International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 10 | Oct 2019 www.irjet.net p-ISSN: 2395-0072

EFFECT OF RAPID FLUCTUATION IN TEMPERATURE ON HYBRID FIBRE REINFORCED CONCRETE

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Abstract - *In present study, an attempt has been made to develop hybrid normal strength concrete mix sample by addition of polypropylene fibre (PP) at a fixed percentage (0.3% of total weight of cement) and steel fibre in varying percentage of 0.5%, 1%, 1.5%, 2% and 2.5% (by total weight of cement). For this M35 grade of concrete was designed as per the accordance of BIS: 10262-2009. Various laboratory tests were performed in order to evaluate the performace of concrete such as compressive and split tensile strength test, UPV test before and after exposure to heat to determine whether a fire exposed concrete structure and its component are still structurally sound or not. Along with these tests, percentage change in weight of specimen was also recoreded after heating.*

***Keywords*:** Hybrid Fibre Reinforced Concrete, Elevated Temperature, Polypropylene Fibre, Steel Fibres.

1. Introduction

Concrete is a composite material that consists of a binding medium within which are embedded particles of aggregate, usually a combination of fine aggregate and coarse aggregate. Concrete has been the leading construction material for a century and its strength is a frequently investigated property because it gives a good indication of the overall quality of concrete.

Figure: 1. Concrete Structure After Exposure to Fire.

The addition more than one type of fibre in concrete is known as Hybrid Fibre Reinforced Concrete. The concept of using fibres as reinforcement in the concrete mixture is not a new study. Fibers have been used for concrete reinforcement since prehistoric times though technology has improved significantly, as is applicable for other fields. In the early age, straw and mortar were used for producing mud bricks, and horsehair was used for their reinforcement. As the fiber technology developed, cement was reinforced by fibers in the early twentieth century.

Table 1: Effect of Different Temperatures on Concrete

Temperature	Effect on concrete with increase in temperature
100-140˚C	Evaporation of free water from the concrete m
300˚C	Cement paste shrinks due to evaporation and aggregate will expand
400-600˚C	Calcium hydroxide in the cement paste breaks to calcium oxide and water from chemical reaction start evaporates. This will cause reduction in concrete strength
550˚C and above	The aggregate start to decompose cause significant decline in strength of concrete.

Polypropylene (PP) is a thermoplastic polymer used in a huge variety of applications including packaging and labeling, textiles, stationery and reusable containers of various types, laboratory equipment, automotive components and polymer banknotes. Polypropylene (PP) fibre puts effect on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact and chloride penetration. It is chemically inert and any chemical that can harm these fibres will probably be much more detrimental to the concrete matrix.

2. Objectives of the Study

The objectives of this study are:

- To develop hybrid normal strength concrete mix sample by addition of polypropylene fibre (PP) at a fixed percentage (0.3% of total weight of cement) and steel fibre in varying percentage of 0.5%, 1%, 1.5%, 2% and 2.5% (by total weight of cement).
- To determine compressive and split tensile strength of designed concrete mix after its exposure to different temperatures and sudden cooling and comparing it with reference mixes.
- Perform UPV test before and after exposure to heat to determine whether a fire exposed concrete structure and its component are still structurally sound or not.
- To find out the percentage change in weight after heating of specimens.
- To determine the optimum value of fibre content.

2. Mix Proportion

Grade designation : M35

Type of cement : OPC 43 grade

Maximum nominal size of aggregate : 20mm

Minimum cement content : 320 kg/m3

Maximum water cement ratio : 0.45

Workability : 75mm

Exposure condition : Severe (for RCC)

Method of concrete placing : Pumping

Degree of supervision : Good

Type of aggregate : Crushed angular

Maximum cement content : 450 kg/m3

Chemical admixture type : Superplasticizer

Mix Proportions for Trial

Cement = 390 kg/m3

Water = 163.8 kg/m3

Fine aggregate = 638.11 kg/m3

Coarse aggregate

i) 20 mm = 608.62 kg/m3

ii) 12.5 mm = 728.99 kg/m3

Chemical Admixture = 3.90 kg/m3

Water-cement ratio = 0.42

Table 12: Mix Proportioning of HFRC

Mix group	% PP	% SF	Wt. of PP (kg/m3)	Wt. of SF (kg/m3)	Cement content (kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/m3)	Water content (kg/m3)	Super plasticizer (kg/m3)
R	0	0	0	0	390	638.11	1337.61	163.8	3.9
G1	0.3	0.5	1.17	1.95	390	638.11	1337.61	163.8	3.9
G2	0.3	1.0	1.17	3.9	390	638.11	1337.61	163.8	3.9
G3	0.3	1.5	1.17	5.85	390	638.11	1337.61	163.8	3.9
G4	0.3	2.0	1.17	7.8	390	638.11	1337.61	163.8	3.9
G5	0.3	2.5	1.17	9.75	390	638.11	1337.61	163.8	3.9

3. Results and Discussion

COMPRESSIVE STRENGTH RESULTS:

Compressive strength increases by increasing the fibre content. This improvement can be attributed to the fact that polypropylene and steel fibre bridge cracks because of which growth can be controlled. It can be seen from mixes R to G3, the value of compressive strength increases and there after decreases, this indicates that excess of fibres have adverse effect on strength due to introduction of additional defects during the processing stage. Hence, the optimum packing stage of particles and fibres cannot be achieved. The hybrid concrete reinforced with 0.3% PP and 1.5% PP has the optimum value.

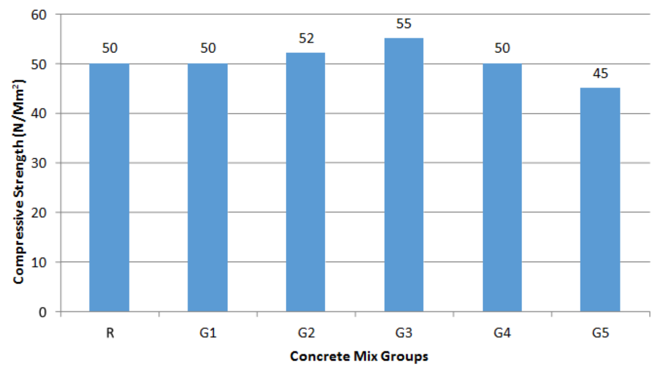

Figure: 2. Compressive Strength of Concrete Mix.

RESIDUAL COMPRESSIVE STRENGTH RESULTS:

After the curing period of 28 days the specimens of size 100 mm×100mm were heated for 30 minutes and 1 hour at different elevated temperatures of 200, 400 and 600˚C. After heating the specimens were cooled down to room temperature by water rapidly.

Figure 2. Heating and Cooling of sample.

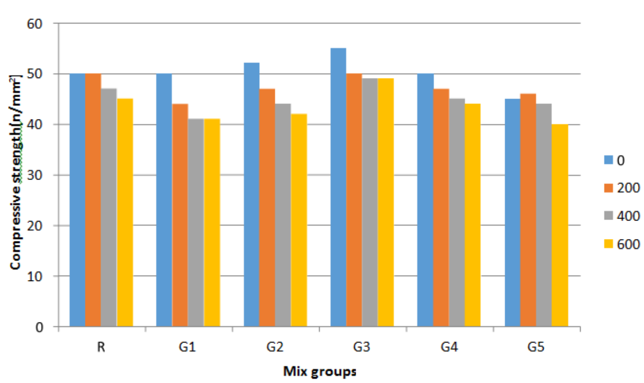

Figure 2. Residual Compressive Strengths of Mixes after Heating Period Of 30 Minutes.

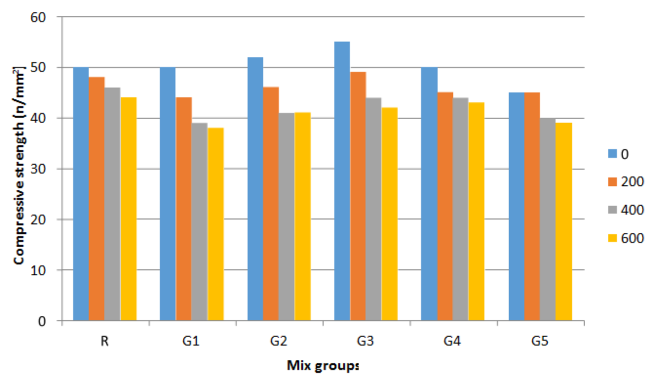

Figure 2. Residual Compressive Strengths of Mixes after Heating Period of 1 Hour

SPLIT TENSILE STRENGTH RESULTS:

Maximum split tensile strength was found for G3 mix i.e. 5.45 N/mm2. The split tensile strength increases as the replacement increases till G3 mix and then it starts to decrease with the increase in replacement.

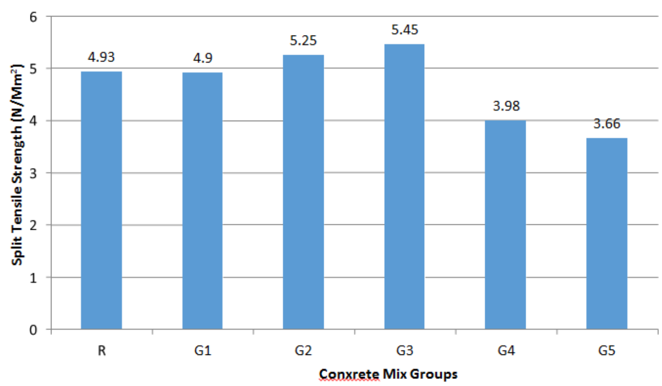

Figure: 3. Split Tensile Strength of HFRC Mix at 28 days.

RESIDUAL SPLIT TENSILE STRENGTH RESULTS:

The residual split tensile strengths of six types of concrete mixes subjected to different elevated temperatures of 200, 400 and 600˚C and suddenly cooled by quenching in water are given below in table no 17. The specimens were heated in the furnace at its maximum temperature level for 30 minutes and 1 hour separately.

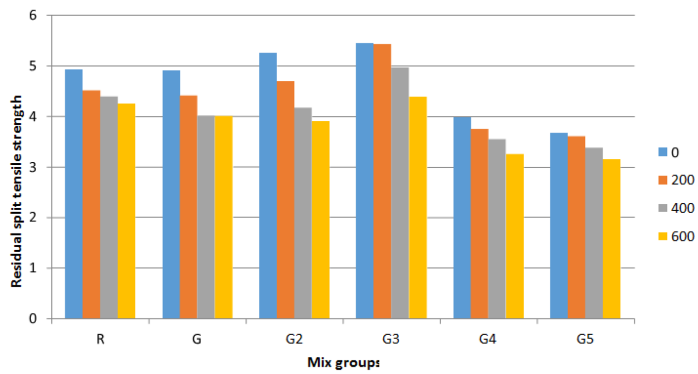

Figure 2. Residual Split Tensile Strengths after 30 Minutes Exposure.

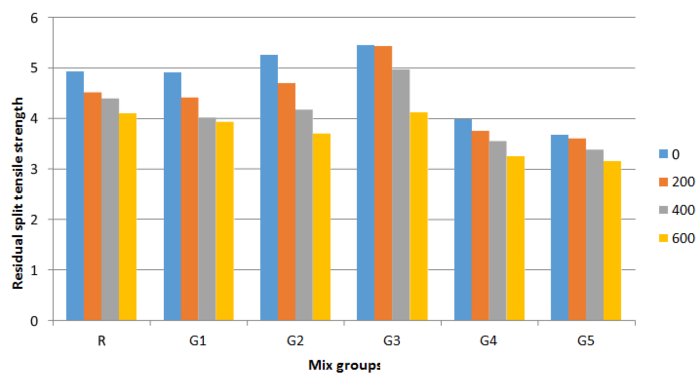

Figure 2. Residual Split Tensile Strengths of Mixes after Heating Period of 1 Hour.

ULTRASONIC PULSE VELOCITY TEST

The result of ultrasonic pulse velocity test shown in table 21, Figure indicates that addition of polypropylene and steel fibre have negative effect on the ultrasonic pulse velocity of hybrid fibre reinforced sample. The reduction in ultrasonic pulse velocity could be due to the inclusion of a lower density ingredient polypropylene (910 kg/m3).

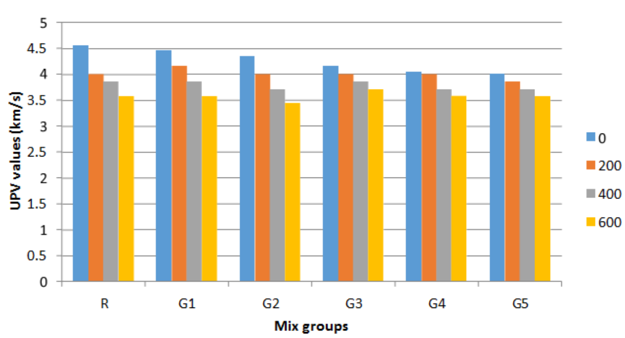

Figure 2. UPV Measurements on Specimens at temperature 0 °C, 200 °C, 400 °C and 600°C.

UPV measurements carried out on heated concrete cubes shows a reduction of velocity from

4.54 km/s to 3.44 km/s with the increase in temperature from 0˚C to 600˚C which shows an acceptable and consequent gradual degree of deterioration in the quality of concrete. This reduction in UPV could be due to the micro pathways which may be generated due to melting of polypropylene fibre.

EFFECT OF HEATING AND COOLING REGIME ON WEIGHT

The average range of variation is 0.3% to 4.3% for the temperature range from 200 to 600˚C when the specimens are heated for 30 minutes and 2.1% to 5% when the specimens are heated for 1 hour. From the figures, it is clear that duration of heating has a significant impact on weight of concrete.

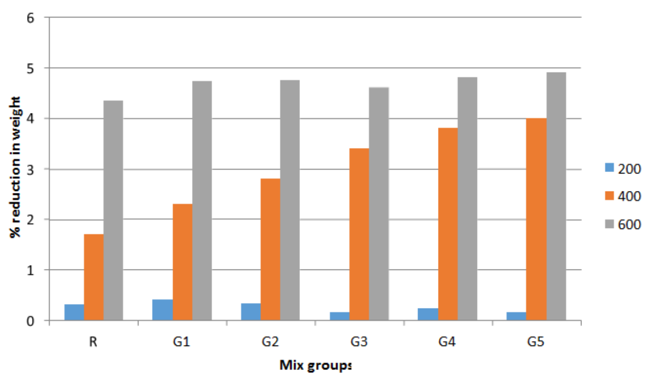

Figure: 6. Percentage Reduction in Weight for 30 Minutes Exposure.

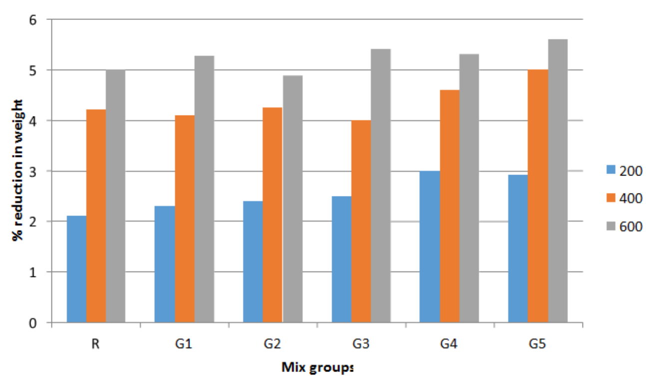

Figure 2. Percentage Reduction in Weight for 1 hour Exposure.

4. Conclusions

After evaluating the performance of various concrete mixes, the final conclusions drawn for the present experimental study are:

1. As the percentage of fibre content increases, the compressive strength of specimens also increases upto some extent. Mix reinforced with 0.3%PP and 1.5% SF has the optimum value of compressive strength. Afterward the compressive strength decreases gradually.
2. As the percentage of fibre content increases the split tensile strength of specimens also increases upto some extent. Mix reinforced with 0.3%PP and 1.5% SF has the optimum value of split tensile strength. Afterward the compressive strength decreases gradually.

3. As the temperature level increases the residual compressive strength decreases when the samples were heated for 30 minutes. Addition of fibre has the positive effect on residual compressive strength. Mix G3 reinforced with (0.3% PP+ 1.5% SF) show the optimum value. There is no significant difference between the residual compressive strength of the specimens heated in the temperature range of 400˚C and 600˚C. Explosive spalling doesn't occur in any specimen at any temperature level.
4. Heating duration of 1 hour also reflects almost similar results as compared to 30 minutes heating. Some hair line cracks and edge spalling were observed when the specimens are heated at maximum temperature level of 600˚C for 1 hour.
5. As the percentage of fibre content increases the split tensile strength of specimens also increases up to some extent. Mix reinforced with 0.3%PP and 1.5% SF has the optimum value of split tensile strength. Afterward the compressive strength decreases gradually.
6. As the temperature increases the residual split tensile strength decreases for both the heating period of 30 minutes and 1 hour. HFRC mix G3 reinforced with 0.3% PP and 1.5% SF shows the maximum value of residual split tensile strength.
7. UPV measurements carried out on heated concrete cubes show reduction of velocity from 4.54 km/s to 3.44 km/s with the increase in temperature from 0˚C to 600˚C. The reduction in the pulse velocity in HFRC mixes that contained PP and FF was significantly higher than normal concrete mix for all additional ratios.
8. As per the prediction, the total percentage of weight loss of the specimen increases as the exposure temperature increases. The average range of variation is 0.3% to 4.3% for the temperature range from 200 to 600˚C when the specimens are heated for 30 minutes and 2.1% to 5% when the specimens are heated for 1 hour. From the figure 31 and 32 it is clear that duration of heating has a significant impact on weight of concrete.

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