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Effect of Fire on Concrete and Enhancement in Fire Resistance Capacity of Concrete

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Abstract: Concrete is widely used for the construction of infrastructures such as buildings, bridges, cooling towers, chimneys, industrial and other numerical structures. Fire is one of the most destructive accidental loads that a structure can be subjected during its lifetime. The amount of damage caused will depend mainly on the severity and the duration. The physical properties of concrete and the reinforcing steel are modified by the temperature and duration of fire. Assessment of fire damaged concrete usually starts with visual observation followed by ultrasonic pulse velocity measurements and tests on core samples. This paper outlines a methodology for assessing the concrete cubes at laboratory on samples prepared. A number of cubes samples heated i.e on variable fire temperatures and tested in two conditions. 1.M20 Grade design mix normal concrete cube samples. 2. M20 grade design mix with added carbonated aggregate. The evaluation of the cube samples after heating on varies temperature was also carried out using compressive test followed by load test.

Keyword: Thermal Analysis, Strength Analysis

I. INTRODUCTION

Fire is a physical event, which is difficult to extinguish once, started and most of the time compensatory damages and losses to be formed by is impossible. A building exposed to fire-fighting continues, long hours, and then service of the building after the disaster has become impossible. The loss of life and property are bigger when the structure of building fails before evacuating all of the users. And it shall be also provided that to minimize damages caused by fire, to ensure sustainability of performance after fire and to have a value of compressive strength allowing users to evacuate in time to ensure survival during the fire. Especially in our country, a large part of the buildings is constructed as concrete structures. Because of this fact, concrete must be designed to provide high performance which is used in buildings having high risk of fire, building structure and in fire compartments. At high temperatures, the most important mechanisms that effect losing the values of the compressive strength of concrete and bearing capacity are losing the quality of components in the concrete microstructures which occurs at the end of chemical reactions and creating surface cracks and explosions. The best optimal mix of concrete should aim to provide desirable thermal properties while struggling to minimize the potential for explosion fragmentation and decreasing the values of compressive strength.

Choosing components to develop the properties of at high temperatures.

II. PROBLEM STATEMENT

As a result of temperature increases, in physical and chemical negativities occur in structure of concrete. In the first stage from the physical point of a change is observed in the colour of concrete in certain temperature limit. But this negativity, does not significantly affect the structural properties. However, if we look at the chemical changes in the concrete structure, explosive spalling, integrity and losing bearing capacity is seen as an important problem. Therefore, concrete which is used in construction of high fire risk structures, should be designed to allow to protect the integrity and bearing capacity of the building during the period of evacuation of all users to the outside of the building or safe compartments. Hence, the concrete needs to be created that may have minimum damage after fire or to continue bearing capacity at least at the end of a possible fire. Therefore, it is important to know how concrete perform such temperature value. Only with this way we can improve the behaviour of concrete that exhibit against fire. The temperature degree that concrete integrity can remain stable should be designated depending on the function of the place. Concrete which is used in to create fire compartments and in the will be likely to have high fire risk places structural systems, should be protect load-carrying without impairing the structural integrity capacity to the highest temperature.

In addition, it is important in the way of to reach users to secure point of the building before collapse the structure of the building. Also the protection of concrete integrity and bearing capacity up to high temperature degrees is important to determine the reach of the inhabitants to the secure points before collapse of building. Therefore, concrete used in this places, should maintain aggregate

and cement that continue the value of durability of concrete to the top-up to temperature and certain proportions of pozzolan additives should be added to the mixture to receive higher values of the upper temperature limit.

To improve the behaviour of concrete against fire with these methods:

- 1) *Stage*: It is determined how mechanisms occur at which temperature values within the concrete, depending on the type of selected aggregate and cement.
- 2) *Stage*: It is determined what proportions and what kind of components should be used to improve these drawbacks, and at which temperature values how they react.

Inevitably, concrete structures are exposed to fire and high temperature during its life service which creates changes in concrete properties detrimentally and also sometimes causing failure.

Therefore, it is considerably significant to understand factors that control concrete performance during fires.

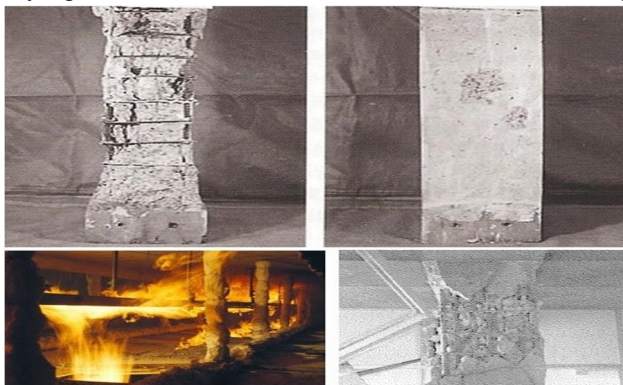


Fig.3.1: Concrete Element Exposed to Fire

III. PRESENT WORK

A. Factors Affecting Performance Of Concrete During Fire

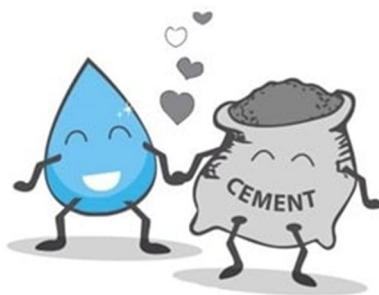
Factors that control the performance of concrete during fire include:

- 1) Water to binding material ratio
- 2) Moisture content
- 3) Type of aggregate used to produce concrete
- 4) Supplementary cementitious materials
- 5) Fibers

B. Water to Binding Material Ratio

One of the factors that influence the performance of concrete during fire is the water to binding material ratio. The smaller the ratio of W/B ratio the better the performance of concrete subjected to fire.

It is proven that the decrease of compressive strength and modulus of elasticity of concrete with high w/b ratio (0.6) is greater than that of concrete with low w/b ratio (0.28-0.35). This trend is the same for lightweight concrete and concrete made with cement replacement materials such as fly ash and slag.



It should be noticed that concrete with low w/b ratio would suffer spalling at lower temperature compare with concrete with high w/b ratio.

C. Moisture Content of Concrete

Moisture content directly affects the performance of concrete during fire. It is shown that the increase of moisture content would increase the possibility of concrete spalling due to high pore vapor pressure.

The level of moisture content is based on the relative humidity and nature of coarse aggregate. If the level of relative humidity is greater than eighty percent, then concrete would suffer spalling when exposed to fire.

D. Type of Aggregate Used to Produce Concrete

Aggregate occupy about 60-70% of volume of concrete, so aggregate properties considerably influence the performance of concrete during fire. There are three common types of aggregated used to produce concrete namely carbonate like limestone, siliceous such as granite and sandstone and lightweight aggregates such as expanded clay and ceramist sand.



Fig.5.4.1: Carbonate Aggregate for Concrete



Fig.5.4.2: Sandstone Aggregate



Fig.5.4.3: Lightweight Aggregate

The performance of concrete made from each type of aggregate is different due to properties of these aggregates.

It is demonstrated that, fire and spalling resistance of concrete made from carbonate aggregate is greater than concrete produced using siliceous aggregate. This is because the specific heat of carbonate aggregate is larger than of siliceous aggregate.

The higher the specific aggregate the better the resistance of concrete against spalling due to fire.

Apart from large heat capacity, there are other factors that contribute the enhancement of fire resistance of carbonate aggregate for example durability and ductility.

As far as lightweight aggregate is concern, it is expected to exhibit great performance during fire since thermal conductivity of such aggregate is low and hence its resistance to heat is high.

It is shown based on test that, concrete produced using lightweight or carbonate aggregate exposed to 648.80C would retain compressive strength whereas concrete made from siliceous aggregate would lose half of its compressive strength when exposed to the same degree of temperature.

E. Supplementary Cementitious Materials

Generally, blending cementitious materials such as blast furnace slag and fly ash improve the performance of concrete subjected to fire. But the influence of cementitious materials is not the same and type of aggregate is also affect concrete performance.

It is demonstrated based on tests that; compressive strength of conventional concrete would be entirely lost at temperature of 1050C whereas concrete produced using cement plus 80% slag replacement would lose around 82% of its compressive strength.

Additionally, supplementary materials would increase the resistance of concrete to spalling during fire. Unlike other supplementary materials, silica fume would outperform by normal concrete when they are exposed to the same degree of fire.



Fig.5.5.1: Fly Ash for Fire Resistance of Concrete



Fig.5.5.2: Silica Fume for Fire Resistance of Concrete

F. Fibers in Concrete

By and large, the addition of fiber would improve the performance of concrete exposed to fire. For example, it is shown that the addition of polypropylene increases the resistance of concrete to spalling.

However, it does not enhance mechanical properties of concrete noticeably. It is recommended to mix 0.1 to 0.5 percent of polypropylene to improve spalling resistance. It is advised to use long fibers if it is anticipated that concrete would be subject to high temperature.

Steel fiber is another type of fiber which can be blended with concrete. Spalling resistance of concrete mixed with steel fiber is inferior to that of concrete blended to polypropylene, but mechanical properties of concrete is generally improved.

So, it can be said that the addition of fibers would enhance the performance of concrete subjected to fire.



Fig.5.6.3: Polypropylene Fiber to Increase Fire Resistance of Concrete

G. Preparation of Concrete Specimen

- 1) All the materials i.e. Cement, Fine Aggregates, Coarse Aggregate and Water with proportion 1:1.5:3 (Cement:Sand:Aggregate) for M20 grade were mixed thoroughly on plane non porous surface.
- 2) Similarly, M20 grade of fire resistant concrete were prepared as per Mix Proportion by using 45% carbonated aggregate and 55% siliceous aggregate.
0.5% polypropylene fiber by weight of a total cement has been added to mix.
Fly ash 20% by weight cement added.
Similarly Silica fumes 10% by weight of cement added to the mix.
Super plasticizer added to maintain water cement ratio low as possible. Quantity of sand remain same as per design mix.
- 3) The moulds of 150mm x 150mm x 150mm dimensions were prepared to cast the concrete cubes of M20 grade for both samples by oiling the inner sides of moulds.
- 4) The matrix were poured into the moulds with each corner properly filled and well tamping with tamping rod to prevent any voids and honeycombing.
- 5) The moulds were kept for 24 hours at room temperature.
- 6) The cubes were then taken out from the moulds and kept in the water tank for 28 days for curing.
- 7) After 28 days the cubes were taken out from the tank and 3 cubes of each sample were tested for compressive strength on Compression Testing Machine.
- 8) Similarly, remaining cubes of each sample were tested for different temperatures and different cooling Methods.



Fig.5.7: Equipment- CTM & Electric Furnace

IV. RESULT AND DISCUSSION

Both normal and fire resistant concrete specimens once subjected to elevated temperatures, small surface cracks were observed. The magnitude and extent of cracks were somewhat negligible up to 300°C. Magnitude and extent of cracks increased for normal because the temperature increased above 300°C. However, a lot of cracks were noticed just in case of normal concrete compared to fire resistant concrete.

At high temperatures of exposure, the sharp edges of the specimen become blunt. Up to 600°C, the failure pattern of concrete cubes was found to be similar to that of control concrete. Colour change of (light pink) surface of the specimen has been discovered at 600°C. The concrete after exposure to 900°C. was found to be red hot and concrete looked slightly pink even after cooling. The cubes crushed into little pieces underneath load and explosive spelling was determined at 900°C.

There is a reduction in compressive strength with temperatures of exposure. The reduction in compressive strength with temperature occurred for each normal concrete and fire resistant concrete. the average loss in strength in M20 grade concrete is about 7.4%, 12%, 19.8%, and 43.5% at, 300°C, 600°C, 900°C and 1003°C respectively, whereas concrete of M20 grade for fire resistant concrete has shown a loss in strength of 5.2%, 7.9%, 14.8%, and 31.6% at 300°C, 600°C, 900°C and 1003°C respectively.



Fig. 4.1: Concrete specimens subjected to 300°C and 600°C

In general, the normal concrete mixes usually have high paste to aggregate content compared to fire resistant strength. Therefore, additional loss of strength in normal concrete is also because of occurrence of small cracking because of thermal incompatibility of hardened cement past and aggregates. In case of fire resistant concrete increase in strength was determined at 300°C, there is also intensifying association with temperature to 300°C. This method is similar to the strength increase behaviour usually determined in steam curing.



Fig. 4.2: Concrete specimens subjected to 900°C

V. CONCLUSION

- A. The loss in compressive strength at elevated temperature is more in case of normal concrete compared to fire resistant concrete.
- B. Strength of concrete decreased with increase in temperature. Decrease in compressive strength is more at normal concrete of 900°C.
- C. Testing after air cooling of specimens resulted in more loss of strength followed by testing after water quenching and testing at hot condition.
- D. The hardness of surface is low for the specimen at hot state, followed by the other states i.e. water quenching and air cooling.
- E. The mass loss is more up to 300°C. Critical degradations in strength is observed above 300°C.

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