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Strength Evaluation of Damaged Structures – A Case Study of Fire Damaged Building.

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Abstract: *Fire is one of the major sources of disaster in case of industrial buildings. There is financial loss & threats to many lives working in the industry. After a fire incident, the first question from structural point of view arises is whether the construction can be repaired and can be used faster or need to reconstruct. The decision must be based on an assessment of the status of the structure. This paper present a case study on the structural assessment of building damaged by fire and discussed on the strength evaluation techniques by visual inspection and NDT testing. At the end of the investigation, structural analysis is carried out to determine the repair methods. As few members were affected more while major members were not affected much, therefore it is decided to repair the building and use it.*

Key words:

Fire damaged concrete, destructive testing, Non destructive testing, USPV, Rebound Hammer test.

1. Introduction:

Properties of reinforced concrete structure affected and deteriorated, when it subjected to fire. The important properties affected are loss in compressive strength, loss of elastic modulus, cracking and spalling of concrete, reduction in yield strength, ductility and tensile strength of steel, loss of bond between concrete structures are damaged to a certain extent. During the fire they may retain a residual load bearing capacity. It could therefore economical to repair the damaged structures as cost for demolition and rebuilding can be avoided, further it can be reused faster.

This paper discussed on the case study of a fire damaged building. The building is RCC framed Ground + Two upper floors. The building is constructed 50 years ago. Due to the fire raw material like carbon powder and rubber is burnt. The machine mounted on first floor is damaged. Aluminium partition and M.S grill of windows is broken and damaged due to fire. Effect of the fire to the structural components can be seen from the shaded colour of wall, columns and beams, at all over the surfaces. The structural assessment was aimed to investigate effect of fire to the elements inside the building, to investigate the condition of the main structural element due to the fire and to recommend overall condition of the building.

Reinforced concrete structure behaviour as fire resisting element caused most of fire damaged structure being reused after the fire, provided structural assessment has been carried out. Effect of the fire level to the structural element inside the fire damaged building need to be investigated in order to ascertain the existing capacity and condition.

Important information about the building like type of structure, year of construction, grade of concrete, loads assumed is collected. Also information about cause and point of fire initiated, predicted fire temperature, duration of fire is collected.

NDT (Non Destructive Testing) and laboratory techniques are very used. In situ techniques are advantages as directly applicable on concrete surface in non destructive way. For instance to check concrete hardness Schmidt Rebound Hammer is used. Ultrasonic pulse velocity and Rebound Hammer tests conducted on large area in short time duration. But these techniques provide limited information on the depth of fire damage inside the concrete.

On the other hand, partial destructive test like core drilling is useful to know the depth damage. The cores are drilled at the most infecting zone detected. All above techniques are very useful in the evaluation of fire damaged structure and provide necessary information for repair and residual load bearing capacity.

2. Site investigation:

2.1 Visual assessment :

Visual inspection has been conducted for all elements inside the building. All the RC members are checked for cover, concrete, spalling, cracks, deflection, and bond condition between steel and concrete. All surface are checked and inspection for colour change, surface crazing, cracking etc.

Visual inspection on ground floor shows that RC members are not affected by the fire. Majority member surfaces does not show any colour change range of temperature is < 300 0 c (ref table 1)

Table – 1 Colour changes in concrete at range of temperature (Ref 4-5)

Range of temperature	Colour	Appearance	Condition
T <3000 C	Normal	Normal	Normal
300 ≤ T < 600	Pink to red	Cracking	Sound but may be strength loss
600 ≤ 950	Whitish grey	Spalling steel exposed & powder existence	Weak
T ≥ 950	Buff	Extreme spalling	Extreme/ severe

No colour change on surface is noticed; plaster at certain location is cracked and spalled. Slab covers at certain panels are spalled cause of oxidation of steel. All structural steel members supporting the machinery is in good condition. Connections are also in good condition. Concrete floor surface damaged due to wear and tear.

On the first floor, reclaimed rubber, machine oil, FRP pallets and drums were kept, Rubber is burnt partially and pallets are melted partially. Remains of MS frame of oil drums neither bent nor melted. RC beam and slab in the grid B26-B27, D28-D29 were affected by fire and heat. Spalling of concrete cover is observed. Reinforcement is exposed in certain members. Inspection of mild steel reinforcement in RC members doesn't show any debond condition. No powdered steel existence is observed. Freshly broken concrete shows grey colour. Plaster of all members is completely damaged on the first floor plaster surface shows crazing and cracking.

Carbon powder, whitening powder, silica and power oil is stored on second floor. Entire surface area turned black due to smoke. No cracks colour change cracking, spalling of concrete is observed on second floor. Material stored on 2 nd floor is not burnt.

Total thickness of coating for R/F bars as available for various members is:

Columns = Cover 35 mm + Plaster 15 mm + Neeru 3 mm = 53 mm

Beams = Cover 25 mm + Plaster 15 mm + Neeru 3 mm = 43 mm

Floor Slab = Cover 20mm + Plaster 10 mm + Neeru 4 mm = 34 mm

Referring IS 1642:1989 clause 6.1 (table 8 & table 9) clause 7.1(table 10). Based on observed effective cover and requirement of IS 1642 towards expected cover thickness, judgement can be developed to what extent fire has affected the RC members.

Thus cover for columns is adequate for stated duration of 4h of fire and cover for beams is adequate for 1 hr and cover for slabs is adequate for 2 hr rating. Actually, plaster and especially Neeru finish have found to help protecting plaster surface to a great deal so that almost no physical damage was seen in RC members. It is not certainly known whether some of cracks seen in beams were existent prior to fire.

Figure 1: Interior view of first floor of damaged building

2.2 Non Destructive Testing:

The observation from the visual inspection has shown that all RC elements were just externally affected by the fire. NDT test and core drilling test is still been carried out to ascertain the existing concrete uniformity and fire depth in members.

2.2.1.1 Schmidt Rebound hammer :

The Schmidt Rebound hammer has been used widely to detect surface hardness of a material. The test is carried out on ten locations of selected members. The test is conducted based on IS 13311 part.2-1992. The probable accuracy of prediction of concrete strength in a structure by the Rebound hammer is ± 25%. The average strength by Rebound hammer is 24.94 MPA.

2.2.1.2 Ultrasonic pulse velocity test (USPV) :

UPV test is conducted to measure depth of the fire damaged concrete layer. This test is conducted as per IS 13311- 1-1992 .The fire damaged layer has a lower wave speed than the underlying non-damaged concrete. The Ultrasonic pulse velocity through the concrete is dependant of the elastic properties and density of the concrete. Therefore, areas with poor elasticity or low density such as fire damaged concrete can be detected with this method.

The main advantage of this test is it is very easy to investigate the uniformity of the concrete, consequently fire damaged areas can be readily determined. It is recommended to use UPV results with co-relation with other tests.

UPV test is taken on core samples taken from fire exposed area and unexposed area.UPV test is conducted at different length of core starting from fire exposed site. The UPV test is also conducted on in-situ structural member beam, column and slab. The test conducted in all members is nearly same. The average UPV test 3.16KM/Sec showing medium quality rating of the concrete.

Figure 2: USPV test on column and Beam

2.2.1.3 pH test of concrete :

To determine the pH level of concrete, the phenolphthalein indicator is used. The solution of indicator remains colourless in acids but turns reddish or pink in alkalis. It is possible to judge the temperature and neutralization depth through the change of colour in the test surface of concrete, which permits the soundness and the reusability if the concrete exposed to fire to be judged.

When the indicator was applied after chipping out the surface of concrete, significant change in the colour was immediately observed. Therefore the members of frame not have experienced a maximum temperature of more than 5000c.

2.3 Destructive Testing:

To determine depth of fire damaged in the concrete layer, a core test is performed. Core samples from different locations. In normal condition without exposing to fire, the colour of the concrete is light grey. However after heating above 3000 c, the colour can change from normal to pink.

The core samples are tested for compressive test of existing concrete also. The core samples are tested in laboratory. The samples give the average compressive strength 14.89 MPa.

Figure 3: Core collected at site

3. CONCLUSIONS:

There is no appearance of severe damage for reinforced concrete elements, except for spalling of mortar. No cracks are found on the concrete surface. Strength of concrete members has been estimated by using Rebound hammer and core test. From the test results it indicates that strength of concrete is not affected. Comparison of colour and texture shows that the elements were experiencing less than 300^0c temperature.

RC members affected externally only. There is no appearance of severe damage for RC members except spalling of plaster and cover concrete at certain parts of beam and slab. The concrete to steel bond was determined to be good. The building is constructed 30 years ago. The grade of concrete used is M15 and mild steel reinforcement cover to concrete members is good. As grade of concrete is M15, section size of members is large, which might be beneficial, in case of fire incidents. It is recommended to do the surface repair of slab and beam.

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