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Effect of Fire on Compressive Strength of Concrete

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Abstract: *In the structural design of buildings, it is necessary to design the structure to safely resist exposure to fire. However it is usually necessary to guard against structural collapse for a given period of time. The collapse occurs due to shrinkage and cracking of concrete after firing of the building. The main loss of the concrete due to fire is the loss of compressive strength. That happens due to spilling of concrete. The main objective of the present study is to present the effect of fire on the mechanical properties of concrete, such as a compressive strength, drying shrinkage before and after exposure to fire flame and to study the crack pattern in concrete exposed to fire.*

Key Points: *Concrete, fire, compressive strength, cracks.*

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I. Introduction

Concrete is a composite material composed mainly of water, aggregate, and cement. Usually there are additives and reinforcements included to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses. Concrete is universally used as a construction material which can be molded into any shape that man desires can be provided at a reasonable cost a material that can be designed to ensure high compressive strength. Concrete is a most widely used construction material with present estimated annual consumption of more than 6 billion tons a year all over the world. From the present trend, the future of cement concrete application looks brighter not only because of its better engineering properties but also on accounts of its better ecology and environmental acceptance.

Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products. Slower oxidative processes like rusting or digestion are not included by this definition. The flame is the visible portion of the fire. If hot enough, the gases may become ionized to produce plasma. Depending on the substances alight, and any impurities outside, the color of the flame and the fire's intensity will be different. Fire in its most common form can result in conflagration, which has the potential to cause physical damage through burning. Fire is an important process that affects ecological systems around the globe. The positive effects of fire include stimulating growth and maintaining various ecological systems. Fire has been used by humans for cooking, generating heat, light, signaling, and propulsion purposes. The negative effects of fire include hazard to life and property, atmospheric pollution, and water contamination. If fire removes protective vegetation, heavy rainfall may lead to an increase in soil erosion by water. Also, when vegetation is burned, the nitrogen it contains is released into the atmosphere, unlike elements such as potassium and phosphorus which remain in the ash and are quickly recycled into the soil. This loss of nitrogen caused by a fire produces a long-term reduction in the fertility of the soil, which only slowly recovers as nitrogen is "fixed" from the atmosphere by lightning and by leguminous plants such as clover.

II. Literature Review

Some of the studies reported are as:

Elizzietal. In (1987) investigated the influence of different temperature on the compressive strength and density of concrete.

Habeeb in (2000) investigated the effect of high temperature on the mechanical properties of high strength concrete (HSC).

Neville (1995) works on workability, which approximately means a concrete water content, shrinkage is unaffected by an increase in the cement content, or may even decrease, because the water /cement ratio is reduced and the concrete is therefore, better able to resist shrinkage.

Although many researchers worked on the effect of fire on concrete to study the effect of fire on strength properties of concrete but in the present paper emphasis is given to study the effect of fire on compressive strength of concrete because plain concrete in very strong in compression and weak in tension. So, only plain concrete has been considered to know the effects of fire on plain concrete in the present paper.

Objective of the present study:

The main objectives of the experimental program are to study the effects of fire on the compressive strength of concrete.

III. Methodology

To achieve the above objective experimental tests were performed on two sets of 9 samples each with different composition, mix and W/C ratio. Nine concrete specimens were tested before exposure to fire and nine concrete specimens were tested after firing for one hour. Three different Mix (M15, M20, and M25) with PPC cement were prepared by nominal mixing. The W/C ratios used in three sets to achieve different results for compressive strength were 0.40, 0.45 and 0.50.

In this way, two sets of nine different samples of concrete were prepared with different W/C Ratio and different mixes and these specimens were tested before and after the effect of fire. Nine such specimens were tested before firing and other nine specimens were tested after firing and we observed the change in their compressive strength and variation with change in grade of concrete and with change in water cement ratio.

IV. Results and Discussions

The main objectives of the experimental program are to study the effects of fire on mechanical properties of concrete i.e. compressive strength, shrinkage cracks. To achieve these objectives a set of experiments were designed.PPC cement was used with different water cement ratio. Three different grades of concrete were taken for this experiment. The concrete mix was prepared by volume. Locally available coarse and fine aggregates were used. Hearth furnace was used for firing of concrete cubes. Standard cube mold of size 150mm x 150mm x 150 mm were taken for preparing cube samples. The testing was done on Compressive Testing Machine. The compressive strength of concrete was calculated before and after the effect of fire. The following results were obtained from the experiments and were tabulated below after analylizing:

Compressive Strength:

For W/C Ratio: 0.40 Mix Grade	**28 days Compressive strength, MPa before effect of Fire**	**28 days Compressive strength, MPa After effect of fire**
M15	16.88	12.14
M 20	21.25	16.14
M 25	26.81	21.33
For W/C Ratio: 0.45 Mix Grade	**28 days Compressive strength, MPa before effect of Fire**	**28 days Compressive strength, MPa After effect of fire**
M15	15.55	11.77
M 20	19.84	15.10
M 25	24.96	20.95
For W/C Ratio: 0.50 Mix Grade	**28 days Compressive strength, MPa before effect of Fire**	**28 days Compressive strength, MPa After effect of fire**
M15	14.22	11.40
M 20	18.14	14.59
M 25	24.51	20.73

From the results, it is observed that the compressive strength decreases after firing for every grade of concrete. But the decrement vary when grade of concrete or water cement ratio change.

The percentage loss in compressive strength of concrete with different grades M15, M20 and M25 with different Water cement ratio 0.40, 0.45 & 0.50 is tabulated below.

MIX	W/C Ratio	28 days Average compressive strength before the effect of fire	28 days Average compressive strength After the effect of fire	Change in Strength	%age lose in Strength
M15	0.40	16.88	12.14	4.74	28.08
M15	0.45	15.55	11.77	3.78	24.30
M15	0.50	14.22	11.40	2.82	19.83
M20	0.40	21.25	16.14	5.11	24.04
M20	0.45	19.84	15.10	4.74	23.89
M20	0.50	18.14	14.59	3.55	19.57
M25	0.40	26.81	21.33	5.48	20.44
M25	0.45	24.96	20.95	4.01	16.06
M25	0.50	24.51	20.73	3.78	15.42

From the above table, it is concluded that when water cement ratio increases, the percentage loss in compressive strength of concrete decreases. This is due to adsorbed water content present in the concrete mix, which shows its action slightly after fire. When water cement ratio increases the percentage loss in compressive strength decreases after firing i.e. W/C ratio 0.40 have more loss as compare to W/C ratio 0.45 and 0.50 have the least loss. When the grade of concrete increases the percentage loss in compressive strength decreases after firing. i.e. As the grade or W/C ratio of concrete increases, the losses due to firing decreases.

Conclusions

From the experimental results, the following conclusions have been drawn from the present study:

- If water cement ratio in any of concrete mix increases, the percentage loss in compressive strength decreases i.e. if water cement ratio is more in concrete mix the water adsorbed in concrete reduces the loss due to fire.
- The percentage loss in compressive strength of concrete also decreases when the grade of concrete improves i.e. the loss in M-25 grade of concrete are lesser than M-20 or M15 grade of concrete.
- For a fire resistive concrete, a rich graded concrete is recommended.

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