Review on 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 15,20,25,30,35,40, and 45℃ and cured by means of submerging them in curing tanks that were maintained at 30℃. Water-cement ratio adopted was 0.45 and PPC cement was used .Compressive strength after 1day,3day,7day,28 day and 56 day were evaluated and the results were plotted in graphical representation for easy understanding. 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℃ for PPC cement concrete specimens.

Key words: compressive strength, casting and curing temperature, aggregates, water- cement ratio.

1. 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. When the cement reacts with water a hydration reaction takes place and product of hydrations are formed and after that it starts to harden.

Concrete is generally classified as normal concrete and special concrete. Normal concrete is the one which is made up of cement, sand, coarse aggregate mixed in suitable proportion with water to attain desirable strength. Special concrete is the one which has additional component called admixtures. Admixtures may be mineral or chemical admixtures. Admixtures are used to modify the properties of fresh and hardened concrete. Admixtures improves the strength, durability and workability of a concrete. The common admixtures are air entertaining admixtures, water reducing admixtures also called as plasticizers, retarders and accelerators.

Generally concrete is mixed and tested at a temperature of 27+2°C.But this temperature is quite different in-situ especially in Indian subcontinent where temperature varies adversely generally ranging from even less than 0°C is few places to even greater than 50°C in few parts of India. Generally this factor is not considered during sites but 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 design calculation so that the designed structure can attain the required strength after required time as per our calculations. The effect of higher casting and curing temperature results in higher initial strength but lower final strength. Higher temperature results in increase in the hydration process of cement due to which rate of reaction increases. 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 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

2. LITERATURE REVIEW

The quest of perfection has lead the mankind to look continuously for the improvements in existing technology in order to make it more and more fool proof for the coming ages. For any step that is to be taken, the knowledge of path and obstacles is imperative. The review of literature in the field of research serves the same purpose. The following section aims to show the effect of casting and curing of concrete at different temperatures on properties of concrete.

Burg, Ronald G., "The influence of Casting and Curing Temperature on the Properties of Fresh and Hardened Concrete", Research and Development Bulletin RD113, Portland Cement Association, Skokie, Illlinois, U.S.A., 1996 [1] reviewed the effect of casting and curing temperature on the properties of fresh and hardened concrete. The author casted and cured concrete of cylindrical shape of size 102x203mm.The author used casting/curing temperature of 23/23,32/32,10/10 and 23/10ºC respectively and noticed its effect on strength of 3,7,14,28 and 56 days. The studies revealed that concrete casted and cured at 23ºC has gained 75% of its 28-day strength at seven days for concretes that were casted and cured at 32ºC ,3 days compressive strength was 70% of 28 day compressive strength. Further, he noticed that the effect of low temperature casting and curing was lower early strength and higher later age strength and for concretes that were casted and cured at higher temperature was lower final strength but higher earlier strength.

Nasir, Muhammad & Al-Amoudi, Omar & Al-Gahtani, Husain & Maslehuddin, M. (2016). "Effect of casting temperature on strength and density of plain and blended cement concretes prepared and cured under hot weather conditions",Journal on Construction and Building Materials,pp.531-533,2016 [2] studied the effect of casting temperature on strength and density of plain and blended cement concretes prepared and cured under hot weather conditions. The specimens used by them were of 100mm cube and were casted at a temperature of 25,32,38 and 45ºC respectively. The compressive and split tensile strengths were recorded after 3,7,28,90,180 days. The studies revealed that compressive strength and tensile strength of the specimens increased with an increase in concrete casting temperature during the early ages of up to7 days. However, at later ages of 28–180 days, the strength increased upto 32-38ºC but decreased with further increase in temperature for an OPC temperature. This was due to the fact because with increase in temperature hydration process of the cement increased during initial days but after that it reduced because of the fact that increased rate of hydration resulted in formation of porous microstructure that resulted in non-uniform distribution of C-S-H gel which resulted in decrease of strength at later ages.

Ghani, U & Shabbir, Faisal & Khan, Kamran. ,"Effect of temperature on different properties of concrete", 31st Conference Our World in Concrete and Structures, pp 3-8,2006. [3] studied the effect of moisture and temperature on the mechanical properties of concrete. The authors casted cubes of size 152x152x152mm and tested M15,M20, M25 grade of concrete at a the temperature of 5,28 and 55ºC respectively at different water cement ratio. They concluded that increase in curing temperature resulted in higher initial strength but lower final strength which was due to the fact of increase in rate of hydration process during early stages but lower strength in final stages due to presence of porous structure due to which density decreases and hence strength decreases. Further, this effect was more pronounced in lower water cement ratio then higher water cement ratio.

Kim, Jin-Keun & Hun Han, Sang & Chul Song, Young," Effect of temperature and aging on the mechanical properties of concrete: Part I", Journal on Cement and Concrete ,Vol. 32.pp 1087-1094,2002[4] studied the effect of temperature and aging on the mechanical properties of concrete. The authors did their testing on cylinders of size 100x200 mm and tested the strength at 1,3,7 and 28 days. The cylinders were subjected to a temperature of 10,23,35 and 50ºC and were casted by assuming water-cement ratio of 0.50 and 0.40 respectively. The studies concluded that the 28- day compressive strength of concrete with water cement ratio of 0.40 was the highest and for the concrete cured at a temperature of 50ºC at 0.50 water cement ratio was the lowest. Similar results were noted for split tensile strength of concrete, Young's modulus and Poisson's ratio of concrete.

N. Shoukry, Samir & William, Gergis & Downie, Brian & Y. Riad, Mourad," Effect of moisture and temperature on the mechanical properties of concrete", Journal on Construction and Building Materials, pp 688-696,2011. [5] prepared cylindrical concrete sample of 0.15m diameter and 0.305m height and kept curing temperature variation between -25ºC to 55ºC.The author studied the effect of curing temperature variations on mechanical properties such as compressive strength, split tensile strength and modulus of elasticity of concrete. The results obtained by them matched with the results obtained from the previous studied. With increase in temperature and moisture content the compressive strength, split tensile strength and Modulus of Elasticity of concrete decreased. This was due to the fact that higher temperature reduces the final strength as more porous structure is formed which decreases the strength as well as durability of concrete.

Hayri and Bulent Baradan ,"The effect of curing temperature and relative humidity on the strength development of Portland cement mortar", Journal on Scientific Research and Essays Vol. 6(12), pp. 2504-2511, 2011. [6] prepared mortar samples of size 50 cubic and 40x40x160 mm prismatic mortars. The mortar mixture was prepared with water-cement ratio of 0.5 and sand/cement ratio of 3. The samples were cured at a temperatures of 4ºC at 75% relative humidity,15ºC at 75% relative humidity, 15ºC at 55% relative humidity,32ºC at 35% relative humidity and compressive and flexural strengths were recorded after 2,7,14,21 and 28 days. The author concluded that 28-day strength at 4ºC ,75% relative humidity was highest and 15ºC, 55% relative humidity was lowest. They concluded that both temperature and moisture conditions have adverse effect on the compressive as well as flexural strength of concrete as higher temperature increases initial strength but decreases the final strength.

Eren, Özgür. "Strength development of concretes with ordinary Portland cement, slag or fly ash cured at different temperatures", journal on Materials and Structures, Vol. 35, pp 536-540, November 2002 [7] casted cubes of size 100x100x100 mm and used 100% OPC,30% fly ash,50% fly ash and 50% OPC,30% slag and 70% OPC,50% slag and 50% OPC. The samples were cured at a temperature of 1,3,7,28 and 90 days for water-cured specimens at 6,20,35,60 and 80ºC respectively. For 100% OPC cement 90 day strength of concrete cured at 6ºC has higher strength than concrete cured at 80ºC.But the 7 day strength of concrete cured at 80ºC was higher than concrete cured at 6ºC whereas for other type of cements 90 day strength of concrete cured at 80ºC has higher initial as well as final strength than the concrete cured at 6 ºC. This was due to the effect of slag that was added to OPC which resulted in higher initial and final strength with increase in temperature whereas for 100% OPC the results matched with the previous researches.

Suwan, Teewara & Fan, Mizi & Braimah, Nuhu," Micro-mechanisms and compressive strength of Geopolymer-Portland cementitious system under various curing temperatures", journal on Materials Chemistry and Physics,pp 219-225, 2016[8] tested compressive strength of OPC cement, geopolymer portland cement and geopolymer cement specimens of size 40mm x 40mm x160mm size and subjected them to a temperature varying from 10ºC ,20ºC,30ºC.40ºC,50ºC,60ºC and 70ºC respectively for a period of 24 hours. The strengths of the sample were measured after 3 and 28 days respectively. At 3 day strength of OPC cured at 20ºC was 50 Mpa and for OPC cured at 70ºC was 54Mpa.The author also found that for OPC 28-day strength at 20ºC was nearly 65Mpa whereas at 70ºC was 61 Mpa which was lesser than 28 day strength measured on 28th day. They also concluded that for geopolymer Portland cement 28 day strength at 20ºC was 12Mpa and for 70ºC it was 60Mpa.This result was different from the results obtained for OPC cement because of addition of Polymer.Similar results were obtained geopolymer concrete as well.

Klieger Paul, "Effect of Mixing and Curing on strength of Concrete" , Journal of ACI, Vol 53 ,1958 [9]casted and cured concrete samples at temperatures of 40,55,73,90,105 and 120F and were tested at a age of 1,3,7, 28 days ,3 months and 1 year respectively .Three types of cement were used namely ASTM I,ASTM II,ASTM III and in all cases water cement ratio of 0.35 was used. For all cases 7-day strength for 73F temperature was lower than 120 F temperature but 28day strength of 73F temperature was much higher than 120F.The author also concluded that at 1,3 and 7days concrete strength increases with increase in casting and curing temperature of concrete but decreases the 3 month and 1 year strength considerably. Further, it was also concluded that temperature influenced the flexural strength developed similar to the results shown in the case of compressive strength development.

A. M. Neville ,"Properties of concrete",Fifth Edition ,chapter 8 , Pearson Publications. **[10]** explained that a rise in the curing affects increase the rate of hydration process. Although a higher temperature during placing and setting increases the very early strength, it may adversely affect the strength from about 7 days onwards. The explanation is that a rapid initial hydration appears to form products of a poorer physical structure, probably more porous, so that a proportion of the pores will always remain unfilled. It follows from the gel/space ratio rule, that this will lead to a lower strength compared with a less porous, though slowly hydrating, cement paste in which a high gel/space ratio will eventually be reached.

CONCLUSION

Testing of concrete is done in a controlled temperature which is generally 27 ±2 ºC which is very different from the actual conditions in our country where temperature may rise even above 45ºC due to which actual properties of fresh and hardened concrete gets affected adversely. Casting and Curing at higher temperature speed up the rate of chemical reactions of hydration and thus affects greatly the early strength of concrete. Higher temperature during the initial contact between the cement and water decreases the process time of the dormant period so that the overall structure of the hydrated cement paste establishes early than actual time. Though higher temperature during casting and curing increases the initial strength, it actually decreases the strength from 7 day onwards. This is due to the fact that rapid hydration results in poorer porous internal structure so that the pores always remains unfilled. Due to this compressive strength decreases with time as the structure is poorly densed internally. Higher temperature results in low gel/space ratio which is due to non-uniform distribution of product of hydration within the paste. Further, this effect was more pronounced in lower water cement ratio then higher water cement ratio. The studies showed that effect of temperature gets reduced by addition of slag or geopolymer combined with cement due to which effect on decrease of the later strength gets reduced.

REFERENCES

[1] Burg, Ronald G., "The influence of Casting and Curing Temperature on the Properties of Fresh and Hardened Concrete", Research and Development Bulletin RD113, Portland Cement Association, Skokie, Illlinois, U.S.A., 1996.

[2] Nasir, Muhammad & Al-Amoudi, Omar & Al-Gahtani, Husain & Maslehuddin, M. (2016). "Effect of casting temperature on strength and density of plain and blended cement concretes prepared and cured under hot weather conditions",Journal on Construction and Building Materials,pp.531-533,2016

[3] Ghani, U & Shabbir, Faisal & Khan, Kamran. ,"Effect of temperature on different properties of concrete", 31st Conference Our World in Concrete and Structures, pp 3-8,2006.

[4] Kim, Jin-Keun & Hun Han, Sang & Chul Song, Young," Effect of temperature and aging on the mechanical properties of concrete: Part I", Journal on Cement and Concrete ,Vol. 32.pp 1087-1094,2002

[5] N. Shoukry, Samir & William, Gergis & Downie, Brian & Y. Riad, Mourad," Effect of moisture and temperature on the mechanical properties of concrete", Journal on Construction and Building Materials, pp 688-696,2011.

[6] Hayri and Bulent Baradan ,"The effect of curing temperature and relative humidity on the strength development of Portland cement mortar", Journal on Scientific Research and Essays Vol. 6(12), pp. 2504-2511, 2011.

[7] Eren, Özgür. "Strength development of concretes with ordinary Portland cement, slag or fly ash cured at different temperatures", journal on Materials and Structures, Vol. 35, pp 536-540, November 2002.

[8] Suwan, Teewara & Fan, Mizi & Braimah, Nuhu," Micro-mechanisms and compressive strength of Geopolymer-Portland cementitious system under various curing temperatures", journal on Materials Chemistry and Physics,pp 219-225, 2016.

[9] Klieger Paul, "Effect of Mixing and Curing on strength of Concrete" , Journal of ACI, Vol 53 ,1958.

[10] A. M. Neville ,"Properties of concrete",Fifth Edition ,chapter 8 , Pearson Publications.