IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 3 Ver. VII (May - June 2017), PP 60-64
www.iosrjournals.org

Experimental Study on Strength Reduction Factor in Concrete Specimen Subjected To High Temperature

K.Thamaraiselvan[1], V.Jeevanantham[2], A.Parthiban[3]
[1,2]*Dept of Civil Engineering, Panimalar Engineering college, Nazarethpettai,Chennai-123*
[3] *Assistant Professor-Dept of Civil Engineering, Panimalar Engineeringcollege, Nazarethpettai, Chennai-123*

Abstract: *The concrete loses its strength and stiffness when exposed to high temperatures as they accumulate damage. The primary question remaining after a exposure to high temperature is what level of residual strength and the stiffness exists for material. This residual strength is particularly important for high-rise structures where post-fire decision-making hinges on functionality of the columns. This study specifically addresses the experimental program carried out to assess the residual compressive strength of cube specimens. Three type of concretes viz normal , high strength and fly ash concrete specimens were considered. These specimens are tested in two separate condition states. The first representing air-cooled state involves heating the specimen to the required temperature for prescribed duration and air cooled to the room temperature. Phase two involves heating the specimen to the required temperature for the prescribed duration and immediately cooled to the room temperature by immersing it in the water or called water quenched. The strength and stiffness degradation of concretes for various grades has been studied and compared with the similar studies carried by other researchers.*

Keywords*: residual strength, fire resistance, elevated temperatures, exposed duration,*

I. Introduction

In general concrete was good in resisting high temperature. In situations like fire accidents the concrete was exposed to high temperatures above 200° to 300° C, the concrete tends to loose its strength and stiffness depending on the temperature, the exposed duration. The different types of structural concrete have been used in the modern construction viz normal, high strength and fly ash concrete. The behaviour of these concretes when exposed to high temperatures has significance in design to safely withstand the effect of high temperature loads in addition to sudden cooling by spraying water on heated specimens such as quenching. The slender columns of high-rise buildings made of high strength concretes are vulnerable for the progressive collapse of the structure itself due to the effect of high temperature exposure. The primary question remaining after a fire accident scenario is what level of residual load carrying capacity and the stiffness exists for the concrete member. The residual strength is particularly important for high-rise structures where post-fire decision-making situations hinges on the overall functionality of the columns. The recent codes such as IS have made progress towards designing the structure for the possible exposure to high temperatures in the concrete structural elements. Unless complete failure occurs in the structural element, concrete subjected to high temperature has some level of residual strength and stiffness. Quantifying this level of residual strength and stiffness for various grades of concrete has seen significant treatment in current research. Chakrabarti et al [1] and many researchers have looked at the issue of residual strength, defined it as the level at which a concrete structure fails to carry its prescribed dead load. Studies during heating along with the loads were carried out by Carlos Castillo and AJ Durrani [2], as well as several other types of transient load strategies. Gowripalan et al [3], Phan et al [4] has carried out experiments on transient and residual strengths of high performance concrete subjected to high temperatures and recommended the modified reduction factors. Phan et al [4] studied the residual strength and deformation characteristics of high performance concrete specimens. Kumar et al [5] conducted an experimental and analytical program to investigate the residual capacity. The experimental results showed greater strength and stiffness degradation after exposed to high temperature. This study focus on the residual strength and stiffness degradation of three types of concretes made of Indian cements and fly ash. The specimens were exposed to high temperature and tested for the residual compressive strength. In this paper, an experimental work carried out on the three types of concretes exposed to high temperatures in addition to quenched specimens was presented.

II. Experimental Details

Materials and Mixture proportions:

Three types of concrete mixes representing ordinary, normal, and fly ash concretes are considered for the study. Crushed granite (specific gravity of 2.65) having the maximum aggregate size of 20mm and river sand (specific gravity 2.62)were used as coarse aggregate and fine aggregate respectively. In this investigation for all the mixes ordinary Portland cement of grade 53 confirming to IS12269 (1987), was used. The details of the mix proportion are shown in Table.1.

Table 1 Mix Proportions

Identification	Cement (kg/m^3)	River sand (kg/m^3)	Coarse aggregate (kg/m^3)	Fly ash (kg/m^3)	w/c ratio
Ordinary	380	540	1140	-	0.45
Normal	380	540	1140	-	0.45
Fly ash concrete	264	540	1140	116	0.45

The concrete mixtures were produced in a drum-type mixer. Freshly mixed concrete was used to cast a number of test specimens (standard cubes, cylinders and beams) in steel moulds. A table vibrator was used to achieve full compaction for the moulded test specimens. The specimens used for compressive strength was 150mm cubes and 150mm diameter by 300mm long cylinders. The number of cylinders and cubes tested for each mix are shown in Table 2.

Table 2 Specimen Details

Identification	**No. of specimen**					
	Temperature (°C)					
	Room	200	400	600	800	1000
Air cooled	6	6	6	6	6	6
Quenched	3	3	3	3	3	3

III. Experimental Procedure

All concrete test specimens were demoulded after 24 hours and stored in water at 20°C. At the age of28 days, the specimens were removed from water and surface dried. Then the specimens were subjected to temperatures of 200ºC, 400ºC, 600ºC, 800ºC, and 1000ºC in an electric furnace. The test specimens were removed from the furnace after 2 hours and quenched in a water tank toprovide the maximum thermal shock due to sudden cooling. A number of tests were conducted withthe test specimens to determine the weight changes, ultrasonic pulse velocity, compressive strength,indirect tensile strength and dynamic modulus of elasticity. The split cylinders were used to study thevariations in the colour of concrete due to heating to different maximum temperatures.

IV. Equipment For Heating Of Specimens

The high temperature setup involved an electrical furnace capable of heating up to 1200ºC has a compartmental dimension of 1.0 x 0.8 x 2.0 m. The electrical furnace has thermocouple controller, which was used to measure and control the temperature rise. The steady state condition has been maintained in the furnace chamber for the desired duration by thermocouple-based instrumentation.

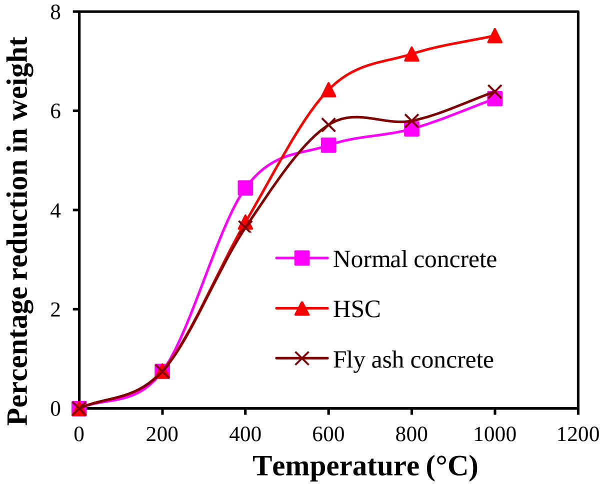
The specimens were placed inside the furnace chamber such a way that the specimens are heated by exposing almost on all the faces of the specimen by means of inner chamber arrangements. This setup has provisions to with stand the pressure of exploding /spalling nature of high strength concrete. Extreme care was taken when handling the heated concrete specimens.The electrical furnace with the heating arrangement is shown in the Figure. 1

Figure 1 Electrical Furnace

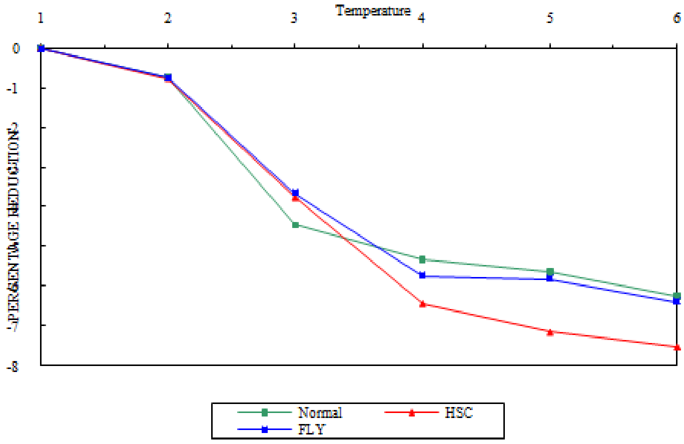
V. Results And Discussion

5.1 Weight changes in concrete on heating and cooling

The observed weight reduction of the three types of concretes subjected to high temperatures in addition to quenched specimens was shown in Table 4.



At 200°C, it was observed that the weight reduction was only 0.75 to 0.8% that is practically negligible. However at 400°C, the loss of weight for high strength concrete is more than the other types of concrete. The same trend continued for higher temperature ranges of 1000°C. The variation of the weight reduction of specimens' made of different types of concretes exposed to high temperature was shown in Fig.3.



5.4 Residual Strength

The specimens exposed to high temperature were removed from the furnace and air cooled to the room temperature. These were weighed in an electronic balance and rebound hammer test was conducted and then the specimens were tested to determine the compressive strength. The compression test was carried out as per Indian standard specification. Standard rate of loading was applied till the crushing of the specimens. All the specimen of different types of concrete was tested for its ultimate compressive strength in the similar method in the same machine including the specimens that are quenched in the water immediately after the exposure of high temperature. The observed residual strength of the cube specimens are shown in Table 4.

Table 4 Residual Strength of Cube Specimens

Temperature (°C)	Normal Concrete		High Strength Concrete		Fly ash concrete	
	Air Cooled	Quenched	Air Cooled	Quenched	Air Cooled	Quenched
0	55.11	55.11	76.44	76.44	53.33	55.00
200	51.55	52.22	56.00	50.67	45.77	50.00
400	36.44	38.22	43.55	41.77	41.77	36.89
600	26.57	29.33	32.00	32.88	31.11	33.77
800	19.11	21.33	17.78	25.77	25.77	21.33
1000	17.7	17.77	7.77	8.65	21.33	17.78

It was observed from Fig.4 that the residual compressive strength of the concrete specimens reduced when subjected to high temperature exposure. At 200°C this reduction was observed to be in the range of about 10% for all types of concrete specimens. At 400°C the reduction was observed as 20% for all types of concrete other than the high strength concrete. The high strength concrete specimens were observed with more reduction of about 25% and about 30% more than the normal and fly ash concrete specimens. At 600°C the high strength concrete specimens were observed to have a reduction of about 40% higher than the normal and fly ash concrete specimens. At 800°C and 1000°C the high strength concrete has almost looses all its strength and the residual strength is practically negligible when compared to its original strength. Whereas the fly ash and normal strength concrete was observed to have some resistance to the high temperature and still about 20 to 30% of original strength is remained as residual strength. Other researchers like Phan et al stated in their publications a similar observation. Hence it was concluded that the high strength concrete was found to have less resistance to high temperatures when compared to the normal strength and fly ash concrete types. The correlation and the proposed residual strength calculation may be made by the equation for the different types of concrete. The proposed equation has very well agreed with the similar model of equations proposed by the earlier researchers such as Phan et al. The values residual strength of these specimens were shown in Table.6.

Table 6 Residual Strength Reduction Factor

Temperature (°C)	Normal Concrete		High Strength Concrete		Fly ash concrete	
	Air Cooled	Quenched	Air Cooled	Quenched	Air Cooled	Quenched
0	55.11	55.11	76.44	76.44	53.33	55.00
200	51.55	52.22	56.00	50.67	45.77	50.00
400	36.44	38.22	43.55	41.77	41.77	36.89
600	26.57	29.33	32.00	32.88	31.11	33.77
800	19.11	21.33	17.78	25.77	25.77	21.33
1000	17.7	17.77	7.77	8.65	21.33	17.78

In the case of specimens quenched immediately in the water after exposed to high temperature was witnessed about 10 to 15% more strength reduction than the air-cooled specimens. This range was still higher as about 20% in the case of high strength concrete specimens. This observation also has very well correlated with the earlier studies. Particularly the quenching after high temperature ranges of 800 and 1000 C the concrete specimens releases fumes that may be harmful. The residual strength was practically negligible in such high strength concrete specimens exposed temperatures of this range. However the fly ash concrete specimens and normal strength concrete specimens were found to be better in case of sudden quenching of the specimen in water after exposure to higher temperatures.

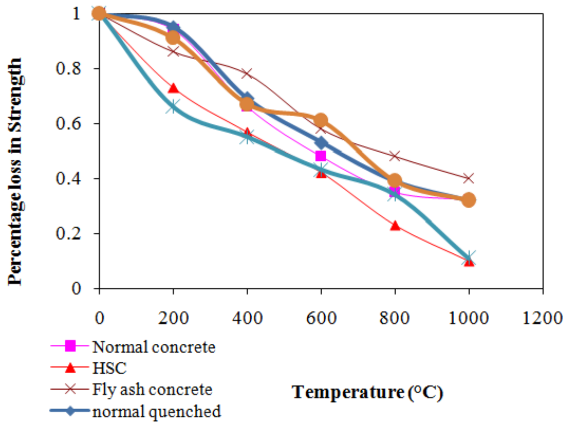


Figure.4 Residual Strength of Cube Specimens

VI. Conclusions

Three types of specimens viz normal, high strength and fly ash concretes were studied for their residual strength by exposing it to high temperatures upto 1000C for a period of 2 hours after steady state. Changes in the physical condition were observed in all the specimens exposed to high temperatures. The weight of the specimen has reduced marginally in 200 C temperatures. In higher temperatures the reduction was observed to be higher. About 8% weight loss was observed as maximum in high strength concrete specimens at 1000C. At 500C sudden explosive spalling was observed in few high strength concrete specimens. Specimens exposed to

200 to 400 C temperatures the average reduction of compressive strength was 20% and 25% respectively. The reduction was found to be more in high strength concrete specimens. At 600 and 800C the residual strength was observed to be around one fourth of its original capacity. Further the rate at which the strength reduced is comparatively more in high strength concrete specimens than other types. The performance of fly ash concrete exposed to high temperature was comparatively better than all the three types of concrete.

References

[1]. S.C. Chakrabarti and Arvind Kumar Jain (1999), "Strength properties of concrete at elevated temperatures - A review", The Indian Concrete Journal, Aug.1999, pp.495-501.

[2]. Carlos Castillo and AJ Durrani, (1990) "Effect of transient High Temperature on high strength Concrete", ACI Materials Journal, Jan-Feb, 1990, pp.47-53.

[3]. N. Gowripalan, P. Salonga and C.Dolden, " Residual strength of High Performance Concrete Subjected to high temperatures"

[4]. K. Mani and N.Lakshmanan, (1986), "Determining the extent of damage due to fire in concrete structures by ultrasonic pulse velocity measurements", Indian Concrete Journal, July, 1986, pp.187-191.

[5]. V. Kumar, B.N. Roy and A.S.R. Sai, (1990) "Effect of temperature on the properties of superplasticsed concrete, The Indian Concrete Journal, July, 1989, pp.350-352.

[6]. N.S. Bhal and J.P. Jain, (1999) "Compressive strength of concrete subjected to elevated temperatures", The Indian Concrete Journal, Aug.1999, pp.503-507.