Significance of Analysis of Fire Effects on Concrete Structures

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Abstract— **In the structural design of building, 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 is the loss of compressive strength. That happens due to spilling of concrete.The main goals of this study are:**

1. **Studying the fire effect on the mechanical properties of concrete, such as a compressive strength, drying shrinkage before and after exposure to fire flame.**
2. **Studying the fire effect on the cracking tendency and pattern in concrete cubes before and after exposure to fire flame.**
3. **Studying the fire flame effect on the shrinkage cracking of the specimens before and after exposure to fire flame.**
4. **To form a safe concrete where loss after exposure to fire is least.**

To achieve the above goal we perform a set of 18 experiments with different composition, mix and W/C ratio. Nine concrete specimens were test before exposure to fire and nine concrete specimens were test after firing for one hour. We use PPC cement and three different Mix (M15, M20, and M25) were prepared by nominal mixing. The W/C Ratio was also used in three sets to achieve different results for compressive strength.0.40, 0.45 and 0.50 W/C Ratio were used for making concrete mixes. In this way nine different samples of concrete were prepared with different W/C Ratio and mix. And the specimen was test before and after the effect of fire. In these way eighteen specimens was tested.

Different test results together with literature review were used to analyze the effects of fire on concrete. From the experiment it is observed that the compressive strength of concrete improves by improving the grade of concrete and the percentage lose in strength of concrete also decreases when a rich grade of concrete is used. On the other side W/C ratio also affects the percentage loses. When W/C ratio increases compressive strength of concrete decreases but after the exposure to fire, the percentage lose in strength also decreases.

Key Words : **Fire effects, Concrete, Temperature, Aggregates**

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I. INTRODUCTION

INTRODUCTION TO CONCRETE

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.

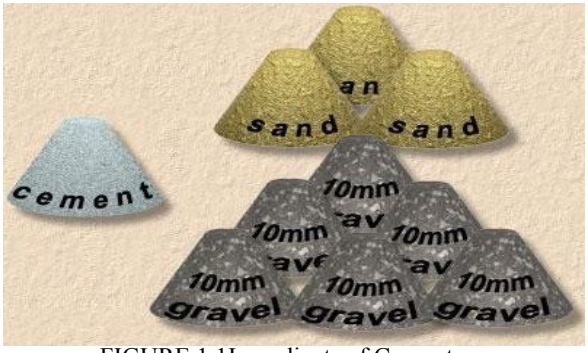

FIGURE 1.1Ingredients of Concrete

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 for the reasons that :

1. It is usually the cheapest and most readily available construction material.
2. It is plastic in nature when in green state and can be molded in desired shapes and sizes.
3. It has good resistance against water passage.

It has better ecological acceptance.

INTRODUCTION TO FIRE

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.

TYPES OF FIRE

Building Fires

We fight fires in every sort of building: people's homes, in high rise office buildings, factories, shops, schools, restaurants, hotels, electrical substations, sporting facilities, scout halls and museums.

In all building fires, the priority is to save lives. Firefighters are trained to search a burning building, wearing breathing apparatus to protect themselves from the smoke, and rescue any occupants. In homes, this includes searching in and under beds, in cupboards or behind furniture or anywhere else where someone may have fallen or hidden. In high rise buildings and commercial premises like factories and shopping centers, firefighters work with the building fire.

wardens and use the fire safety systems to protect and evacuate the occupants as well as conducting search and rescue.

The second priority is to save property. We aim to stop the fire spreading and then put it out as fast as possible, minimizing the damage to property. In 2001/02 we confined 65% of building fires to the object or room of origin. Once the fire is out, we assist the building owners and occupiers by salvaging furniture or other items from the damaged area, protecting them from further smoke or water damage, making sure that nothing is left smoldering and all safety hazards are identified and the premises are secure.

Fires

Fires in industrial premises present particular challenges to firefighters as they involve a wide range of machinery, industrial processes and products. Often, special firefighting techniques have to be used. For example, foam rather than plain water may be used to smother chemical fires. Fires inside industrial machinery can be hard to get to and there may be the risk of dust or gas explosions. Fires in bulk storage areas can also be difficult; the product being stored may be flammable, explosive, corrosive or poisonous and it can be difficult for firefighters to get at the seat of the fire to put it out. For example, fires in piles of car tires create large quantities of toxic smoke and can take days to put out as the unburnttyres have to be moved away from the burning tires. While fighting these sorts of fires we also monitor the effect of the fire on the environment and take measures to limit the damage, for example by building dams to contain the water running off the fire so that it does not pollute the environment.

Structural Fire

A structure fire is a fire involving the structural components of various buildings. When the fire affects the compressive strength of the concrete. Different structural members effect by the effect of the fire. Cracks occur in the different components of the building. And it results week compressive strength.

OBJECTIVES OF THE STUDY

The main objectives of the study is to form a fire proof concrete for the structure which are mainly affected by fire i.e. Chimney kitchen slabs, Nuclear Reactor walls, Missile launching pads etc. And aluminum fiber may be used to control the effect of fire on concrete.

THE MAIN GOALS OF THIS STUDY

1. Studying the fire effect on the mechanical properties of concrete, such as a compressive strength, drying shrinkage before and after exposure to fire flame.
2. Investigation the fire endurance of reinforced concrete beams.
3. Studying the fire flame effect on the immediate deflection of reinforced concrete beams and comparing the results with control beams.
4. Studying the fire effect on the cracking tendency and pattern in reinforced concrete beams before and after exposure to fire flame.
5. Studying the fire flame effect on the shrinkage cracking of the specimens before and after exposure to fire flame.

To introduce a fire proofing concrete for some special applications

METHEDOLOGY USED FOR THE EXPERIMENT

To achieve the above goal we perform a set of 18 experiments with different composition, mix and W/C ratio. Nine concrete specimens were test before exposure to fire and nine concrete specimens were test after firing for one hour. We use PPC cement and three different Mix (M15, M20, and M25) were prepared by nominal mixing. The W/C Ratio was also used in three sets to achieve different results for compressive strength. 0.40, 0.45 and 0.50 W/C Ratio were used for making concrete mixes. In this way nine different samples of concrete were prepared with different W/C Ratio and mix. And the specimen was test before and after the effect of fire. In these way eighteen specimens was tested.

STRUCTURE OF THE RESEARCH

The thesis has six chapters that discuss various aspects of concrete and fire, related with relevance of the thesis. Chapter one explains the background and the objectives of the research. Chapter two is literature review which provides a general understanding of previous studies and theories related to the research .Chapter three discusses the properties of materials used in the investigation. Chapter four deals with the experimental program that was used in the research. Chapter five is about the analysis and discussion of the results

obtained from the study. The last chapter draws conclusions from the research.

METHODS AND MATERIAL USED

The rise in temperature causes a decrease in the strength and modulus of elasticity for both concrete and steel reinforcement. However, the rate at which the strength and modulus decrease depends on the rate of increase in the temperature of the fire and the insulating properties of concrete. Note that concrete does not burn. Once the temperature time relationship is determined using a standard curve or from the method described above, the effect of the rise in temperature on the structure can be determined. The rise in temperature causes the free water in concrete to change from a liquid state to a gaseous state. This change in state causes changes in the rate with which heat is transmitted from the surface into the interior of the concrete component.

Cement

Portland Pozzolana Cement is a kind of Blended Cement which is produced by either intergrading of OPC clinker along with gypsum and pozzolanic materials in certain proportions or grinding the OPC clinker, gypsum and Pozzolanic materials separately and thoroughly blending them in certain proportions.

It is essential that Pozzolana be in a finely divided state as it is only then that silica can combine with calcium hydroxide (liberated by the hydrating Portland Cement) in the presence of water to form stable calcium silicates which have cement properties. The pozzolanic materials commonly used are:

Volcanic Ash.
Calcined Clay.
Fly Ash.
Silica fumes.

Coarse Aggregates

Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. They can either be from Primary, Secondary or Recycled sources. Primary, or 'virgin', aggregates are either Land- or Marine-Won. Gravel is a coarse marine-won aggregate; land-won coarse aggregates include gravel and crushed rock. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. Secondary aggregates are materials which are the by-products of extractive operations and are derived from a very wide range of materials.

Fine Aggregates

Fine aggregates are the aggregates which passing from 4.75 Mic. Locally available fine aggregates are used for research purpose.

Water

The water used in the concreting work was the potable water as supplied in the concrete lab of our college. Water used for mixing and curing was clean and free from injurious amounts of oils, acids, alkalis, salts and sugar, organic substances that may be deleterious to concrete.

FIRING OF CONCRETE

The firing of concrete cubes is done on hearth furnace in smithy shop of NIILM University, Kaithal. The Concrete specimens were fire for one hour at constant coal firing. The specimens were test after six hours when they remove from hearth furnace.

WATER CEMENT RATIO

It is the ratio by weight of water to the weight of cement expressed as percentage decimal fraction in cement concrete. Maximum water cement ratio specified for durability = 0.50 (Refer IS: 456-2000 Table 5).

Therefore, the water/cement ratio adopted = 0.40, 0.45 and 0.50.

MIXING OF CONCRETE

The three main options for mixing concrete are:

- Mixing by hand - this is probably only suitable where less than about ¼m³ of concrete is required for a job providing that a reasonably fit person is available.
- Using a cement mixer - this is generally suitable where between about ¼m³ and 2m³ of concrete is required. It will require continuous mixing of loads and normally someone else to do the laying of it.

Buying in Ready Mix - for jobs requiring more than about 2m³ of concrete, it is probably best (and cost effective) to buy in a lorry load of ready mixed concrete.

EXPERIMENTAL WORK

The main objectives of the experimental program are to study the effects fire on mechanical properties of concrete i.e. compressive strength of concrete. In this experiment we use different specimen for checking the effects of fire on concrete structure. To achieve this objective, an experimental setup is designed.

A set of eighteen specimens was prepared for achieving the objective of present study. Nine specimens were test before firing and other nine specimen were test 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.

First of all we check the properties of general material which is used for preparing the concrete mix. The materials are cement, fine aggregates, coarse aggregates and water. After checking properties of these materials we prepare concrete mix and then check the compressive strength of concrete cubes to achieve:

1. The fire effect on the mechanical properties of concrete, such as a compressive strength, drying shrinkage before and after exposure to fire flame.
2. The fire effect on the cracking tendency and pattern in concrete cubes before and after exposure to fire flame.
3. The fire flame effect on the shrinkage cracking of the specimens before and after exposure to fire flame.
4. To form a safe concrete where loss after exposure to fire is least.

TESTING OF MATERIALS

The objective of this program is to obtain the properties of the different constituent materials to be used for making the specimens for the experimental studies. The data is useful to classify the cement, sand and coarse aggregate. These values will be used for further studies for the calculation of mix design. These values also confirm the right type and quality of the materials used.

Firing of Specimen

The firing of concrete cubes is done on hearth furnace in smithy shop of SUS Engineering College. The Concrete specimens were fire for one hour at constant coal firing. The specimens were test after six hours when they remove from hearth furnace.

CONCRETE FIRING MATERIALS

Wood and coal pieces were used in a furnace for firing of concrete. Coal is a natural dark brown to black graphite like material used as a fuel, formed from fossilized plants and consisting of amorphous carbon with various organic and some inorganic compounds. Dry wooden pieces and coal both were used for firing of concrete.

FIRING OF CONCRETE

The firing of concrete cubes is done on hearth furnace in smithy shop of NIILM University, Kaithal. The Concrete specimens were fire for one hour at constant coal firing. The specimens were test after six hours when they remove from hearth furnace.

Analysis:

The above studies represent different cases of compressive strength loss in concrete after exposure to fire. In some studies the variation in temperature and different heating cycle is used to check the change in compression strength in concrete. Some of the researcher use crack and workability concept. 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.

RESULTS FOR EXPERIMENTS

Three concrete mixes (M15, M20, M25) with three different W/C ratios (0.40, 0.45, 0.50) was taken and six samples of each type of mix were prepared. Three cubes were tested without firing and three cubes were tested after firing. The testing was done after 28 days pond curing. The cubes were fire for one hour in hearth furnace and compressive strength was checked on compressive strength test machine.

Mix Designation	Area (mm^2)	Load (kN)	Compressive Strength (N/mm^2)	Average Compressive strength (N/mm^2)
M15	22500	385	17.11	16.88
	22500	375	16.66	
	22500	380	16.88	
M20	22500	475	21.11	21.25
	22500	485	21.55	
	22500	475	21.11	
M25	22500	595	26.44	26.81
	22500	610	27.11	
	22500	605	26.88	

COMPRESSIVE STRENGTH RESULTS:

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

TABLE 1: Compressive strength of concrete M15, M20 and M25 grade with water cement ratio 0.40 before and after effect of fire.

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

TABLE 2: Compressive strength of concrete M15, M20 and M25 grade with water cement

ratio 0.45 before and after effect of fire.

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

TABLE 3: Compressive strength of concrete M15, M20 and M25 grade with water cement ratio 0.50 before and after effect of fire

From table 1, table 2, and table 3 it is observed that the compressive strength of concrete decreases after firing. Average 15% to 30% loss in compressive strength was observed. When water cement ratio was 0.40 the loss in compressive strength was more as compare to water cement ratio 0.45 or 0.50.

The present investigation was undertaken to study the effect of fire on characteristic strength of concrete. To achieve the objectives of the present study, eighteen specimens were prepared. Nine specimens with different grade of concrete and water cement ratio were test before firing and other nine specimens were test after firing. The results of the testing compared to check the percentage loss in compressive strength of concrete after firing. The compressive strength was determined for the mixes at the curing age of 28 days. The results obtained for the above mixes were compared to investigate the effects of fire on concrete. The conclusion drawn from this study is presented in this chapter.

CONCLUSIONS

Based on the results obtained in the present investigation, the following conclusion can be drawn-

A. The results obtained in the present study indicates that 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.
B. The percentage loss in compressive strength of concrete also decreases when the grade of concrete improves i.e. the loss in M25 grade of concrete are lesser than M20 or M15 grade of concrete.
C. To form a fire resistive concrete it is suggested that a rich graded concrete must be chosen because the void ratio is less in that kind of concrete. And due to less void ratio effect of fire is less due to in serviceability of air.
D. Due to rich water cement ratio the water which adsorbed in the concrete reduces the loss due to expose of fire.
E. The rich water cement ratio is suggested in such structure where firing action is more, for example chimneys, missile launching pads, air craft runways, furnaces and nuclear projects.

In general increase in water cement ratio reduces the compressive strength of concrete but in case of firing it reduces the percentage loss in compressive strength after firing.

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