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Comparative Study on Effect of Cooling Methods on Compressive Strength of Standard And High Strength Concrete Subjected To Real Fire

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ABSTRACT: *Aim of this study is carried out to assess the effect of real fire on compressive strength of concrete. Sixty concrete cubes of 100 mm size, divided equally over two different grades of design mix concrete viz. M35, M65 were cast. After 28 days curing & 24 hours air drying, the cubes were subjected to real fire range for three different exposure times viz. 1 h, 2 h, 3 h. The heated cubes were cooled at different cooling methods like air cooling and water quenching and then subjected to compressive strength test. As the duration of fire exposure increased, standard concrete performed better than high strength concrete by retaining 27% RCS for air cooling and 23% for water quenching method. In hot state, high strength concrete performed better than standard concrete by retaining 6% RCS.*

Keywords: *Real fire, Air cooling, Water quenching, Residual compressive strength*

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I. INTRODUCTION

Concrete is a composite material which is made of filler and a binder. Typical concrete is a mixture of fine aggregate (sand), coarse aggregate (rock), cement, and water. The usage of concrete is increasing from time to time due to the rapid development of construction industry. The utilization of concrete is not only in building construction but also in other areas such as road construction, bridges, harbor and many more. Concrete has a few confinements regardless of its numerous advantages. Concrete has a relatively low tensile strength, low ductility, low strength-to-weight ratio, and is susceptible to cracking. Subsequently innovation in concrete has been developing in numerous points of view to enhance the quality and properties of concrete.

Concrete is known for its non conductive and fire resistance but continuous exposure to fire may vary its properties. During fire accident the concrete is cooled with water and Concrete structures exposed to forest fire are cooled in air. Many applications like linings in blast furnace, nuclear reactors, oil well tanks. Concrete is exposed to sustained temperatures as required for hours. National building code specifies 3 h fire exposure for class 3 or 4 buildings. If there is a fire accident in an high raised building the minimum time for firefighting is 3 h.

NBC [1] specifies fire exposure 3 h for class 3 and 4 buildings. Hence, the objective of present study is to compare the effect of

1. Air cooling on compressive strength of M35 and M65 concrete exposed to real fire for 1 h, 2 h, 3 h duration.
2. Water quenching on compressive strength of M35 and M65 concrete exposed to real fire for 1 h, 2 h, 3 h duration.
3. Hot state condition on compressive strength of M35 and M65 concrete exposed to real fire for 1 h, 2 h, 3 h duration.

II. LITERATURE REVIEWS

1 **Chi-Sun Poon et.al 2003 [2]** done experimental investigation to evaluate the performance of Metakaolin (MK) concrete at elevated temperatures up to 800°C. Eight normal and high strength concrete mixes incorporating 0%, 5%, 10% and 20% MK were prepared. The residual compressive strength, chloride-ion penetration, porosity and average pore sizes were measured and compared with silica fume, flyash and pure ordinary Portland cement concretes. It is found that after an increase in compressive strength at 200 °C, the MK concrete suffered a more severe loss of compressive strength and permeability related durability than the corresponding SF, FA and OPC concretes at higher temperatures. Explosive spalling is observed in both normal and high strength MK concretes and the rate of spalling increased with higher MK contents.

2 **Subhash C. Yaragal et.al 2010 [3]** done investigations on the cube samples subjected to elevated temperatures ranging from 100 ^{o}C to 800 ^{o}C, in steps of 100 ^{o}C with a retention period of 2 hours. After exposure, weight losses and the residual compressive strength retention characteristics are studied. Test results indicated that weight and strength significantly reduced with an increase in temperature. As the exposed temperature increased, loss in weight of specimen increased, above 200 ^{o}C. With increase in grade of concrete, there is a decrease in loss of weight of specimen after subjecting it to elevated temperatures. In general there is a substantial loss (74%) in strength from 100 ^{o}C to 800oC for M20, M25 & M30 grades of concretes. However for M35, M40 & M45 grades, strength loss is 80%. The observed minimum residual strength was 18% for M45 at 800 ^{o}C.

3 **Y.N. Chan 1999 [4]** done experimental investigation on Residual strength and pore structure of high-strength concrete and normal strength concrete after exposure to fire. Based on normal strength concrete (NSC) and high-strength concrete (HSC), with compressive strengths of 39, 76, and 94 MPa respectively, damage to concrete under high temperatures was identified. After exposure to temperatures up to 1200 °C, compressive strength and tensile splitting strength were determined. Results show that HSC lost its mechanical strength in a manner similar to that of NSC. The range between 400 and 800 °C was critical to the strength loss. High temperatures have a coarsening effect on the microstructure of both HSC and NSC. On the whole HSC and NSC suffered damage to almost the same degree, although HSC appeared to suffer a greater worsening of the permeability-related durability.

III. MATERIALS AND METHODOLOGY

Cement used is Puzzolana Portland cement conforming to, IS: 1489-1987 [5] is used. The cement was tested in accordance to test methods specified in IS: 4031 [6] and results obtained are shown in Table 1.

Table 1 Properties of Cement

S.No.	Name of Test	Experimental value	Requirements as per IS: 1489-1987 [5]
1.	Normal Consistency (%)	33	-
2.	Specific gravity	3.12	3.15
3.	Initial setting time (min)	180	More than 30
4.	Final setting time (min)	220	Less than 600
5.	Fineness (%)	8.2	10
6. (i) (ii) (iii)	Compressive strength (MPa) 3 days 7 days 28 days	26 36 46	Greater than equal to 23 Greater than equal to 33 Greater than equal to 43

The material which is passing through 4.75 mm sieve is known as fine aggregate. Locally available natural river sand is used as the fine aggregate. The fine aggregate was used in this study conforming to IS: 383-1970 [7]. The material which is retained on 4.75 mm sieve is known as coarse aggregate. Locally available coarse aggregate having average size of 10mm and 20 mm is used in this study confirming to IS: 383-1970[7].

II. MIX DESIGN PROPORTIONS

S.NO	MATERIALS	M35 (kg/m3)	M65 (kg/m3)
1	Cement	394	530
2	Coarse aggregates	1237	1220
3	Fine aggregates	626	500
4	Water	177.3	141
5	W/C ratio	0.42	0.27

IV. REAL FIRE TEST ARRANGEMENT

Cubes after curing are placed in real fire arrangement, where cubes are kept in fire for duration of 1h , 2h, 3h.Fire is kept continuously for required duration of fire.

Fig.3.2 Real fire test arrangement

V. RESULTS AND DISCUSSION

The percentage residual compressive strength of Standard concrete (M35) & High strength concrete (M65) grade concrete after exposed to real fire.

4.1 Study on variation of Residual compressive strength of air cooled concrete after exposed to 1 h, 2 h, 3 h durations

Fig.3.1 shows variation of percentage residual compressive strength of M35 and M65 grade air cooled concrete after exposed to real fire. The decrease in Residual compressive strength of M35 and M65 from 1 h to 2 h is 9% and 6% respectively. And percentage decrease from 2 h to 3 h is 18% and 12% respectively. From 1 h to 3 h the decrease in strength is 27% and 18% respectively. Referring to the results, both the concrete lost their strength after exposed to real fire and air cooled. The loss of strength may be due to loss in moisture content, chemically combined water and physically bound water. Further loss in strength may be attributed for decomposition of C-S-H gel. n real fire, duration of exposure of concrete specimens increased there is a significant loss in strength from 1 h to 3 h duration. This observation is contradictory to the findings of many researchers such as Vani et.al [5], Gopal Raju et.al[6] and Mohammad bhai et.al[7]. Whose studies are carried out on concrete exposed to elevated temperatures with help of ISO 834 fire rating curves and leaving scope for further research.

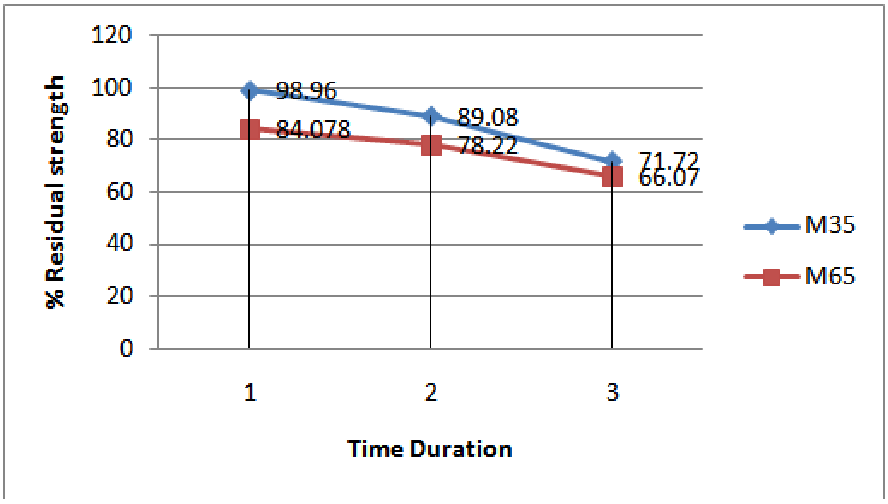

Fig.4.1 variation of percentage residual compressive strength of M35 and M65 grade concrete exposed to real fire after air cooling

4.2 Study on variation of Residual compressive strength of water quenching concrete

Fig.4.2 shows variation of percentage residual compressive strength of M35 and M65 grade water quenched concrete after exposed to real time fire. The decrease in compressive strength of M35 and M65 from 1 h to 2 h is 6% and 4% respectively. And percentage decrease from 2 h to 3 h is 23% and 17% respectively. From 1 h to 3 h the decrease in strength is 29% and 21% respectively. Referring to the results, both the concrete lost their strength after exposed to real fire and water quenched. The loss of strength may be due to loss in moisture content, chemically combined water and physically bound water. Further loss in strength may be attributed for decomposition of C-S-H gel and thermal shocking.

Thermal shock experienced by specimens quenched in water due to the sudden contact of hot specimens with water. In real fire, duration of exposure of concrete specimens increased there is a significant loss in strength from 1 h to 3 h duration. This observation is contradictory to the findings of many researchers such as Vani et.al [8] and Ahmed [9] whose studies are carried out on concrete exposed to elevated temperatures with help of ISO 834 fire rating curves.

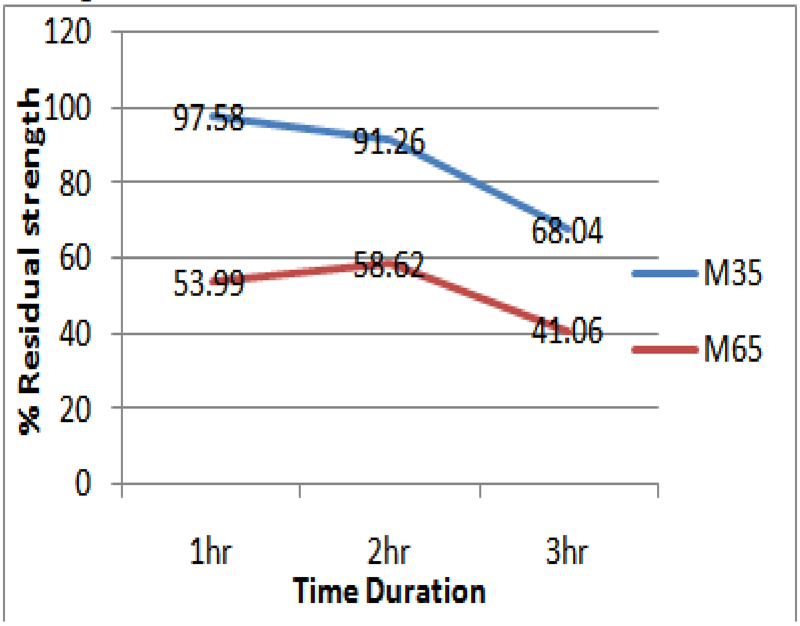

Fig.4.2 variation of percentage residual compressive strength of M35 and M65 grade water quenched concrete after exposed to real fire

4.3 Study on variation of Residual compressive strength of concrete at hot state condition

Fig.4.3 shows variation of percentage residual compressive strength of M35 and M65 grade hot state concrete after exposed to real time fire. As duration of fire exposure increases the strength of concrete decreased. The decrease in compressive strength of M35 and M65 from 1 h to 2 h is 1% and 4% respectively. And percentage decrease from 2 h to 3 h is 19% and 2% respectively. From 1 h to 3 h the decrease in strength is 20% and 6% respectively. Referring to the results, both the concrete lost their strength after exposed to real fire while they are in hot state. The loss of strength may be due to loss in moisture content, chemically combined water and physically bound water. Further loss in strength may be attributed for decomposition of C-S-H gel.

In real fire, duration of exposure of concrete specimens increased there is no significant loss in strength from 1 h to 3 h duration. This observation is similar to the findings of many researchers such as Srinivasa Rao et.al [10] whose studies are carried out on concrete exposed to elevated temperatures with help of ISO 834 [11] fire rating curves.

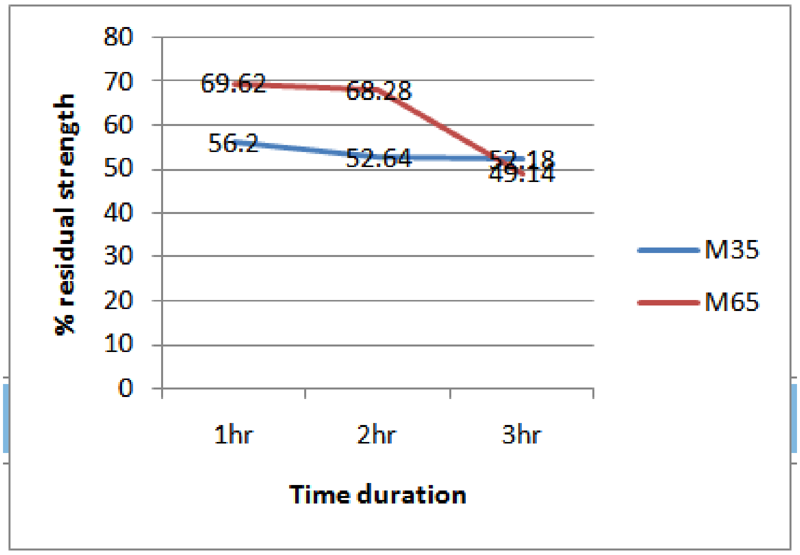

Fig.4.3 Variation of percentage residual compressive strength of M35 and M65 grade hot state concrete after exposed to real fire

4.4 Comparative Study on variation of Residual compressive strength of air cooled, water quenched, hot state concrete

Fig.4.4 shows variation of percentage residual compressive strength of M35 and M65 grade air cooled, water quenched, hot state concrete. It was observed that as fire exposure duration increases the strength of the concrete decreased gradually. In Air cooled method there is decrease in residual compressive strength of 10% and 18% for M35 and 6% and 12% for M65 at 1h to 2h and 2h to 3h duration of real fire. In water quenching method, the decrease of RCS is 6% and 23% for M35 and 50% deduction of strength for M65 at 1h to 2h and 2h to 3h duration of real time fire. In this cooling method slight increase in RCS at 1h to 2h duration for M65 grade concrete. In Hot state condition, decrease of RCS is 1% and 19% for M35, 4% and 2% for M65 grade concrete. In Real fire the SC shows better strength than the HSC. Only in the case of hot state condition HSC shows slight increase in RCS.

For M35 grade specimens cooled in air performed better than water quenched concrete and hot state condition For M65 grade specimens performed better in hot state condition than air cooled and water quenched concrete. Strength loss in Water quenched specimens is attributed to thermal shock. The gain in strength exhibited by water quenched specimens may be due to rehydration.

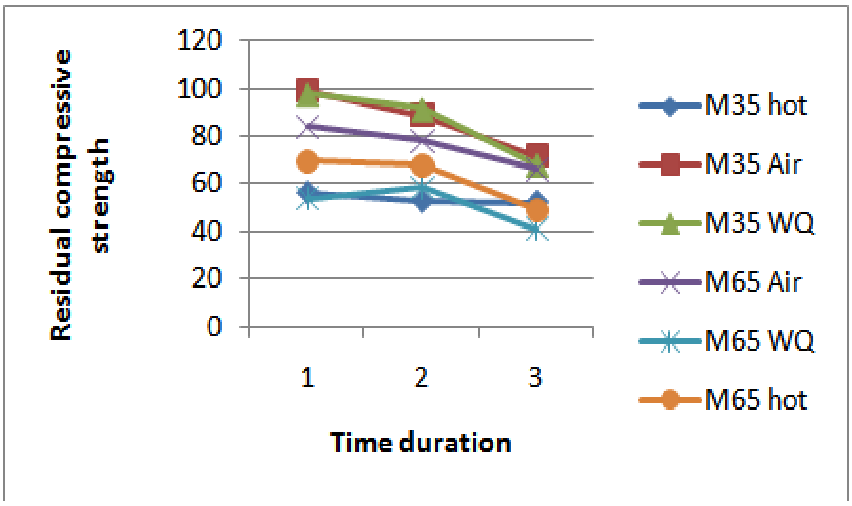

Fig.4.4 Variation of Residual compressive strength of air cooled, water quenched and hot state concrete

V. CONCLUSION

Considering the performed experimental and theoretical study, the following conclusions can be reached:

1. In air cooling method, standard concrete performed better than high strength concrete by retaining 27% of residual compressive strength for 1 h to 3h duration of fire exposure.
2. In water quenching method, Standard concrete performed better than high strength concrete by retaining 23% of residual compressive strength for 1 h to 3h duration of fire exposure.
3. In hot state, high strength concrete performed better than standard concrete by retaining 6% of residual compressive strength for 1 h to 3h duration of fire exposure.
4. For high strength concrete performed better in hot state than air cooling and water quenching method.
5. Standard concrete performed better in air cooling and water quenching method than hot state.
6. As the duration of exposure increased M35 and M65 loss their strength.
7. As the duration of fire exposure increased for Air cooling and water quenching is significant strength loss as high as 27% from 1h to 3h.
8. In hot state, as the duration of exposure increases there is no significant loss in 1h duration of real fire.

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