Environmental Engineering Department
University of Cyprus
75, Kallipoleos *Street,* 1678 Nicosia, Cyprus

*e-mail: ageorg44@ucy.ac.cy
†e-mail: pantaz@ucy.ac.cy

ABSTRACT

Fiber reinforced cementitious composites (FRCC) made with hybrid Polyvinyl Alcohol Fibers and high amounts of fly ash, show advantageous mechanical properties in terms of very large tensile strain capacity and ductility and are considered the future of cement based construction [1].

The amount of cement replacement by fly ash in the composite in the order of 60%, reaching 34% by weight of total mixed materials is contributing towards the reduction of CO_2 emissions from cement production, recycling a material (fly ash) that would otherwise be exposed and eliminating the use of coarse aggregate thereby further decreasing exploitation of natural resources.

Simultaneously the addition of fibers within the composite increases ductility and energy absorption in structural members made of this material, further reducing the need for stirrup and hoop reinforcement, enhancing durability of the structural member and limiting the deterioration due to cracking and the need for restoration after seismic events. Due to the high strength and very high tensile strain ductility it provides the opportunity for a leap forward in novel construction products particularly in the sector of prefabricated concrete.

Experimental test results on the composite with and without different types of fibers (PP and PVA) and different length of fibers (8 and 12mm) on uniaxial compression, extension, split and push off specimens showed the connection between tensile and shear strength increases in this class of sustainable materials, owing to the addition of fibers which controls cracking and deterioration, and to the fine packing of particles achieved through the very large fly-ash content and the absence of coarse aggregate, which render the porosity very low favorably contributing towards the reduction of permeability.

REFERENCES

[1] Li, V.C., *Engineered Cementitious Composite (ECC): Material, Structural, and Durability Performance*. Concrete Construction Engineering Handbook, 1–47, 2007.

NEW PERMEABILITY REDUCING ADMIXTURE FOR SUSTAINABLE CONCRETE

Giorgio Ferrari[1], Gianluca Bianchin[1], Vincenzo Russo[1], Danilo Passalacqua[1]
Gilberto Artioli[2], Luca Valentini[2]
[1]Mapei SpA, Milano (Italy)
[2]Departement of Geosciences, University of Padua (Italy)

The sustainability of concrete is strictly related to its durability. Water is the main source of premature deterioration of concrete structures, by carrying aggressive chemicals such as chloride and sulfates into the concrete structure. The critical factors that contribute to the long-term environmental stability and chemical durability of concrete are a dense microstructure, a fine pore structure and low capillary porosity. All these characteristics help to produce very low permeability and ionic diffusivity, and resist the intrusion of aggressive elements that damage concrete and corrode the steel reinforcements. The addition of supplementary cementing materials (SCMs) into concrete mixtures has been gaining acceptance with respect to improving durability and reducing permeability. In addition, a class of materials referred to as permeability-reducing admixtures (PRAs) have been developed to improve concrete durability through controlling the water movement as well as by reducing chloride ion ingress and permeability. This presentation describes a new permeability reducing admixture able to effectively reduce the movement of water under hydrostatic head pressure (PRAH). The new admixture is an aqueous suspension of nano-sized metal transition polymeric silicate hydrate. The new inorganic polymer truly catalyzes the fast nucleation of CSH from hydrating cement, not only onto the surface of cement grains but also the homogeneous nucleation in the capillary pores of hydrating cement paste. The crystallization of CSH in the capillary pores refines the porosity of cement paste of the whole concrete and significantly increases the resistance to water penetration under pressure. The mechanism of homogeneous crystallization of CSH in the capillary pores was demonstrated by Synchrotron XRD micro-Tomography (XRD-μT) and by Scanning Electron Microscope (SEM) investigations. The effectiveness of the new admixture was verified by testing the permeability of concrete by European Standard EN 12390-8 by exposing the concrete specimens to a water pressure of 0.5 MPa for 72 hours and then measuring the water penetration. The results indicated that the new admixture is highly effective in reducing the penetration of water, compared to a reference concrete with the same W/C. The new admixture increases the early strength development of concrete and can be used in conjunction with WR and HRWR to produce concrete with outstanding mechanical performances and durability.

PAPER AS ADDITIVE IN CONCRETE MIXTURES FOR LOW RESISTANCE BLOCKS

MARCELA S. SOARES*, EDUARDO A. B. AGUIAR* AND GUSTAVO B. GOMES*

* Universidade Estadual do Maranhão (UEMA)
Cidade Universitária Paulo VI s/ n
São Luís, Maranhão, Brasil
e-mail: marcelasilv.soares@gmail.com; eduardoaguiar.eng@live.com;
gustavobeckman@gmail.com.
www.uema.br

Key words: Waste, Concrete, Paper.

Abstract: The production of waste is an inevitable phenomenon which occurs daily and its proportions depend on the size of population and local economic development. The usage of recycled materials in civil constructions may be an important way to eliminate urban waste, being a way of reducing the costs of deposition and treatment, and also a way of minimizing the aggressive effects of this type of material on the environment. Thus, we can highlight the usage of paper in the production of concrete, since this material represents one of the greatest types of waste in the world. It can thus be reusable and, moreover, produce a concrete with greater benefits for the environment, mainly because of paper's limited recyclability. This study aims to analyze the behavior of concrete with the addition of paper. Thus, behavior and properties of concrete made with different proportions of paper added to the mixture were analyzed, while also setting a standard mixture and analyzing differences between both concrete. A total of 56 specimens were produced with the same cement, aggregate and water amounts, whilst several specimens contained different quantities of cut and shredded paper. Slump tests were performed prior to the casting to determine the effects of the paper addition over workability. After the proper molding and curing, specimens were submitted to axial compressive strength tests at the ages of seven, fourteen, twenty-one, and twenty-eight days. Every concrete containing cut or shredded paper presented significantly loss of workability regardless of the amount added. Concretes with shredded paper presented loss of strength as the paper amount in the mixture was increased, while the addition of cut paper increased compressive strength in every quantity tested. It was also estimated the amount of paper allowed in 1 m³ of concrete based on the results, reaching up to almost 11 thousand A4 sheets. Based on the disclosed data, it is possible to emphasize the importance of producing low resistance concrete blocks with the use of recycled paper, as a way to reduce impacts caused by this type of waste on the environment, contributing to environmental construction.

Possible Reusing of Household Ceramic Wastes as Mineral Admixtures in Ecological Cement/Concrete

Yining DING[a], Huiwen DONG[b], Yongchao ZHANG[a], Cecília AZEVEDO[c]

a) Institute of Structure Eng. Dalian University of Technology, Dalian 116023, China

b) Hubei Power Transmission and Transformation Company

c) Centre of the Mathematics, University of Minho, Portugal

Abstract: Both the Ceramic wastes and the pollution of the cement industry can cause strong damage to the environment and the sustainable development. In the present study, the pozzolanic activity of household ceramic waste powder was investigated by SAI test and Frattini Test; the possibility of the partial substitution of Portland cement blended with ceramic waste powder was analyzed. The results indicate that the compressive strengths of mortar containing ceramic waste at both early age and after 28 days were generally increased as the ceramic waste ratio increased up to at least 15% replacement, and the ground ceramic waste show clear pozzolanic activity.

Key Words: X-ray method; Chemical properties; Strength; Pozzolanic activity and Frattini test

Properties of Alkali-Activated Fly Ash Mortars Made With Multiple Activators

Nader Ghafoori, Kimberly Sierra and Meysam Najimi
Department of Civil and Environmental Engineering and Construction, University of Nevada, Las Vegas, 4505 Maryland Parkway, Box 454015, Las Vegas, Nevada 89154-4015

Class F fly ash was activated with an alkaline solution composed of various dosages of sodium hydroxide and sodium silicate as activators. A constant solution-to-binder ratio 0.46 and fine aggregate-to-binder ratio of 2 was used. Two sodium hydroxide concentrations of 5 and 10 M, and sodium silicate-to-total solution ratios of 0.20 and 0.60 were used. Upon batching, the studied mortars were sealed cured for 3 hours at 60°C prior to de-molding and curing at 85°C until testing. The evaluated properties included workability, compressive strength, modulus of elasticity, absorption, void content, rapid chloride migration, and resistance to freezing and thawing. Compressive strength was evaluated after 1, 3 and 7 days of curing. Modulus of elasticity, absorption, rapid chloride migration and freezing and thawing resistance were evaluated after 7 days of curing.

The studied alkali-activated fly ash mortars displayed good performance as alternative binders for production of alkali-activated fly ash concrete. Test results showed that, for a given sodium silicate-to-total solution ratio, an increase in sodium hydroxide concentration allowed for improvement in strength, stiffness, absorption, void content, and resistance to freezing and thawing and chloride penetration. However, these properties were affected by the studied sodium silicate-to-total solution ratios. When sodium silicate-to-total solution ratio of 0.20 was used, the properties of the studied alkali-activated mortars improved with increases in sodium hydroxide concentration. The contrary was found for the mortars containing sodium-silicate-to–total solution ratio of 0.60.

Properties of high fluidity concrete using fine powder of melt-solidified slag from municipal waste as an admixture

Tohru Kimura*, Tatsuya Numao† and Kimio Fukuzawa††

* Dept. of Urban and Civil Engineering, Ibaraki University
4-12-1 Nakanarusawa, Hitachi, Ibaraki, Japan
e-Mail: kimura@mx.ibaraki.ac.jp, web page:http://www.ibaraki.ac.jp

† Dept. of Urban and Civil Engineering, Ibaraki University
4-12-1 Nakanarusawa, Hitachi, Ibaraki, Japan
e-Mail: numao@ mx.ibaraki.ac.jp, web page:http://www.ibaraki.ac.jp

†† Dept. of Urban and Civil Engineering, Ibaraki University
4-12-1 Nakanarusawa, Hitachi, Ibaraki, Japan
e-Mail: fukuzawa@ss.iij4u.or.jp, web page:http://www.ibaraki.ac.jp

ABSTRACT

In Japan, part of municipal waste is fused at a high temperature more than 1,200℃ to adapt the upper limit of dioxins in the residual material, in accordance with the "Law Concerning Special Measures against Dioxins" enforced on January 2000. Production volume of melt-solidified slag made from municipal waste is about 850,000,000kg every year. Part of the melt-solidified slag made from municipal waste is effectively utilized as aggregate for concrete and road.

Considering that a large amount of energy is used to produce the slag, a higher price material should be replaced by the slag. Many of the melt-solidified slag made from municipal waste is made through quenching process. The melt-solidified slag made through the quenching process has the latent hydraulic property.

We propose to use the fine powder of melt-solidified slag as as an admixture of high fluidity concrete.

Several properties of high fluidity concrete, such as compressive strength, drying shrinkage and pore size distribution are examined varying kind of melt-solidified slag and changing specific surface area of the slag powder.

The experiments revealed that fine powder of melt-solidified slag from municipal waste is effectively used as an admixture of high fluidity concrete.

REFERENCES

[1] Kimio Fukuzawa et al. (2007). " Strength of mortar and concrete using fine powder of molten slag made from municipal waste as a cementitious material" Sustainable Construction Techno., pp. 333-337.(in Japanese)

[2] Kazuyuki Torii et al.(2003). "Physical-chemical properties and alkali-silica reactivity of molten slags" Proceedings of the Japan Concrete Institute Vol.25,No.1., pp. 623-628.(in Japanese)

[3] Masafumi Kitatsuji et al.(2002)."Utilization of the gasification-Melting slag from municipal solid waste as fine aggregate for concrete" Concrete research and technology Vol.13(2)., pp.89-98, (in Japanese)

[4] Masafumi Kitatsuji (2013). "Influence of expanding concrete by Free-CaO and metallic aluminum" Environment Solution Technology., pp.35-42.(in Japanese)

Properties of Self Consolidating Concrete Containing Natural Pozzolan

Nader Ghafoori, Meysam Najimi, Mohammadreza Sharbaf
Department of Civil and Environmental Engineering and Construction, University of Nevada, Las Vegas, 4505 Maryland Parkway, Box 454015, Las Vegas, Nevada 89154-4015

In recent years, self-compacting concrete (SCC) has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. For such applications, fresh concrete must possess high fluidity and good cohesiveness. The use of fine materials such as Natural Pozzolan (NP) can ensure the required concrete properties.

In this study, the influence of NP on properties of SCC was investigated. A constant cementitious material of 475 kg/m3 was used. The natural pozzolan replaced a portion of Portland cement at the levels of 15, 22.5, 30 and 37.5% by weight. A uniform water-to-cementitious materials ratio of 0.4 was used to produce 5 distinct mixtures including control concrete. Upon batching, the studied SCCs were cast in cylindrical and beam-shaped specimens and moist- cured for 28 days prior to testing. The evaluated properties included flow, J-ring, T50, compressive and flexural strengths, modulus of elasticity, rapid chloride permeability and rapid chloride migration.

The results of this investigation showed that higher amounts of high range water reducing admixtures were required in natural pozzolan contained SCCs in order to meet target flow properties. Moreover, transport properties and passing ability of SCC was improved by increases in replacement level of natural pozzolan. On the other hand, slight reductions were observed in strength properties of the studied natural pozzolan contained self- consolidating concrete.

RECYCLED AGGREGATE: COMPLIANCE WITH LEGAL REQUIREMENTS

César Medina[◊], Isabel F. Sáez del Bosque[◊], Agustín Matías*, Blas Cantero[◊], Eloy Asensio†, Moisés Frías†, María Isabel Sánchez de Rojas†

*, ◊ Escuela Politécnica de Cáceres
Universidad de Extremadura, Unidad Asociada UEX-CSIC
Avenida de la Universidad, s/n, 10003, Cáceres (España)
E-mail: cmedinam@unex.es / isa.f.saez@gmail.com/ amatias@unex.es/ bcantero@alumnos.unex.es

† Instituto de Ciencias de la Construcción Eduardo Torroja
Consejo Superior de Investigaciones Científicas
C/ Serrano Galvache, 4, 28033, Madrid (España)
E-mail: eloyadl@ietcc.csic.es/ mfrias@ietcc.csic.es/ srojas@ietcc.csic.es

ABSTRACT

Construction and demolition waste (C&DW) has acquired particular prominence in Europe in the present context of sustainability. The C&DW generated in Spain accounts for one of the country's most significant waste flows. Despite the present crisis, the national construction industry generated 79.4 million tonnes of such waste in 2009-2013. Against this backdrop, the use of recycled aggregate is becoming standard practice in construction, particularly in civil works. According to the European Aggregates Association (UEPG), 183 million tonnes were used in Europe in 2012. This paper reports on the analysis of the physical, chemical, mineralogical and mechanical properties and chemical composition of aggregates sourced from construction and demolition waste management plants. The findings are compared to the legal requirements presently in place and a practical guide is put forward for the possible use of this material in construction.

RESEARCH ON SPRAY TYPE HIGH DUCTILITY PVA FIBER CONCRETE USED FOR THE DEEP ROADWAY SUPPORTING KEY TECHNOLOGY

YUANZHI BI*, SHUMEI GAO†
* School of Environmentand Civil Engineering,
Jiangnan University
1800 Lihu Road WuXi City Jiangsu Province P.R. China
e-mail: biyz2006@126.com, www.jiangnan.edu.cn

† School of Science, Jiangnan University
1800 Lihu Road WuXi City Jiangsu Province P.R. China
e-mail: gaosm@126.com, www.jiangnan.edu.cn

ABSTRACT

The supporting structural of deep coal mine roadway, whose surrounding rock has the characteristics of soft rock engineering, is required to be of high strength and certain toughness. The biggest disadvantage of common shotcrete as supporting material is the great brittleness, poor toughness and easy cracking destruction under the rock pressure. To solve this problem, the technique of adopting high ductility PVA fiber shotcrete as the supporting material is proposed in this article. Moreover, the PVA fiber dispersion problem is solved by using horizontal mixer to mix and bag the fiber, fly ash, sand and other materials together on the ground in advance, the under-well concrete mixing problem is handled by the study of coal mines with small spiral type mixer, and the mixer equipment selection and spraying techniques are introduced. Real practice has been carried out in No.34 mining area of cheji colliery. Result shows that the strength of the shotcrete layer reached 32 Mpa, the toughness I_{20} reached 45.65 which is 38 times higher than common concrete, the injection efficiency reached 3.8 m3 / h. It provides a new method for deep mine roadway and soft rock tunnel supporting, which has a broad prospect.

For any further request, please contact the Secretariat:
1800 Lihu Road WuXi City
Jiangsu Province P.R. China
Tel: +8613013606916
Fax: +8651085912280
E-mail: biyz2006@126.com

REFERENCES

[1]Kong. H. J., S. Bike., and Li. V.C "Constitutive Rheological Control to Develop a Self-Consolidating Engineered Cementitious Composite Reinforced with Hydrophilic Poly(vinyl alcohol) Fibers" [J]. Cement and Concrete Composites, (2003) 25:333-341,
[2]Kong. H. J., S. Bike, and Li. V.C., "Development of a Self-Consolidating Engineered Cementitious Composite Employing Electrosteric Dispersion Stabilization"[J]. Cement and Concrete Composites, (2003) 25:.301-309,
[3] Xiaoxing Shi. “Building Engineering Fibers”[M]. Beijing：Chemical Industry Press, 2008, 44
[4] JG/T 3064-1999. “Steel Fiber Reinforced Concrete”[S]. Beijing：Standards Press of China, 1999, 7-9
[5] Yang Chengjiao, Huang Chengkui, Che Yi, Wang Boxin. “Properties and Impermeability of Hybrid Fiber Reinforced Concrete” [J].Journal of Building Materials, 2008:(2)89-93
[6] Zhang Lihui,Guo Liping，Sun Wei1，Zhang Wenxiao.Rheological property and fiber dispersion of high ductility cementitious composites. JOU RNAL OF SOUTHEAST UNIVE RSITY,(2014)44:1037-1040

Reuse of waste discarded by the ceramic industry as high quality components of concrete

M.J. Pelufo[*], N. Salomon[†] M. Muñoz* and P.Serna*

[*] Departamento de Ingeniería de la Construcción y PIC
Edificio 4C, Universitat Politècnica de València
Camino de Vera s/n, 46022 Valencia, Spain
Email:; mjpelufo@cst.upv.es; marmuosi@alumni.upv.es; pserna@cst.upv.es
† École National des Ponts Paris Tech
6 et 8 avenue Blaise- Pascal - Cité Descartes
Champs-sur-Marne - 77455 Marne- la- Vallée cedex 2
Nicolas.salomon@eleves.enpc.fr

ABSTRACT

Numerous studies have already been conducted on the use of construction and demolition waste (CDW) for the production of concrete, grounded for reasons of environmental nature, due to the generation of large volumes of waste and the difficulty of its management.

The objective of the research is to expand the study to non-hazardous industrial waste, in order to give value to these wastes as high quality components of concrete, since in technical terms it can be concluded that the quality of CDW is lower than the quality of natural aggregates.

This study evaluates the behavior of non-hazardous waste produced by the ceramic industry reused as components of concrete. The Density, water absorption and particle size of the ceramic waste is determined, and the A & A modified curve is used for different values of the parameter "q" in order to adjust the grading curve.

Control specimens are prepared with natural aggregates, and the compressive strength of these is compared with the compressive strength obtained by the specimens in which natural aggregates are replaced by ceramic industrial waste. All specimens were prepared for the same workability in order to enable a valid comparison of results.

The results show that in general the compressive strengths obtained using ceramic industry waste are similar to the compressive strengths obtained with natural aggregates, being greater to those obtained with natural aggregates for the value of $q = 0.25$ for the A & A modified curve.

Seismic retrofitting of concrete structures in Switzerland: repair instead of demolish. Government's approach to school buildings.

Fernando Ortiz Quintana*

*smt ag ingenieure + planer
Werkhofstrasse 52, 4500 Solothurn, Switzerland
e-mail: ortizquintana@hotmail.com, web page: http://www.smt.ch

ABSTRACT

Buildings are built at a certain point in time, designed according to the at the time current codes and expected to fulfil the initial and expected requirements of the original client. During the lifespan of the buildings new uses might be required, updated codes will apply and knowledge of material aging will develop. Not much after the finishing of the building the question will rise, whether the building complies with the newest safety standards.

The most relevant new additions to code-prescribed safety requirements in buildings are, for most European countries, fire protection and earthquake safety. In the case of earthquake safety, the requirements in form of seismic action have increased in size by several times in the last few decades. In the case of Switzerland, buildings codes until 1989 considered a seismic action 5 to 10 times lower than those today. This fact is of great relevance to owners, government and designers since the immense majority of building stock in Switzerland dates from before 1989. Most schools, hospitals and government premises belong to this group.

The Swiss government and engineering institutions have confronted this situation and have issued guidelines for the seismic assessment of existing structures. These guidelines do not only cover the analysis of the building's earthquake safety but also define terms and situations specific to the seismic retrofitting that facilitate the discussion among engineers and owners, stablishes a general framework of responsibilities, describe scenarios, and set clear economic boundaries to aid in the decision making. An intensive promotion for the assessment and retrofitting of public buildings to meet current safety standards has been carried out by the government in the last years and all relevant public buildings, including schools, are planned to be assessed. In the cases where the earthquake safety does not suffice, the vast majority of them, efforts to retrofit instead of demolish are not to be spared.

Self-compacting concrete made with recovery filler from hot-mix asphalt plants: mechanical properties.

A. Romero-Esquinas[*], J.M. Fernández[*], J.R. Jiménez[†]

* Inorganic Chemical Area. University of Córdoba, School of Engineering Sciences of Belmez, Avda. Universidad s/n, CP 14240, Belmez, Córdoba, Spain
e-mail: *:* um1feroj@uco.es

† Construction Engineering Area. University of Córdoba, Ed. Leonardo Da Vinci, Campus de Rabanales, Ctra. N-IV, km-396, CP 14014, Córdoba, Spain
e-mail: *:* jrjimenez@uco.es

ABSTRACT

Concrete is one of the most used in the building materials sector. However, it is not considered a material friendly environment by the great amount of non-renewable natural resources consumed. The concrete industry is evolving constantly and finding more efficient technologies. The emergence of self-compacting concrete (SCC) was a significant development in the building industry and it has become widespread in recent years in civil engineering and construction, especially in the precast industry. The SCC requires incorporation of specific superplasticizers and dust (filler) to achieve and maintain adequate self-compactability properties. This fine natural aggregate is extracted from gravel pits or quarries and obtained by grinding, leading to high energy consumption and environmental degradation [1]. At some industrial, wastes are generated with very fine size of particle, such as "filler recovery" that is generated in plants of hot mix asphalt (HMA). Its production is about 4% by weight of the HMA produced [2]. Being HMA production in Europe of 277.3 million tons in 2013.

This paper describes a feasibility study of the residual filler HMA (RF), dolomitic nature, for the production of SCC. For that, it was carried out a complete characterization of the material that has allowed comparing their properties with those of commercial natural filler, siliceous nature (SF) and determining that its features make it act for use in SCC. Then the comparative study was performed among SCC made from natural filler (SCC-SF) and SCC manufactured with HMA residue (SCC-RF) in fresh and hardened state. According to the standard EHE-08, a concrete HAC-40 / AC / 16 / IIIc, was used as reference. The SF was replaced by the RF by weight. These dosages satisfied the recommendations of the EFNARC. The results show a similar behavior fresh state in the two types of concrete. Regarding the hardened study, there is a decrease in mechanical strength in the concrete made with the residue, 22% with respect to compressive strength, 8% for the flexural strength and 17% in splitting tensile strength. This decrease is evident with the application of UPV test. And a reduction of modulus of elasticity is observed also. In conclusion, due to the characteristics of the RF, its application in SCC reduces mechanical resistance compared to SCC made with commercial filler.

REFERENCES

[1] SC. Kou, CS. Poon, "Properties of self-compacting concrete prepared with coarse and fine recycled concrete aggregates", *Cem Concr Compos,* Vol. 31, no 9, pp. 622–627, (2009).

[2] J. Martín, JR. Montero, F. Moreno, JP. Sala, MC. Rubio, "Feasibility analysis of the reuse of waste filler of bituminous mixtures for the production of self-compacting concrete", *Materials & Design*, Vol. 46, pp. 372-380, (2013).

Simplifications for Considering the Contribution of the Reinforcement in the Compression Zone for Designing More Efficient RC Frame Elements

Andrei Faur*, Attila Puskas†

* Department of Structures, Faculty of Civil Engineering
Technical University of Cluj-Napoca
C-tin Daicoviciu Street, no. 15, 400020, Cluj-Napoca, Romania
e-mail: Andrei.Faur@dst.utcluj.ro - Web page: http://constructii.utcluj.ro

† Department of Structures, Faculty of Civil Engineering
Technical University of Cluj-Napoca
C-tin Daicoviciu Street, no. 15, 400020, Cluj-Napoca, Romania
e-mail: Attila.Puskas@dst.utcluj.ro - Web page: http://constructii.utcluj.ro

ABSTRACT

The optimal design of reinforced concrete frame elements is of primary concern in obtaining significant material cost reductions and efficient structural frame systems. Despite the availability of a multitude of design methods, starting from the simple ones to the more complex, some of which are numerically implemented in the majority of structural analysis software, there are still doubts that these analytical tools are exploited to their full potential. This lack of fully understanding the mechanisms which develop in reinforced concrete frame elements (and their simplified representation used for design purpose) can generate into inefficient and higher cost structural systems.

The scope of this paper is to present an analytical method that permits the evaluation of the resisting moment for reinforced concrete frame elements by taking into account the reinforcement located in the compressive zone with its real contribution. While in the majority of other design methods, where the contribution of the compressed reinforcement is usually neglected or is considered only through the use of more complex mathematical models, the alternative presented here enables such complex calculations to be performed without resorting to iterations of any kind. As long as the compression state at sectional level can be identified and localized on the axial-moment diagram, it can be shown that, for common reinforcing percentages and arrangements, the calculus of the resisting moment is straight-forward for some particular stress states, while for the other ones it can be reduced to simple operations of linear interpolation.

One of the basic principles of the proposed method stands in the proper use of the available concrete and steel material uniaxial constitutive laws. In order to highlight this important feature of the method and its sensitiveness to certain combinations when adopting the two types of material models, a parametric study is performed with the uniaxial constitutive laws proposed by the EC2 Standard [1]. Other complex material laws are also referred to for a better representation of the strain hardening phenomenon [2], [3].

REFERENCES

[1] "Eurocode 2, 1991. Design of Concrete Structures, Part 1: General rules and rules for buildings, ENV 1992-1-1."

[2] J. B. Mander, M. J. N. Priestley, and R. Park, "Theoretical Stress-Strain Model for Confined Concrete " (1988)," *J. Struct. Eng.*, vol. 114, no. 8, pp. 1804–1826, 1988.

[3] M. J. N. Priestley, G. M. Calvi, and M. J. Kowalsky, *Displacement-Based Seismic Design of Structures*. IUSS Press, Pavia, Italy, 2007.

Strength Properties and Eco-Efficiency of Low Carbon Strain-Hardening Cement Composite (SHCC)

Sun-Woo Kim*, Hyun-Do Yun†, Wan-Shin Park‡, Young-Il Jang‡, Sun-Woong Kim‡, Jong-Won Lee‡ and Yi-Hyun Nam‡

* Department of Construction Engineering Education
Chungnam National University
305-764, Daejeon, South Korea
e-mail: sw.kim@cnu.ac.kr, web page: http://www.cnu.ac.kr

† Department of Architectural Engineering
Chungnam National University
305-764, Daejeon, South Korea
e-mail: wiseroad@cnu.ac.kr, web page: http://www.cnu.ac.kr

‡ Department of Construction Engineering Education
Chungnam National University
305-764, Daejeon, South Korea

ABSTRACT

This paper presents the experimental results of an attempt to develop low carbon strain-hardening cement-based composite (SHCC) using recycled materials. In general, SHCC exhibits desirable mechanical properties including strain hardening and ductility. However, SHCC is composed of silica sand and a high volume of cement, which makes it more energy intensive than conventional concrete. The aim of this study is to promote SHCC sustainability in infrastructure design through the use of recycled materials. Alternative recycled materials – sand and fly ash are used to partially replace silica sand and cement, respectively, in SHCC specimens. The effects of the recycled materials on the strength properties of the SHCC specimens are examined by conducting compressive, flexural and uniaxial tensile tests. Test results indicate that fly ash improves both the bending and uniaxial tensile performance of SHCC due to an increase in chemical bond strength at the interface between the reinforcing fibers and cement matrices. As determined from an environmental impact assessment, fly ash in SHCC reduces carbon dioxide emissions. Fly ash helps to gain carbon credits and reduce negative environmental impacts. The use of recycled materials tends to show a reduction in carbon dioxide emissions. In other words, the low carbon SHCC helps to save natural resources and promote sustainability in civil engineering materials.

ACKNOWLEDGEMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT & Future Planning (NRF-2015R1C1A1A02036481)

REFERENCES

[1] V.C. Li, M. Lepech, S. Wang, M. Weimann & G. Keoleian, “Development of green ECC for sustainable infrastructure systems”. *In Workshop on Sustainable Development and Concrete Technology*, Beijing, China, pp. 181-192, (2004, May).

[2] B.L. Damineli, F.M. Kemeid, P.S. Aguiar, V.M. John, “Measuring the eco-efficiency of cement use”. *Cem. Concr. Compos*. **32**, pp.555–562, (2010).

Structural behaviour of recycled concrete: mechanical strength, shrinkage and bond strength

S. Seara Paz*, V. Corinaldesi†, B. González Fonteboa*, F. Martínez-Abella

*University of A Coruña (UDC)
Universidad Politécnica de Cataluña
Campus Elviña s/n, 15071 A Coruña, Spain
e-mail: gumersinda.spaz@udc.es
e-mail: bfonteboa@udc.es
e-mail: fmartinez@udc.es

† Università Politecnica delle Marche
Dipartimento SIMAU
Via Brecce Bianche 12, 60131 Ancona, Italy
e-mail: v.corinaldesi@univpm.it

ABSTRACT

In this paper the mechanical properties of recycled aggregate concrete (RAC) were characterized by replacing different percentages of natural coarse aggregate with recycled coarse aggregate (0%, 20%, 50% and 100%) and three different water to cement ratios (0.40, 0.45 and 0.50). The results made it possible to establish the differences between the mechanical properties of conventional concrete and the recycled concrete depending on the replacement percentage. This experimental program was developed into two phases (part 1 and part 2), which were carried out in different laboratories, first phase (part 1) in Spain (at the laboratory of La Coruña University) and the second one (part 2) in Italy (at the laboratory of the Università Politecnica delle Marche). Overall, 16 different concrete mixtures were manufactured.

Firstly, consistency was identified. Then, compressive strengths at 3, 7 and 28 days were obtained in order to define the time-dependent curve. After that, tensile splitting strength and elasticity modulus were defined, and finally, shrinkage and pull-out tests were carried out. It was thus found that:

• As already noted by different authors, the density and mechanical strength, compressive and tensile splitting, of recycled aggregate concrete decreases as the recycled aggregates content increases. When the compressive strength of 100% replacement recycled aggregate concretes is analyzed, these reductions reach 20-30% depending on the water to cement ratio. Recycled concretes whose control concrete shows lower compressive strength, undergo lower strength drops than those concretes with higher compressive strengths.

• Shrinkage of recycled concretes increases with the replacement percentage and shows a delayed time-dependent development due to internal curing effect

• The bond strength at 28 days declined with the increase of recycled aggregate content showing a behavior similar to compressive strength. For recycled concretes with 100% replacement, bond strength was respectively reduced 22-27% depending on the water to cement ratio. Again, recycled concrete with lower compressive strength undergoes smaller bond strength drop compared to conventional concrete.

• Normalized bond strength was calculated taking into account the square root of the experimental compressive strength of each concrete at each age. It shows a decrease with the increase of recycled aggregate content. It means that the amount of recycled aggregate does influence bond strength.

REFERENCES

[1] L. Evangelista, M. Guedes, J. De Brito, A.C. Ferro, M.F. Pereira, “Physical, chemical and mineralogical properties of fine recycled aggregates made from concrete waste”, *Constr Build Mat,* Vol. 86, pp. 178-188, (2015).

[2] AS. Brand, JR. Roesler, A. Salas, “Initial moisture and mixing effects on higher quality recycled coarse aggregate concrete”, *Constr Build Mat, Vol.* 79, pp. 83-89, (2015).

Study of buckling of SMA reinforcements in concrete elements

Pereiro Barceló, Javier*, Bonet Senach, José Luis[†]

[*] Science and Technology Concrete Institute (ICITECH)
Universitat Politècnica de València
Camino de Vera s/n, 46022 Valencia, Spain
e-mail: japebar@upv.es

[†] Science and Technology Concrete Institute (ICITECH)
Universitat Politècnica de València
Camino de Vera s/n, 46022 Valencia, Spain
Email: jlbonet@cst.upv.es

ABSTRACT

Shape Memory Alloys (SMA) are becoming more and more useful in construction world every day. This material can be attractive to use in seismic design due to its superelasticity and high deformation capacity. However, its low young modulus in relation to steel can cause buckling of compressed bars. This phenomenon can cause significant reductions of strength and deformation capacity. In order to prevent this from happening, the structural codes (EHE-08 [1], EN 1992-1-1:2004 [2]; ACI-318 [3]) restrict the relationships between diameters of transversal and longitudinal reinforcements, and determine minimum separations of transversal reinforcement, always talking about steel. There is no design regulation to prevent buckling of SMA bars.

Research of reinforcement buckling requires numerical models and experimental campaigns to understand and quantify this phenomenon. However, in scientific literature, there is a lack of experimental campaigns specifically focused on the study of reinforcement buckling, inserted into a concrete section. The rigorous detection of onset of reinforcement buckling is not an accurately measured variable in literature. In addition, there is a total absence of experimentation when considering very high performance concrete (VHPC) and SMA reinforcements. For all of these reasons, there is insufficient data at one's disposal to be able to evaluate numerical models or to draw conclusions about reinforcement buckling.

In this work is presented the experimental results about buckling of SMA in form or nickel and titanium (Ni-Ti) in VHPC columns under compressive and eccentric loading. Experimental differences between SMA and steel reinforcements will also show. Moreover experimental results and theoretical existing model will be compared.

REFERENCES

[1] Comisión Permanente del Hormigón. Code on structural concrete EHE-08. Ministerio de Fomento.

[2] European Committee for Standardization. Eurocode 2: design of concrete structures – Part 1: General rules and rules for buildings. EN 1992-1-1; December 2004.

[3] ACI 318-08. Building code requirements for reinforced concrete. American Concrete Institute, Detroit; 2008.

Study of Environmentally Friendly Bedding Mortars Prepared with Recycled Aggregates and Biomass Ash

E. Fernández Ledesma[*], V. Corinaldesi[†], J. Ramón Jiménez*

* Construction Engineering Area. University of Córdoba, Ed. Leonardo Da Vinci, Campus de Rabanales, Ctra. N-IV, km-396, CP 14014, Córdoba, Spain
e-mail: *:* jrjimenez@uco.es

† Università Politecnica delle Marche
Dipartimento SIMAU
Via Brecce Bianche 12, 60131 Ancona, Italy
e-mail: v.corinaldesi@univpm.it

ABSTRACT

This work is aimed at evaluating the possibility of reusing waste from demolished concrete building as aggregate for bedding mortars replacing virgin aggregate. Concrete is the most used construction material, with estimated annual production of 10 billion cubic meters. Since 60–80% of the concrete volume is taken by aggregates, the overall consumption of natural aggregates is very high, generating huge pressure on surrounding ecosystems. The environmental impact of aggregate extraction is particularly severe regarding sands, with distinct problems associated to different extraction or production technologies. Sand extraction from seaside increases erosion and retreating coastline, harming inland protection and fauna and flora habitats, and changing wave and tie behavior. Sand extraction from riverbed or lakebed alters flow regimes, affecting surrounding structures and local ecosystems. Finally, the production of fine aggregates presents high energetic cost and raises difficulties concerning fresh concrete, given their high angularity [1].
Besides to recycled aggregate the mortars studied in this paper were prepared with another kind of waste: a biomass ash coming from paper mill sludge, which is a by-product of paper production. Paper mill sludge is composed of mineral fillers, inorganic salts, small cellulose fibres, water and organic compounds. Paper mill sludge is often burnt in order to reduce the waste disposal and sometimes to recover heat. This process is achieved by incineration at high temperature (> 800°C). During incineration, paper and organic compounds are burned out, whereas mineral fillers and inorganic salts are trans-formed into the corresponding oxides at higher temperatures. CaO, Al_2O_3, MgO and SiO_2 are the most abundant oxides in incinerated paper mill sludge [2]. The obtained paper mill sludge ash is classified as waste, and at present it is mainly conferred to landfill at high costs.
In order to evaluate the quality of joining mortars made of recycled aggregate and biomass ash, both mechanical behavior of cementitious mortars and the interaction between mortar and brick in terms of bond strength developed at the interface mortar– brick were studied. The experimental results show that mortars containing recycled aggregates develop lower mechanical strength with respect to the reference cementitious mortar, particularly when recycled aggregates and biomass ash are used together. Nevertheless, the bond strength at the interface between the mortar and the brick comes out to be higher if an inorganic primer made of a microcement paste is used. However, concerning bedding mortars, the mechanical performance of the overall mortar–brick system, strictly related to the mortar–brick adhesion, makes the mortar bond strength certainly more important than its mechanical strength. In conclusion, the use of materials coming form C&D waste recycling instead of sand as well as of biomass ash for the production of bedding mortars, especially in the presence of an inorganic primer, proved to be profitable not only for the obvious environmental advantages but also in terms of mortar–brick interface, which is generally recognized as the weak chain link of the masonry assemblage.

REFERENCES

[1] L. Evangelista, M. Guedes, J. De Brito, A.C. Ferro, M.F. Pereira, “Physical, chemical and mineralogical properties of fine recycled aggregates made from concrete waste”, *Constr Build Mat,* Vol. 86, pp. 178-188, (2015).

[2] CT. Liaw, HL. Chang, WC. Hsu, CR. Huang, “A novel method to reuse paper sludge and cogeneration ashes from paper mill”, *J Hazard Mater*, Vol. 58, pp. 93–103, (1998).

Study of Mechanical Properties of High Performance Concrete with Addition of Stabilized Nanosilica
ICCS16

Paulo R. N. Filho[†], Adriana G. Gumieri[†], José M. F. Calixto[†*], Cáudio Silva[††] and Alberto D. Quiñones[†††]

[†] School of Engineering, Federal University of Minas Gerais (UFMG)
Av. Antônio Carlos, 6627, Pampulha, 31270-901 Belo Horizonte, MG, Brazil
e-mails: paulonolli@gmail.com; adriana@demc.ufmg.br; calixto@dees.ufmg.br
web page: http://www.ufmg.br

[††] BETONMIX Concretos
BR 381 s/n, Lote 02, km 450, Bom Destino, 33060-112 Santa Luzia, MG, Brazil
email: claudio.silva@betonmixconcreto.com.br, web page: http://www.betonmixconcreto.com.br

[†††] TECNOSIL/SILICON
Rua Americo Simões, 119 A, Bairro São Roque da Chave, 13295-000 Itupeva, SP, Brazil
email: alberto@tecnosilbr.com.br, web page: http://www.tecnosilbr.com.br

ABSTRACT

Nanomaterials can improve the mechanical properties and durability of concrete. In the high-performance concrete (HPC), a good dispersion of materials is an essential factor for improving its properties. In this study, the influence of the addition of stabilized nanosilica in compressive strength and secant modulus of elasticity of the high performance concrete was evaluated at the ages of 7, 14 and 28 days. Three different concrete mixes were produced: one containing stabilized nanosilica, another containing a mixture of silica fume and stabilized nanosilica, and a reference concrete. The incorporation of the nanosilica in the polycarboxylate superplasticizer contributed to a better application and efficiency of the nanosilica in the concrete, since the nanosilica was easily homogenized in the concrete mix. Results showed a substantial increase in the concrete compressive strength as well as secant modulus of elasticity, even with the reduction of the cement consumption. The results also showed that there's a synergistic effect between the nanosilica and silica fume. The results indicated that nanosílica is very advantageous, especially when mixed with the silica fume, and can be a good alternative to produce concrete with high compressive mechanical properties and reduction in cement content.

REFERENCES

[1] M. Bolhassani and M. Samani, "Effect of type, size, and dosage of nanosilica and microsilica on properties of cement paste and mortar" *ACI Mat. Jour.,* Vol. **112,** N. 2, pp. 259 -266, (2015).

[2] H. Madani, A. Bagheri and T. Parhizkar, "The pozzolanic reactivity of monodispersed nanosilica hydrosols and their influence on the hydratation characteristics of Portland cement", *Cem. Conc. Res.,* Vol. **42**, N. 12, pp. 1563-1570, (2012).

[3] G. Quercia, G. Hüsken and H. J. H. Brouwers, "Water demand of amorphous nano silica and its impact on the workability of cement paste", *Cem. Conc. Res.,* Vol. **42**, N. 2, pp. 73-74, (2011).

Sulphate Resistance of Concrete containing Recycled Granulated Steel as a Partial Replacement of Fine Aggregate

U. M. T. Quadir*, K. Islam#, A. H. M. M. Billah†, M. S. Alam† and S. M. Muniruzzaman#

* North South University
Bashundhara R/A, Dhaka-1229, Bangladesh.
E-mail: upal.quadir@northsouth.edu, Web page: http://www.northsouth.edu/faculty-members/seas/ceed-faculty-members/upal-mohammad-towfiqul-quadir

Military Institute of Science and Technology
Mirpur Cantonment, Mirpur, Dhaka-1216, Bangladesh.
E-mail: kamrul1@ualberta.edu, Web page: http://ce.mist.ac.bd/employees/kamrul-islam/

† The University of British Columbia
3333 University Way, Kelowna, BC V1V 1V7, Canada.
Email: shahria.alam@ubc.ca - Web page: https://people.ok.ubc.ca/shaalam/

ABSTRACT

The aim of this paper is to investigate the performance of concrete containing Recycled Granulated Steel (RGS) as a partial replacement of Fine Aggregates (FA) when exposed to a 5% sodium sulphate solution. RGS was introduced as a replacement to FA at up to 60% by weight. Concrete specimens were immersed in a sodium sulphate solution to be tested in compression according to ASTM C1012 and ASTM C452. A comparison was also performed with the unexposed specimens in terms of mechanical strength, physical impact (i.e., linear and volumetric shrinkage), and micro-structural transformation of concrete specimens through Scanning Electron Micrograph (SEM) images. The results of this study revealed that the compressive strength of concrete containing RGS reduced by 20% compared to the control concrete when exposed to 5% sodium sulphate solution for 28 days. Moreover, RGS concrete specimens experienced maximum 4.4% volume change after sulphate exposure due to the formation of ettringite while the control specimens experienced 2% volume change.

REFERENCES

[1] C. Thomas, J. Setien , J. A. Polanco, P. Alaejos, and M.S. de Juan, Durability of recycled aggregate concrete, Construction and building materials, Vol **40**, pp 1054-1065, (2013).

[2] M. Bhutta, W. Hussin, M. Azreen, and Tahir, M., Sulphate resistance of geopolymer concrete prepared from blended waste fuel ash, J. Mater. Civ. Eng., Vol. **26(11)**, 04014080, (2014).

Sustainability assessment of different reinforcement alternatives for precast concrete segmental linings

A. de la Fuente*†, A. Blanco†, S. Cavalaro† and A. Aguado†

† Construction Engineering Department
Universidad Politécnica de Cataluña (UPC BarcelonaTECH)
Campus Norte UPC, 08034 Barcelona, Spain
Email: albert.de.la.fuente@upc.edu
Email: ana.blanco@upc.edu
Email: sergio.pialarissi@upc.edu
Email: antonio.aguado@upc.edu

ABSTRACT

Nowadays, several tunnels bored with Tunnel Boring Machines (TBM) are already in service and various dozens are being constructed around the world. The internal support of these usually consist of precast concrete segmental rings with a low – moderate amount of concrete since these elements are mainly compressed in service conditions and low tensile stresses only appear during initial transient situations (demoulding, stocking, transportation, manipulation and thrust of the jacks).

Alternatively, structural fibres have proved to be an interesting solution to replace part or the total amount of the rebars. In fact, fibre reinforced concrete (FRC) has already been applied in more than fifty TBM constructed tunnels so far. However, the use of FRC is not consolidated yet in this type of tunnels due to the lack of specific design methods until the publication of the last version of the Model Code 2010 as well as the high inertia to change exhibited by the technical community.

In this scientific contribution, a multi-criteria decision-making model based on the MIVES method is proposed for assessing the sustainability index of precast concrete segments. This model is able to take into account the three main pillars of the sustainability (economic, environmental and social). By using this model, different reinforcement alternatives (rebars, fibres or the hybrid solution) can be assessed for specific boundary conditions (e.g., tunnel and segment geometry, concrete dosages, transport distances, risks during the manufacturing of the segments). Likewise, this model is designed to minimize the subjectivity of the decision and to facilitate the task of deciding which concrete reinforcement strategy is the most suitable in terms of sustainability. Finally, the model is used to assess the sustainability of different precast concrete segments (with different reinforcement solutions) which are potential alternatives to be used in a real tunnel placed in the metropolitan area of Barcelona.

REFERENCES

[1] O. Pons, A. de la Fuente. “Integrated sustainability assessment method applied to structural concrete columns”, *Construct Build Mater*, Vol. 49, pp. 882-893, (2013).

[2] M. di Prisco, G. Plizzari, L. Vandewalle. “Fibre reinforced concrete: New design perspectives”, *RILEM Mater & Struct*, Vol. 42, pp. 1169, (2009).

[3] A. de la Fuente , A. Blanco, P. Pujadas, A. Aguado, “Experiences in Barcelona with the use of fibres in segmental linings”, Tunnelling & Underground Space Tech, Vol. 27**,** pp. 60-71, (2012).

[4] ***fib*** Bulletins 65-66 (2010), Model code 2010 Final Draft. fédération internationale du

[5] L. Liao, A. de la Fuente, S. Cavalaro, A. Aguado. “Design of FRC tunnel segments considering the ductility requirements of the Model Code 2010”, *Tunnelling Underground Space Tech*, Vol.47, pp. 200-210, (2015).

The Changing Nature of Fly Ash and its Reuse

Christopher R. Shearer

Department of Civil and Environmental Engineering
South Dakota School of Mines and Technology
501 E. Saint Joseph St., Rapid City, SD 57701, USA
Email: chris.shearer@sdsmt.edu, Web page: http://www.sdsmt.edu

ABSTRACT

Over the past few decades, there have been significant changes in fly ash production and usage around the world. New renewable energy and emissions requirements, particularly in Europe and the U.S., have encouraged the co-combustion of alternative fuel sources with coal [1]. This has led to the production of co-fired fly ash, which is a by-product of coal fired with a secondary fuel (typically some form of biomass to reduce CO_2 emissions). This research examines the impact these production changes have had on the chemical and physical composition of fly ash by analyzing a suite of co-fired fly ash samples. Their use as supplementary cementitious materials (SCMs) in concrete and as precursors for alkali-activated geopolymers are also investigated through strength, durability, and characterization testing. The results indicate that co-fired fly ashes can improve the properties of concrete and can be used to develop highly polymerized geopolymers.

Changes in energy and environmental regulations have also resulted in the closure of a number of coal power plants. As a result, the amount of usable, high-quality fly ash is expected to diminish. This is cause for concern for the concrete industry, because fly ash is one of the best tools currently available to improve the durability of concrete and demand for fly ash reuse is expected to remain high in the foreseeable future. One strategy to meet this demand is to reclaim the large quantities of non-recycled fly ash currently located in landfills and ponds [2]. In addition to the co-fired fly ash study, this research presents a literature review on the state-of-the-art of fly ash reclamation and processing techniques. Topics covered include the beneficiation potential of ash ponds as well as existing beneficiation technologies for fly ash such as physical separation, electrostatic separation, microwave heating, froth flotation, and biological and chemical additives. These technologies may also be used to treat co-fired fly ashes that do not meet current standards.

REFERENCES

[1] B. Leckner, “Co-combustion: A summary of technology”, *The Alliance for Global Sustainability*, Gothenburg, Sweden, (2007).

[2] M. A. Tyra, J. G. Groppo, T. Robl, and T. Minster, “Using digital mapping techniques to evaluate beneficiation potential in a coal ash pond”, *International Journal of Coal Geology*, Vol. 54, pp. 261-268, (2003).

The effect of particle size distribution on early age chemical shrinkage of cement pastes

Ximena Gaviria[1]*, Jorge IvánTobon[1]

1. Materials and Minerals Department,
Universidad Nacional de Colombia, Medellín, Colombia
Zona Ingeominas: Calle 75 No 79 A – 51, bloque M-17
e-mail: xgaviri@unal.edu.co, web page: http://unal.edu.co/

ABSTRACT

The purpose of this research is to determine the effect of particle size distribution on chemical shrinkage at early ages. The term early ages corresponds to hydration times of maximum 24 hours. In this work, two different types of commercial cement were used (Type I cement, and white with limestone filler). Three particle size distributions (PSD) were used for each cement type. To achieve the three PSD a sieving process was done, separating and using the particles retained in the 325 (45µm) sieve from those passing de 400 (38 µm) sieve. So, the three PSD used for each cement were the as-received condition, the coarser condition (particles retained in the 325 sieve) and finer condition (particles passing the 400 sieve). Cement pastes were prepared according to ASTM C305 standard. The water to cement (w/c) rate was constant for each cement type. The w/c for each cement was determined as the w/c rate for normal consistency for the as-received condition. The chemical shrinkage was evaluated according to ASTM C1608. To determine the phases and their quantities in the different cements, the DRX technique was used and the Rietveld method was applied to the anhydrous cements. The chemical shrinkage test was stopped at 1, 6, 12 and 24 hours of hydration to determine the effect of the initial phases on the early chemical shrinkage.

The hydration process was analyzed at these four times. As expected, the hydration kinetic increased as the particle size distribution was finer. As the hydration kinetic increased, the chemical shrinkage was greater during the total test time. From the DRX and Rietveld analyses it can be concluded that the increase in the hydration kinetic is not only due to the finer PSD, but also from the change in the quantity of the anhydrous phases during the sieving process. There is a synergic effect on the hydration process and on the early age chemical shrinkage due to PSD and mineralogical composition.

A lot of works have established the effect of water to cement rate, aggregate incorporation, use of superplasticizer and the effect of mineralogical composition among other variables on early age chemical shrinkage.

The originality of this work resides on the evaluation of the effect of particle size distribution on the chemical shrinkage and hydration process at early ages. On the other side there is an effect of the sieving process on the initial mineralogical composition of anhydrous cements. Therefore this research turned into a synergic effect of particle size distribution and anhydrous phases on early age chemical shrinkage.

Keywords*: chemical shrinkage; particle size distribution; Rietveld method; hydration process.*

REFERENCES

[1] Barcelo, L., Moranville, M., & Clavaud, B. (2005). Autogenous shrinkage of concrete: a balance between autogenous swelling and self-desiccation. Cement and Concrete Research, 35(1), 177–183.

[2] Baroghel-Bouny V, Mounanga P, Khelidj A, Loukili, A, Rafai N. Autogenous deformations of cement pastes. Part II. W/C effects, micro–macro correlations, and threshold values. Cement and Concrete Research 36 (2006) 123 – 136

[1] Corresponding author: xgaviri@unal.edu.co, Tel +57-4-4255000

[3] Beltzung, F., & Wittmann, F. H. (2005). Role of disjoining pressure in cement based materials. Cement and Concrete Research, 35(12), 2364–2370.

[4] Bentz, D. P. (2008). A review of early-age properties of cement-based materials. Cement and Concrete Research, 38(2), 196–204.

[5] Bentz, D.P; Jensen, O.M; Hansen, K.K; Olesen, Stang, H. Haecker, C.J.(2001) Influence of cement particle-size distribution on early age autogenous strain and stresses in cement-based materials. Journal of American Ceramic Society, 84, (1), 129-135

[6] Bouasker, M., Mounanga, P., Turcry, P., Loukili, a., & Khelidj, a. (2008). Chemical shrinkage of cement pastes and mortars at very early age: Effect of limestone filler and granular inclusions. Cement and Concrete Composites, 30(1), 13–22.

[7] Bullard, J. W., Jennings, H. M., Livingston, R. a., Nonat, A., Scherer, G. W., Schweitzer, J. S., Scrivener, K. L. (2011). Mechanisms of cement hydration. Cement and Concrete Research, 41(12), 1208–1223.

[8] Craeye, B, De Shutter, G, Desmet, B, Vantomme, J, Heirman, G, Vandewalle, L, Cizer, Ö, Aggoun, S, Kadri, E.H. et al (2010). Effect of mineral type on autogenous shrinkage of self-compacting concrete. Cement and Concrete Research, 40, 908-913

[9] Holt, E. (2001). Early age autogenous shrinkage of concrete. PhD Thesis. Technical Research Center of Finland.

[10] Holt, E. (2005). Contribution of mixture design to chemical and autogenous shrinkage of concrete at early ages. Cement and Concrete Research, 35, 464-472.

[11] Holt, E., & Leivo, M. (2004). Cracking risks associated with early age shrinkage. Cement and Concrete Composites, 26(5), 521–530.

[12] Justnes, H. (2000). Correlating the deviation point between external and total chemical shrinkage with setting time and other characteristics of hydrating cement paste. Proceedings of the International RILEM Workshop. 17 pp. 57 –73.

[13] Kristiawan, S.A (2013). Performance Criteria to Assess Shrinkage Cracking Tendency in Concrete Overlay. Procedia Engineering , 54, 82 – 100

[14] Loukili, A, Chopin, D, Khelidj, A, Le Touzo, J.Y. (2000). A new approach to determine autogenous shrinkage of mortar at an early age considering temperature history. Cement and Concrete Research 30 (2000) 915-922

[15] Lura, P; Jense, O.M; Breugel, K. (2003). Autogenous shrinkage in high-performance cement paste: An evaluation of basic mechanisms. Cement and Concrete Research, 33(2), 223–232.

[16] Mounanga P, Baroghel-Bouny V, Loukili A, Khelid A. Autogenous deformations of cement pastes: Part I. Temperature effects at early age and micro-macro correlations Cement and Concrete Research 36 (2006) 110– 122

[17] Mounanga, P., Khelidj, A., Loukili, A., & Baroghel-Bouny, V. (2004). Predicting Ca(OH)2 content and chemical shrinkage of hydrating cement pastes using analytical approach. Cement and Concrete Research, 34(2), 255–265.

[18] Pang, X , Benta, D.P, Meyer, C, Funkhouser, G.P, Darbe, R. (2013). A Comparison Study of Portland Cement Hydration Kinetics as Measured by chemical shrinkage and isothermal calorimetry. Cement and concrete composites (en edición)

[19] Yodsudjai, W y Wang, K. Chemical shrinkage behavior of pastes made with different types of ments. Construction and Building Materials 40 (2013) 854–862

[20] Yoo, D.Y, Park, J.J, Kim, S.W, Y, Y.S. (2013). Early age setting, shrinkage and tensile characteristics of ultra high performance fiber reinforced concrete. Construction and Building

Use of incinerated sewage sludge ash in concrete production

Nina Stirmer[1], Ana Baricevic[2], Domagoj Nakic[3] and Drazen Vouk[4]

[1] University of Zagreb Faculty of Civil Engineering Department of Materials
Kaciceva 26, 10 000 Zagreb, Croatia
e-mail: ninab@grad.hr, web page: http://www.grad.unizg.hr

[2] University of Zagreb Faculty of Civil Engineering Department of Materials
Kaciceva 26, 10 000 Zagreb, Croatia
Email: abaricevic@ grad.hr - web page: http://www.grad.unizg.hr

[3] University of Zagreb Faculty of Civil Engineering Department for Water Research
Kaciceva 26, 10 000 Zagreb, Croatia
Email: dnakic@ grad.hr - web page: http://www.grad.unizg.hr

[4] University of Zagreb Faculty of Civil Engineering Department for Water Research
Kaciceva 26, 10 000 Zagreb, Croatia
Email: dvouk@ grad.hr - web page: http://www.grad.unizg.hr

ABSTRACT

At the beginning of the twentieth century, about 10% of the world's population lived in cities. By 2050, the global population is expected to reach between 8.3 and 10.9 billion. Rapid population growth and urbanization already has a dramatic effect on the increased demand for appropriate wastewater management. In Croatia, only about 43% of the population are connected to the public sewage network and only 23% are connected to the treatment plants with adequate level of treatment. By becoming the member state, Croatia has made the commitment to construct treatment plants of total capacities of 4.000.000 PE (250.000.000 m3 of wastewater). This implies that annually about 215.000 tonnes of dehydrated and stabilized sludge will be obtained and its further application needs to be investigated.

The basic objective of the presented research is to explore the possibilities of recycling of the sewage sludge for preparation of innovative products in concrete industry. Physical and chemical characteristics of incinerated sewage sludge ash (ISSA) from different treatment plants are investigated, since the possibility of recycling sewage sludge depends a great deal on its composition. Obtained results imply that ISSA may be used in concrete production, partially substituting cement or as inert filler, depending on concrete requirements.

REFERENCES

[1] Donatello, S. and Cheeseman, C.R., 2013. Recycling and recovery routes for incinerated sewage sludge ash (ISSA): A review, Waste Management, 33, 2328-2340.

[2] Yusuf, R.O., Moh'd Fadhil, M.D., Ahmad, H.A., 2012. Use of sewage sludge ash (SSA) in the production of cement and concrete – a review. Int. J. Global Environmental Issues, Vol. 12, Nos. 2/3/4. 214-228.

USE OF PHOTOCATALYTIC CEMENTS FOR HEAVY DUTY URBAN ROADS

Gian Luca Guerrini [1], Raul Crespo [2], Rafael Jurado [2]

1 Italcementi Group, Via Stezzano, 87, 24126 Bergamo (Italy)
2 Sociedad Financiera y Minera S.A. Carretera de Almería Km 8 29070 Málaga (Spain)

Abstract
Among the different photocatalytic solutions available on the market, i.active® cements by Italcementi Group are the most common raw materials currently utilized for the manufacturing of building products possessing an added value in terms of sustainability and durability.
Main purposes for its use is depolluting effect, especially to improve the air quality in urban environments. Further, another environmental advantage in their use is in terms of mitigation of urban heat island effects.
i.active CARGO is an innovative self-percolating photocatalytic cementitious grout for making semi-flexible pavements designed for heavy loads. Thanks to its rheological performance (high flowability), this cement slurry can percolate through highly porous asphalt pavements. As a result, it fills the voids and forms a monolithic structure that can withstand heavy loads both under static and dynamic conditions (by combining enhanced physical and chemical resistance with high strength.
Its special cementitious matrix makes the road surfaces more resistant to high temperatures than the traditional asphalt-based solutions and contributes to promoting safety as it does not undergo the traditional heat deformation phenomena, eliminating such phenomena as rutting and wear, enhances durability and reduces ordinary maintenance costs
Moreover, thanks to its bright colored surface (albedo effect), i.active CARGO reduces the pavement's temperature and improves comfort
Currently, i.active® cements are commercially available in Europe, North America, North Africa and, India. Almost three million square meters of photocatalytic cement-based surfaces, all applications, have been already applied and this number is expected to grow substantially in the coming years.
This paper gives a complete overview of the product performances to help engineers to design sustainable and durable paved surfaces that typically represent from 30% to 60% of developed urban areas.

Keywords: cement, quality, depolluting, photocatalytic properties, SRI, heavy duty, roads

VALORISATION OF GRANITE CHIPPINGS IN THE DESIGN OF NEW CEMENT MATRICES

Gabriel Medina[◊], Isabel F. Sáez*, Moisés Frías[†], María Isabel Sánchez[†], César Medina[Δ]

[◊] Escuela de Ingenierías Industrial e Informática
Universidad de León
Campus de Vegazana, s/n, 24071 León (España)
E-mail: gmedinaia@gmail.com/ gmedm@unileon.es

*, [Δ] Escuela Politécnica de Cáceres
Universidad de Extremadura, Unidad Asociada UEX-CSIC
Avenida de la Universidad, s/n, 10003, Cáceres (España)
E-mail: isa.f.saez@gmail.com / cmedinam@unex.es

[†] Instituto de Ciencias de la Construcción Eduardo Torroja
Consejo Superior de Investigaciones Científicas
C/ Serrano Galvache, 4, 28033, Madrid (España)
E-mail: mfrias@ietcc.csic.es/ srojas@ietcc.csic.es

ABSTRACT

The use of natural stone in construction is varied and becoming increasingly widespread, despite the presence of other materials such as concrete or fired clay brick and similar. Granite quarrying and hewing entail the generation of large volumes of waste whose stockpiling in uncontrolled landfills constitutes a significant environmental problem. This research attempted to valorise such waste in the cement industry, which is characterised by a demand for large volumes of raw materials and a wide spectrum of end products. The waste was first characterised physically and chemically to assess its potential for use in the cement industry. Subsequent determination of the physical and mechanical properties of the new waste-bearing cement showed it to be standard-compliant.

Valorization of a waste into cementitious material: dredged sediment for production of self compacting concrete

F. Rozas [*], A. Castillo , I. Martínez, M. Castellote[*]
[*] Institute of Construction Science "Eduardo Torroja" (IETcc-CSIC)
28033- Madrid, Spain.

ABSTRACT

In the last years, lot of research has been done in including wastes into concrete, mainly for secondary uses but also trying to accomplish with structural performance. Even though there are a lot of contributions in this area, and society concerns about the reutilization of waste in concrete fabrication, the research is mainly focused on the reuse of several wastes, as industrial, demolition or glass, for most abundant, but is rare to found research works including dredged sediments as a waste to be use in concrete fabrication. On the other hand, it is remarkable that no general rules, as established protocols, are found in the bibliography. In this way, there are no previous efforts in order to systematically evaluate and decide on the feasibility for including a waste into a cementitious matrix.

Filling this gap is the objective undertaken in this paper, which presents general guidelines to be followed in order to analyse the feasibility of including a waste material in the production of one of the most widely used building materials: concrete. First of all, the compatibility of the waste with a cementitious material has to be assured; then, if necessary, a decontamination step will be carried out; after, decision on the type of material has to be taken based on different aspects, with special emphasis on the granulometry. As a last step, mechanical, environmental and durability properties have to be evaluated. Then the procedure is illustrated with a full example, obtaining a self compacting concrete (SCC) including dredged sediment taken from a Spanish harbour. The reason for choosing SCC as the product to be constructed has been derived from the characteristics of the waste, taking into account its special characteristics in relation with their intrinsic environmental friendly technology: is able to flow by its own weight, eliminating the need of vibration, which can be translated into substantial reduction in energy, labour cost and construction time. Additionally, it contributes to a better working environment by eliminating the impact of noise and vibration as well as a making more comfortable the periods of works for the affected society.

Keywords:

Protocol, waste treatment, cementitious material, dredged sediment, self-compacting concrete.

AUTHORS INDEX

Platinum Sponsor

Gold Sponsor

Supporting Organizations