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Behavior of High Strength Concrete Subjected to Elevated Temperature

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Abstract: ***The High strength concrete defined as per IS 456 as the concrete having characteristic compressive strength more than 65 MPa. The concrete when subject to fire i.e. elevated temperatures loses its properties at a rapid rate. In the present investigation, ordinary vibrated concrete of M90 grade was developed as per the IS 10262. The hardened properties of concrete like compressive strength and split tensile strength were determined for concrete at ordinary temperature. The concrete specimens were subjected to elevated temperatures of 400°C, 600 °C, and 800 °C and then the specimens were brought to room temperature under different cooling regimes like air cooling and water quenching. The compressive residual strength of concrete was determined and a typical compared was made with the control specimen. The decrease in compressive strength of concrete at 800 °C was high compared to that at 400 °C.***

Keywords : High strength concrete, Elevated temperature, Normal concrete.

I. INTRODUCTION

Concrete is a material regularly utilized in building any structures. In case any sudden fire accident, the properties of concrete might change, like cracks may develop which then shortens the life of the structure due to the high temperatures caused during fire accident. So the design of structures with proper fire safety measures is a very important aspect that is being considered in recent times. The behaviour of concrete under fire depends upon the constituents of it i.e. aggregate, cement and other materials. Due to this there has been a lot of study on high performance concretes like Self- Compacting concrete (SCC), High strength concrete (HSC) which give high strength and many other advantages.

In recent past High strength concrete has gained importance and is being used widely instead of normal strength concrete. It is obtained by reducing the w/c ratio and increasing the aggregate content, cement content and other admixtures were added not to compromise on the strength of concrete.

To understand how concrete structures behave when exposed to high temperatures, the effect of temperatures on it has to be studied for various situations.

The difference in Compressive and Split Tensile Strength are some of the parameters that are studied when exposed to high temperatures.

Rama Seshu et al (2013) it was said that compressive strength has been reduced with rise in temperature. Higher strength loss was observed in SCC compared to NC irrespective of cooling regimes. N.Anand (2014) it as reported that the compressive, split tensile, flexural strengths of SCC have been decreased with the rise in temperature. The reduction of strength in SCC increased with increase in grade of concrete. M. S. Al-Lami et al (2017) it was reported that most SCC showed better performance that NC under 200°C, while at 300°C and 400°C the performance was less. Venkatesh Kodur et al (2014) reported that concrete undergoes many physical and chemical changes due to which properties change and also spalling in HSC occur when exposed to elevated temperatures. S. Hacemi et al (2014), performed tests on High Performance concrete (HPC), High Strength concrete (HSC) and Normal Strength concrete (NSC) from which he conclude that there has been slight improvement in strength until 400°C and after that temperature the strength has decreased irrespective of type of concrete. R Sri Ravindrarajah et al (2002) reported that there was about 90% loss of strength in HSC when exposed to 1000°C even when other binding materials were used in partial replacement of cement.

PRESENT STUDY

This study presents the properties of HSC when exposed to elevated temperatures. It mainly focuses on comparing the strengths of HSC at different temperatures under different cooling regimes. In this paper concrete of grade M90 was designed according to Indian standards [7]. In this study a total of 28 cubes of size 100x100x100mm and 28 cylinders of size 100x200mm were cast. The cubes and cylinders were made into different sets for testing at various temperatures and cooling regimes.

II. MATERIALS

a) **Cement:** In this study OPC of 53 grade of specific gravity of 3.141 confirmed to code IS: 269-2015[8] was used.

b) **Fly ash:** As this is a high strength concrete, fly ash was used which was procured from a local dealer. This fly ash was kept in oven for 48hrs at 102°C to get rid of the moisture content in it, sieved through 150microns and then used for the mixes as prerequisite.

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c) **Fine aggregate(FA)**: Sand which was used was sieved through 2.36mm sieve and confirmed to be of zone-III of specific gravity 2.48.

d) **Coarse aggregate (CA)** :Crushed stoned used was sieved through 10mm and retained on 4.75mm freed from all impurities and had a specific gravity of 2.64.

e) **Super Plasticizer**: High performance super plasticizer MasterGlenium SKY 8233 was used as admixture for the high strength NC to reduce to water content and to attain high strengths.

f) **Water:** The water available in the lab was used for all the mixes.

III. MIX PROPORTIONS

The proportion of mix for normal concrete is given in table-1. The water content for mix was taken as 0.32

Table-1 Mix proportions for NC

S.no.	Material per $1m^3$	kg/m^3
1	Cement	600
2	C.A	773
3	F.A	673
4	Water	196 lt
5	Fly ash	100
6	Super plasticizer	2.75 lt

A. Casting and Testing of specimens

The mould of standard size 100x100x100mm cube and cylinders of size 100x200mm was fit without gaps between the plates. All the materials were used as per the mix design for the calculated volume. Then the whole mix was put in a concrete mixture and mixed for 20 min until all the materials were uniformly mixed. After filling the moulds with concrete, they were put on a vibrating table for 2 min to eliminate any air voids present in the moulds. After 1 day, the casted cubes and cylinders are kept for curing for a period 28 days and then specimens were removed and dried for 1 day. Later they were heated at different temperatures 400^{o}C, 600^{o}C and 800^{o}C for 1hr i.e. after the necessary temperature was attained, the specimens were kept for 1hr and then cooled in 2 different ways (Air cooling and Water quenching). All the specimens were then tested for split tensile and compressive strengths and the values are listed in tables 2 and 3.

IV. RESULTS AND DISCUSSION

In this project, the specimens those were exposed to different temperatures and cooled by different regimes are tested for results. The cooling regimes are:

- **Room temperature** (reference specimens)
- **Air cooling (AC)**: Specimens that were heated are taken out and let to cool naturally at room temperature.
- **Water quenching (WQ):** After the specimens were heated, they were put immediately in water for 1 day then removed and air dried to be tested.

The change in Compression and Split Tensile strength of HSC that are exposed to high temperatures and cooled by different regimes are shown in the fig. 1-4.

A. **Temperature effect on Concrete**: From the tables 2&3 it can be clearly indicated that, due to rise in temperatures there has been a consistent reduction in the strength of concrete except for 400^{o}C where there is a minute increase in strength.

a) **Split Tensile strength:** Table 2 shows the Tensile strength of concrete which was calculated by taking an average of 4 test specimens (cylinders) for each cooling regime at certain temperature. There has been a significant loss in strength of concrete with rise in temperature. Till 400^{o}C the loss in strength was about 18% and for 600^{o}C and 800^{o}C the loss in strength is about 33% and 64% respectively.

b) **Compressive strength:** The results shown in table 3 indicate compressive strength, which was calculated by taking average of 4 test specimens (cubes) for each cooling regime at a particular temperature. The strength of concrete has slightly increased at 400^{o}C irrespective of the cooling regime and after 400^{o}C the strength has decreased consistently with a low of 40% of the initial strength. The increase in strength till 400^{o}C might be due to the expulsion of water in the cubes.

B. Cooling regime effect on Concrete

As mentioned, the cubes and cylinders after heating are cooled by 2 regimes and the Split tensile and compressive strength variations of concrete are shown in tables 2&3.

a) **Split Tensile Strength:** The Tensile strength of HSC shown in table 2 where the performance of concrete by air cooling regime has been better when compared to water cooling regime. The strength at 400^{o}C, 600^{o}C and 800^{o}C has decreased by 5%, 24% and 7% respectively in water quenching regime compared to air cooling regime.

b) **Compressive Strength:** The compressive strength values are listed in table 3, from which we can tell that, the performance of concrete by air cooling regime has been better when compared to water cooling regime. The strength at 400^{o}C, 600^{o}C and 800^{o}C has decreased by 8.3%, 14.5% and 15% respectively in water quenching regime compared to air cooling regime.

Table 2-Split Tensile Strength

Temp in (^{o}C)	Split Tensile Strength (MPa)		Loss of strength (%)	
	Air cooling	Water quenching	AC	WQ
Room temp.	4.89	4.89		
400	3.98	3.76	18	23
600	2.66	2.02	45	58
800	0.95	0.89	80	81

Table 3-Compressive Strength

Temp in (°C)	Compressive strength (MPa)			
	Air cooling	Water quenching	Loss of strength (%)	
Room temp.	97.79	97.79	AC	WQ
400	107.36	98.39	-9.7	-0.6
600	77.41	65.87	20	32
800	41.5	35.23	57.5	64

The figure 1-4 indicates Compressive and Split tensile strength of HSC subjected to elevated temperature and cooled by different cooling regimes.

Figure-1 Compressive strength by AC

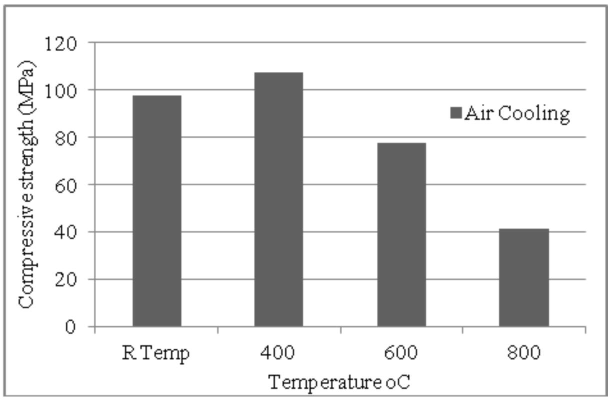


Figure-2 Compressive strength by WQ

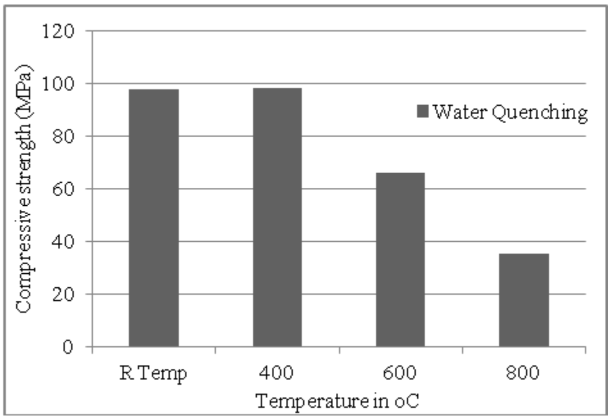


Figure-3 Split Tensile strength by AC

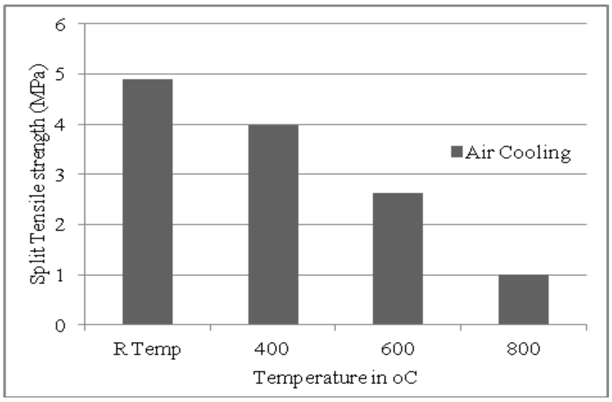
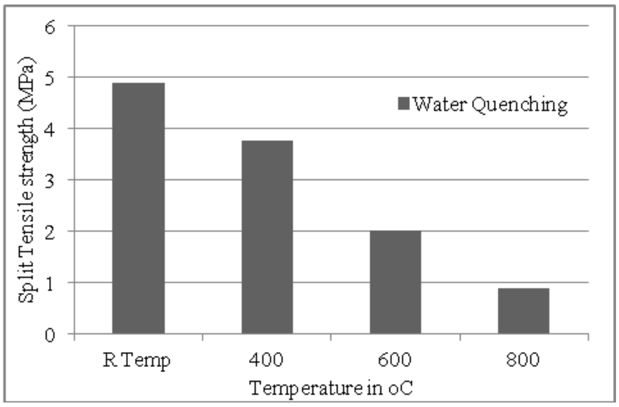


Figure-4 Split Tensile strength by WQ



V. CONCLUSIONS

From this study the subsequent conclusions are drawn:

- 50mm slump was obtained when tested for fresh properties immediately after mixing.
- In the case of air cooling regime compressive strength has increased from room temperature to 400°C, at this temperature the strength has increased by 9% and then has decreased significantly from 600°C for air cooling regime. This is similar in the case of water quenching.
- Split tensile strength, has decreased with rise in temperature irrespective of cooling regimes.
- Specimens when left to cool by itself (air cooling) at room temperature, has showed better performance compared to the specimens that were cooled by water quenching regime. This has been same for both compressive and Split tensile strength.
- HSC has shown increase in strength till 400°C and after that with rise in temperature there has been sharp reduction in strength of concrete.

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