Discussion Forum

Some studies on the effect of carbonation on the engineering properties of concrete

Dear Sir,

This has reference to the paper titled 'Some studies on the effect of carbonation on the engineering properties of concrete', by B.B. Das, S.K. Rout, D.N. Singh and S.P,. Pandey published in The Indian Concrete Journal, March 2012, Vol. 86, No. 3, pp.7-12.

The increased burning of fossil fuels all over the world for producing energy and for transportation generates carbon dioxide (CO_2) at a level which is not possible for Mother Nature to remove. As a result the amount of carbon dioxide present in the atmosphere is now about 35 percent higher than it was a century and half ago. The upper safety limit for atmospheric CO_2 is 350 parts per million (ppm). Atmospheric CO_2 levels have stayed higher than 350 ppm since early 1988; As of Mar. 2012 the level is 394.45 ppm.[22]

The carbon emissions from the production and transport of construction materials are a significant part of the construction industry. Carbon dioxide is the principal emission from the cement industry. CO_2 is released when lime stone is heated to produce calcium oxide, during the production of cement. About 60% of CO_2 produced in cement manufacture arises from the above calcination reaction itself and the rest is due to the high temperature needed to drive the calcination of limestone. Globally, the cement industry contributes approximately 5 percent to all industrial carbon dioxide emissions. Several solutions have been proposed to reduce the environmental impacts of the production of concrete.[23]

However, during the life cycle of concrete, it reabsorbs about 20 percent of the CO_2, thus partially mitigating the effect during manufacturing; this process is commonly referred to as *carbonation*. Concrete does not even necessarily have to be directly exposed to the atmosphere for this process to occur. Underground concrete piping and foundations can absorb CO_2 from air in the soil, and underground and underwater applications might absorb dissolved carbon dioxide (carbonates) present in groundwater, freshwaters and salt waters.[24] When carbon dioxide is absorbed into concrete many chemical reactions take place. These usually result in a lowering of the pH in the portion of the concrete where significant amounts of carbon dioxide have been absorbed. Till now, scientists are not in a position to know how much CO_2 is absorbed in concrete and how long does it take to affect reinforcements.

Under these circumstances, the present paper assumes greater importance. It confirms the general perception that strength of concrete is improved due to the fact that carbonated concrete is a denser than un-carbonated concrete. The authors have also shown that the carbonation decreases the porosity and electrical conductivity of concrete. Thus it is seen that though strength is enhanced, the durability is compromised.

During the recent e-conference on durability on concrete structures, several engineers expressed that improper curing is the main cause for the deterioration of concrete structures.[25] Since curing is not included as a work to be completed at site, it is not given proper importance and even the minimum curing period as stipulated in codes of practices are not followed, under the pretext of fast construction.[26] It is important to note that the use of cementitious materials like flyash results in slow strength development and demand more curing periods than normally specified in codes. Also, the use of grade 53 cement, generally available in the market and develops high early strength, requires more precaution with respect to curing.

In these circumstances, where concrete structures are not even cured for the mandatory 7 to 10 days (clause 13.5.1 of IS 456), why the authors chose to cure the specimens for 28, 56, 90 and 120 days? Moreover, the curing of cubes under water may not correlate with the properties of concrete cured at site, where the curing may not be perfect.

Carbonation in concrete depends on environment and quality of concrete, which is based on water/cement ratio, cement content, type of cement, type and dosage of admixture, compaction, water-curing period, and type of coating. It has been shown that the water/cement ratio is one of the main factors affecting carbonation.[27] AI-Khaiat et al showed that the values of 'K' in Eqn. (2) ranged from 2.1 to 7.8 as the water/cement ratio increased from 0.45 to 0.8 (cement content varied between 456 and 256 kg/m^3). They also derived the following relation between concrete strength and depth of carbonation.

$$y = -0.3936x + 28.387 \qquad ......(3)$$

where y is the carbonation depth in mm and x is the concrete strength in MPa. Another important conclusion made by them is that six days of water curing is necessary and is adequate to lower the carbonation depth to a level comparable to 13 or even 27 days of water curing.

Similar relation between water/cement ratio has been observed by the authors (Figure 2)- carbonation depth increases as the water cement ratio increases. But the K values obtained by the authors are different. Can the authors explain the difference? Has the authors developed any equation to correlate the carbonation depth measured in the accelerated test to the same damage in the real environment, so that it will be more useful to practicing engineers?

References

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The authors' reply

Dear Sir,

The authors thank the discusser for appreciating their research work. The primary importance of this study was to make out the effect of carbonation on the engineering properties of concrete. The authors believe that the comments raised by the discusser can be summarized as follows:

1. Correlation between the results of laboratory cured specimens to that of field practiced concrete specimens

2. Relationship between compressive strength and carbonation depth of concrete and the associated value of carbonation coefficient (K)

The authors will try to explain the above mentioned issues in the following way.

The properties of hardened concrete is quite dependent on the level and type of curing, proper curing increases the strength, durability and also the volume stability. With proper curing, concrete becomes stronger, more impermeable, and more resistant to stress, abrasion, and resistance to freezing and thawing.[28] The temperature of curing and the duration of moist curing are the key factors for proper curing. Because, the rate of hydration is controlled by the quality and quantities of the cementitious materials present in mix as well as the ambient temperature and the availability of moisture in the mix.[29,30] The period of curing is usual to specify a minimum of seven days for ordinary Portland cement concrete but with slower-hardening cements a longer curing period is desirable.[29] As per IS 456, curing conditions are being defined as the exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacking, canvas, hessian or similar materials and kept constantly wet for at least seven days from the date of placing concrete in case of ordinary Portland cement-and at least 10 days where mineral admixtures or blended cements are used. The cement is being used in this study is of 53 grade ordinary Portland cement and it is to be noted that, the use of grade 53 cement, generally available in the market and develops high early strength, requires more precaution with respect to curing. Considering this aspect, the authors choose to cure the concrete specimens for a minimum period of 28 days to ensure the stability inside the specimens of the concrete.

The investigation carried out here is in a temperature and moisture controlled laboratory and the correlation to the field and site condition is being established at this moment. Once this relationship is established, it will be of a great help to the practicing engineers.

We hope the discusser is referring to equation 1 (there is no equation 2) in the paper by Al-Khaiat et al. $d = K\sqrt{t}$, where the value of K varies from 2.1 to 7.8. The investigation reported by Al-Khaiat et al., is based on the research carried out on white Portland cement, sulphate resisting cement along with the ordinary Portland cement. Further, it is to be noted that along with the variation in cement types, the research work carried out in hot and arid climate of Kuwait by Al-Khaiat et al. were exposed to a natural hot and arid environment for a time period of 8.6 years, whereas the research investigation reported here is only on ordinary Portland cement and is based on the accelerated carbonation studies which were carried out in a controlled environment laboratory.

Based on the data presented in Table 5 and Table 7, a statistical correlation between carbonation depth (d) and compressive strength (f_c) was proposed and reported by the authors as a linear relationship with regression coefficients, $R^2 = 0.81$.[31]

$$d = 48.1 - 0.6 \times f_c \qquad ......(4)$$

References

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