EFFECT OF SPRAYING WATER WHILE FIRE FIGHTING ON CONCRETE STRENGTH PROPERTIES

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ABSTRACT

In general, water is used as fire controlling element. Throwing or spraying of water in fire that spread inside a concrete structure can affect in rapid cooling of concrete element as well. Eventually, performances of concrete structures after exposure to an accidental fire need an assessment for its durability. Therefore, it is required to examine the effect of rapid cooling of concrete to find out the extent to which it actually have loses its strength. In the presented paper, the results of a laboratory program is presented which was carried out to observe the residual strength of normal strength concrete after burning in an uncontrolled fire.

Concrete cylindrical specimens were casted in the laboratory. These specimens were tested at 90 days of age before and after burning in cellulose fire for two hours to a maximum temperature of 600°C. Burnt specimens were quickly cooled by spraying water immediately after burning. After 48 hours of cooling, the strength parameters of these burnt specimens were tested and compared with the same age of unburnt specimens. It was found that nearly 50 percent of the concrete strength can be lost in case of rapid cooling of concrete with water.

Keywords: *Normal strength concrete, Elevated temperature, Residual strength, Rapid cooling.*

1. INTRODUCTION

In recent times, fire accidents became a regular phenomenon worldwide. Despite of implementation of various measures, rules and regulations, there are still several instances of fire outbreak occurring every year, resulting in significant losses of lives, livelihoods (through injuries), equipments and materials [1]. Statistics from Fire Service and Civil Defense showed that around 250,000 fires occurred in Bangladesh between January 1, 1997 and December 31, 2018. Figure 1 shows various incident of fire happened in last decade that have shocked the country and will be in memory for a longer period of time. Some of the events actually put the respective authorities in pressure to introduce new rules and regulation to stop such scale of fire incident. In reality it is difficult to impose all these rules in every corner of densely growing cities like Dhaka.

a) Fire at Nimtoli, Dhaka (June 2010)

b) Tazreen Fashion Garments Fire fighting (0n November 24, 2012)

c) Fire on 15 storied Zaman Tower, Paltan, Dhaka (on Dec 29, 2018)

d) Locals fight flames during the fire at Churihatta Lane in Old Dhaka's Chawkbazar area (on February 20, 2019)

e) Fire on 22 storied F R Tower, Banani, Dhaka (on March 28, 2019)

f) Fire fighters are controlling a fire

Figure 1: Remarkable disastrous fire events in Bangladesh in last decade *(source-online news portal)*

The major cities of Bangladesh are growing faster after the year 2000 than all other time in history. Massive structures and mega projects like elevated express way and metro rail are in construction phase now. The construction industry largely depends on concrete elements all over the world and Bangladesh is not an exception. Buildings are mostly constructed with concrete except in slum areas. Thus whenever a fire spreads in the city area, concrete structures are supposed to get exposed to that fire. Fire can even spread in the adjacent structures depending upon the weather condition, construction material, socio-economic pattern of life, response time to fire and geographical location etc.

In real situation, concrete structure can be exposed to high temperature in various ways. Among them accidental fire is the most common reason to be exposed to high temperature of a concrete structure. The other ways of exposure to elevated temperature happen when concrete structure is used for furnace wall, industrial chimneys, floors blow boilers and nuclear pressure vessels etc. In Bangladesh, industrial buildings like garments, chemical warehouses are more prone to fire events. Even today, despite of having wide ranges of construction materials, in case of fire exposure reinforced concrete usually pose better performance than steel (Varona et al, 2015). Though concrete are believed to have better fire resistance than other building material, it cannot help stopping spread of fire and can lose strength significantly if exposed for a prolong time.

In residential building, fire is generally spread out by the burning of home use items like wooden furniture, clothes etc which in fact creates cellulose fire condition. Although there are different ways to extinguish the fire, in case of any fire outbreak, people think of water to put the fire off (figure 1 d) from the closest reach source. Still sometimes the fire event in any single structure can sustain for more than a day. Even the fire fighting agencies use water to stop and control fire as shown in figure 1 f. Concrete structures can have severe damage both due to exposure of high temperature and even sudden cooling of its surfaces with water as a result of thermal shock, which causes different stresses in the concrete members. In figure 2, it is shown the structures after Nimtoli, Dhaka fire events in 2010.

Fire resistance of concrete is affected by various factors like the type of aggregates and cement used in its composition, the temperature and duration of the fire, sizes of structural members, and moisture content of concrete (Phanl, 2001).The behavior of concrete exposed to high temperatures is complex. At that time, considerable change in the chemical composition and physical structure of the concrete occurs. If the concrete is dry or the heat is applied slowly, relatively little permanent damage is done with concrete. If the concrete is wet when the heat is suddenly applied, the production of steam within the concrete can cause spalling. The dehydration such as the release of chemically bound water from the calcium silicate hydrate (CSH) becomes significant above about 110°C. The dehydration of the CSH gel and the thermal expansion of the aggregates increase internal stresses and from 300°C micro cracks are induced through the material. Dissociation of Calcium Hydroxide [$Ca(OH)_2$], one of the most important compounds in cement paste, at around 530°C resulting in the shrinkage of concrete. The fire is generally extinguished by water and CaO turns into [$Ca(OH)_2$] causing cracking and crumbling of concrete. Therefore, the effects of high temperatures are generally visible in the form of surface cracking and spalling. Some changes in color may also occur. The alterations produced by high temperatures are more evident when the temperature exceeds 500°C, the changes that caused at this temperature are considered irreversible. CSH gel, the strength giving compound of cement paste, decomposes further above 600°C. At 800°C, concrete is usually crumbled and above 1150°C feldspar melts and the other minerals of the cement paste turn into a glass phase. As a result, severe microstructural changes are induced and concrete loses its strength and durability(Arioz, 2007).

Figure 2: Concrete structures after Nimtoli fire incident (in 2010, *source-online news portal*)

In this paper, the strength behavior of concrete was examined when the specimens were exposed to uncontrolled cellulose fire and then cooled with spraying water on them. The results of the study may be useful for the people who work for the rehabilitation of fire exposed concrete structure and also for the fire fighters in dealing with water spraying to put off fires.

2. METHODOLOGY

2.1 Preparation of Specimens

Concrete cylinder specimens of 100X200mm size were prepared were prepared with OPC cement, black stones of 20mm down size, sand (FM 2.80). ASTM standard procedure was followed to find out the material properties such as specific gravity, weight density. Afterwards, ACI Mix design procedure was used to produce concrete cylinders of 25MPa with a slump value of 80-100 mm. Specimens were then kept in water curing tank for 28 days.

2.2 Testing

After 28 days of water curing, three specimens were tested for strength properties, rest were kept in room environment. Then at 90 days after casting followed by 28 days moisture curing, three specimens were tested at room temperature (25 ± 5°C) for compressive strength and splitting tensile strength respectively; and these results were considered as reference result. After that the remaining samples were burnt in cellulose fire for two hours to a maximum elevated temperature of 600°C. Then the burnt specimens were rapidly cooled in water. After 48 hours of cooling, the specimens were tested for compressive and tensile strength properties; and the results were then compared with the reference samples.

Figure 3: Burning arrangement of concrete specimens.

Figure 4: Burning of concrete specimens in cellulose fire.

Figure 5: Rapid cooling of burnt specimens

3. RESULT AND DISCUSSION

The result presented here is a partial presentation of the laboratory experiment work to find out the concrete degradation in fire for changes in different parameter. The result below in the table 1 is showing that rapid cooling of concrete can come to effect in loosing its strength by a maximum of 50% of its average actual strength.

Table 1: Test results of strength for before and after burning of specimen

For Reference Samples			**For Burnt Specimens**			
Specimen number	**Compressive Strength (MPa)**	**Avg. Compressive strength (MPa)**	**Specimen number**	**Compressive Strength (MPa)**	**Residual Compressive strength (MPa)**	**Loss in Compressive strength (%)**
1	24.6		7	12.3	49.4	50.6
2	25.4	24.9	8	14.5	58.2	41.8
3	24.7		9	13.0	52.2	47.8
Specimen number	**Tensile Strength (MPa)**	**Avg. Tensile strength (MPa)**	**Specimen number**	**Tensile Strength (MPa)**	**Residual Tensile strength (MPa)**	**Loss in Tensile strength (%)**
4	2.4		10	1.4	56.6	43.4
5	2.5	2.46	11	1.3	52.8	47.2
6	2.5		12	1.4	56.6	43.4

The fire in this study was an uncontrolled cellulosic one to match with the reality. The temperature data at three different locations were recorded continuously; and a maximum of 600^0C was recorded that was lasted for about 5 minutes of its peak. After the burning of the concrete samples, no cracks or sign of damage on the surfaces was noticed. Specimens were looking healthy despite the results depicted almost 50 percent loss in strength.

4. CONCLUSIONS

From the test results, it is revealed that cellulose fire exposure can affect the strength properties; it causes almost 50% of strength loss of concrete when being cooled rapidly in water. In addition to that normal strength concrete does not show any physical damage in case of cellulosic fire event having the maximum temperature of 600^0C. There are a lot of other factors that needed to be considered in such a study for example the duration of fire. Also for a better understanding, a standard fire curve is needed to use. Hence, it can be considered as the limitation of this study; but a real life fire is actually an uncontrolled one. Other concrete properties like aggregate type & sizes, cement type, strength parameter etc may have impact on the result. Further study can be made with the variation of these properties.

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