Influence of casting and curing temperature on compressive strength of concrete

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Abstract – **This paper reports the results of a study conducted to investigate the effect of casting temperature under constant curing conditions on the compressive strength of concrete specimen of size 150x150x150mm made from PPC cement. The concrete specimens were cast at 15 °C,20 °C,25 °C,30 °C,35 °C,40 °C, and 45°C and cured by means of submerging them in curing tanks that were maintained at 30°C. Water-cement ratio adopted was 0.45. Compressive strength after 1day, 3day, 7day, 28 day and 56 day were evaluated and the results were plotted in graphical representation and in tabular form. The optimum casting temperature for the plain concretes was found by measuring compressive strength of concrete .The optimum casting temperature was noted to be 30°C for PPC cement concrete specimens.**

Keywords: Compressive strength, Casting and curing temperature, aggregates, water- cement ratio, slump, heat of hydration, rate of gain and loss of strength, optimum temperature.

I INTRODUCTION

Concrete is the second most consumed thing on this planet after water. Concrete is a composite material made up of cement, sand, coarse aggregates and water. There are many factors which affect the mechanical properties on concrete like casting temperature, composition ,curing temperature ,curing methods, presence of certain chemicals, external weather conditions etc.They may have different effect on initial strength and later age strengths .So it becomes important for us to investigate the effect of each factor individually so that concrete can achieve the required strength within proper time so that structure can handle the calculated load projected on it.Generally concrete is mixed and tested at a standard temperature in laboratory.But this temperature is quite different in fields especially in Indian subcontinent where temperature varies adversely generally ranging from even less than -20°C is few places to even greater than 50°C in few parts of India. Generally this factor is not considered during sites but has been observed that it can affect the strength of concrete at later stages adversely. So it becomes important for us to consider the effect of casting and curing temperature in our calculations so that the designed structure can attain the required strength after required time as per our need and as per our requirement.

The effect of higher casting and curing temperature results in higher rate of gain of initial strength but lower rate of gain of final strength. Higher temperature results in increase in the hydration process of cement due to which rate of reaction increases due to which gain of strength during initial stages increases. It is observed that higher casting temperature results in poorer structure which is filled with voids due to which the structure filled is incomplete and highly porous as the pores remain unfilled and due to absence of cement paste in these pores the strength as well as durability of concrete gets affected. It is also understood by gel/space ratio rule that higher temperature results in lower gel/space ratio due to which final strength is generally low. Higher temperature results in non-uniform distribution of hydration products within the cement paste as there is not much time available for the mixing of the hydration products due to which a porous C-S-H gel is formed which affects long time strength. High temperature during casting period generally decreases the dormant period so that the hydrated structure is formed very quickly which is not completely packed and a porous structure is formed due to which many properties gets affected like compressive strength, split tensile strength, bond strength, flexure strength, durability of concrete, density of concrete etc.

II MATERIALS

A) AGGREGATES Natural sand and crushed aggregates were supplied from a local supplier in Chandigarh only. The coarse aggregates used were of 20mm size only. Specific gravity of aggregates was 2.78, Bulk density of coarse aggregates was 1480 kg per m^3, Water absorption of coarse aggregates was 1.01%. Specific gravity of fine aggregates was calculated as2.64. and Zone of sand was Zone III.

B) CEMENT Cement used was PPC cement of Duraton brand. The cement was supplied by local supplier only. Being a PPC cement it had higher durability of concrete structure due to less permeability of water. More resistance towards the attack of alkalies , sulphates , chlorides and chemicals. Due to high fineness, PPC has better cohesion with aggregates. The Consistency of cement was found to be 32.5% and initial setting time was found to be 25 minutes.

C) CONCRETE Concrete grade of M25 was used. Since it was of M25 grade mix design had to be performed for this. Water cement ratio adopted was 0.45 and slump value taken was between 75-100mm for design purposes. Weight of coarse aggregate taken per m^3 was 1264.76 kgs and the weight of fine aggregates taken per m^3 was 646.32 kgs. Weight of cement taken per m^3 was 390kgs and weight of water taken per m^3 was 175.5 kgs.

III. CASTING OF SPECIMENS

Firstly initial setting time for cement has to be determined. For initial setting time of cement standard consistency of cement has to be determined.. After this initial setting time of cement was determined. After calculation of initial setting time of cement the materials were batched properly first and then transferred to a mixer for proper mixing. First dry mixing is done so that the ingredients are uniformly mixed in a mixer of 90 litre capacity. After that water is added and then wet mixing is done. After that the mixture is transferred to the mold and kept in vibrating table for vibration and then immediately the molds and then kept at the required temperature in the temperature regulator or oven for the time calculated previously from initial setting time calculation. After that they were taken out from the temperature controller and kept there for one day and after that the samples were kept undisturbed for this duration and after then they were demolded. For this study the cubical specimens were kept in temperature regulator at a temperature of 15°C,20°C,25°C,30°C ,35°,40°C and 45°C respectively for a time period of 25 minutes which was actually the initial setting time of the cement. A total of 105 cubical samples were cast overall during whole study. For each temperature a total of 15 samples were prepared as 3 samples were required to be tested in 1,3,7,28 and 56 days respectively.

IV. CURING PROCEDURE

After removing the cubical specimens from the molds after 1 day from taking out of the desired temperature from the temperature controller they were transferred to water bath/curing tanks and kept at a temperature of nearly 30°C.Since the temperature outside was quite high sometimes ,temperature in the curing tank fluctuated and in order to lower the temperature in the curing tank sometimes ice blocks had to be added as well as the fans were kept running in that room. The samples were kept there after demolding and were taken out after successive intervals of 1,3,7,28 and 56 days respectively and then put under compressive testing machine after drying it under fans for few minutes.

V. TESTING OF SPECIMENS

After keeping the specimens in temperature regulator for specified duration they were taken out and kept for few minutes to dry properly. Total of 3 cubical specimens of size 150x150x150mm were taken each time and put to testing and average of the given values were taken as the compressive strength of that specimens. The testing machine had the capacity of 300KN.Specimens were tested after 1,3,7,28 and 56 days respectively corresponding to 15,20,25,30,35,40 and 45°C respectively. After all the values of compressive strength was recorded a graph was plot between strength vs casting temperatures. Compressive strength experiment was as per IS 516:1959. All the materials used were in surface saturated dry state.

VI TEST RESULTS

A) Cubes cast at 15°C and cured at 30°C:

When the concrete specimens were cast at 15°C and cured at 30°C then 1 day strength that was noted was 10.67Mpa, 3 day strength of 13.27Mpa, 7 day strength of 19.02Mpa,28 day strength of 28.33Mpa and 56 day strength of 33.31Mpa. It was noticed that 28 day strength was almost 48% more of 7 day strength and 56 day strength was almost 21.10% more of 28 day strength.

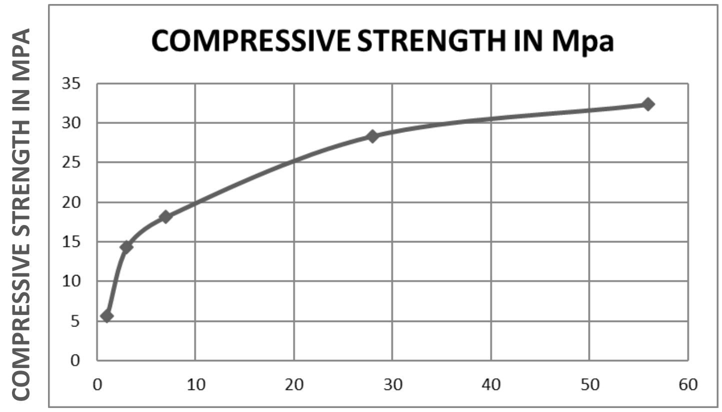


Fig 1 Compressive strength vs days graph for cubes cast at 15°C and cured at 30°C

B) Cubes cast at 20°C and cured at 30°C.

When the concrete specimens were cast at 20°C and cured at 30°C then 1 day strength that was noted was 11.733Mpa, 3 day strength of 15.68Mpa, 7 day strength of 21.58Mpa,28 day strength of 30.17Mpa and 56 day strength of 36.53Mpa.The 28 day strength was almost 44% more of 7 day strength and 56 day strength was almost 21% more of 28 day strength.

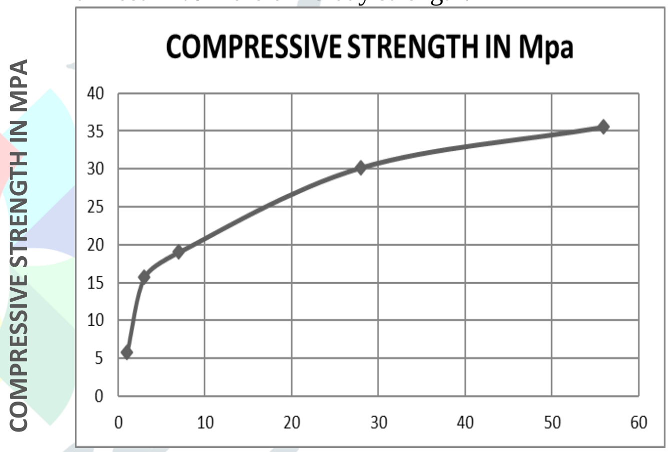


Fig 2 Compressive strength vs days graph for cubes cast at 20°C and cured at 30°C

C) Cubes cast at 25°C and cured at 30°C.

When the concrete specimens were cast at 25°C and cured at 30°C then 1 day strength that was noted was 12.58Mpa, 3 day strength of 16.59Mpa, 7 day strength of 23.65Mpa,28 day strength of 32.35Mpa and 56 day strength of 37.58Mpa. The 28 day strength was almost 36% more of 7 day strength and 56 day strength was almost 16% of 28 day strength 38.33Mpa.The 28 day strength was almost 39.84% more of 28 day strength and 56 day strength was almost 12.11% of 28 day strength.

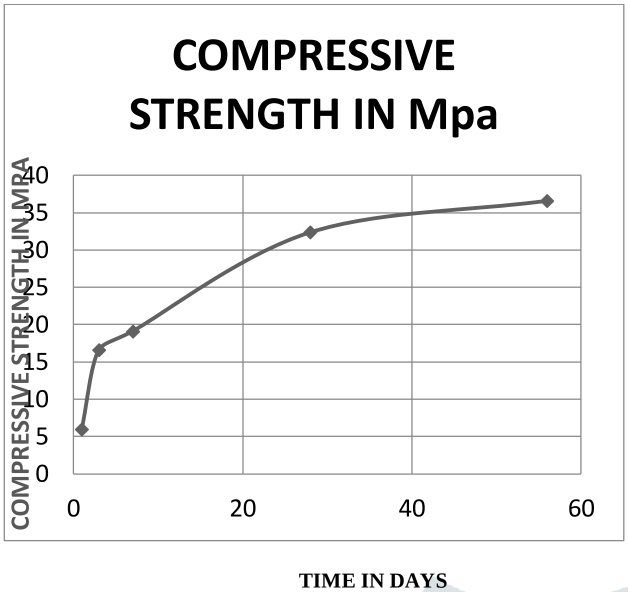


Fig 3. Compressive strength vs days graph for cubes cast at 30°C and cured at 30°C

D) Cubes cast at 30°C and cured at 30°C. When the concrete specimens were cast at 30°C and cured at 30°C then 1 day strength that was noted was 6.174 Mpa, 3 day strength of 17.56Mpa, 7 day strength of 22.22Mpa,28 day strength of 33.59Mpa and 56 day strength of 37.33Mpa.The 3 day strength was almost 52% of the 28 day strength and 7 day strength was almost 67% of 28 day strength.56 day strength was almost 11% of 28 day strength.

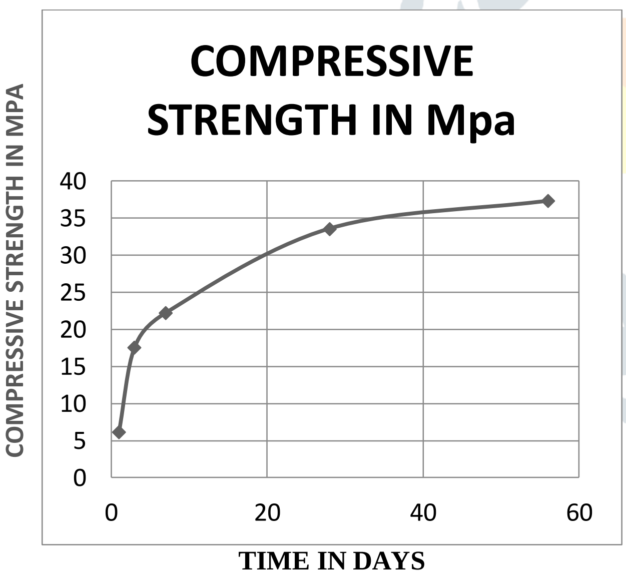


Fig 4 Compressive strength vs days graph for cubes cast at 3ZZ0°C and cured at 30°C

D) Cubes cast at 35°C and cured at 30°C.

When the concrete specimens were cast at 35°C and cured at 30°C then 1 day strength that was noted was 13.85 Mpa, 3 day strength of 18.44Mpa, 7 day strength of 25.95Mpa,28 day strength of 32.65Mpa and 56 day strength of 34.55Mpa.The 28 day strength was almost 25.68% more of 7 day strength and 56 day strength was almost 5.8% of 28 day strength.

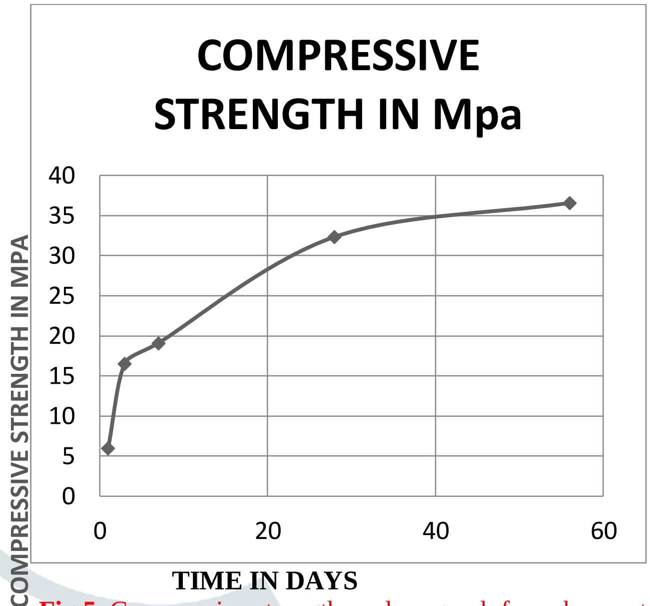
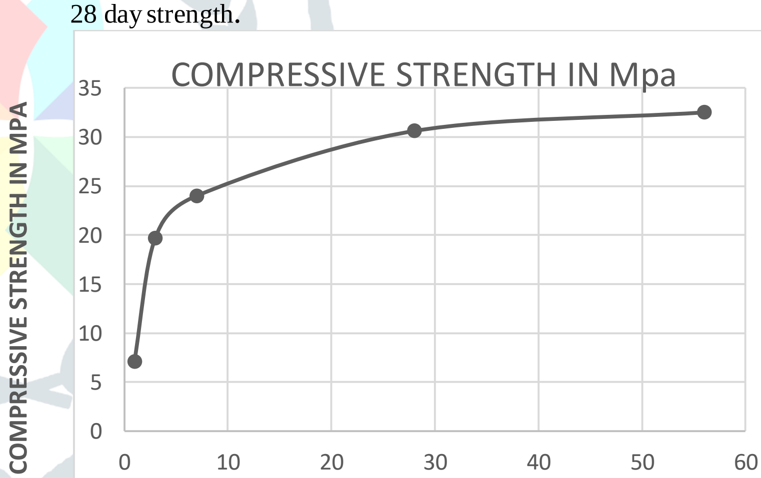


Fig 5. Compressive strength vs days graph for cubes cast at 35°C and cured at 30°C

E) Cubes cast at 40°C and cured at 30°C.

When the concrete specimens were cast at 30°C and cured at 30°C then 1 day strength that was noted was 14.02Mpa, 3 day strength of 19.67Mpa, 7 day strength of 26.52Mpa,28 day strength of 30.58Mpa and 56 day strength of 33.67Mpa.The 28 day strength was almost 15.3% more of 28 day strength and 56 day strength was almost 10.11% of 28 day strength.



TIME IN DAYS

Fig 6 Compressive strength vs days graph for cubes cast at 40°C and cured at 30°C

F) Cubes cast at 45°C and cured at 30°C.

When the concrete specimens were cast at 45°C and cured at 30°C then 1 day strength that was noted was 14.55 Mpa, 3 day strength of 20.22Mpa, 7 day strength of 27.50Mpa,28 day strength of 30.05Mpa and 56 day strength of 31.33Mpa.The 28 day strength was almost 84% 9.70% more than that of 28 day strength and the 56 day strength was almost 4.2%of 28 day strength.

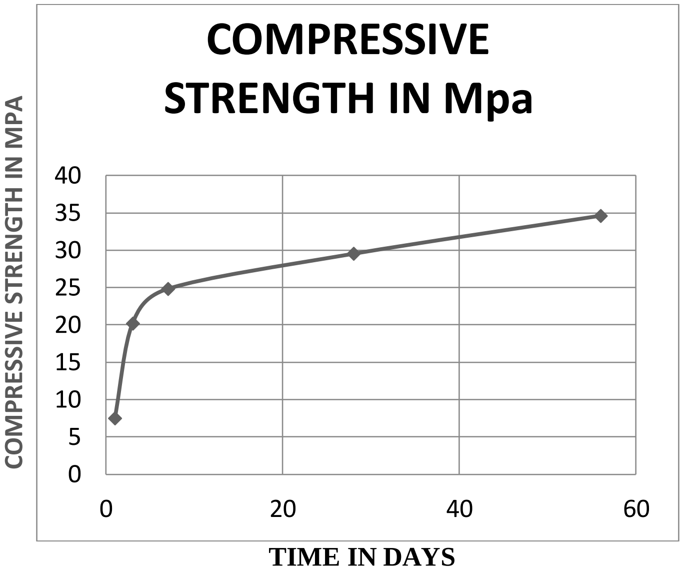


Fig 7. Compressive strength vs days graph for cubes cast at 45°C and cured at 30°C

VII ANALYSIS OF TEST RESULTS

The compressive strength of PPC cement concrete specimens at 15°C,20°C,25°C,30°C,35°C,40°Cand 45 °C and tested after 1,3,7,28 and 56 days of curing is depicted in Figure and table below respectively. The curing temperature was maintained at nearly 30°C.

Figures and table below show the variation of compressive strength with ages for specimens cast at a temperature of 15°C,20°C,25°C,30°C,35°C,40°C and 45°C.Generally it was observed that compressive strength increased with increase in casting temperature upto the initial stages i.eupto 7 days. But the results were very different after later stages i.e after 28 days and 56 days respectively. It was observed that the strength after 28days and 56 days reduced as increase in casting temperature was noted. It is quite clear from the figure below. As clear from the figure the compressive strength kept on increasing upto 7 days in all the cases of casting temperature. But decrease in final strength was recorded for cases in which casting temperature was increased above 30°C. Since alter age strength is much important than initial strength it can be observed that above 30°C the final strength will decrease as compared to the temperature below 30°C.Thus temperature of 30°C is the optimum temperature because at this temperature concrete is able to attain highest final strength as well as moderate initial strength.Very high casting temperature results in low final strength whereas very low casting temperature results in very low initial strength and moderate final strength. It can be easily understood from the table and figure given below:

TEMP.	1 DAY	3 DAY	7 DAY	28 DAY	56 DAY
15°C	10.67	13.27	19.02	28.33	33.31
20°C	10.73	15.68	19.45	30.17	35.53
25°C	10.98	16.57	20.48	32.35	36.58
30°C	10.17	17.56	21.02	33.59	37.33
35°C	10.67	18.44	21.95	32.45	35.55
40°C	11.12	19.67	22.52	30.65	32.55
45°C	11.55	20.22	23.86	29.55	31.67

Table 1 Compressive strength in Mpa vs time in days

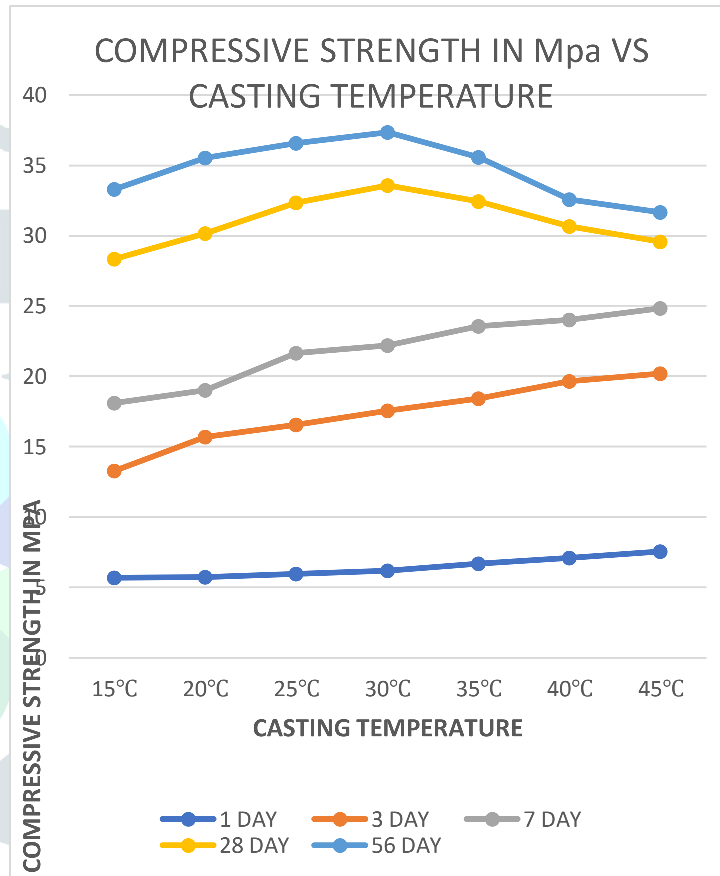


Fig 8.Compressive strength vs days

As clear from the given figure and table above it is clear that the compressive strength was found to be increased with an increase in the casting temperature during the early ages of up to 7 days. This increase in the compressive strength was due tothe increased rate of hydration of cement at high temperature. High temperature during casting period generally decreases the dormant period so that the hydrated structure is formed very quickly which is not complete.

It is observed that higher casting temperature results in poorer structure which is filled with voids due to which the structure filled is incomplete and highly porous as the pores remain unfilled and due to absence of cement paste in these pores Despite the fact that high concrete temperature influences the rate of setting and tends to enhance the early strength gain, it has an adverse effect on the later age (28 days onwards) strength . It is observed that higher casting temperature results in poorer structure which is filled with voids due to which the structure filled is incomplete and highly porous as the pores remain unfilled and due to absence of cement paste in these pores the strength as well as durability of concrete gets affected. It is also understood by gel/space ratio rule that higher temperature results in lower gel/space ratio due to which final strength is generally low. Higher temperature results in non-uniform distribution of hydration products within the cement paste as there is not much time available for the mixing of the hydration products due to which a porous C-S-H gel is formed which affects long time strength.

VIII CONCLUSIONS

From the given experimental work the following conclusion can be made:

1. The later age compressive strength increased with increase in casting temperature upto 30℃ only. After that the compressive strength decreased with increase in casting temperature for concrete specimens. But in later stages i.e after 28 days drop in compressive strength was noticed.It was due to the fact that with increase in temperature more porous microstructure is developed and C-S-H gel within the concrete in not uniform.
2. The optimum temperature found from experimental data was 30℃ as rate of gain of strength at later ages were higher as compared to other temperature.

ACKNOWLEDGEMENT

The authors would like to acknowledge the support of the National Institute Of Technical Teachers Training and Research Institute Chandigarh in providing materials, facilities and expertise to carry out this research.

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