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EFFECT OF ELEVATED TEMPERATURE ON COMPRESSIVE STRENGTH OF CONCRETE

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Abstract: *Concrete undergoes significant change when exposed to high temperature resulting in changing in structural properties. A research program was carried out to investigate the compressive strength after heating of air and water cooled concrete in addition to polypropylene fiber. The concrete were subjected to temperature of 30°c, 100°c, 300°c, 500°c, 600°c, 700°c and 800°c in muffle furnace with exposure duration of 30 mints, 1hour, 2 hour and 4 hour with and without polypropylene fiber and they were cooled by two cooling regimes: water and air. Water cooling, which resulted in a significant thermal shock, bit severe deterioration in compressive strength at 700°c and 800°c compared to air cooling. Experimental results indicate that compressive strength may decreases with increasing the temperature and exposure duration. Also it indicates that the use of polypropylene fiber is required to prevent the spalling of concrete when exposed to elevated temperature.*

Keywords: *Thermal properties, Compressive Strength, elevated Temperature, Fire Induced spalling*

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INTRODUCTION

Concrete is a composite material composed of crushed stones (coarse aggregate), sand (fine aggregate) and hydrated cement (binder). Concrete with some additives has been used in special structures, such as nuclear reactors and storage tanks for crude oil and hot waters, whereas concrete subjected to elevated temperature, silica fume is being strongly suggested as admixture to improve the properties of concrete in general and its durability in particular. M-20 grade of concrete can be used at the residential buildings, public buildings. Exposure to fire is undoubtedly the most destructive process that a concrete structure can be subjected to during its service life. The resistance of concrete depends on the duration of fire and the exposure temperature. The processes of heat penetration into a concrete mass are extremely important. Under high temperature effect, chemical composition, physical structure and moisture content of concrete changes. Heating to high temperatures causes the dehydration of hardened cement paste and conversion of calcium hydroxide into calcium oxide in which chemically bound water is gradually released to become free water. Aggregates also lose their evaporable water and hydrous aggregates dehydrate at high temperatures, and undergo crystalline transformation accompanied by a significant volume expansion. The thermal conductivity of concrete depends on the conductivity of its constituents, namely the cement paste and the aggregate. Concrete conductivity in general is known to decrease with increased temperature. The thermal conductivity of concrete at elevated temperatures is affected by two main factors as the type of aggregate and the moisture content of the concrete.

CONCRETE AT ELEVATED TEMPERATURE

Concrete is an organic material. At higher temperature the strength and durability of the concrete get decreases. At high temperature spalling of concrete occur. Spalling is the phenomenon in which chunks of concrete fall off from the surface of a concrete structure when exposed to high and rapidly rising temperature. Spalling in concrete is a complex phenomenon and is primarily dependant on the rate of temperature rise (fire scenario, thermal gradients) permeability typically related to strength and extent of silica fume and other conditions geometry, aggregate type, and moisture content. Spalling occurs when the pore pressure in a concrete layer, due to evaporated moisture, exceeds the tensile strength of concrete.

Fire resistance of concrete is affected by factors like temperatures, duration and condition of the fire. The type of materials used in the construction has porosity and moisture content of concrete, its thermal properties and the size of structural member and the type of construction determines the fire resistivity of the material and increase in the size of structural member that increase the fire resistance. To determine the resistance of the concrete samples exposed to high temperatures and in order to determine the compressive strength of concrete at elevated temperatures.

Hence, it is important to understand the changes in the concrete properties due to its exposure to extreme temperatures.

SIGNIFICANCE OF THE WORK

The present work focuses on study of compressive strength of concrete subjected to elevated temperatures, effect of cooling regime on strength of normal concrete at elevated temperatures. In this project the compressive strength of normal M-20 grade concrete in addition to polypropylene fiber at temperature 30°C, 100°C, 300°C, 500°C, 600°C,7 00°C and 800°C is tested with the different type of cooling air and water quenching.

SYSTEM DEVELOPMENT

M-20 grade of concrete is normal Concrete in its plastic state. As per IS 10262:2009 the mix shall be designed to produce the required grade of concrete having the designated workability, and characteristic compressive strength, which will not be less than the appropriate values. The required mix design will be obtained by changing the corresponding values with respective area. Then we can obtain the required mix design for M-20 grades of concrete. .

The mixes properties constituents are reported in table,

Material	Cement	Sand(FA)	Aggregate (CA)	Water
Kg/m3	383	728.22	1104.69	192

The three concrete cubes with and without polypropylene fiber of size 150mm x150mmx150mm were casted with above proportion and tested after 7 days of curing for compression. The experimental program is performed to investigate the behavior of concrete at elevated temperature for 30 minute, one hour, two hour, and four hour, and then cooled by different cooling types. The specimens are heated up to 30^0C, 100^0C, 300^0C, 500^0C, 600^0C, 700^0C and 800^0C, and the temperatures are measured and recorded at different time. The specimens cooled to room temperature by two methods, namely water cooling and air cooling.

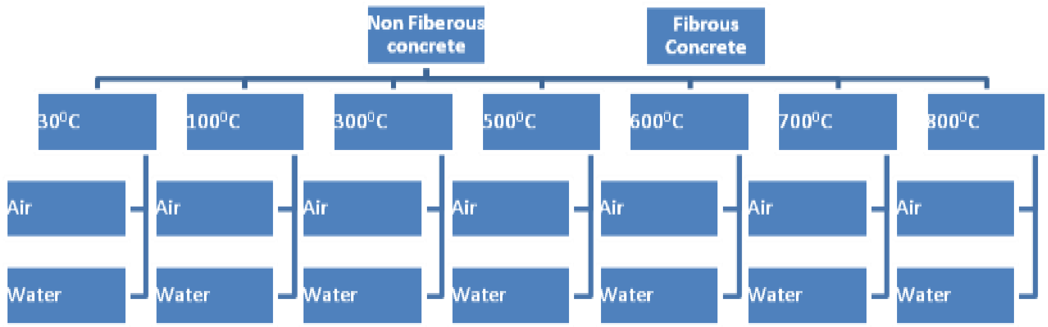
Heating Procedure

At the designated curing age the specimens were taken out and heated to 30 ºC, 100ºC, 300ºC, , 500ºC, 600ºC, and 800 ºC,) with and without polypropylene fibers in an muffle furnace. The heating rate will be 5 ºC for 30 mint, 1 hr, 2 hrs & 4hrs exposure to temperatures in the furnace.

Temperature Range	Changes
20-200^{0}C	slow capillary water loss and reduction in cohesive forces as water expands
300-400^{0}C	break up of some siliceous aggregates (flint)
400-500^{0}C	portlandite decomposition
500-600^{0}C	573^{0}C quartz phase change in aggregates and Sands
600-800^{0}C	second phase of the C-S-H decomposition,(calcium silicate hydrate)

Test Procedure

The following flow charts show the test procedure.

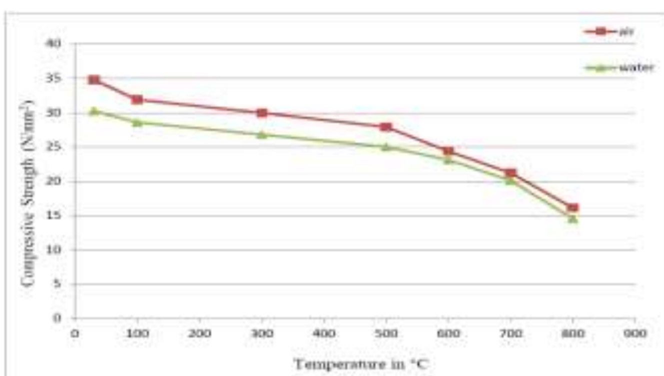


RESULTS & DISCUSSION

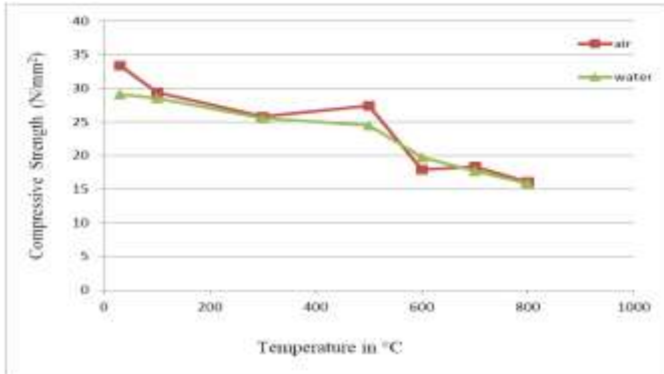
To study the performance of modified M-20 grade of concrete with and without polypropylene fiber at 7 days curing. The performance of each modified concrete were analyses based on compressive strength of concrete.

TABLE 1. Compressive Strength of Non Fibrous & Fibrous Concrete for 30 Minute

Sr. No.	Type of cooling	Temperature (°C)	Average Compressive Strength (N/mm^2)	
			Non Fibours concrete	Fibrous Concrete
1.	Water Quenching	30	30.23	29.11
	Air		34.78	33.42
2.	Water Quenching	100	28.58	28.52
	Air		31.89	29.40
3.	Water Quenching	300	26.78	25.56
	Air		29.96	25.81
4.	Water Quenching	500	25.01	24.54
	Air		27.89	27.40
5.	Water Quenching	600	23.12	19.76
	Air		24.34	17.90
6.	Water Quenching	700	20.10	17.70
	Air		21.21	18.34
7.	Water Quenching	800	14.55	15.85
	Air		16.11	16.70



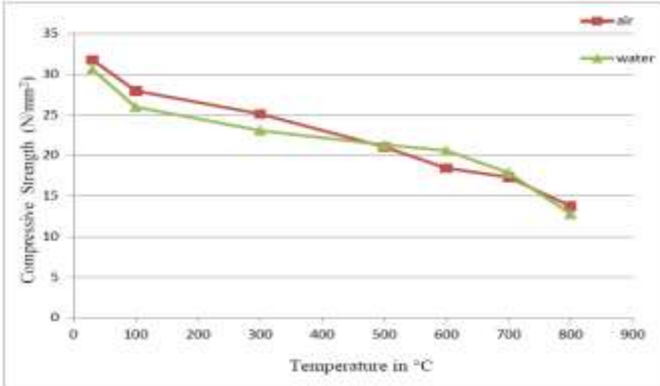
Compressive strength of M-20 grade concrete for 30 minute



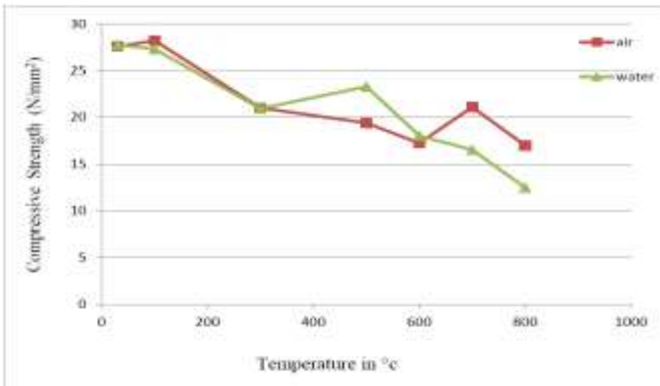
Compressive strength of M-20 grade with PPF for 30 minute

TABLE 2. Compressive Strength of Non Fibrous & Fibrous Concrete for 1 hour

Sr. No.	Type of cooling	Temperature (°C)	Average Compressive Strength (N/mm²)	
			Non Fibrous concrete	Fibrous Concrete
1.	Water Quenching	30	30.59	27.77
	Air		31.78	27.60
2.	Water Quenching	100	25.96	27.31
	Air		27.96	28.21
3.	Water Quenching	300	23.06	20.94
	Air		25.11	21.02
4.	Water Quenching	500	21.31	23.29
	Air		21.05	19.41
5.	Water Quenching	600	20.58	18.04
	Air		18.42	17.24
6.	Water Quenching	700	17.86	16.53
	Air		17.32	21.11
7.	Water Quenching	800	12.79	21.50
	Air		13.75	16.99



Compressive strength of M-20 grade concrete for 1 hour

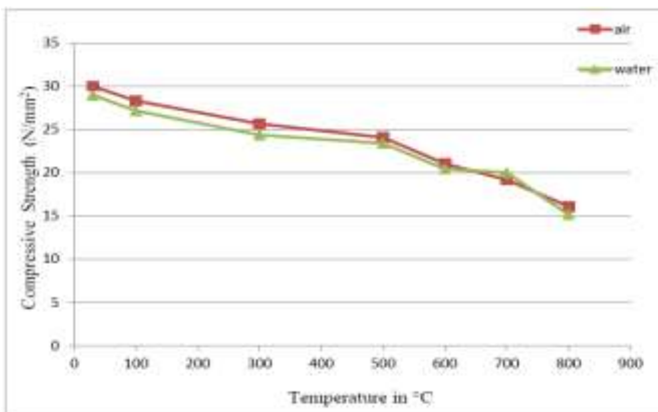


Compressive strength of M-20 grade with PPF for one hour

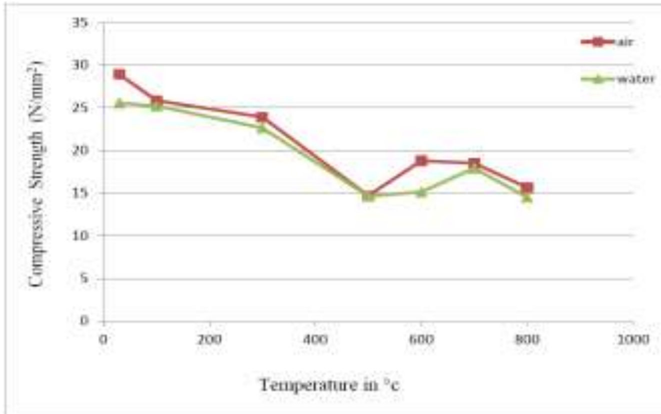
TABLE 3. Compressive Strength of Non Fibrous & Fibrous Concrete for 2 Minute

Sr. No.	Type of cooling	Temperature (°C)	Average Compressive Strength (N/mm^2)	
			Non Fibrous concrete	Fibrous Concrete
1.	Water Quenching	30	28.99	25.57
	Air		30.01	28.92
2.	Water Quenching	100	27.16	25.21
	Air		28.32	25.85
3.	Water Quenching	300	24.36	22.64

	Air		25.65	23.91
4.	Water Quenching	500	23.40	14.65
	Air		24.07	14.69
5.	Water Quenching	600	20.44	18.13
	Air		21.03	18.79
6.	Water Quenching	700	20.02	17.92
	Air		19.20	18.50
7.	Water Quenching	800	15.14	14.53
	Air		16.08	15.66



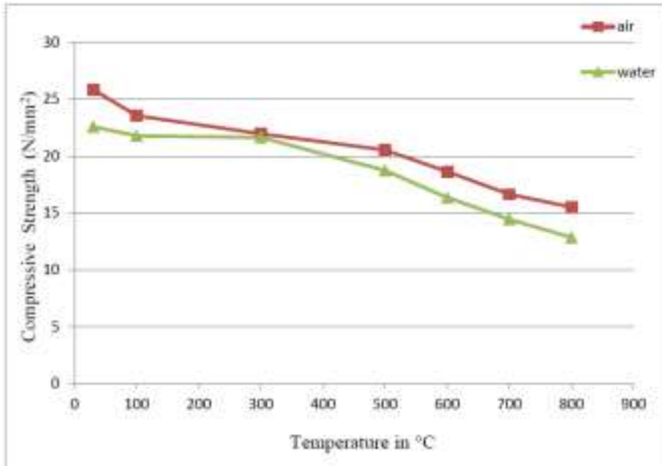
Compressive strength of M-20 grade concrete for 2 hour



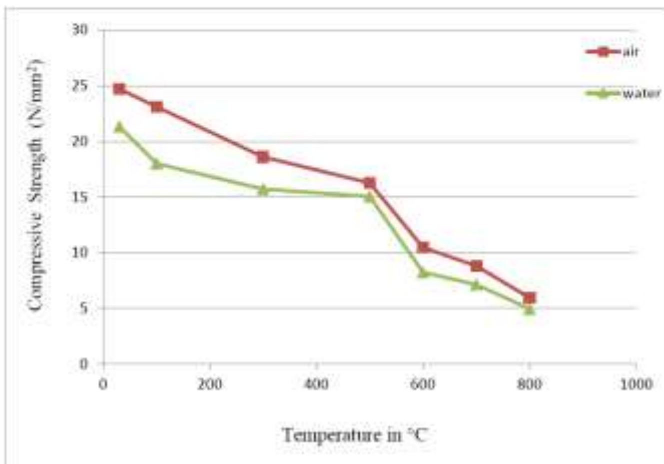
Compressive strength of M-20 grade with PPF for 2 hour

TABLE 3. Compressive Strength of Non Fibrous & Fibrous Concrete for 4 Minute

Sr. No.	Type of cooling	Temperature (°C)	Average Compressive Strength (N/mm^2)	
			Non Fibrous concrete	Fibrous Concrete
1.	Water Quenching	30	22.58	21.33
	Air		25.86	24.72
2.	Water Quenching	100	21.78	17.99
	Air		23.56	23.10
3.	Water Quenching	300	21.64	15.72
	Air		21.96	18.60
4.	Water Quenching	500	18.75	15.05
	Air		20.54	16.26
5.	Water Quenching	600	16.36	8.23
	Air		18.65	10.48
6.	Water Quenching	700	14.45	7.14
	Air		16.65	8.80
7.	Water Quenching	800	12.86	4.96
	Air		15.30	5.96



Compressive strength of M-20 grade concrete for 4 hour



Compressive strength of M-20 grade with PPF for 4hour

The above results for compressive strength of M20 grade concrete are obtained, when the given concrete specimens is heated at an elevated temperature of 30ºC, 100ºC,300ºC,500°,600°,700°and 800°for 30 minutes, 1hour , 2 hour, 4hour cooled by water quenching and air up to room temperature. These concrete specimens were cured at 07 days under submerged condition in water tank.

CONCLUSIONS

- Concrete specimen when cooled from 800^{0}C to room temperature of different heating time percentage reduction in compressive strength is 5.45% to 51.86% for water quenching and 8.30% to 53.68% for air cooling with respectively.

- Concrete specimen with PPF when cooled from 800^{0}C to room temperature of different heating time percentage reduction in compressive strength is 1.65% to 54.98% for water quenching and 2.21%, to 38.44% for air cooling with respectively.
- Concrete strength decreases with increasing temperature
- Compressive strength in air cooling is higher than in water cooling.

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