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EARLY AGE TEMPERATURE PROFILES IN AIR CURED CONCRETE SPECIMENS

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ABSTRACT

The early age of concrete has been recognised as having much to contribute towards the long term performance of concrete. The hydration of cement paste is affected by the environment in which the concrete is cured. In this paper, the temperature inside concrete specimens cured in the air in laboratory were monitored for a period of thirty-six hours from the time water was added. These were matched with the ambient temperature of the laboratory over the same period. It was observed that for all the five mixes considered, the inside temperature of the concrete specimens rose above the ambient temperature as from five hours after casting. It stayed above the ambient until twenty four hours after casting. The implication is that for optimisation of concrete strength within the environment considered, curing of concrete should commence not more than five hours after casting.

KEY WORDS: Early, Age, Temperature, Curing, Ambient

INTRODUCTION

The problem of quality assurance for concrete in structures is a well-known one which has not been completely resolved. In reinforced concrete, steel has a reasonable predictable behaviour while concrete has a lot of variables which depend on the operators in the industry. While steel reinforcement are produced under well controlled factory environments, concrete is produced at site. Even the ready mixed concrete produced by specialist operators are still subject to a number of variations. Teychenne, Franklin and Entroy [1979] have listed the variations to include those due to the quality of material used and those in the mix proportions due to the batching process. Cement consignments delivered from the same factory have been found to have different fineness. Aggregates supposedly from the same quarry have also shown some variations in grading and particle shape. Granted that a lot of care has been exhibited in selecting ,measuring , mixing , and pouring the concrete, the method used in compacting the well placed concrete may still alter a number of properties. Even after properly compacting and finishing the concrete, the handling of the finished concrete may still introduce other problems. This handling of the finished concrete, known as curing , is the subject of this paper.

THE IMPORTANCE OF CURING

Curing has been defined by Spears[1983] as a procedure for insuring the hydration of the Portland cement in newly-placed concrete. Hydration of Portland cement is the chemical reaction between the particles of Portland cement and water to form the hydration product, cement gel, which is only formed in water-filled spaces. The hydration process therefore proceeds until the cement available for hydration is exhausted or the water-filled capillaries in the paste is completely filled by the cement gel. The ideal situation is therefore one in which the cement gel formed by the hydration reaction has just enough water filled space to contain it. If the concrete is allowed to dry out rapidly, there may not be enough free water to complete the cement hydration process. In order to optimise the benefits of the cement hydration process, it is very necessary to understand properly the relationship of the cement hydration process to the curing of concrete, the natural drying rate of concrete and the appropriate humidity environment to be maintained within the concrete. Tests carried out by Powers [1947] led to the conclusion that hydration of cement paste ceases below 80 percent relative humidity and effort should therefore be made to maintain the humidity above 80 percent by keeping the concrete saturated as long as practicable. The timing of the commencement of curing is very important. Allowing concrete to dry out at an early age results in reduction of strength, durability and increased permeability.

The Portland Cement Association [1979] released a document which showed the effect of curing concrete under various environmental conditions. From the report, it is clearly shown that the compressive strength of concrete cured throughout in air will be about 55 percent of the same concrete cured under moist condition throughout the first 28 days. This is very revealing in that the 45 percent reduction in strength is very significant. Adequate curing results in reduced permeability, reduced thermal shock effects, reduced scaling tendency and reduced cracking. On the other hand, it increases strength, abrasion resistance, durability, pozzalanic activity and resistance to plastic cracking. According to Gebler [1983], plastic cracking appears when water evaporates from freshly placed concrete faster than the concrete can bleed water to the surface. He also listed the condition which either singly or collectively, increase the evaporation rate and the potential for plastic shrinkage cracks to occur. These were high concrete temperature, low humidity high winds and low ambient temperature.

Gebler [1983] performed a series of experiments to demonstrate the effect of the above parameters - concrete temperature, humidity, winds and ambient temperature on the rate of evaporation from concrete surface. Two very interesting conclusions that were drawn from his work concerning the concrete and ambient temperatures were as follows:

[a] whenever the concrete temperature exceeded the ambient temperature, the rate of evaporation was likely to increase, assuming that humidity and wind speed remained constant;

[b] even when a relative humidity of 100 percent was available, evaporation continued from the concrete as long as the concrete temperature remained higher than the ambient temperature under the same wind speed. The explanation for this is that evaporation continued

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because of the difference between the vapour pressure in the air and that at the surface of the concrete.

It is therefore evident that the relationship between the concrete temperature and the ambient temperature determines whether evaporation takes place from a concrete surface. The engineer on a project site should therefore be interested in knowing the probability of ambient temperature falling below concrete temperature, especially in the early ages of the concrete. This formed the basis of the investigation reported in this paper. The variation of concrete and ambient temperature was monitored for a concrete cylinder specimen for a period of 36 hours for five different concrete mixes. These temperatures were then compared to highlight the periods during which the concrete temperatures rose above the ambient.

EXPERIMENTAL PROCEDURE

For the experiment, five different concrete mixes were selected for consideration. Details of the mix proportions used will be presented during the discussion of results. For each of the mixes, eight cylinder specimens [100*200mm] and six[6] cubes[100*100mm] were produced. Two of the cylinders carried maturity meters with one of them also carrying a thermocouple which was installed in such a way that the junction was at the same location with the maturity meter probe, that is, at the middle of the concrete cylinder specimen. The mixing, placing, compaction and finishing was arranged to finish within ten[10] minutes of addition of water at the end of which the reading of the thermocouple and maturity meters commenced. The following readings were taken for each mix:

[a] the ambient temperature and time of adding water;
[b] the ambient temperature, time and thermocouple readings ten[10] minutes after the addition of water;
[c] the ambient temperature, time, maturity and thermocouple readings every five[5] minutes for another one hour after commencement of readings;
[d] the ambient temperature, time, maturity and thermocouple reading every ten[10] to fifteen[15] minutes up to the [8th] hour after addition of water;
[e] the ambient temperature, time, maturity and thermocouple readings every hour from the 8th to the 36th hour.

The intervals selected for the reading was to enable proper monitoring of the temperature variations during the early hours when a lot of hydration reaction was expected to have taken place. The six[6] concrete cube specimens were cured under normal 28 day curing conditions in the laboratory. Three[3] of these cubes were crushed at the age of seven[7] days while the remaining three[3] were crushed at 28 days.

RESULTS AND DISCUSSION

Figures 1 to 5 show the plot of the ambient and concrete temperatures against time and also plots of the difference between them against time. Table 1 presents a summary of major observations during the experiments and the parameters for the mixes used for the experiments.

TABLE 1 : Summary of Mix Proportions and Observations

MIX NO	WATER/ CEMENT RATIO	AGG./ CEMENT RATIO	T1 [HOURS]	T2 [HOURS]	T3 [HOURS]	7-DAY STRENGTH [N/mm²]	28-DAY STRENGTH [N/mm²]
1	0.40	3.5	5.25	23.5	33.0	34.98	45.03
2	0.40	4.8	5.50	24.0	29.7	39.24	47.61
3	0.40	5.1	5.60	23.2	-	31.93	40.80
4	0.45	4.8	6.40	23.7	32.2	28.39	36.03
5	0.55	4.8	7.20	23.7	32.6	20.35	30.80

T1 = time before concrete temperature first exceeded ambient temperature.
T2 = time before ambient temperature exceeded concrete temperature again.
T3 = time before concrete temperature overtook ambient temperature the second time.

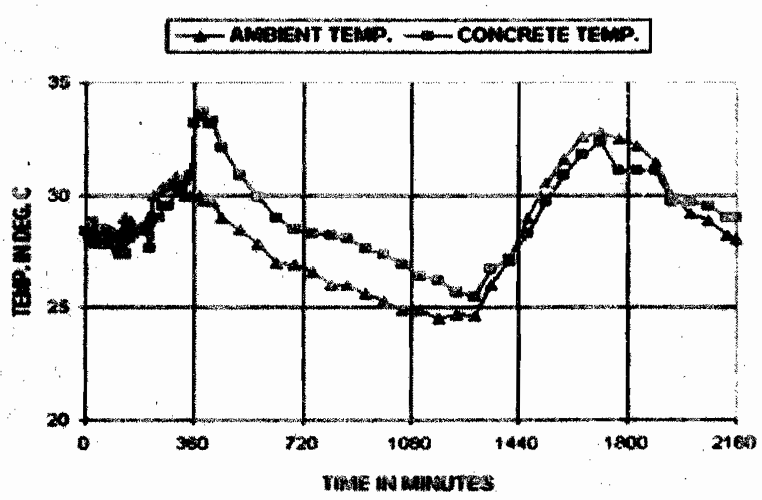

FIG. 1a TEMPERATURE PROFILE FOR MIX 1

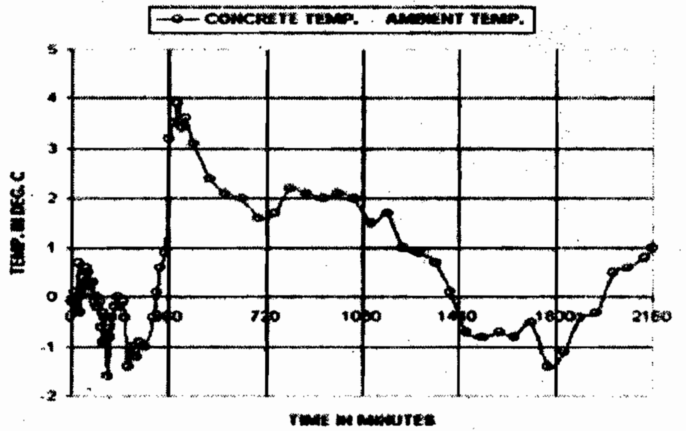

FIG. 1b DIFFERENCE BETWEEN CONCRETE AND AMBIENT TEMPERATURE FOR MIX 1

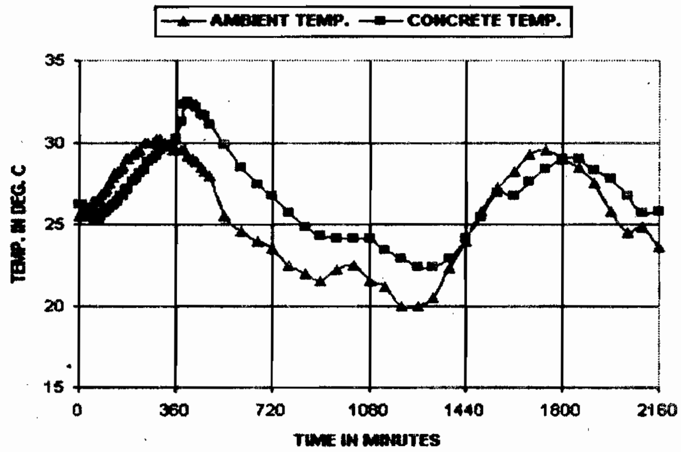

FIG. 2a TEMPERATURE PROFILE FOR MIX2

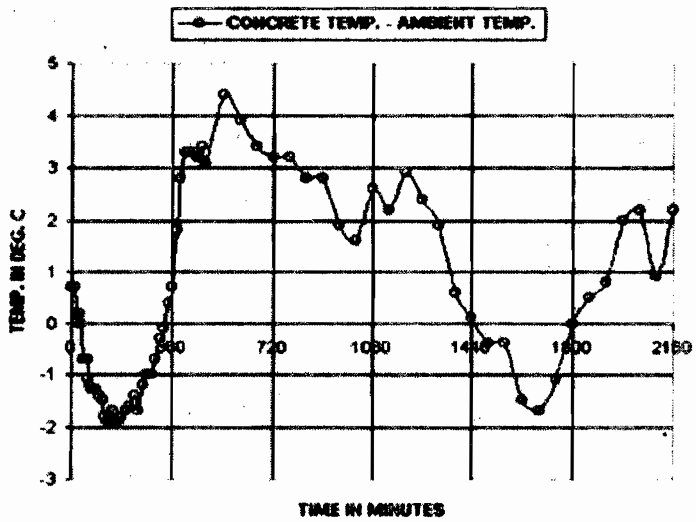

FIG. 2b DIFFERENCE BETWEEN CONCRETE AND AMBIENT TEMPERATURE FOR MIX 2

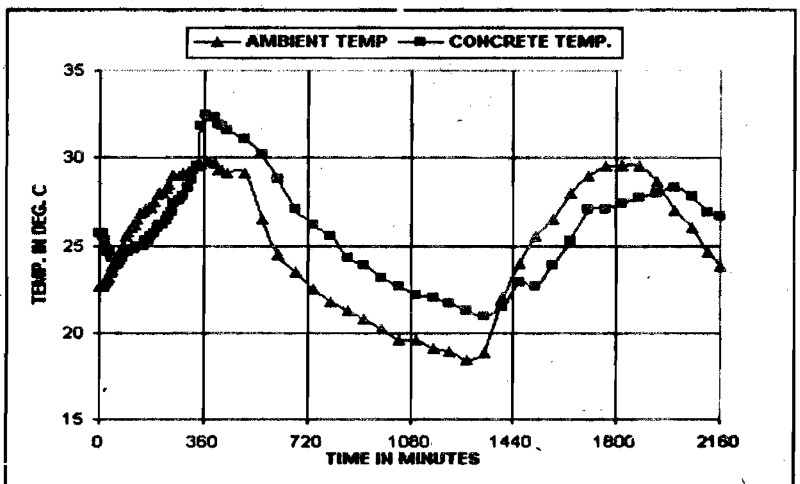

FIG. 3a TEMPERATURE PFOFILE FOR MIX 3

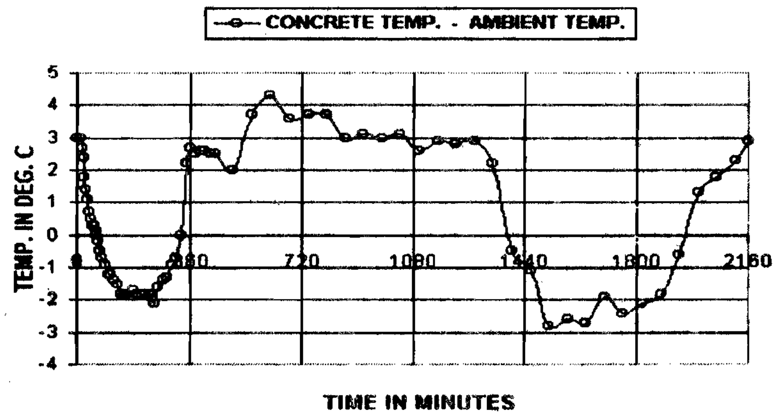

FIG. 3b DIFFERENCE BETWEEN CONCRETE AND AMBIENT TEMPERATURE FOR MIX 3

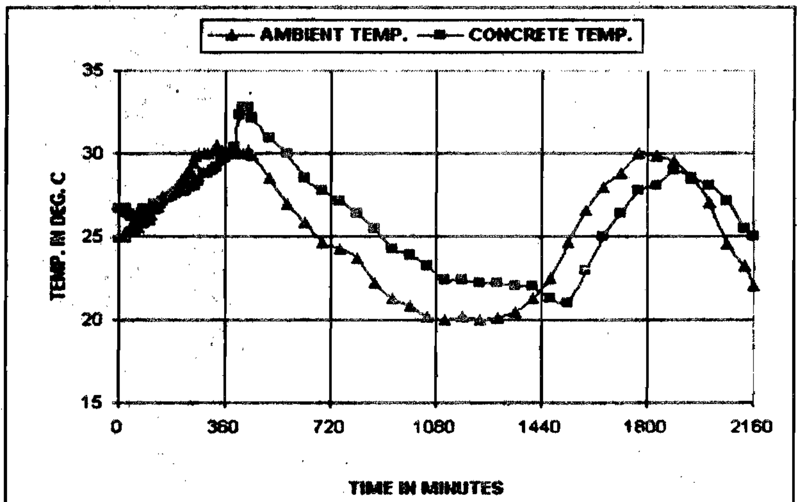

FIG. 4a TEMPERATURE PROFILE FOR MIX 4

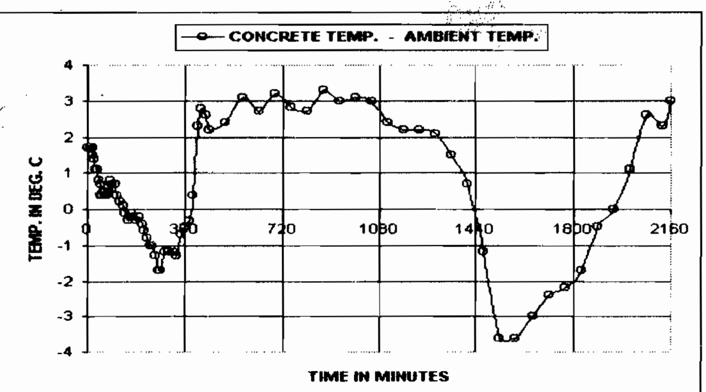

FIG. 4b DIFFERENCE BETWEEN CONCRETE AND AMBIENT TEMPERATURE FOR MIX 4

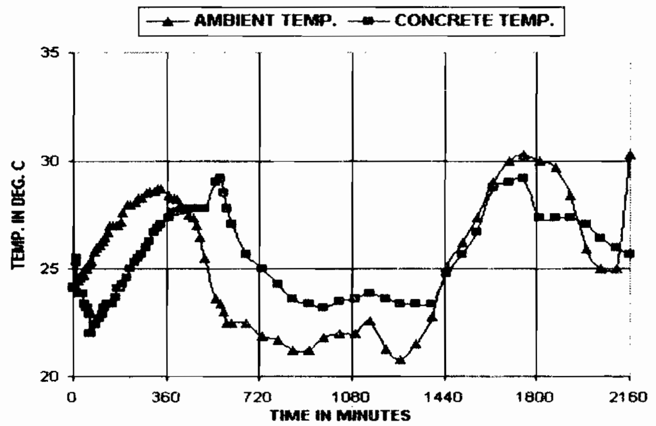

FIG. 5a TEMPERATURE PROFILES FOR MIX 5

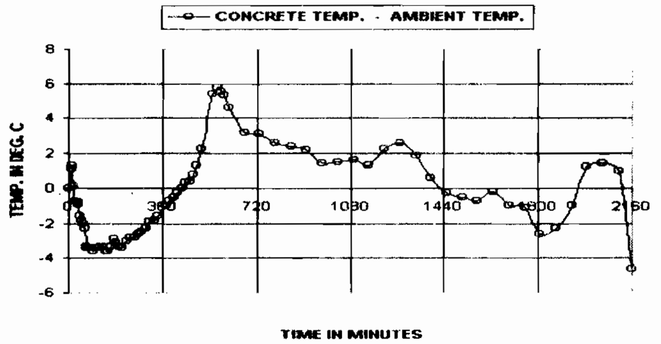

FIG. 5b DIFFERENCE BETWEEN CONCRETE AND AMBIENT TEMPERATURE FOR MIX 5

From the figures and table, it is evident that for the mixes considered, the time elapsed before the concrete temperature started exceeding the ambient temperature ranged between 5hours 15minutes and 7hours and 12minutes. The time at which the ambient temperature again overtook the concrete temperature ranged from 23hours 12minutes to 24hours after the commencement of readings. The time taken for the concrete temperature to overtake the ambient temperature a second time ranged from 29hours 42minutes to 33hours.

Considering all the five[5] mixes, it is reasonable to conclude that after five[5] hours, there is every reason to expect the concrete temperature to exceed the ambient temperature. Curing must of necessity commence not later than five[5] hours after the casting of the concrete. It is also evident that between the 5^{th} and 24^{th} hour, a lot of hydration reaction takes place resulting in the higher concrete temperatures observed in this range.

CONCLUSION

Based on the results of this study, the following conclusions can be drawn:

[a] the hydration process within concrete results in increase in the internal temperature of concrete specimens;

[b] for tropical conditions under which these experiments were conducted, the internal temperature of concrete mixes overtake the ambient temperature after five hours from time of adding water;

[c] the internal temperature remains above the ambient temperature till about twenty four hours after addition of mixing water;

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