# Thermal Resistant Concrete Under Elevated Temperature

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***Abstract***

*The need and to cater the demands of the construction industry, extensive and elaborate research work is being carried out in the area of Concrete Technology. Research work have been pursued to develop new variants in concrete like composite concrete, special concrete. In this present study experimental of Mechanical behavior of concrete using steel fiber cum calcium silicate.Steel fiber is used for increasing the tensile strength and impact resistance and calcium silicate is used for fire resistance material, so it is decided to use both the materials to get high strength as well as heat resistance of the structure. Cylindrical specimen were exposed to high temperatures of 300 ⁰c,400 ⁰c, and 500 ⁰c.Physical and mechanical properties of the developed mixes including residual compressive strength, mass losses, and water absorption have been determined. The result shows that the strength and heat resistance of the concrete have increased with the use of steel fibers and calcium silicate.*

***Keywords: Thermal resistant, High temperature, Residual compressive strength, Mass losses***

## I. INTRODUCTION

The frequent cases of fire occurrences in buildings have always been of great concern to the society for the risks it poses to both human lives and property. Fires can occur at any time in a building and the safety of occupants and the ability of structures to maintain its integrity are very important to the people. Building codes and regulations specify detailed measures for the safety of structural members in the event of a fire. They categories construction materials with particular emphasis on their fire resistance and recommends fire suppression systems required for various building types. Hence, the objective of fire safety is to protect life and property. The fire safety requirements of materials are based on the ability of structural elements built with the materials to maintain its load-bearing capability at various fire conditions. In other words, the fire resistance rating of a structural member can be said to be proportional to the period of time it can resist in terms of structural integrity and stability to standard fire conditions. Structural members are to be designed to satisfy the requirements of serviceability and safety limit states for various environmental conditions. Fire represents one of the most severe conditions and hence the provision of appropriate fire safety measures for structural members is a major safety requirement in building design. The basis for this requirement can be attributed to the fact that, when other measures for containing the fire fail, structural integrity is the last line of defence. According to the Merriam-Webster dictionary (2012), "A structure is the arrangement of part of elements as dominated by the general character of the whole''. A structure could also be said to be a complex entity, constructed from the arrangements of several parts. In engineering and architecture, a structure is a body or assembly of the body elements to form a system capable of resisting loads. The effects of loads on physical structures are determined through structural analysis. Structures can also be categorised by the type of material used for its construction.

Structural engineering depends on the knowledge of materials and their properties, in order to understand how different materials support and resist loads. The choice of what material to use for construction depends on some factors: material properties (strength and durability), cost (acquisition, technology, maintenance, sustainability), aesthetics/taste and constructability. Common structural materials are concrete, steel, bricks, timber, fibre reinforced plastic (FRP) composites. Each of these materials resist fire differently and scientist are working tirelessly to improve their fire rating. Fire resistance can be defined as the ability of structural elements to withstand fire or to give protection from it (IBC, 2006). This includes the ability to confine a fire or for a structure to continue to perform its structural functions after fire incidence or both. Fire Resistance Rating (or fire rating), is defined as the duration of time that an assembly (roof, floor, beam, wall, or column) can endure a "standard fire" as defined in ASTM E 119 (ASTM, 2000).

## II. LITERATURE REVIEW

Anthony Nkem (2015)Studied the effects of fire on coconut husk fibre and polypropylene fibre reinforced concrete.0.5% of coconut and polypropylene fibres and exposed to temperatures of 200oC, 400oC, 600oC, 800oC and 1000oC after 7, 14, 21, and 28 days of curing.It can be easily deduced that at 7 days, coconut fibre reinforced concrete has a higher compressive strength and higher fire resistance having as much as 10.29% of strength gain at the ambient temperature and 19.57% residual strength after exposure at 1000oC.It can be easily concluded that the presences of either of the two types of fibres increases the compressive strength of concrete especially at the lower temperatures up to 400 degree C, with greater increase in the coconut fibre samples than polypropylene sample.The percentage increase in the compressive strength of the concrete samples show that the coconut fibers' produce a higher strength increase over the polypropylene fibers. The addition of both fibers did not just increase the compressive strength, but test results have proved that they also increase the fire resistance property of the concrete.

Abdullah Keyvani (2014)investigated thermal performance and humidity intrusion effects and fire resistance test.Thermal performance was evaluated for different temperatures and humidity for two types of AAC walls with coating and without coating.Fire resistance test was carried out for determining the ability of AAC material to withstand fire in six different temperatures increasing from 100°C to 1000°C. AAC losses its mass and mechanical properties subjected to the high elevated temperature above 500°C

## III .MATERIAL COLLECTION

i)CEMENT:

Ordinary Portland cement(53 grade) cement conforming to IS 8112 was used. Various laboratory tests were conducted on cement and the properties such as standard consistency, initial and final setting time, were determined as per IS 4031 and IS 269-1967.The results conform to the IS recommendations.

ii)FINE AGGREGATE:

River sand zone II was used in this study

iii)COARSE AGGREGATE:

The coarse aggregate particles passing through 20mm and retained on 12.5 mm I.S Sieve used as the natural aggregate which met the grading requirement of IS 383-1970.

iv)WATER:

Ordinary potable water

v)STEEL FIBER:

Crimped Steel Fiber were used.(Aspect ratio:20)

vi) CALCIUM SILICATE:

Calcium silicate a product is used as filling material, in this investigation. Calcium silicate purchased from astra chemicals, Chennai were used. The properties of calcium silicate were showed in Table 1

| S.NO | Oxide composition | Calcium Silicate |
|---|---|---|
| 1 | SILICA ( SiO2) | 78. 5 |
| 2 | CALCIUM ( CaO) | 19. 2% |
| 3 | CHLORIDES | TRACES |
| 4 | SULPHATE | TRACES |
| 5 | LEAD (Pb) | 5 |
| 6 | ARSENIC ( As ) | 2 |

Table 1 : Properties of Calcium Silicate

## III .MIX DESIGN

Mix design for control specimen (as per code IS10262-1982)

1)Target Strength

fck' = fck+1.65S

fck' = 38.25 N/mm$^2$

ii) Selection of w/c ratio

The free water cement ratio required for the target strength 38.25 N/mm2 is 0.38From figure 1 IS 10262-1982

Max w/c ratio = 0.38

iii) The selection of water and sand content:

For 20 mm nominal size of aggregate and sand confirming to grading zone II.

Water content per m3 of concrete = 186 kg.

Sand content as percentage of total aggregate by absolute volume =35%

Adjustment is made according to IS code.

Table 2 : Adjustment of values in water & Sand

| DESCRIPTION | WATER CONTENT | % OF SAND |
|---|---|---|
| Zone – 2 | 0 | 0 |
| IS 456 : 2000 (Pg. No :17) Compacting factor | 3 | 0 |
| Each 0.05 increase (or) decrease | 0 | -4.4 |
| Total Adjustments | 3 | -4.4 |

Required sand content as percentage of total aggregate by absolute volume = 35 - 4.4

= 30.6%

Required water content = 186 + (186 × 3) / 100

= 191.58 l/m3

Determination of Cement content

Cement content = (191.58/0.38)

= 504.15 kg/m3

Determination of Fine and Coarse aggregate

FA = 488.64 kg/$m^3$

CA = 1148.8 kg/$m^3$

| SPECIMEN | CSF-1 | CSF-2 | CSF-3 | CSF-4 |
|---|---|---|---|---|
| CEMENT | 96% | 93% | 90% | 87% |
| FINE AGGREGATE | 100% | 100% | 100% | 100% |
| COARSE AGGREGATE | 100% | 100% | 100% | 100% |
| CALCIUM SILICATE | 3% | 6% | 9% | 12% |
| STEEL FIBER | 1% | 1% | 1% | 1% |
| WATER RATIO | 0.38 | 0.38 | 0.38 | 0.38 |

Tab le 2 : Mix Proportion

IV.RESULTS AND DISCUSSIONS

1.COMPRESSIVE STRENGTH TEST

| S.No | Combination | Compressive strength of concrete N/$mm^2$ | |
|---|---|---|---|
| | | 7 DAYS | 28 DAYS |
| 1 | Control | 20.8 | 31.11 |
| 2 | CSF-1 | 21.8 | 32.66 |
| 3 | CSF-2 | 21.11 | 30.8 |
| 4 | CSF-3 | 17.3 | 28 |
| 5 | CSF-4 | 15.3 | 24.44 |

Table.3 Compressive strength Test

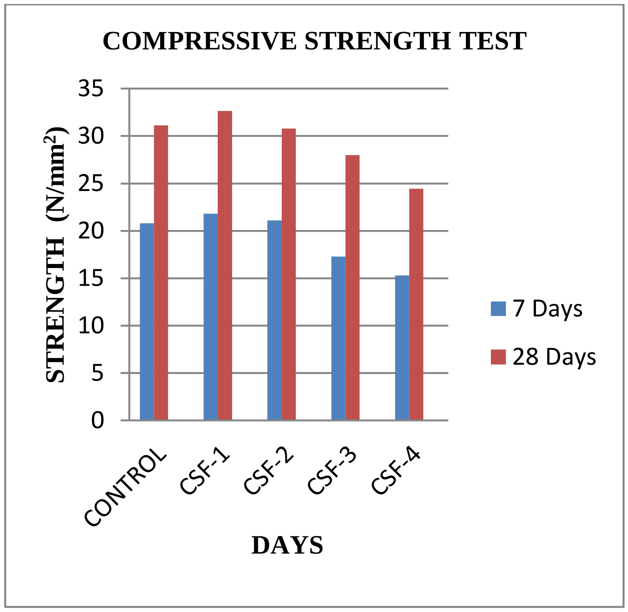


Fig: 1 COMPRESSIVE STRENGTH TEST

2.SPLIT TENSILE STRENGTH TEST

| S.No | Combination | Split Tensile strength of concrete N/$mm^2$ | |
|---|---|---|---|
| | | 7 DAYS | 28 DAYS |
| 1 | Control | 1.55 | 2.33 |
| 2 | CSF-1 | 1.69 | 2.829 |
| 3 | CSF-2 | 1.84 | 2.47 |
| 4 | CSF-3 | 1.25 | 1.414 |
| 5 | CSF-4 | 0.51 | 0.707 |

Table 4 Split Tensile strength Test

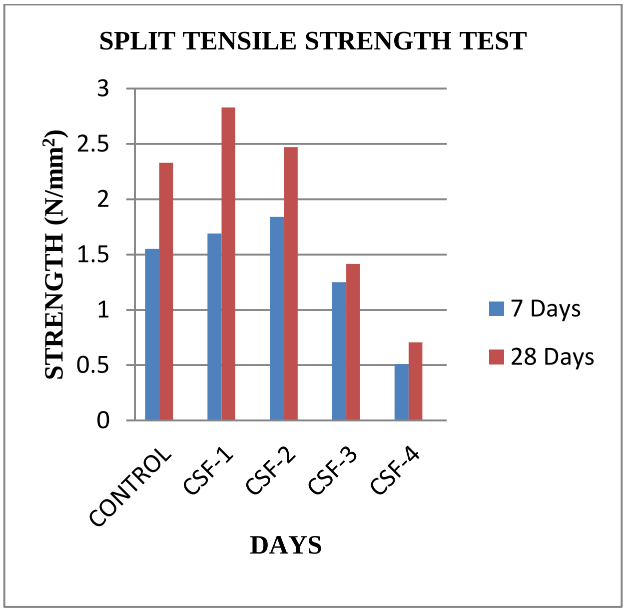


Fig 2 Split Tensile strength Test

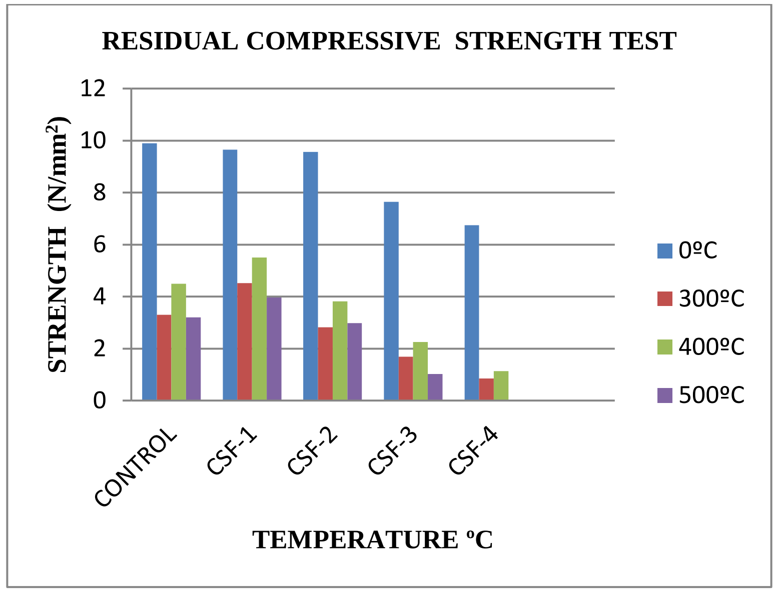


Fig.3 Residual compressive strength test

3..RESIDUAL COMPRESSIVE STRENGTH TEST

| S.no | Combination | Before heating | After heating (300°C) | After heating (400°C) | After heating (500°C) |
|---|---|---|---|---|---|
| 1 | Control | 9.90 | 3.30 | 5.5 | 3.2 |
| 2 | CSF-1 | 9.65 | 4.52 | 4.57 | 3.96 |
| 3 | CSF-2 | 9.57 | 2.82 | 3.82 | 2.98 |
| 4 | CSF-3 | 7.65 | 1.69 | 2.26 | 1.02 |
| 5 | CSF-4 | 6.75 | 0.8488 | 1.13 | 0 |

Table:5 Residual compressive strength test

4.THERMAL CONDUCTIVITY TEST

Thermal conduction is the transfer of heat from one part of a body to another with which it is in contact. Thermal conductivity is defined as ability of material to transmit heat and it is measured in watts per square metre of surface area for a temperature gradient of 1 K per unit thickness of 1 m. The thermal conductivity is not always constant. The main factors affected the thermal conductivity are the density of material, moisture of material and ambient temperature. With increasing density ,moisture and temperature the thermal conductivity increases too.Important is inner structure of materials. Metals and other dense solid materials tend to have high levels of conductivity, whereas materials with very small amount of solid matter and large proportion of voids (gas or air bubbles, not large enough to carry heat by convection) have the lowest thermal conductivities

**$T_r = T_w + Q/4K * r^2$ (Solid cyclinder)**

**$Q = V*I$**

**$T_r - T_w / T_o - T_w = {}_{1-} r^2$**

where

**$T_w$ = Wall or surface top**
**$T_r$ = Temperature at radius**
**$T_o$= Temperature at mid plane**
**r= Radius of specimen**
**q =Heat flow**

| S. no | Mix | Before heating 300°C | After heating 300°C | Before heating 400°C | After heating 400°C | Before heating 500°C | After heating 500°C |
|---|---|---|---|---|---|---|---|
| 1 | Control | 2.161 | 2.048 | 2.378 | 2.270 | 2.478 | 2.347 |
| 2 | CSF-1 | 2.306 | 2.184 | 2.394 | 2.259 | 2.238 | 2.178 |
| 3 | CSF-2 | 2.084 | 1.981 | 2.070 | 1.965 | 2.308 | 2.298 |
| 4 | CSF-3 | 2.011 | 1.904 | 2.237 | 2.126 | 2.222 | 2.169 |
| 5 | CSF-4 | 1.932 | 1.799 | 2.175 | 2.063 | 2.096 | 1.965 |

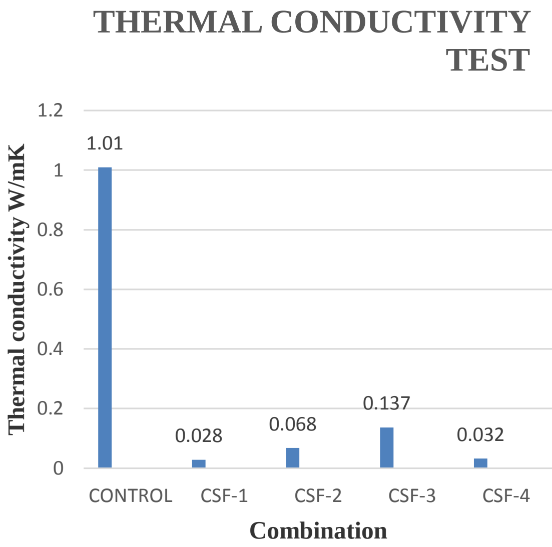


Fig: 4 THERMAL CONDUCTIVITY TEST

5.WATER ABSORPTION TEST

| S.no | Combination | Dry weight | Wet weight | Percentage of water absorption |
|---|---|---|---|---|
| 1 | Control | 8.787 | 8.889 | 1.16 |
| 2 | CSF-1 | 8.677 | 8.767 | 1.037 |
| 3 | CSF-2 | 8.520 | 8.671 | 1.77 |
| 4 | CSF-3 | 8.269 | 8.467 | 2.394 |
| 5 | CSF-4 | 8.004 | 8.289 | 3.56 |

Table:6 Water Absorption test

6.MASS LOSSES

The mass of concrete specimens was measured and the losses in mass were calculated and compared. There may be too many causes of loss in weight after high temperature exposure. However spalling or expulsions of chunks of material from the surface layers are principal causes of loss in weight

Table:7 Mass Losses

## V.CONCLUSION

The following conclusions could be drawn from the present investigation.

- The Maximum values of compressive strength (32.66N/mm$^2$),Split tensile strength(2.829 N/mm$^2$), after 28 days with addition of 1% steel fiber and 3%calcium silicate in to the mix as compare with normal M30 grade concrete without any additives.
- All the specimen upto 500ºc did not show any sign of cracks.
- The residual compressive strength test result shows that there is a reduction in the compressive strength after heating the concrete at 500 ºc for 1hour
- The unit weight of the concrete decreased when it was exposed to elevated temperature. This finding is due to the release of bound water from the cement paste and the occurrence of air voids in the concrete.
- Generally thermal conductivity of concrete is 1.2-1.75 W/mK. But in this type of concrete reduce the thermal conductivity ,so it is better thermal property of concrete.
- Finally the test result indicate that addition of minimum percentage of calcium silicate increasing compressive strength as well as thermal resistant.

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