Proceedings Paper:
Idowu, O and Black, L (2015) Effects of Improper Curing on Concrete Durability. In: Proceedings of the 35th Cement and Concrete Science Conference. 35th Cement and Concrete Science Conference, 26-28 Aug 2015, Aberdeen, UK.

Effects of Improper Curing on Concrete Durability

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Summary

This research investigates the effect of improper curing on concrete durability, considering the effects on carbonation and sorptivity. Experiments were performed on 100mm concrete cubes cured for 28days under ideal and ambient conditions. The depth of carbonation was determined after exposing samples to 100% CO_2 at 20°C and 65% RH. Sorptivity testing was performed on samples dried in an oven at 40^0 C to constant weight. The results show that improper curing increases sorptivity and susceptibility to carbonation as addition of PFA reduces sorptivity and the depth of carbonation.

Keywords: Concrete, carbonation, sorptivity, curing, durability

1 Introduction

The impact of improper curing is commonly measured by the impact on strength development, and such instances may not appear to demonstrably affect the concrete quality and is not appropriate parameter to measure durability of a structure. Gopalan (Gopalan, 1996) wrote that the most important properties that affected the durability of a concrete were the pore structure and alkalinity of the cover concrete, and these can be followed by measuring the sorptivity and carbonation respectively. These factors are greatly influenced by the curing of concrete. Improper curing usually leads to very weak and porous materials near the surface of the concrete which is vulnerable to ingress of various harmful substances from the environment.

The importance of curing cannot be neglected because the outer 30 to 50mm is mostly affected, due to the high rate of evaporation of water from the concrete surface. Consequently, this depth constitutes the cover zone for most reinforced concrete construction. Furthermore, there is a growing trend in the use of supplementary cementitious materials in construction, so as to reduce consumption of cement, and thus lower the embodied carbon. However, such SCMs hydrate more slowly and require longer moist curing durations to improve durability. Similarly, high strength concretes, with water:cement ratios below 0.4, need adequate curing for maximum performance.

This study therefore investigate the effects of improper curing on carbonation and sorptivity of concrete cubes prepared with and without PFA (a common SCM), plus the impact of selected other mix design parameters.

2 Experimental methods

100-mm concrete cubes were cast using CEM I 52.5N with 10 mm diameter uncrushed coarse aggregate and quartz sand of diameter 150 µm to 5mm. The aggregates were oven dried and mains water within the laboratory was used.

Target strengths were 20, 50 and 80Mpa and target slumps of 10-30 and 60-180 mm, defined hereafter as “dry” and “wet” were used. Each mix was cured under two conditions, one in the fog room at 99% RH and the second one under ambient conditions at 20^0C, 42 % RH.

The depth of carbonation was determined on cubes cured for an initial 28 days by exposing samples at 20°C and 65% RH (using a saturated NaBr solution). Samples were exposed to pure CO_2 for two weeks and carbonation depths were determined by spraying a freshly broken surface with alcoholic 1% phenolphthalein solution. The average depths of carbonation were measured at two point's perpendicular to three faces of the broken concrete cubes. The depths of penetration of the trowelled face were ignored due to the influence of trowelling.

Sorptivity tests were carried out on concrete cubes which had been cured for 28 days under the two different curing conditions and dried in an oven at 40°C to constant mass. Drying at this temperature was preferred, as it does not modify the capillary pore structure or decompose ettringite. After drying, the lower areas on the sides of the specimens were coated with petroleum jelly so as to ensure unidirectional flow; the coated samples were placed in a trough of water, with the water level kept at about 5mm from the base of the specimens. The specimens were removed from the trough and weighed at different time intervals up to one hour to evaluate mass gain. At each of these times, the mass of water adsorbed by each of the specimen were obtained, and from this the sorptivity coefficient *(k)* were calculated using the expression

$$K = A\sqrt{t} / Q$$

Where Q is the amount of water adsorbed in cm^3, t is the time in secs, A is the cross-sectional area of the specimen that was in contact with the water in cm^2, and k is the sorptivity coefficient in $cm/s^{1/2}$.

3 Results and discussion

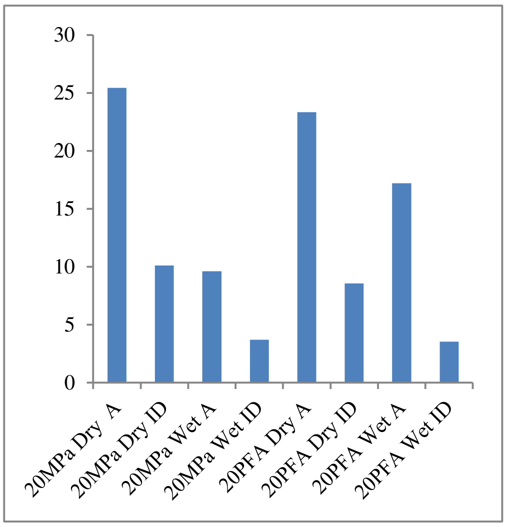

Figure 1.Carbonation depth

Table 1.Sorptivity values

	CEMI Dry sorptivity	CEMI wet sorptivity	PFA dry sorptivity	PFA wet sorptivity
20 Ideal	0.0074	0.0097	0.0072	0.0095
20 Amt	0.235	0.0244	0.0252	0.0244
50 Ideal	0.0067	0.0122	0.0088	0.0089
50 Amt	0.0122	0.0176	0.0152	0.0188
80 Ideal	0.0154	0.0244	0.0118	0.016
80 Amt	0.0256	0.0395	0.0188	0.0277

The different factors were found to impact on carbonation depths (Fig. 1). Unsurprisingly, samples cured under ideal conditions carbonated less than those cured under ambient conditions. Comparing the dry mixes (10-30mm slump) with the wet ones (60-180mm slump), the former carbonated to a greater depth than the latter. Finally, the addition of PFA was found to have a mixed impact. Ideally cured PFA blends performed as well or better than the equivalent CEM I mixes, but composite samples cured under ambient conditions behaved considerably worse than the CEM I equivalents. The decrease in carbonation depth is about 79.35% between the wet ambient cured PFA samples and wet ideal cured samples. Addition of PFA results to increase in carbonation depth on wet mixes cured under ambient conditions this is about 79.21% thus ambient cured wet mix PFA concretes carbonated more than ambient cured wet mix CEM I concretes.

It was clearly shown that lower grades of concretes (20MPa) were carbonated in all the mixes while higher grades of concretes (50MPa and 80MPa) cured at 28days under ambient and ideal conditions for both CEM I and PFA concretes did not carbonate which is similar to the results of Jia et al (Jia et al., 2011)

The compressive strength of CEM I wet mixes, ideally cured were higher than those of the equivalent PFA compressive strength at 28 days, but the carbonation depths were lower; indicating that strength is not always an appropriate measure of durability.

In all the tested samples, concretes cured under ambient conditions had higher sorptivity values than concretes that were cured under ideal conditions (Table 1). Comparing the CEM I mixes; the ideally cured wet mixes had higher sorptivities than the ideally cured dry mixes. (The same applies for the non-ideally cured samples). The same is true for the PFA blends. So, the increased water content of the mixes appears to lead to higher sorptivity. Effects of improper curing were more pronounced on PFA concretes than CEMI concretes. Addition of PFA reduces sorptivity, as ideal cured PFA samples have lower sorptivity than ideal cured CEM I concrete.

4 Conclusions

The results show that improper curing increases sorptivity and susceptibility to carbonation while addition of PFA reduces sorptivity and the depth of carbonation. However, it was found that all wet mixes have a higher sorptivity than the dry mixes which suggest that, the increased water content appears to lead to higher sorptivity. Also higher strength concrete seems to lead to greater sorptivity.

5 References

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