XV International Conference on Durability of Building Materials and Components
DBMC 2020, Barcelona
C. Serrat, J.R. Casas and V. Gibert (Eds)

Degradation of Concrete Structures from the Climate Change Perspective

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Keywords: *Carbonation, Climate Change, Real Carbonation Data, Reinforcement Corrosion.*

1 Effects of Climate Change on Concrete Degradation

Several studies agree that climate change will cause new considerations and establish new conditions for the construction industry. Due to climate change, the risks of damage induced by carbonation in concrete can increase by more than 16% by the year 2100. It has also been found that, as a consequence of climate change, the corrosion rate could increase by 15% if the temperature increases by 2 °C (Stewart *et al.*, 2011, 2012). Research developed for concrete infrastructures in China has determined, taking into account the same climatic parameters mentioned above, that carbonation depth could increase by 45% in reinforced concrete structures by the year 2100 (Peng and Stewart, 2016). Later, other studies showed that global warming could advance the time of failure by 31% or decrease the service life up to 15 years for moderate levels of aggressiveness (Bastidas-Arteaga *et al.*, 2013).

1.2 Carbonation-Induced Degradation in Paraguay

Herein, a database with 327 carbonation depth measurements in different structures of Paraguay has been analyzed in order to know the real carbonation rate in RC structures. The carbonation data of the case study corresponds to buildings located in urban area with a service life of up to 30 years. The interventions were made between 2013 and 2019. As for their constructive characteristics, these buildings are constructed with Ordinary Portland Cement.

Through a statistical analysis of the real carbonation data, the results suggest that can be expected a carbonation depth that has almost the same thickness than the cover. This result is quite important since the probability of corrosion onset is too high considering the loss of alkalinity of concrete due to carbonation. Also, it has been seen that the slabs were the most compromised elements from the point of view of the corrosion initiation by carbonation. This is deduced since the mean cover thickness (12.30 mm) was practically equal to the mean of the carbonation depth (12.15 mm) in the slab structures.

Considering the carbonation tests results, an analysis was performed in order to determine the carbonation-induced corrosion risk. Then, this analysis has shown that almost half of the cases analyzed (49.91%) present a considerable corrosion risk or imminent corrosion initiation caused by carbonation. That means the carbonated thickness in the concrete is higher than the cover thickness, which compromises its durability. Thereby, it can be said that almost 50% of the buildings analyzed in the urban area of Asunción, whose were built no more than 30 years ago, are structures in the beginning of the last stage of its corrosion degradation.

2 Carbonation Modelling

The carbonation model applied in this research is a deterministic one-dimensional numerical diffusion model for a gaseous medium through a porous substrate based on Fick's Second Law (Talukdar *et al*., 2012.). After running the carbonation model, it can be said that the RC structures in Paraguay would be under considerable corrosion risk considering the forecasting climate changes. It has been found that the maximum carbonation depth is reached for a best climate scenario between 12% and 20% earlier than in the control scenario. On the other hand, the carbonation depth could increase between 14% and 16% for the worst-case scenario.

Another aspect to consider of the simulation results of the carbonation model is the relation of the concrete strength with the carbonation resistance. The higher the strength of the structure, the greater the carbonation resistance, which is reflected in the corrosion initiation times. The main reason for this behavior is the porosity of the material. The concrete strength is directly related to the porosity of the material so that the diffusion of gases within the concrete is limited in the materials of greater resistance.

3 Conclusions

Quality control during the construction process is of utmost importance to ensure a minimum concrete cover, which is one of the most critical factors on the initiation of corrosion time. Furthermore, structures are not appropriately designed and executed according to the consideration of environmental effects. One of the most outstanding results given by the carbonation model for the structures of Paraguay was the expected early degradation in the next years due to climate change effects.

Finally, one of the most concerning conclusions regarding the climatic phenomenon is given by the fact that the carbon dioxide accumulated in the earth's atmosphere cannot be reduced to acceptable levels until within a few centuries. Then, this situation suggests that the best strategy to deal with this problem involves adaptation measures rather than mitigation measures.

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