RESEARCH ARTICLE

SAMRIDDHI Volume 14, Special Issue 1, 2022 Print ISSN : 2229-7111 Online ISSN : 2454-5767

Fire Resistance of Concrete Structure- A Review

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ABSTRACT

Fire resistance is one of the key factor which aids toward the durability of a structure. Concrete is the most widely used construction material and is also an effective material for structural fire protection. Physical and thermal properties are used to measure the fire resistance of concrete. Three main reasons of concrete fire resistance are: non-combustible, non-toxic, low thermal conductivity (concrete retain slow rate of heat transfer). The lower value of concrete thermal conductivity behaves like a perfect shield to protect the material and adjacent space from fire damage. Fire resistance of concrete depend on a few different factors mainly: aggregate type, moisture content, density, thickness. Aggregate type suitable for fire resistance of concrete are Limestone, dolomite and lime rock. This paper reviews works done by various researches on the effect of aggregates towards the fire resistance of concrete.

Keywords: Aggregate type, Fire resistance, thermal conductivity.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology, (2022); DOI : 10.18090/samriddhi.v14spli01.12

INTRODUCTION

Fire resistance of concrete is the capability of concrete to resist a fire**.** Safety against fire is one of the most important aspects while considering the serviceability of a structure. Fire hazards become an unavoidable mishap in this highly dependent world [1]. About 60% to 70% of concrete volume is engaged by aggregates. The built up pressure prompt stresses. With the rise of fire, the induce stresses increases gradually to a limit that exceeds the tensile strength of concrete and big portion falls out from concrete surface which is known as spalling [2]. Depending on the aggregate type, loss of strength of concrete is greatest at temperature above 450-600°C. When concrete expose to fire, water starts to evaporate and form pore water pressure.

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How to cite this article : Yumkham, B., Shijagurumayum, C., Suresh, T. (2022). Fire Resistance of Concrete Structure- A Review.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology, Volume 14, Special Issue (1), 63-67.

Source of support : Nil

Conflict of interest : None

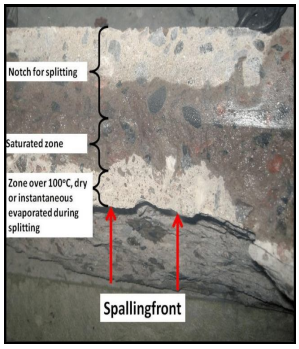

Figure 1: Spalling of concrete due to moisture penetration during a fire test [2]

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Considering different degrees of temperature, the degree temperature of 800°C was maintained constant with the exposed duration of 120 minutes. Indirect tensile strength, compressive strength and porosity were measured and exposed to the temperature. The result indicates that dolomite aggregate has the highest resistance of fire while natural aggregate has least effect.

Compared to normal aggregate, concrete consisting of carbonate aggregate experienced lesser heat transfer with the same thickness. Carbon aggregate gives increased in fire resistance for the concrete [3]

Table-1: Effect of Concrete on Various Temperatures

Temperature Degree Celsius	Effect in concrete
100	Simple Dilation
100-150	Evaporable water lost
150-500	Large change in density observed on above 300°C
400-500	Calcium hydroxide is decomposed Ca(OH)2------> CaO+H2O

MATERIALS USED

- Fine aggregate
- Coarse aggregate
- Cement
- Water
- Polypropylene fiber
- Mineral admixtures

METHODOLOGY

Properties of Aggregate of Concrete

To obtain a good concrete mix, aggregates need to be clean, hard and strong. Aggregates are divided in two distinct categories- fine and coarse. Particles greater than 0.19 inch are termed under coarse aggregate whereas fine aggregate consist of natural sand or crushed stone with particle size passing through a 3/8 inch sieve.[3]

Carbonate aggregates (limestone, dolomite and lime rock) consists of calcium or magnesium carbonate or groupings of the two. When disclosed to fire, carbon dioxide is rout out and calcium or magnesium oxide remains. The reaction activates at the exterior exposed to fire and headed to the opposite side. As compared to normal-weight aggregates, carbonate aggregates shows better results in a fire.[4]

Silicious aggregate consists of silica and include granite and sandstone. Aggregates with lightweight are usually made up of clay or slate. Concrete comprising lightweight aggregate and carbonate aggregate can hold their compressive strength up to about 650°C.[4]

Preparation of Concrete Specimen

Casting and testing of concrete cube in different temperatures. All materials i.e. cement, fine aggregate, coarse aggregate, water and admixture will be mixed thoroughly. Sujit Kumar Sulakhe et.al.[7] used moulds of dimension 150mm×150mm×150mm to cast the concrete cubes of M20. A.M.K. Abdelalim [8] used local ordinary Portland cement with coarse aggregate like natural gravel, basalt and dolomite with maximum aggregates size of 20mm. Jasira Bashir et.al. [11] used M25 grade with water cement ratio of 0.50. Replaced fine aggregate by 0.5% of polypropylene fiber.

EXPERIMENTAL FINDINGS OF VARIOUS RESEARCHERS

Kore Sudarshan D. et.al. [5] Used Portland Pozzolana Cement as the material. Performed experiment on impact of fire on mechanical properties of concrete containing marble waste. Marble waste used was crushed into crusher to obtain desired gradation of coarse aggregate. The test specimen were exposed to fire at different temperatures of 200, 400, 600, 800°C

200°C → not considerable variation were observed on the external and internal of the concrete specimen

400°C → indicated some petty reaction in color as compared to that of specimen exposed to 200°C.

600°C → red color dominated on the surface of the specimen.

800°C → the surface of the concrete specimen has twisted into dark patches.

Sanket R et.al. [6] Performed experiment on performance of concrete during fire exposure. The result of different parameters such as aggregate type, exposure time including condition and temperature were investigated. It was observed that temperature above 300°C, petty cracks are made through the material, mechanical strength and thermal conductivity were set up to be slowly degraded.

At 550°C dehydration takes place. At this temperature aggregates were found to be deteriorate which leads to shrinkage of concrete.

Sujit Kumar Sulakhe et.al. [7] Conducted experiment using 53 grade standard Portland cement. The bulk

density and relative density of 1.56g/cc and 2.65g/cc were used.85% of coarse aggregate passing through 20mm size and retained on 12.5 mm size were added to 15% of coarse aggregate passing through 25mm size and retained on 20mm were used to obtain a well graded aggregate.

A.M.K. Abdelalim et.al. [8] Measured the effect of aggregate on fire resistance of normal concrete (NC) and self-compacting concrete (SCC). Measured compressive and indirect tensile strength of both the concretes made with altered aggregate types, at 3,7,14 and 28 days. And investigated the result of Polypropylene fibers (PF).

As a result, it was observed that dolomite aggregates provide the highest compressive strength results compared with that of basalt and natural aggregate for both NC and SCC.

Polypropylene fibers got no effect on compressive strength but it improves the splitting tensile strength of both NC and SCC.

Shoib Bashir Wani et.al. [9] Performed experiment on Fire Impact on Concrete Structures. Introduced few solutions to improve fire safety like 1. Fire Wall and Barrier Wall

2. Fire Door

→ Vertical (" Roll-Up") Fire Doors

→ Horizontal ("Sliding") Fire Doors

3. Penetration Protection

Observed that improve structural design methodology, testing for fire protection materials, technology and system, changing building operations and maintenance functions and materials that constitute elements of the fire protection system must be introduced to reduce fire threat.

Alexandra R.L. Kushnir et.al. [10] Considered replacing and partially replacing traditional ingredients, such as Portland cement and quartz sand aggregates with alternatives material as a viable method to reduce the environmental impact of cement and concrete production.

Used (sourced from industrial waste) such as natural zeolites for proper replacement of Portland cement in the construction of concrete. Made cylindrical samples with all the same age and to >> 28 days. Cleaned and dried samples were kept in a container to temperature of 100, 200, 300,400, 500, 750 or 1000°C.

C. Britez et.al. [11] Performed experiment on Fire Impacts on Concrete Structures. Observed that concrete loses approximately 25% of its original compressive strength at temperatures around 300°C and loses approximately 75% when this temperature reaches 600°C.

S. Iffat et.al. [12] Mentioned a new method for determining fire exposure used by fire protection engineers such as calculating the fire load density in a compartment, effect of active fire protection system, severely fire affected concrete be stripped from the steel reinforcement.

Investigated on spalling, cracking, fire developing stages of concrete specimen, solutions to improve fire safety, physical and chemical response to fire.

Jasira Bashir et.al. [13] Performed experiment to progress a fire resistance of concrete by replacing fine aggregate partially with half percent of Polypropylene fibers. Polypropylene fiber and conventional concrete were casted, after 7 and 21 days of curing fire test were conducted on the samples.

He also mentioned that Polypropylene fiber is the lightest fiber accessible

Hongying Dong et.al. [14] Observed the fire resistance act of recycled aggregate concrete columns with diverse concrete compressive strengths. Designed four full-scaled concrete columns to perform the fire resistance of recycled aggregate coarse (RAC) components with diverse concrete compressive strength.

Two cube specimens were casted by normal concrete with compressive strength pertaining to a grade of M20 and M30, respectively, while the other two were made from recycled coarse aggregate (RCA) concrete of M30 and M40 grade, respectively.

RESULTS AND DISCUSSION

Cracks were seen inside the concrete specimen at 600°C and 800°C caused by unsuited thermal expansion of concrete paste and aggregate at raised temperature.

It was also observed that by increasing temperature of fire absorber the water absorption increases with test specimen. Water absorption increases with slow pace till temperature of 400°C however upon reaching temperature range of 600-800°C the water absorption rate increases drastically.[5]

Stated that type of aggregate significantly influences in the performance of fire resistance of concrete. Siliceous aggregate concrete weakens when exposed to temperature above 600°C. The siliceous aggregate concrete are spoiled at boundary at the temperature of 600. As compared to dolostone concrete, limestone concrete experiences more decrease in compressive strength.

Cracks were present in calcareous aggregate concretes at around 600°C. Damaged at the boundary were observed when exposed to 750°C and if cooled. It is due to the de-carbonation of CaCO3. [6]

Complete numbers of 12 cubes of 150×150×150mm size casted with grade M20. 3 specimens were exposed to 100°C and tested instantly at hot state. Similarly, testing conducted on specimens exposed to 300, 600 and 900°C.

It was identified that the loss of strength of the concrete subjected to the high temperatures were 5, 45 and 70%, respectively, for 300, 600 and 900°C. [7]

Perceived that at the measured ages, the outcomes of compressive and tensile strength of self-compacting concrete is more than normal concrete. Fine filling particles which increase the packing density of concrete attributed to the imperviousness achieved with SCCs and also develops both compressive and tensile strength of concrete.

Effect of aggregate type on the compressive strength of NC and SCC after exposed to elevated degrees of temperature of 200, 400, 6000 and 800°C [8]

Fire Following Earthquake (FFE) could be a serious threat to structures that are partially damaged in a prior attacked may lead to the quick collapse of structure. He concluded that increase in elastic modulus and tensile strength of concrete id possible through the introduction of steel fibers to perform better during fire exposure. [9]

Revealed that as zeolite increases relative mass change of concrete did not change. He also stated that the huge change in physical and chemical properties of the concrete are caused by the decarbonation of dolomite aggregates.

Detection of thermal micro cracking started at 100-200°C. Thermal micro cracking in the concretes was the effect of thermal expansion mismatch of different minerals and dihydroxylation of cement [10]

The results showed that the high strength concrete behaved in an upright manner under fire, with 95% of its cross-sectional area maintained after the fire stimulation test (only 5% effectively reduced by spalling). [11]

At around 250°C, spalling started to occur. Concrete start to drop its strength at the temperature of 300!. At 550-600°C, it can be seen that cement based materials experienced creep and lose their load bearing capacity. At and above 600°C, concrete drops its capability to function at its full structural capacity. [12]

The outcomes of compressive strength of Polypropylene fiber reinforced concrete at altered temperatures is shown in Table 2.

Table-2: Compressive strength of concrete in 7 days

	Compressive strength of concrete in 7 days		
Temperature (^{0} C)	**Conventional Concrete (N/Mm^2)**	**Polypropylene Reinforced Concrete (N/Mm^2)**	**Percentage Increase (%)**
27	22.4	23.83	6
300^0 C	20.22	22.1	4.17
800^0 C	10.62	12.43	14.46

The outcomes of split tensile test of Polypropylene fiber reinforced concrete at altered temperatures for 7 days is shown in Table 3. [13]

Table-3: Split tensile test in 7 days

	Split Tensile Test in 7 days		
Temperature (^{0} C)	**Conventional Concrete (N/Mm^2)**	**Polypropylene Reinforced Concrete (N/Mm^2)**	**Percentage Increase (%)**
27	1.62	2.42	33.05
300^0 C	1.21	2.03	40.39
800^0 C	0.93	1.7	13.88

The fire resistance period of the specimen, from the initial time of the test until the specimen fails, is determined when the axial deformation becomes greater than or equal to H/100 (mm). H is the valid height of column on fire.[14]

CONCLUSION

In this paper, several researches have revealed that compressive and tensile strength depends on the temperature to which concrete specimen were exposed to fire. Compressive strength decreases with increase in temperature. The compressive strength value upto an exposure temperature of 400°C acceptable. However upon reaching 600°C and higher, both the compressive strength and split tensile strength drops quite low, incorporating polypropylene as an reinforcement improves the tensile strength of concrete not only at room temperature but also at high temperature reaching 800°C. The alterations in

concrete properties like tensile strength, color, compressive strength, thermal conductivity and spalling with regard to altered temperatures are shown in this paper. For improvement of fire resistance of concrete additional fibers similar to glass fibers which have good fire resistance properties can be used. Fire resistant of concrete can also be enhanced by using natural fibers similar to coir fibers in concrete.

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