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Experimental Study on Accelerated Curing of Concrete

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ABSTRACT

prefabrication industry wherein high early age strength enables the removal of the formwork within 24 hours thereby reducing the cycle time resulting in cost saving benefits. The most adopted curing techniques are steam curing at atmospheric pressure, warm water curing, boiling water curing and autoclaving. A typical curing cycle involves a preheating stage, known as the "delay period" ranging from 2 to 5 hours; heating at the rate of 22oC/hour or 44oC/hour until a maximum temperature of 50-82oC has been achieved; then maintaining at the maximum temperature, and finally the cooling period wherein, the temperature is gradually reduced and allowed to fall to ambient levels. The whole cycle should preferably not exceed 18 hours.

Keyword: Accelerated curing , high early age strength, cost saving benefits, warm water, curing and autoclaving.

1. INTRODUCTION

At heightened temperatures, the reaction of the concrete proceeds at a greater pace, hence the rate of gain of strength is higher. However, the later age strength is adversely affected by the high temperature. Hence, the selection of the cycle time is a trade off between the economical cycle time and the ultimate compressive strength.

The cost of the equipment needed for accelerated curing is generally offset by the cost saving benefits of a reduced cycle time. Since the formwork may be removed within 24 hours, the cast girders may be lifted and shifted into the stocking yard, while the casting bed and the formwork become available for the next cycle. The overall project time is reduced, and hence it is a widely used technique in the industry. The prefabricated girders and sections being erected in the Delhi Metro, and Bangalore Metro have all been cured using steam curing techniques.

Pozzolona increases the later age strength of concrete as it reacts with calcium hydroxide and turns it into calcium-silicate-hydrates (C-S-H). Pozzolanic materials also improve the durability of the concrete. Pozzolona such as Fly Ash are easily available as waste products of coal thermal power plants. When used as partial replacements for cement, they help reduce the carbon footprint of the cement industry which is a highly energy intensive industry responsible for high amounts of CO_2 emissions.

However portland pozzolona cements have higher activation energy and therefore, their rate of hydration is lower as compared to ordinary portland cement

(OPC). This results in lower early age strength as compared to OPC. This results in delayed release of prestressed strands and increased cycle time periods in the precast industry. Accelerated curing techniques radically help to increase the rate of strength gain. It has been shown that steam curing improved the 1 day compressive strength values of high volume fly ash concrete mixtures (40%, 50% and 60% fly ash by replacement) from 10MPa to about 20MPa which is sufficient to enable the removal of formwork and greatly aids the precast concrete industry.

The fast paced construction projects around the world today heavily depend upon the precast manufacture of concrete sections. The precast industry makes use of accelerated curing methods to rapidly gain high early age strength so that the formwork may be removed and the casting bed becomes free to be used for the next batch of concrete sections. This technique is also advantageous under cold weather conditions as the hydration of concrete is slowed at

Objective Of This Study

The aim of the project undertaken is to study the strength gain of concrete during the curing cycle, cured using warm water, accelerated curing technique with varying percentages of flyash as partial replacement of cement.

1. **High Early Age Strength-** Precast, prestressed concrete elements are frequently used in buildings and other structures to reduce the building time. It is important that the elements are prestressed as early as one day of age, and the formwork is made available for the next cycle.
2. **Greenhouse Gas Emissions-** Highly reactive cements contain a high percentage of clinkers, which means that large amounts of CO_2 gas (which is a greenhouse gas) is released into the atmosphere during production of the cement. This is inconsistent with the goal of reducing the global rise in temperatures. Hence the use of pozzolanic material in partial replacement of cement can be envisaged. Pozzolanic materials improve the performance of accelerated cured concrete elements.
3. **Reactivity of Cements-** Locally available cements may not be as reactive as is required for the early release of the prestressed strands. An accelerated curing technique if employed can eliminate this problem.
4. **Thermal Stresses-** The heightened temperatures involved in the accelerated curing procedures could cause micro-cracks which would adversely affect the durability of the concrete. Hence, a delay period is allowed before the commencement of the procedure to allow the concrete to gain minimum tensile strength.

2. LITERATURE REVIEW

Topcu & Toprak[1] (2005) studied the early-strength gain of concrete with heat treatment. The effects of accelerated curing temperature and fine aggregate on early strength as well as the relationships between early strength–28-day strength and strength maturity have been studied. Cube concrete specimens produced with a 10-cm constant slump value, 0.59 w/c ratio, and with two different types of fine aggregate were subjected to three-phase cure processes. The concrete were preheated for 1 hour after being replaced concrete in the mould.

Erdem et al[2] (2003)studied the effects of various delay intervals on setting time of concrete. Concrete mixtures C25 and C40 were made at the laboratory temperature 23° C. The reference specimens of C25 and C40 were continuously cured at 23° C and 100% relative humidity until they were tested in compression at the end of 1, 3, 7, 28, and 90 days. For each type of concrete, three standard cylinder specimens (15 x 30 cm) were tested at each age and the average values were calculated to obtain the reference strength values. Four different delay intervals (t, t-1, t-2, and t-3 hours) and two different steam curing periods at 80° C (5 and 10 h) before they were allowed to cool down to the ambient temperature (23° C) over a 5- h period.

Turkel and Alabas[3] (2005) studied that atmospheric steam curing is a heat treatment which has been used for many years to accelerate the strength development of concrete products, because the hydration rate of cement increases with the increase in temperature, the gain of strength can be speeded up by curing concrete in steam. The object of this study was to determine the properties of this relatively new binder comparatively with conventional PC 42.5 under steam curing. For this purpose, 15-cm concrete cubes were prepared with a water cement ratio (W/C) of 0.44 and were subjected to steam curing for five different curing periods of 4, 8, 16, 24 and 36 h under curing temperatures of 65 and 85°C.

3. MIX DESIGN IS10262-2009

Concrete cubes of varying target compressive strength and varying replacement percentage of flyash were cast. 24 hours later, they were removed from their moulds and were put into the accelerated curing tank. The ambient temperatures were noted, and the temperature within the tank was allowed to rise to a maximum of 70°C at a rate of 22°C per hour. Once the maximum temperature has been achieved, at every two hour interval, three cubes were removed, allowed to dry for two hours, and then, their compressive strength was tested. This is done until the eighth hour.

Design of M20 concrete (using PPC)

Water	Cement	Fine Aggregates	Coarse Agg.
156.753	321.054	314.376	1379.97
0.488	1	0.9792	4.298

Design of M30 concrete using PPC

Water	Cement	Fine Aggregates	Coarse Agg.
164	463.5	432.276	1307.1218
0.354	1	0.93	2.82

Design of M40 concrete using PPC

Water	Cement	Fine Aggregates	Coarse Agg.
165.218	545.29	387.192	1271.3375
0.30299	1	0.71	2.33

4. RESULTS AND DISCUSSIONS

4.1 Compressive Strength of Concrete

The size of cube mould is 150mm. Take the random samples from the mix in a ghamela, while concreting. Pour concrete in the cubes in 3 layers. Compact each layer with 35 numbers of strokes with the tamping rod. Finish the top surface by thapi/trowel after compaction of the last layer. Each specimen should be taken from different locations of the proposed concreting. After 24 hours, remove the specimen from the mould. While removing, take care to avoid breaking of the edges. Code the cube with marker. Coding should be self explanatory, building number and the date of casting. Submerge the specimen in clean, fresh water until the time of testing.

Table 1: Percentage Strength vs time plots, M20

Time (Hrs)	M20, 0 % (Mpa)	% Strength Gained	M 20, 5 % (Mpa)	% Strength Gained	M20, 0% PPC	% Strength Gained
2	12.6	47.37	12.4	46.62	7.21	27.11
4	16.3	61.28	15.79	59.36	10.1	37.97
6	18.9	71.05	17.79	66.88	11.33	42.59
8	20.01	75.23	19.08	71.73	13.6	51.13

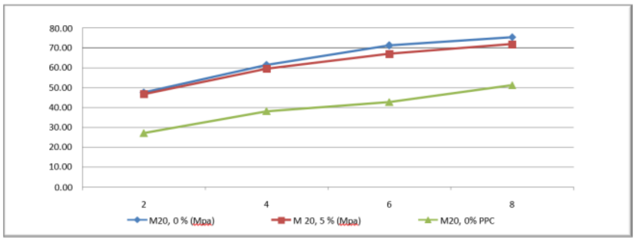

Figure 1: Percentage Strength vs time plots, M20

Table 2: Percentage Strength vs time plots, M30

Time (Hrs)	M30, 0 % (Mpa)	% Strength Gained	M 30, 5 % (Mpa)	% Strength Gained	M30, 0% PPC	% Strength Gained
2	20.93	54.72	19.91	52.05	8.71	22.77
4	23.64	61.80	22.33	58.38	14.84	38.80
6	28.04	73.31	26.36	68.92	17.22	45.02
8	29.87	78.09	28.44	74.35	20.82	54.43

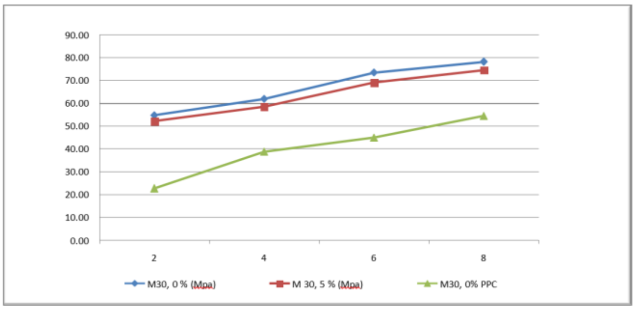

Figure 2: Percentage Strength vs time plots, M30

Table 3: Percentage Strength vs time plots, M40

Time (Hrs)	M40, 0 % (Mpa)	% Strength Gained	M 35, 5 % (Mpa)	% Strength Gained
2	21.11	48.81	20.07	46.40
4	24.01	55.51	22.93	53.02
6	27.16	62.80	26.68	61.69
8	30.36	70.20	29.16	67.42

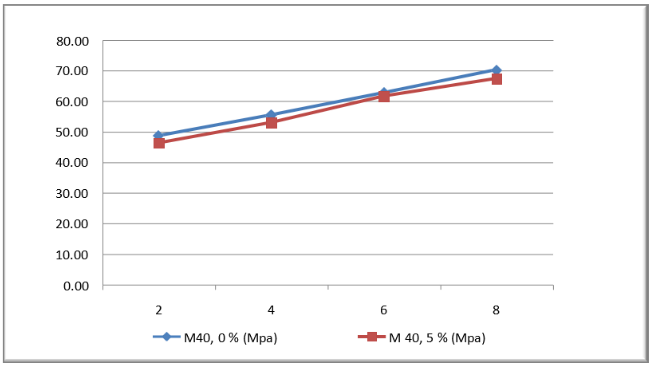

Figure 3: Percentage Strength vs time plots, M40

4.2 Discussions

From the graphs, it can clearly be seen that the compressive strength rises rapidly when maintained at elevated temperatures from 2 to 8 hours. This happens because the rate of the reaction proceeds faster at the temperature of 70°C. However, many organizations prescribe a temperature not exceeding 70, or 82°C. This is because that the ultimate age strength is adversely affected by the higher temperature, even though the strength gain may be rapid. This has phenomenon, known as the "crossover" effect has been explained in section **2.1**. Halit et al[5] have shown the long term effect of the addition of flyash which is not evident in this experiment. Warm water curing accelerates the strength gain of concrete with flyash as partial replacement as compared to standard curing techniques. The accelerated curing did not improve the later age strength of concrete with high volume flyash replacements as much as the standard curing techniques. This technique however is of immense importance if the one day strength is the sole consideration, as in precast, prefabrication units. The one day strength can be seen to be considerable enough to enable the removal of formwork.

5. CONCLUSIONS

Therefore, it may be concluded that the accelerated curing technique may be used with immense benefits if the one day strength is of high importance. However, it adversely affects the later age strength as compared to the standard curing techniques. Further, there are certain precautions which need to be taken before employing this technique, such as the proper determination of the setting time of concrete, the correct equipment to measure the enclosure as well as the concrete temperature, the proper maintenance of the heating cycle without exceeding the maximum prescribed temperature or the maximum rate of temperature rise prescribed.

It is of great economic value to the precast-prefabrication industry wherein the reduced cycle times are of immense importance.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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