TESTING OF RCC BEAMS EXPOSED TO VARIOUS BURNING TEMPERATURES

M. M. Hossain*[1], N Apu[2], U. H Sumaiya[3] and Y Mahmood[4]

[1] *Professor, Ahsanullah University of Science and Technology,Bangladesh, e-mail:* drmonjur@yahoo.com
[2] *Jr. Structural Engineer, Appolo Engineering & Constructions Ltd. Bangladesh, e-mail:* nibasapu@gmail.com
[3] *Student, Institute of Water & Flood Management, BUET, Bangladesh, e-mail:* sumaiyaceaust2014@gmail.com
[4] *Infrastructure Development Officer, BRAC Bank Ltd, Bangladesh, e-mail:* yaseermahmood@gmail.com

ABSTRACT

This paper deals with the behavior of reinforced concrete beams exposed to fire at three different temperature levels. For this purpose eight RCC beam samples were cast with identical cross section. The materials used for the casting of the beams like rebar and concrete were tested. Two reference beam specimens were tested for flexural strength which were not subjected to fire. The other six specimens two in each group were subjected to fire of levels 400˚C, 600˚C and 800˚C respectively for an exposure period of 2 hours which were then allowed to cool naturally up to room temperature. Then flexural strength of all the specimens were measured by an UTM and the results were compared with the two un burnt beams. For the burning purpose a simple furnace was built. The result showed significant decrease in residual strength of the beams with the increase of burning temperature.

Keywords: *RCC beams, clear cover, fire, flexural strength.*

1. INTRODUCTION

Now a day's fire damage in terms of loss of life, homes and livelihoods has become a regular phenomenon. A study of 16 industrialized nations (13 in Europe plus USA, Canada and Japan) found that, in a typical year, the number of people killed by fires was 1 to 2 per 100,000 inhabitants and the total cost of fire damage amounted to 0.2% to 0.3% of GNP (Ashok & Arun, 2013), (Rahul & Mundhada, 2012). UK statistics suggests that, of the half a million fires per annum attended by firefighters, about one third occurs in occupied buildings and these result in around 600 fatalities (almost all of which happen in dwellings) (Ashok & Arun, 2013), (Rahul & Mundhada, 2012). The loss of business resulting from fires in commercial and office buildings runs into millions of pounds each year (Ashok & Arun, 2013), (Rahul & Mundhada, 2012). The extent of such damage depends on a number of factors such as building design and use, structural performance, fire extinguishing devices and evacuation procedures. Appropriate design and choice of materials is crucial in ensuring fire safe construction. Unfortunately, fire can effect almost all kinds of building, often when least expected. Bangladesh during last couple of decades has experienced several fire accidents both in commercial structures (mainly garments) and dwellings. Lack of proper knowledge about fire safety has resulted in structures that are sub-standard from view point of fire resistance. Beams of a building due to their exposure to fire on three faces and sharp bents are prone to more fire damage than other structural elements. So, there is an important need of study on performance of RCC beams under fire. This study is intended to create a general awareness and to improve the existing practices and Code provisions.

2. METHODOLOGY

2.1 Test Specimens

The specimens for testing were RCC beams. Eight RCC beams were cast with same cross-section, length, reinforcement and grade of concrete. All the beam specimens were 5"(Width) × 6"(Depth) × 36"(Length) in size. But testing was carried out on 30 in. span. In casting 1:2:4 (Cement: Sand: Stone Chips) with 0.5 w/c ratio mix concrete and 8mm xtreme 500 w - BSRM steel bar were used. Steel, cement & aggregates from the same batch were used for all specimens. To provide clear cover, 1.5" blocks were placed at bottom. A steel bar 5" length tied perpendicular with main reinforcement at both ends to keep in place and to maintain spacing.

2.2 Simple Furnace

A low cost simple furnace was made using plain steel sheet (18 gauge) having dimensions 4'×1.5'×1'. Two holes of 1" diameter were made on the opposite side walls placed 1ft from each ends and 1.5" above bottom surface.

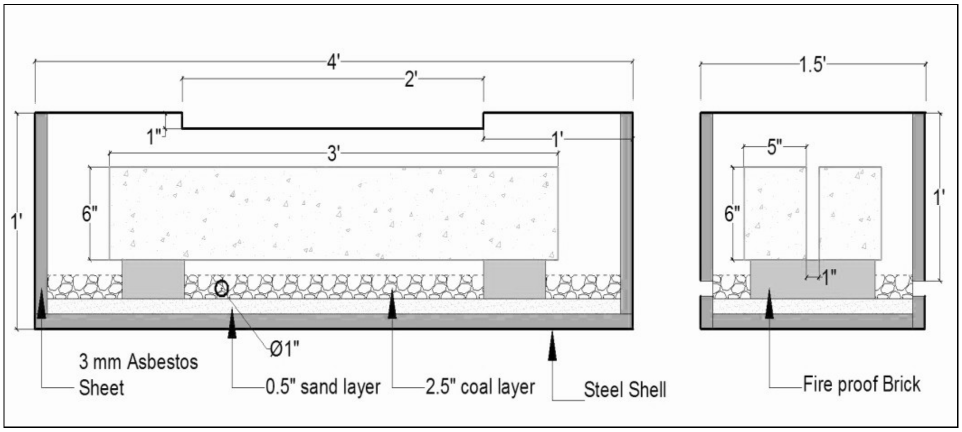

Figure 1: Longitudinal and Transverse section of Simple furnace

These holes were provided for better air circulation inside the furnace. The length wise steel walls are cut 1" deep from the top and folded outwards in order to allow air passage when the furnace is covered. An asbestos sheet of 3mm thickness was provided inside the shell having same height of the shell to protect it from the heat produced inside, during burning.

2.3 Burning

The beams were burnt inside the furnace constructed. Two types of coal, wood coal and stone coal of ratio 2:1 respectively were used for burning. A sand layer having 0.5" thick was placed on the bottom of the shell to restrict the heat transmission. Then approximately 2.5" layer of coal was placed on the sand layer. Continuous air blow was applied to keep the coals burning and to attain and control desired temperature level. The beams were placed inside the shell over two fire clay bricks, and the coal around the beams were burnt .Two beams were

Figure 2: Burning of beam inside the furnace

Burnt simultaneously .Two beams were burnt at 400ºC, the next two beams were burnt at 600ºC and the last two beams were burnt at 800ºC. The sensor of the thermocouple was placed in the gap under the beams to measure the temperature of fire and after each ten minutes temperature readings were recorded. The beams in pair were burnt for two hours after reaching the desired temperature levels. After burning, the beams were taken out of the furnace by hooking the anchor rods and were allowed to cool naturally up to room temperature. Range of temperature and duration of burning followed in this study were also followed by other investigators (Kadhum, 2013), (Ashok & Arun, 2013)

2.4 Testing

To obtain pure flexural failure, two point load testing was carried out. All the beam specimens were cured in a curing tank for 28 days & then tested. Two unburnt reference specimens were tested for the flexural strength using UTM and the results was recorded. The burnt beams were tested in the same way. The load was increased gradually till the failure occurred in a typical fashion. The loads on appearance of flexure and shear crack along with the failure load were recorded. Figure 3 shows the setup for bending test in an UTM along with the samples after tests. Details of beam reinforcement and loading is shown elsewhere (Apu etal, 2014).

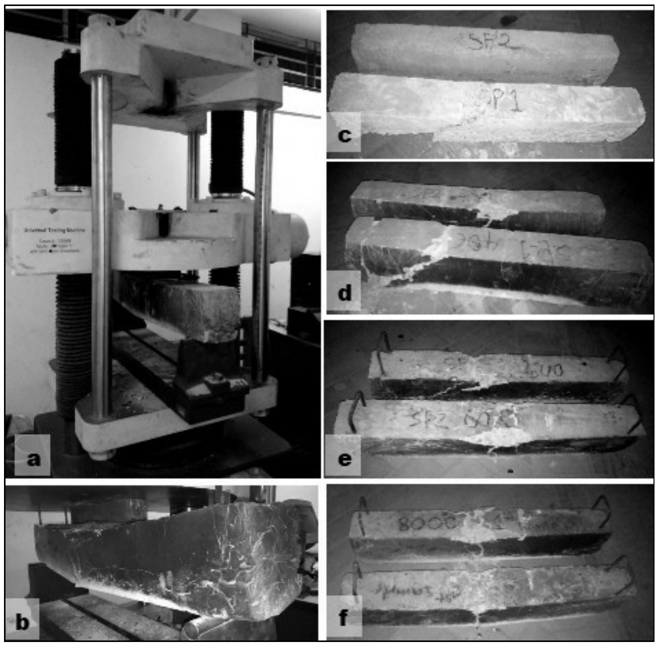

Figure 3: a) UTM setup for Bending test, b) Typical beam at bending , c) Un burnt beams, d) Beams burnt at 400°C, e) Beams burnt at at 600°C, and f) Beams burnt at at 800°C.

3. RESULTS AND DISCUSSION

Table 1 shows the values of different cracking load observed at the time of beam test.

Table 1: Decrease in cracking load and ultimate load with rise in burning temperature.

Temp (^{0}C)	Specimen Identification	Load for Flexural Crack(kip)	Load for Shear crack(kip)	Ultimate load(kip)
Unburnt	SP1	4.16	11.02	14.73
Unburnt	SP2	3.82	10.68	13.69
400	SP1	2.47	10.80	11.47
400	SP2	2.68	10.12	12.20
600	SP1	1.35	9.44	9.53
600	SP2	2.02	9.62	10.03
800	SP1	1.24	8.00	8.30
800	SP2	0.72	7.49	7.60

Figure 4 below shows the behaviour of deflections with decreasing failure loads for beams which were burnt to higher temperature. Similar curves are obtained for all the samples. Gradual decrease in strength was observed from the unburnt beams to the beams subjected to the fire effect up to 800°C. All the curves were approximately linear up to their maximum flexural load. The deflection against the load at this point is comparatively less and once the maximum flexural load is attained, the deflection of the beam increases rapidly and beam undergoes plastic deformation and approaches to failure. The failure phenomena can be regarded as a ductile failure.

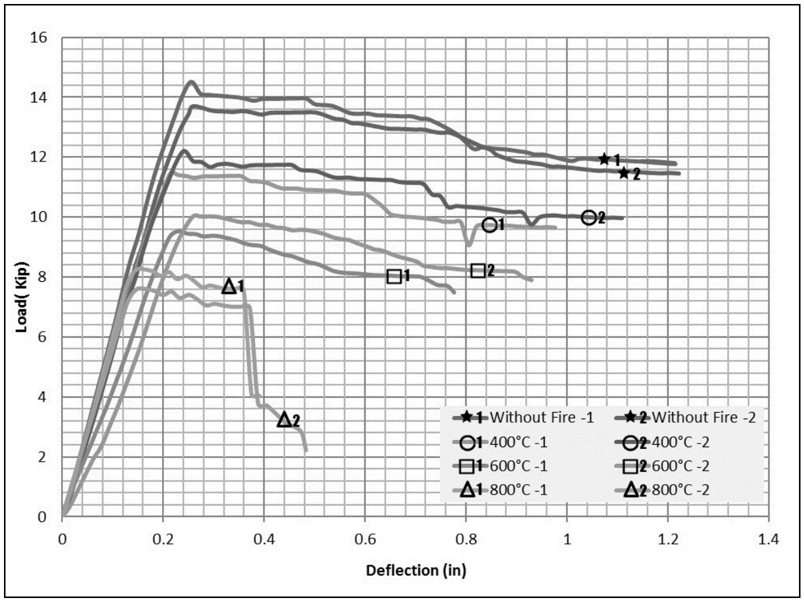

Figure 4: Comparison of load deflection behaviour of unburnt beams and beams burnt at 400° to 800°C

From the above data and the curves it is clear that the fire has considerable effect on the strength of RCC beams. In this study load capacity of the beams burnt at 400°C is found to be reduce by 16.71%, the beams burnt at 600°C is found to be reduce by 31.18% and the beams burnt at 800°C is found to be reduce by 44.05%. So, it is seen that RCC beam element when subjected to fire is a major factor to be concerned.

4. CONCLUSIONS

In general majority of fire damaged RCC structures are repairable. But the observation of effect of elevated temperature at 800°C on the reinforced concrete beams showed that there is significant reduction in flexural strength. The cracking load for flexure for beams exposed to fire at 400°C & 600°C for 2 hours declined by about 35.46% and 57.77% respectively with respect to unburnt beams. But for 800°C there is significant decrease in flexural cracking load by about 75.44% which is alarming. The ultimate strength for beams exposed to fire at 400°C, 600°C & 800°C for 120 minutes were less than that for the reference beam by about 16.71%, 31.18% & 44.05% respectively. To minimize the effect of fire of 400°C immediate quenching and minor retrofitting is recommended. For 600°C of fire effect immediate repairing is prescribed to help to regain its strength. For 800°C of fire effect replacement is suggested.

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REFERENCES

Ashok R. Mundhada & Arun D. Pophale, (2013) " Effect of Elevated Temperatures on Performance on RCC Beams "*International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD) ISSN 2249-6866 Vol. 3, Issue 3, Aug 2013*, 105-112,105-112

N Apu, Y Mahmood & U. H Sumaiya (2014) "The Effect of fire on Flexural Strength of Reinforced Concrete Beam". *Undergraduate Thesis, Dept. of Civil Engineering, Ahsanullah University of Science & Technology, December,2014.*

Rahul P. Chadha, A R Mundhada, (2012) "Effect of Fire on Flexural Strength of Reinforced Concrete Beam", *International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181 Vol. 1 Issue 3,* 1-6.