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EXPERIMENTAL STUDY ON FIRE RESISTING CONCRETE

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ABSTRACT

This project deals with the study of fire resistance of concrete. Achievement of maximum fire resistance is based on the composition of the aggregates used. The resistance can be greatly increased by using special carbonate type aggregates or by the use of polypropylene plastic fibres increases the resistance considerably. Hence our study is done by comparing the compressive strengths of Normal M_{25} cubes, Cubes with 50% partial replacement of Coarse aggregate with Limestone and Cubes with Polypropylene fibres as Admixtures. The compressive strengths were found at 7, 14, 28 days before heating and at 7 and 28 days after heating and is observed that cubes with limestone and polypropylene perform better.

Keywords: Limestone, Polypropylene fibre

I. INTRODUCTION

The danger of fire is present always and everywhere. The imminent danger depends upon actual exposure, and naturally differs if the threatened construction is a pedestrian subway, a roadway tunnel or a subterranean garage in a skyscraper. Concrete is the load bearing material in nearly all built structures and is therefore at high risk, since the entire structure would collapse upon its material failure. Concrete must therefore, independent of the danger scenario, be properly formulated or protected by external measures, in order to hinder failure at high temperature in case of fire. One of the advantages of concrete over other building materials is its inherent fire-resistive properties; however, concrete structures must still be designed for fire effects. Structural components still must be able to withstand dead and live loads without collapse even though the rise in temperature causes a decrease in the strength and modulus of elasticity for concrete and steel reinforcement. In addition, fully developed fires cause expansion of structural components and the resulting stresses and strains must be resisted. In the design of structures, building code requirements for fire resistance are sometimes overlooked and this may lead to costly mistakes. It is not uncommon, to find that a concrete slab floor system may require a smaller thickness to satisfy ACI 318 strength requirements than the thickness required by a building code for a 2-hour fire resistance. For sound and safe design, fire considerations must, be part of the preliminary design stage. Determining the fire rating for a structure member, can vary in complicity from extracting the relevant rating using a simple table to a fairly complex and elaborate analysis. In the United States, structural design for fire safety is based on prescriptive approach. Attempts are being made to develop performance based design approach for structural design for fire. State and municipal building codes throughout the country regulate the fire resistance of the various elements and assemblies comprising a building structure. The 2006 International Building Code (IBC) contains prescriptive requirements for building elements in Section 720. This section is based on ACI 216.1 “Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies and contains tables describing various assemblies of building materials and finishes that meet specific fire ratings.

II.MATERIALS USED

CEMENT: In general, cement is described as a material used to bind the mineral fragments called aggregate. The cement paste acts as glue which makes a cohesive mass with all the aggregates. This bonding is very important of the concrete fails not because of less strength of aggregates but mainly due to failure of bonding.

TESTING OF CEMENT:

Specific Gravity Test :

Table 1 – Specific Gravity of cement

S.NO	Wt.of cement (kg)	Initial reading (ml)	Final reading (ml)	Specific gravity of cement
1.	60	0.3	19.4	3.15

Specific gravity of cement used = 3.15

Fineness Test :

Table 2 – Fineness of cement

S.NO	Size of sieve (μ)	Wt. of cement (g)	Wt. of residue (g)	Wt. of cement passing through the sieve (g)	Fineness of Cement (%)
1	90	100	3	97	97.33
2	90	100	2	98	
3	90	100	3	97	

The Fineness of cement is found to be 97.33%

Consistency Test :

Table 3 – Consistency test for cement

S.NO	Wt. of cement (kg)	Wt.of water added (%)	Amount of water added (ml)	Impenetrate depth from the bottom of the mould (mm)
1	250	27	67.5	34.5
2	250	29	72.5	30.5
3	250	31	77.5	25.0
4	250	33	82.5	20.0
5	250	35	87.5	14.0
6	250	37	92.5	11.0
7	250	39	97.5	6.0

Consistency of cement paste is found to be 39%

FINE AGGREGATE

The locally available river sand is used as fine aggregate in the present investigation. The cleaned fine aggregate is chosen and tested for various properties such as specific gravity, fineness modulus, bulk modulus etc. in accordance with IS : 2386-1963

TESTING OF FINE AGGREGATE :

Specific Gravity Test :

Table 4 – Specific gravity of Fine Aggregate

S. NO	Empty Wt. of pycnometer (W_1) (g)	Wt. of pycnometer + agg (W_2) (g)	Wt. of pycno meter + agg + water (W_3) (g)	Wt. of app + water (W_4) (g)	Sp. Gravity (G)
1	10.71	32.10	48.85	37.75	2.68
2	10.71	32.21	42.66	37.75	2.676
3	10.71	32.22	47.27	37.75	2.75

The specific gravity of sand is found to be 2.702.

Sieve analysis test :

Table 5 – Sieve analysis of fine aggregate

S.No.	IS Sieve Size	Weight retained (gm).	Cumulative Weight retained (gm)	Cumulative %Weight retained	Cumulative % Passing
1	10 mm	0	0	0	100
2	4.75mm	124	124	12.4	87.6
3	2.36mm	221	345	34.5	65.5
4	0.75mm	611	956	95.6	4.4
5	600 Microns	30	986	98.6	1.4
6	300 microns	11	997	99.7	0.3
7	150 microns	2	999	99.9	0.1

8	<150 microns	1	-	100	0.0
9	Total	1000	-	100	-

Fineness Modulus = Cumulative percentage weight retained / 100 = 447.6 / 100 = 4.476

Fine aggregate belongs to Zone III

COARSE AGGREGATE

Crushed angular stone from local quarry is used as coarse aggregate. The cleaned coarse aggregate is chosen and tested for various properties such as specific gravity, fineness modulus, bulk modulus etc. The physical characteristics are tested in accordance with IS: 2386 – 1963.

TESTING OF COARSE AGGREGATE :

Specific Gravity Test :

Table 6 – Specific gravity of Coarse aggregate

S. NO	Empty Wt. of the app (W_1) (g)	Wt. of app+ agg (W_2) (g)	Wt. of app + agg + water (W_3) (g)	Wt. of app + water (W_4) (g)	Sp. Gravity (G)
1	650	1100	1790	1510	2.647
2	650	1100	1800	1510	2.657

The specific gravity of sand is found to be 2.654

b) Water Absorption Test :

Weight of aggregate filled in basket = 5000g

Weight of aggregate after immersing

in water after 24 hours = 5050g

Percentage of water absorbed = $(W_2 - W_3/W_1)$ x 100 = (5050 – 5050)/5000 x 100 = 1%

Aggregate Impact Test :

Table 7 Aggregate impact test

S.NO	Observation	Sample 1(g)	Sample 2 (g)
1	Weight of empty cup (W_1)	780	780
2	Weight of empty cup + aggregate (W_2)	1150	1170
3	Weight of aggregate (W_3)	370	390
4	Wt. of agg. Passing through IS sieve 2.36 mm	65	80
5	Aggregate impact test	17.94%	20.51%

Average impact value of the sample is found to be 19.225%

LIMESTONE

Limestone is used in the construction industry in various applications including new structures and in restoration of historic stone monuments. Exposure to fire and high temperatures cause significant changes in the physical and mineralogical properties of limestone. The aim of this research is to propose a strategy to assess the fire and high temperature performance of limestone.

Fig 1 Limestone

POLYPROPYLENE FIBERS

Polypropylene (PP) is a thermoplastic polymer used in a wide variety of applications. Its molecular formula is $(C_3H_6)_n$. Its density in amorphous state is 0.855 g/cm^3 and in crystalline state is 0.946 g/cm^3. Polypropylene has good resistance to fatigue.

Fig 2 Polypropylene fiber

III.EXPERIMENTAL ANALYSIS

CONCRETE MIX DESIGN

Cement : 350 kg

FA : 748 kg

CA : 1102 kg

W/C ratio : 0.4

Mix proportions : 350/350 : 748/350 : 1102/350

C / FA / CA : 1 : 2.14 : 3.15

Table 8- Quantity of materials used

Material	Conventional concrete (kg)	With PP fibre (kg)	With Limestone (kg)	Total (kg)
Cement	8	8	8	24
Fine Aggregate	18	18	18	54
Coarse Aggregate	25.5	25.5	12.75	63.75
Limestone	-	-	12.75	12.75

Casting :

18 Concrete specimens were casted to test its compressive strength. Among which 6 of them were standard mix concrete cubes, 6 of them were 50% replacement of coarse aggregate by limestone and the rest were using polypropylene as admixture.

Fig 3 – Curing of cubes

COMPRESSIVE STRENGH OF CUBES (7TH DAYS):

After 7 days of curing, the compressive strengths of the three types of concrete cubes were found before heating. One cube of each type was kept in the hot air oven at 400°C for two hour duration and its compressive strength was found with the help of a Compression Testing Machine and the following results were obtained.

Table 9 - Compressive strength test results (7 days)

7th Day Results	Weight of Concrete Cube Specimen (kg)		Compressive Strength of Concrete (N/mm^2)	
	Before Heating	After Heating	Before Heating	After Heating (400°C)
Conventional concrete	8.320	7.913	38.9	36.7
50 % Lime Stone	8.170	8.093	38.2	35.9
Polypropylene Fiber	8.270	7.871	35.6	33.5

Fig 4- Weighing cube specimen

Fig 5 - Compression Testing Machine

COMPRESSIVE STRENGTH OF CUBES (28 TH DAYS) :

After 28 days of curing, the compressive strengths of the three types of concrete cubes were found before heating. Two cubes of each type was kept in the hot air oven at 400°C for two hour duration and its compressive strengths were found with the help of Compression Testing Machine and the following results were obtained.

Table 10- Compressive strength test results (28 days)

28th Day Results	Weight of Concrete Cube Specimen (kg)			Compressive Strength of Concrete (N/mm²)		
	Before Heating	After Heating (Sample 1)	After Heating (Sample 2)	Before Heating	After Heating (Sample 1) (400°C)	After Heating (Sample 2) (400°C)
Conventional concrete	8.320	8.040	7.990	48.5	44.3	45.1
50 % Lime Stone	8.170	8.280	8.190	49.2	48.4	47.9
Polypropylene Fiber	8.270	7.930	8.020	48.2	47.5	47.8

Fig 6 - Hot air oven at 400°C

Fig 7 - cubes after exposing it to 400°C

COMPARISON OF COMPRESSIVE STRENGTH OF CUBES:

The compressive strengths of the concrete cubes after curing of 7, 14 and 28 days were found. The following table shows the comparison of compressive strengths of the concrete cubes after curing of 7, 14 and 28 days.

Table 11 - Comparison of compressive strength

Specimens	7thDay N/mm^2	14thDay N/mm^2	28thDay N/mm^2
Normal	38.9	43.7	48.5
50 % Lime Stone	38.2	42.1	49.2
Polypropylene Fiber	35.6	45.7	48.2

COMPARISON OF COMPRESSIVE STRENGTH OF CUBE SPECIMEN (BEFORE HEATING):

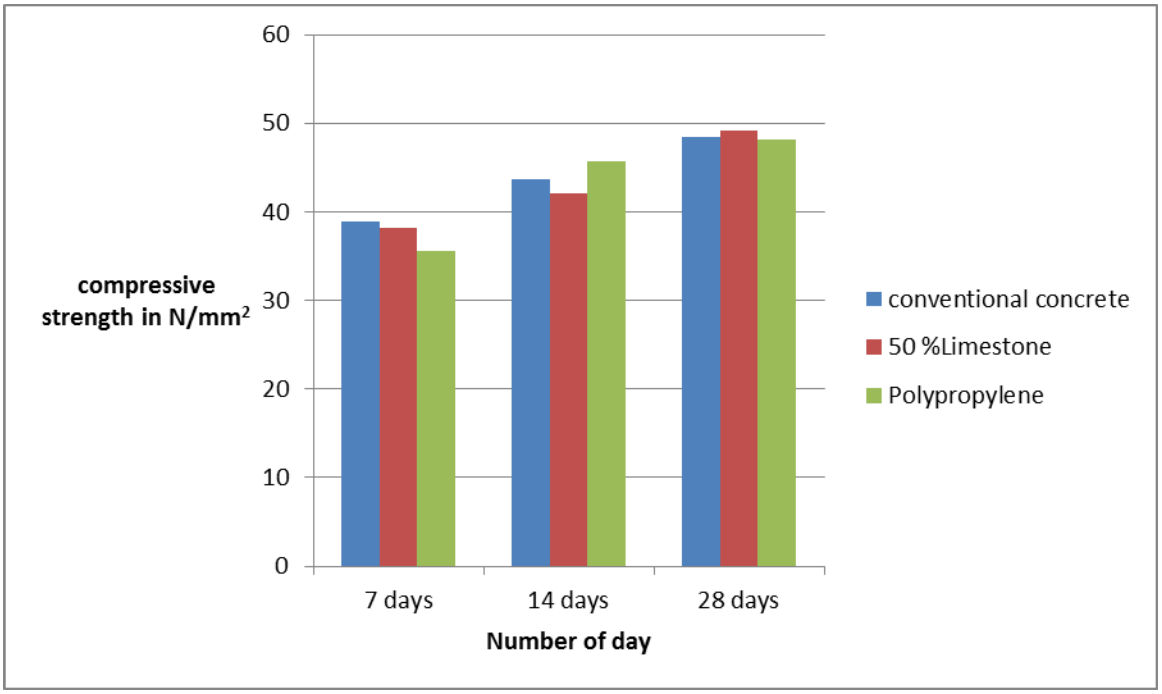

Fig 8 - Comparison of compressive strength of cube specimen (before heating)

COMPARISON OF COMPRESSIVE STRENGTH OF CUBE SPECIMENS (AFTER HEATING):

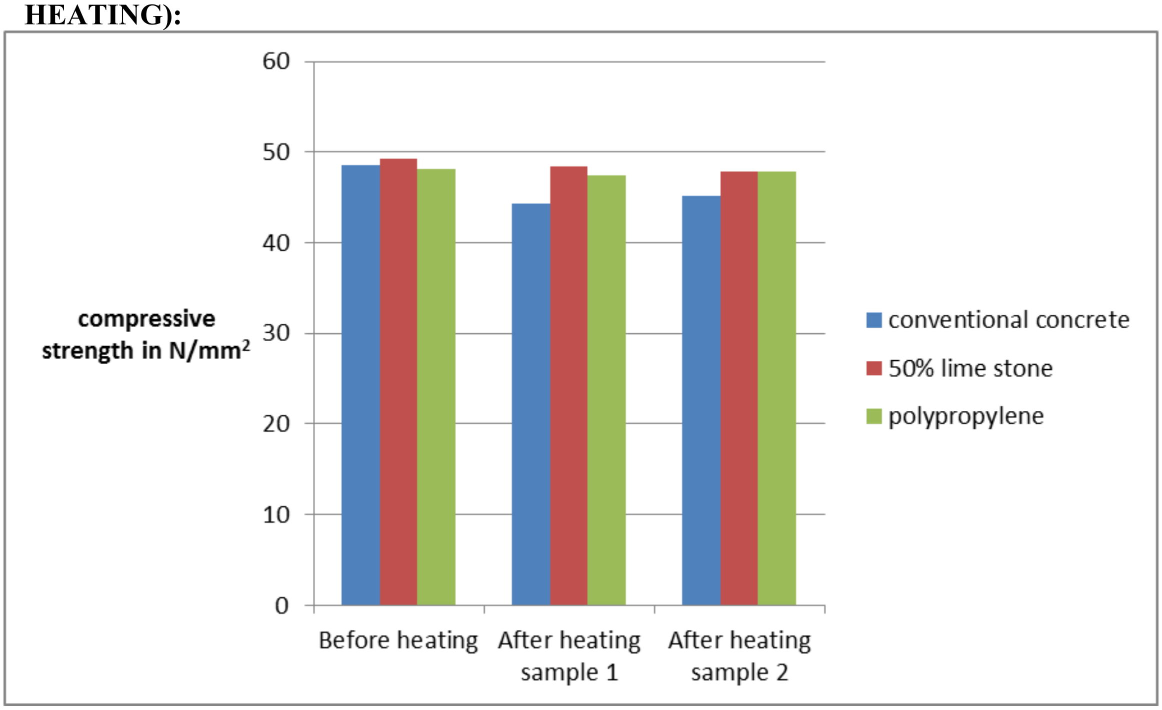

Fig 9 - Comparison of compressive strength of cube specimens (after heating)

IV. CONCLUSION

- The results show that the compressive strength of concrete is affected when it is exposed to a temperature greater than 300°C. It is so because the performance of siliceous aggregate under fire load exposed to a temperature greater than 350°C is not satisfactory.
- Hence as a partial replacement, 50% of coarse aggregate was replaced with limestone which tends to perform well under such conditions. Also by using polypropylene fibers as admixture, concrete tends to perform better. In both the cases, it was found that the compressive strength of concrete was maintained to a greater extent after exposing it to a temperature of 400°C than that of standard mix concrete.
- The cube specimens with 50% replacement of coarse aggregate by limestone, polypropylene fibers as admixtures and standard mix were casted. Its compressive strengths were determined before heating and after allowing it to be exposed to a temperature of 400°C in a hot air oven and were analyzed.
- It was observed that the compressive strength of the standard mix cube specimen was decreased after exposing it to 400°C and the compressive strengths of the other two cube specimens were maintained to a greater extent after exposing it to 400°C when compared with standard mix cubes.

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