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ACCELERATED CURING OF SILICA FUME CONCRETE

PROBLEM STATEMENT

There are several ways to cure concrete in the field. One form of curing that has become popular at precast prestressed concrete plants is accelerated curing. This type of curing is advantageous where early strength gain in concrete is important or where additional heat is required to accomplish hydration, as in cold weather (Cement Association of Canada 2004). Accelerated curing reduces costs and curing time in the production of precast members (Theland 2003).

Concerns with accelerated curing include the potential for increased moisture loss during the curing process and the possible detrimental effect of high temperatures on long-term concrete properties. Currently, information on how accelerated curing affects silica fume concrete is limited. Accelerated curing has been shown to be effective in producing high-performance characteristics at early ages in silica fume concrete (PCI Committee on Durability 1994). However, the heat from the high temperatures greatly increases the moisture loss from exposed surfaces, which tends to cause more shrinkage problems and a reduction in the ultimate strength (Memphis 2004). Therefore, when using accelerated curing with silica fume concrete, the minimum amount of heat necessary for the required strength gain should be used, and the concrete should be allowed to attain initial setting prior to commencing accelerated curing.

Florida Department of Transportation (FDOT) Standard Specifications 346 allows the use of silica fume in concrete as 7 to 9% replacement of cementitious material, together with the usage of high range water reducing admixture (FDOT 2004). Typically, silica fume is used in FDOT higher concrete classes, e.g., Classes V and VI, for increased strength and durability. The 2004 version of the FDOT Standard Specifications for Road and Bridge Construction, Section 450, specify extended moist curing requirements for silica fume concrete. The moist curing must continue for a minimum of three days, immediately after which two coats of curing compound must be applied. The surfaces must then be left undisturbed at least seven days. The process may be sped up through employing accelerated curing techniques for silica fume concrete. ASTM C 684 accelerated curing methods involving elevated temperature water or a high temperature and pressure method are not convenient for large precast prestressed elements (ASTM C 684). However, steam curing silica fume concrete is convenient, and would result in cost savings to precasters and FDOT. With a maximum probable steam curing time of 24 hours, precast concrete products could be turned around much more quickly and, thus, less expensively. Further, steam curing results in more complete hydration of the pozzolanic materials, which increases the strength gain of concrete. The increased cost of the curing process is more than offset by the savings in curing time and extra productivity.

OBJECTIVES

The objective of this study was to verify whether it is feasible to steam cure FDOT Silica Fume concrete. Researchers investigated (1) the possibility of speeding up the curing process of such concrete through steam curing, and (2) the effect of such curing on several desired properties of hardened concrete, such as compressive strength, permeability, shrinkage, and susceptibility to cracking.

FINDINGS AND CONCLUSIONS

The findings and conclusions from this study are summarized in the following:

1. Steam curing silica fume precast concrete elements can be conveniently achieved with existing technology and facilities available in large precast yards. FDOT specifications regarding the temperature regimens during steam curing can easily be met and even exceeded.

2. The steam curing temperature attainable in full-scale pile specimens is influenced by the specimen size. Larger pile specimens displayed higher maximum temperature gains (about 10 deg. C) than did the smaller pile specimens.
3. Steam cured silica fume concrete can achieve the target minimum compressive strengths, as specified by FDOT. In this study, most steam cured laboratory specimens and all field pile specimens reached the 28-day target strength of 41.37 MPa (6,000 psi) for the Class V mixes. All steam cured samples continued to gain in strength with time. At 365 days, both the laboratory and the field pile sample concrete displayed significantly higher compressive strengths than the 28-day strengths.
4. The steam cured samples displayed lower compressive strengths at all ages than their moist cured counterparts. This is consistent with previous research finding on silica fume concrete.
5. Steam curing times of 12, 18 and 24 hours do not seem to play a major role in controlling concrete compressive strengths. There was no consistent pattern of maximum strength displayed by samples from a single source of stem cured duration.
6. The surface resistivity of all samples increased significantly with time. The moist cured specimens gained surface resistivity at a much higher rate than the steam cured specimens, and at 365-day age, the moist cured samples displayed the greatest resistivity.
7. Using published data for comparison purposes, the steam cured specimens in this study displayed low to very low permeability and very low permeability at 28 and 364 day ages, respectively. Greater surface resistivity indicates lower permeability and increased long-term durability of concrete.
8. All steam cured and moist cured specimens showed a general increase in shrinkage with time. Steam curing duration did not seem to play a major role in affecting the shrinkage rates. At later stages, such as the 364 day age, the longer steam curing periods, such as 18 and 24 hours, accelerated the shrinkage growth for the laboratory specimens.
9. The pile specimens showed similar shrinkage trends as the laboratory specimens. The moist cured pile specimens generally showed lower shrinkage than the steam cured specimens. Again, specimens with longer curing time showed more shrinkage than samples with shorter curing time.
10. The size of the pile specimens did not have a significant effect on the shrinkage rate. The larger and the smaller pile samples underwent similar shrinkage with time.
11. The ACI Banson model for shrinkage prediction under-predicts the shrinkage of steam cured specimens at 364 days, and over-predicts shrinkage for the moist cured specimens.
12. During the 364 days of monitoring, no distress of the prestressed piles was observed due to shrinkage cracking. In fact, visual inspections did not show any shrinkage cracks.

BENEFITS

The findings from this study will be very beneficial to precast yards in terms of the mass production of concrete members with silica fume concrete, quick turnaround of such precast concrete members, and overall resulting economy from such efforts. Currently, accelerated curing techniques, such as steam curing, are not allowed for FDOT concrete products containing silica fume. The currently approved moist curing techniques take longer than the steam curing approach. This study has shown that steam curing, 12-24 hours in duration, can be effectively used for FDOT concrete with silica fume.

Short-duration steam curing techniques can drastically improve the turnaround times for the subject precast prestressed concrete products. Precast yards already use steam curing techniques for FDOT concrete products without silica fume. Applying steam curing techniques to the production of silica fume concrete products would allow the precast yards to streamline their production process. The expected result would be increased rates of production and related cost savings, which should translate into economic benefits for FDOT.

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