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EPS LIGHTWEIGHT CONCRETE PARTICLE SIZE EFFECT MODELLING

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Key words: EPS lightweight concrete, Particle size effect, Failure modes, Geometric length, Characteristic material length.

Summary. *An experimental investigation has been conducted on three EPS lightweight concretes containing respectively EPS beads of sizes:* $1mm$, $2.5mm$ *and* $6.3mm$, *in the purpose to confirm the presence of a "particle" size effect on the EPS concrete compressive strength, which is related to EPS beads size. Then , the EPS concrete "particle" size effect law has been identified on the basis of the analysis of EPS concrete failure modes observed experimentally.*

1 INTRODUCTION

A size effect related to the size of expanded polystyrene (EPS) beads had been observed on the compressive strength of EPS lightweight concrete. In fact, it had been shown that the compressive strength of EPS concrete increases with a decrease in EPS beads size (ϕ) for the same concrete density[1,2,3]. So that, the main purpose of this work is to determine the size effect law governing this scaling phenomenon.

2 EXPERIMENTAL MODELLING

An experimental investigation has been conducted on three EPS lightweight concretes of densities ranging from $1200kg/m^3$ to $2000kg/m^3$ and containing respectively three EPS beads sizes: $\phi_0 = 1mm$, $\phi_1 = 2.5mm$ and $\phi_2 = 6.3mm$, to confirm the presence of a "particle" size effect on the EPS concrete compressive strength. Moreover, to free the size effect problem of the specimen size (D), compressive tests have been carried out on homothetic EPS concrete specimens containing homothetic EPS beads; two cylindrical specimen sizes have been considered: (110*220 mm) ($D_1 = 44mm$) and (44*88 mm) ($D_2 = 110mm$), such that: $(\frac{D_1}{\phi_1}) = (\frac{D_2}{\phi_2}) = 17.6$ and $(\frac{D_1}{\phi_0}) = (\frac{D_2}{\phi_1}) = 44$. Compressive tests have shown that strengths obtained with homothetic specimens having a ratio $(\frac{D}{\phi})$ equal to 44 present no “volume” size effect. Whereas, results of compressive tests on homothetic specimens having a ratio $(\frac{D}{\phi})$ equal to 17.6 are slightly affected by a “volume” size effect, notably for high porosity concretes. So that, it is concluded that the RVE, for the EPS concrete compressive strength, is already reached for $(\frac{D}{\phi}) = 44$, but it is most likely not yet reached for $(\frac{D}{\phi}) = 17.6$. Furthermore, compressive tests on the EPS concrete homothetic specimens containing homothetic EPS beads and also on (110*220 mm) specimens have confirmed the presence of a “particle” size effect on the EPS concrete compressive strength, which is related to the EPS beads size (ϕ). Moreover, we have observed that this size effect is very pronounced for low concrete (macro) porosities (low EPS voluminal fractions) and it becomes negligible for very high concrete (macro) porosities (see fig. 1).

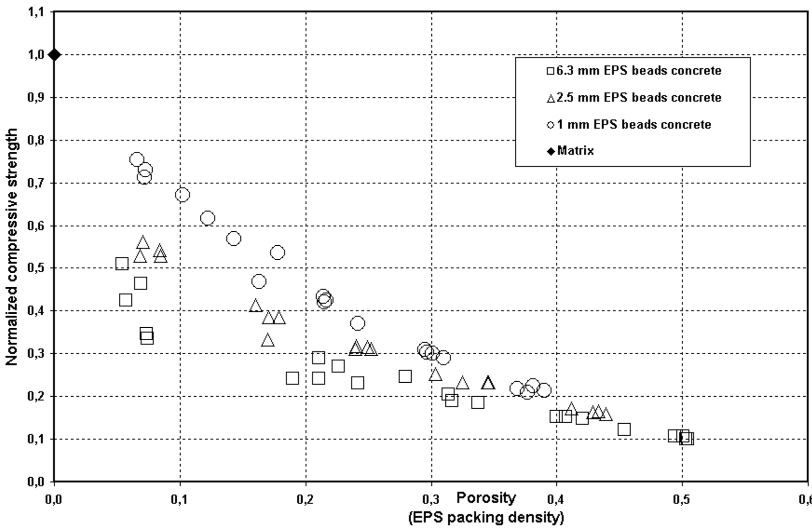

Figure 1: EPS concrete normalized compressive strengths obtained with (110*220 mm) cylinders for each EPS beads size, versus concrete (macro) porosity.

3 EPS CONCRETE “PARTICLE” SIZE EFFECT LAW TYPE

On the other hand, we have shown that EPS concrete “particle” size effect law, at the mesoscopic scale, can not depend only on the EPS beads size (ϕ) through a power law[4] of (ϕ), since we will obtain nonsensical strengths for EPS concretes containing very small EPS beads. That is why, we have concluded that a characteristic material length (l_c), related to the matrix heterogeneities maximum size[5], is inevitably present. Moreover, SEM observations have confirmed the presence in the mortar matrix of heterogeneities (sand grains notably) of a maximum size of $0.25mm$. So that, it is concluded that the EPS concrete “particle” size effect law is a Bazant type structural size effect law[4,6], which is governed by the ratio $(\frac{\phi}{l_c})$, and is depending also on the concrete (macro) porosity (p).

4 EPS CONCRETE "PARTICLE" SIZE EFFECT MODELLING

the EPS concrete "particle" size effect law has been identified on the basis of the analysis of EPS concrete failure modes observed experimentally. In fact, it has been stipulated that the EPS concrete compressive failure occurs in two phases: a first phase of micro-cracks initiation, which is governed only by the concrete (macro) porosity (p), and which can be seen as the end of the elastic linear response of EPS concrete under compressive loading. Then, a second phase of micro-cracking (and/or) macro-cracks propagation, where one of these two failure modes or both modes can occur. So that, it is concluded that the "particle" size effect, observed experimentally on the EPS concrete compressive strength, emanates from this second phase from the competition between these two failure modes. Moreover, it is stipulated that the EPS concrete particle size effect law is governed by the ratio of a geometric length (l_g), which characterizes the EPS concrete microstructure and depends on the EPS beads size (ϕ) and also on the concrete (macro) porosity (p), by the characteristic material length (l_c). This geometric length $l_g(p, \phi)$ has been identified to the EPS beads size (ϕ) for very low concrete porosities, and to the average EPS beads spacing $e(p, \phi)$ for very high concrete porosities. Whereas, the characteristic material length (l_c) has been identified to the width of the EPS concrete matrix fracture process zone[7] (FPZ), and fixed at three times its heterogeneities maximum size[5]. As a consequence, it is concluded that the greater the ratio ($\frac{l_g(p,\phi)}{l_c}$), the more brittle the EPS concrete failure. Moreover, it has been stipulated that the EPS concrete failure becomes brittle, when ($\frac{l_g(p,\phi)}{l_c} \to \infty$). In this case, the EPS concrete "particle" size effect law must tend asymptotically to a power law[4] of the ratio ($\frac{l_g(p,\phi)}{l_c}$), with a power equal to (-1/2), and the EPS concrete normalized compressive strength, for a given concrete (macro) porosity (p), tends to a lower bound given by the function $\mathbf{g}_\infty(p)$. This lower bound $\mathbf{g}_\infty(p)$, giving the EPS concrete normalized strength when the material behaviour is elastic-brittle, has been identified mainly owing to FE calculations on 3D periodic BCC lattice unit cells, for very low concrete porosities (when $p \to 0$). On the other hand, it has been concluded that the EPS concrete "particle" size effect vanishes, when ($l_g(p, \phi) \leq l_c$). In this case, the EPS concrete normalized strength, for a given concrete (macro) porosity (p), is given by an upper bound called here $\mathbf{g_0}(p)$. This upper bound has been identified mainly thanks to the experimental strengths obtained with the (110 * 220 mm) specimens of the three EPS beads sizes concretes, for very high porosities where the size effect vanishes. Finally, for ($\frac{l_g(p,\phi)}{l_c} \geq 1$), the EPS concrete normalized strength for a given (macro) porosity (p), will be ranging between $\mathbf{g}_\infty(p)$ and $\mathbf{g_0}(p)$ (see fig. 2), owing to a "particle" scaling power law of the ratio ($\frac{l_g(p,\phi)}{l_c}$), with a power ranging between zero and (-1/2).

5 CONCLUSION

This "particle" size effect modelling reproduces in a very satisfactory manner the experimental results obtained with the three EPS beads sizes concretes considered in the experimental investigation.

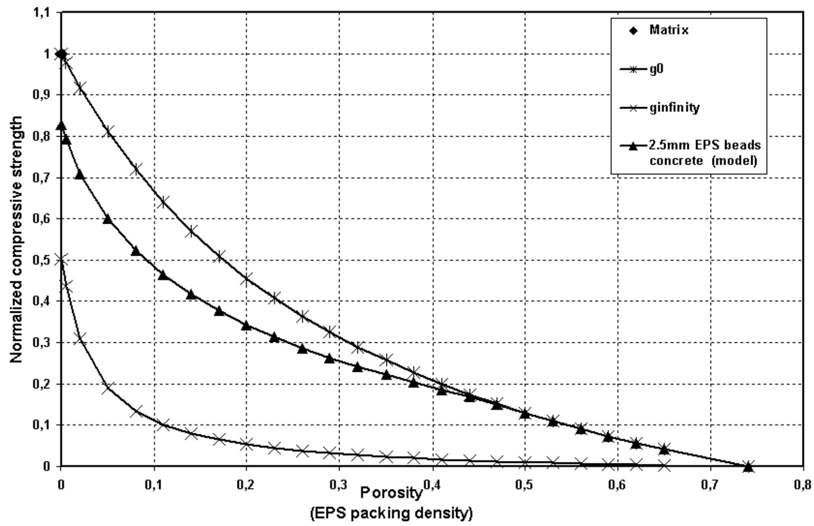

Figure 2: Comparaison between 2.5mm EPS beads concrete normalized compressive strengths given by the size effect model and those given by respectively the upper bound $\mathbf{g_0}(p)$ and the lower bound $\mathbf{g}_\infty(p)$.

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