Journal of Advances in Science and Technology
Vol. 20, Issue No. 1, March-2023, ISSN 2230-9659

To Analysis the In Situ Structural Assessment and Strengthening of Disaster Affected Structures

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Abstract - In India specifically in Metro Cities the residential and commercial buildings construction rapidly increases. The mass of Population and several commercial area are associated in comparatively small area due to land rate and other reasons in metro cities .But due to quite a lot of reasons either manmade and natural theses structure affected by disaster .Fire is one of the major source of such kind of disaster in metro cities because if these kind of fire disaster use of that structure is not to be done by occupants due to these the financial loss may take place and it is also not economical to demolish the buildings and build a new building. To avoid the loss the buildings structural audit is necessary to check its structural stability after fire disaster and the strengthen of building by appropriate method is very much essential After a fire incident the first question from a structural point of view is whether the construction can be refurbished or, in extreme cases, needs to be replaced. The choice of action must be based on an assessment of the status of the structure. This assessment is in turn based on a mapping of damage to the construction. The mapping of damage needs to be accurate to optimise both the safety level and the best solution from an economic point of view. The traditional assessment methods included in the experimental part of the research are: rebound hammer, ultrasonic pulse measurements and microscopy methods. These are compared to optical full-field strain measurements during a compressive load cycle on drilled cores, i.e. the new method proposed to determine the degree of damage in a fire exposed cross-section. Based on the results from the present study an approach with two levels of complexity is recommended. The initial level is to perform an inspection and determine the development, size and spread pattern of the fire .In this research initially study the different NDT techniques. Then next phase the in situ assessment of fire affected building by taking suitable case studies and evaluated the actual structural damage of building and appropriate method for strengthen of building will be suggested by studying the cost effectiveness of each method

Keywords - In situ, Assessment, Structure, Audit, NDT, rebound Hammer strengthen

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INTRODUCTION

In India specifically in Metro Cities the residential and industrial buildings construction rapidly increases. The mass of population and several commercial area are associated in comparatively small area due to land rate and other reasons in metro cities but due to quite a lot of reasons either manmade and natural theses structure affected by disaster. Fire is one of the major source of such kind of disaster. It is also not economical to demolish the buildings and build a new building. Fire is one of the most severe hazards that building structures may experience during their lifetime. If a structure is damaged by fire, it is necessary to investigate the cause of the fire and evaluate the reusability of the damaged structure. In terms of economic efficiency, it may be a better approach to retrofit the damaged components of the structure, instead of demolishing it partially or completely. This decision must be made based on the result of investigations such as the structural audit, visual inspection of the damaged structure, tests on the remaining material, and finite element simulations of the structure or its structural components. To avoid the loss the buildings structural audit is necessary to check its structural stability after fire disaster and the strengthen of building by appropriate method is very much essential.

Purposes of Structural Audit:

The Purposes of Structural Audit are:

- To save Life and Property.
- To know the health of your building and to project the expected future life.

- Highlight the critical areas that need to be attended with immediate effect.
- To proactively assist the residents and the society to understand the seriousness of the
- Problems and the urgency required to attend the same.
- To comply with Municipal or any other statutory requirements

Significance: Exact details of distress at column, beams, and slabs are noted.

1) It is useful for loan application to bank, for loan insurance claim.
2) Audit helps to understand the condition of structure or building before purchase or sale flat.
3) The property owner can understand the exact structural condition of the building.
4) After audit is done it is easier to convince, to get co-operation and fund from members.
5) It is necessary to produce report if required by register, or BMC or another government department.
6) It helps contractor to know the exact nature of distress before touching the structure for repair so chances of increasing the cost is minimum

LITERATURE REVIEW

Mazza and Imbrogno (2019) Author states that the thermal analysis of RCC members in framed structure is carried out for two fire conditions, on the assumption that the fire compartment is confined to the ground and first floor levels. There are four fire-damage conditions are checked, considering only the heating phase, at 30 and 45 minutes of fire resistance, and the overall fire cycle, for fast, medium and slow phases of cooling. The building is supposed to be repaired and retrofitted with hysteretic damped braces (HYDBs), in order to achieve the performance levels imposed by current Italian code in a high-risk seismic zone. Nonlinear static and dynamic analysis of the damped braced and unbraced structures is carried out, with reference to the degradation of R.C. frame members for different fire exposure durations in the design procedure of the HYDBs.

Jun Zhou and Lu Wang (2019) Author describes here that fire accidents in the buildings have led to a great loss of buildings and damage to property in the past two decades. There is a need to provide different approaches to increase structural safety and stability of structural members after fire accidents. This study reviews on the repair of fire-damaged reinforced concrete (RC) members with axial load. The findings of the effects of loading method, physical dimension and bonding behavior on the residual strength of members are presented. Meantime, the available study on the performance of fire-damaged RC members with axial load repaired with steel jacketing, concrete jacketing and fibre reinforced polymer (FRP) jacketing are summarized. This paper described a review of the repair methods for fire damaged compressed reinforced concrete members. The element enlargement method can improve the structural bearing capacity, stiffness, and stability, especially for compressed elements. Although the construction is easy, the clearance of the building is reduced, which affects the subsequent use.

Wenxian Ma, Chunxiang Yin, et.al (2019) Author explains here that the mechanical properties of concrete elements and steel reinforcement are temperature sensitive and also the load bearing capacity of reinforced concrete (RC) structures are very well known to be temperature sensitive, By the severe damage because of the major fires cause in buildings, followed in most cases by their collapse. Since in most cases RC structures survive fire damage, retrofitting fire damaged RC members is a very important subject today. This paper also described the performance of Reinforced Concrete beams and slabs in fire, different repair techniques are considered, among them externally bonded reinforcement, near surface mounted fibre reinforced polymers (FRP), bolted side plating, jacketing with ultrahigh and high performance of concretes, and damaged-concrete replacement. The design equations targets at evaluating the residual load-bearing capacity after repairing are also presented and discussed. Paper conclude that the externally bonded reinforcement (EBR), near surface mounted fibre reinforced polymer (NSM FRP) strengthening, and bolted side-plating (BSP) technique were adopted to repair fire damaged RC beams

Marco Di Ludovico (2018) Author find that there is no appearance of severe damage for reinforced concrete elements, except for spalling of mortar screeding found appeared in certain parts of columns and beams. No crack found on the concrete surface. Strength of concrete beams and columns has been estimated by using Schmidt rebound hammer test. Paper Conclude that strength of concrete is still unaffected by the fire. It shows the finding of the physical inspection on the appearance of the concrete surface, i.e. no indication of degradation of strength of concrete in the building structure.

Antonio Brancaccio (2018) in this paper Author highlights on the importance of in-situ assesment of structures also finalized to properly design and calibrate innovative structural strengthening solutions such as FRP (Fibre Reinforced Polymers). This paper Conclude that overview of the current methods of performing structural surveys, in-situ material testing and innovative techniques for full-scale structural evaluation. Further, the paper aims to describe this topic by presenting a remarkable case study of a fire-damaged reinforced concrete (RC) industrial structure, located in Dubai, on which an extensive experimental procedures on materials and structures was carried out to examine the damages due to the fire.

OBJECTIVES

- To Analysis the structural damage of fire affected buildings from Structural Audit of building by taking actual case studies (1st case study for Identification of Damages for fire affected buildings and 2nd Case study for Identification of Damages for fire affected buildings as well as identification of strengthening technique.
- To do seismic assessment of the damaged building
- To prepare the detail report of structural audit and give recommendation regarding stability of fire affected buildings

METHODOLOGY

This paper deals with methods of estimating the soundness of existing structures, whose life has crossed the age of 50 years. As we know concrete is widely used as a construction material because of its high strength-cost ratio in many applications. Concrete constructions are generally expected to give trouble free service throughout its intended design life. However, these expectations are not realized in many constructions because of structural deficiency, material deterioration, unanticipated over loadings or physical damage and thus Civil structures like buildings, dams, bridges hectare subjected to continuous deterioration over the years. This extent of damage or deterioration greatly depends on the quality of work at the construction stage. The deterioration of buildings can be a result of various factors including fire damage, frost action, chemical attack, corrosion of steel etc. during the life span of the structure. The investigation of soundness is thus essential for finding the present serviceability of the structure and its scope for future developments or for the change in its utilization. Such an investigation can be carried out using the following methods: a) Visual examination b) Non Destructive Testing. Soundness estimation becomes essential for buildings hit by an earthquake, a bomb blast or any other calamity

DATA COLLECTION: SITE DETAILS

The management of SP Concave Roha, Tal. Roha Dist: Raigad has planned to carry out Structural health assessment of their mixer plant building after the fire accident on 12/02/2022. The building has two manufacturing area and mixer plant building attached to the plant area. Fire is caused by electric short circuit at ground floor, at 8.20am. Fire is controlled at 12.30pm. The said building is Ground + two stored RCC framed structure constructed in 1977. Architectural and structural drawings were available for the reference.

DATA ANALYSIS: VISUAL ASSESSMENT:

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

Visual inspection on ground floor shows that RC members are not affected by the fire. No color 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 mixer unit are in good condition. Connections are also in good condition. Concrete floor surface is 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 partially melted. Remains of MS frame of oil drums neither bent nor melted. RC beam and slab in the grid B26-C27, D28-D29 were affected by fire and heat. Spalling of cover concrete is observed. Reinforcement is exposed in certain members. Inspection of mild steel reinforcement in RC members doesn't show any de bond condition. No powdered steel existence is observed. Freshly broken concrete shows grey color. 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 stored on second floor. Entire surface area turned black due to smoke. No cracks, color change, cracking, spalling of concrete is observed on second floor. Plaster surface at certain location was cracked. Material store don second floor is not burn

Ultrasonic Pulse Velocity Test Observations

Table 1: Ultrasonic Pulse Velocity Observations

Sr No	Location	Member	Distance (mm)	Time(ms)	Velocity (Km/Sec)	Method of Test	Remark
UNAFFECTED AREA							
1	P-06 Beam Second Slab Level	Beam	NA	NA	4.6	In Direct	Excellent
2	P-07 Beam Second Slab Level	Beam	400	112.8	5.8	Direct	Excellent
3	P-10 Beam Second Slab Level	Beam	400	113.4	3.5	Direct	Good
4	P-11 Beam Second slab level	Beam	125	28.3	4.4	Semi Direct	Good
5	P-12 Beam Second slab level	Beam	400	107.2	1.7	Direct	Doubtful
6	P-13 Column Second Slab Level	Column	125	32.3	3.8	Semi Direct	Good

7	P-14 Beam Second slab level	Beam	400	122	3.3	Direct	Medium
8	P-15 Beam Second Slab Level	Beam	125	34.1	1.7	Semi Direct	Doubtful
9	P16 Beam Second Slab Level	Beam	400	95.3	4.6	Direct	Excellent
10	P-18 Column First Slab Level	Column	125	24.6	2.3	Semi Direct	Doubtful
11	P-20 Column First Slab Level	Column	125	24.3	3.9	Semi Direct	Good
12	P-21 Beam First Slab Level	Beam	125	25.2	1.8	Semi Direct	Doubtful
13	P-22 Slab First Slab Level	Slab	NA	NA	1.3	In Direct	Doubtful
14	P-23 Column Third Slab Level	Column	450	120.5	3.8	Direct	Good
15	P-24 Column Third Slab Level	Column	450	124.6	3.6	Direct	Good
AFFECTED AREA							
16	P-01 Beam Second slab level	Beam	400	126.2	1.3	Direct	Doubtful
17	P-02 Beam Second slab level	Beam	400	122.3	3.9	Direct	Good
18	P-03 Slab Second Slab Level	Slab	NA	NA	1.8	In Direct	Doubtful
19	P-04 Column Second Slab Level	Column	125	32.1	5.8	Semi Direct	Excellent
20	P-05 Beam Second slab level	Beam	400	98.2	3.6	Direct	Good
21	P-08 Slab Second Slab Level	Slab	NA	NA	2.2	In Direct	Doubtful
22	P-09 Column Second Slab Level	Column	125	36.4	2.2	Semi Direct	Doubtful
23	P-17 Beam Second Slab Level	Beam	400	133.7	3.0	Direct	Doubtful

Table 2: Ultrasonic Pulse Velocity Acceptance Criteria

Sr. No.	Item Description	Concrete Quality Grading					Total Elements
		Very Poor	Poor	Medium	Good	Excellent	
1	R.C.C. Elements	-	10	1	8	4	23
2	Percentage (%)	-	44	4	35	17	100
3	Lowest USPV (m/sec)	<1400	1500	3000	3500	-	-
4	Highest USPV (m/sec)	<1400	2900	3400	4000	-	-
5	Velocity By Cross Probing (m/sec) as per IS – 13311 (Part 1) : 1992 + Leslie and Chessman	Below 2150	2150 To 3000	3000 To 3500	-	-	-
6	Deviation with respective to Good Quality Rating velocity 3500 m/sec	(-) -	(-) 50%	(-) 5%	-	-	-
7	Average USPV in m/sec	3000 (Medium Quality Rating)					
8	Deviation with respective to Good Quality Rating velocity 3500 m/sec	(-) 17%					
9	Acceptance Criteria For USPV as per IS 13311 (Part 1) : 1992	Minimum USPV 3500 m/sec					
10	Average concrete strength by rebound Hammer method (MPA)	25.66 MPA					

Table 3: Comparison of Results of Ultrasonic pulse velocity Observations

Element	Affected Area			Unaffected Area		
	Rebound MPA	USPV KM/SEC	Core MPA	Rebound MPA	USPV KM/SEC	Core
BEAM	23.36	3.63	14.92	18.66	1.92	NIL
COLUMN	29.33	3.32	15.31	19.60	2.40	NIL
SLAB	19.76	1.76	14.33	13.00	1.80	NIL

Core Test Observations

Table 4: Core Test Readings

No	Member No	Dia mm	Length mm	H/D	Failure Load KN	Core Strength MPA	Correction factor IS:516	Equivalent Cube strength MPA
1	BC1	73	130	1.78	47.00	11.22	1.225	13.75
2	BC2	74	120	1.62	54.50	12.68	1.200	15.00
3	BC5	73	130.5	1.78	54.80	13.00	1.225	16.00
4	BC6	73	110	1.50	55.20	13.20	1.200	15.75
5	BC7	74	90	1.21	56.30	13.00	1.163	15.25
6	S1	73.5	130	1.77	48.40	11.42	1.225	14.00
7	S3	73.5	130.5	1.78	50.10	11.82	1.225	14.50
8	C4	74	112.5	1.52	57.40	13.35	1.200	16.00
9	BC4	73.5	95	1.29	54.30	12.80	1.163	14.75
10	BC3	73	80	1.09	24.00	12.90	1.087	14.00
11	S2	73	132	1.80	49.30	11.78	1.225	14.50
12	C1	74	95	1.28	58.00	13.50	1.163	15.75
13	C2	73.5	97	1.32	49.50	11.67	1.187	13.75
14	C3	73.5	85	1.15	59.20	13.95	1.125	15.75

The average strength of core sample as taken in unaffected area is 15.03 MPA while in affected Area 14.75 MPA. The average strength of the building is 14.89 MP

Rebound Hammer Test Observations

Table 5: Rebound Hammer Test Results for Affected Area

Sr. No	Location	Member	Avg. Rebound Number (Avg of 10 readings)	Indicative Compressive Strength (Mpa)
1	P-06 Beam Second Slab Level	Beam	19.8	< 10
2	P-07 Beam Second Slab Level	Beam	28.4	23.3
3	P-10 Beam Second Slab Level	Beam	30.2	26.3
4	P-11 Beam Second Slab Level	Beam	26.6	20.3
5	P-12 Beam Second Slab Level	Beam	27.2	21.3
6	P-13 Column Second Slab Level	Column	30.2	26.3
7	P-14 Beam Second Slab Level	Beam	28.6	23.6
8	P-15 Beam Second Slab Level	Beam	22.8	14.3
9	P-16 Beam Second Slab Level	Beam	31.4	28.3
10	P-18 Column First Slab Level	Column	37.4	38.8
11	P-20 Column First Slab Level	Column	44	51.1
12	P-21 Beam First Slab Level	Beam	39.2	33.4
13	P-22 Slab First Slab Level	Slab	36.4	28.4

Table 6: Rebound Hammer Test Results for Unaffected Area

Sr. No	Location	Member	Avg. Rebound Number (Avg of 10 readings)	Indicative Compressive Strength (Mpa)
16	P-01 Beam Second Slab Level	Beam	32.7	30.5
17	P-02 Beam Second Slab Level	Beam	30	25.9
18	P-03 Slab Second Slab Level	Slab	27.6	14.1
19	P-04 Column Second Slab Level	Column	30.8	27.3
20	P-05 Beam Second Slab Level	Beam	28.4	23.3
21	P-08 Slab Second Slab Level	Slab	29.4	16.8
22	P-09 Column Second Slab Level	Column	26	19.4
23	P-17 Beam Second Slab Level	Beam	28.4	23.3

Note:-

The probable accuracy of prediction of concrete strength in a structure by the Rebound hammer is ± 25 % As per IS code 13311 (Part-I & II)

The average strength of rebound hammer test in unaffected area is 27.30 MPA while in affected Area 22.57 MPA. The average strength of the building is 24.94 MPA.

Table 7: Comparison of Results of all Testing Methods

Element	Affected Area			Unaffected Area		
	Rebound MPA	USPV KM/SEC	Core MPA	Rebound MPA	UPV KM/SEC	Core
BEAM	23.36	3.63	14.92	18.66	1.92	NIL
COLUMN	29.33	3.32	15.31	19.60	2.40	NIL
SLAB	19.76	1.76	14.33	13.00	1.80	NIL

CONCLUSION

In visual inspection, there is no appearance of severe damage for reinforced concrete elements, except for spalling of mortar. No cracks are found on the concrete surface. Comparison of color and texture shows that the elements were experiencing less than 3000c temperature. Strength of concrete members has been estimated by using Rebound hammer and core test. From the Rebound hammer test results, it indicates that average strength of concrete is 24.94MPA (Table no- 7.5 & 7.6), while according to drawings the grade of concrete is M15. The increase in strength of concrete in may because of hardening of surface. The core sample taken from affected area gives the average strength of 14.89 MPA (Table no.-7.4) while from unaffected area average strength is 15.03 MPA (Table no- 7.4). The Ultra Sonic Pulse Velocity (USPV) results show average velocity of 2980 m/s in affected area and 3340 m/s in unaffected area. Average USPV is 3160 m/s. According to IS13311 Part 1:1992, the velocity between 3000 to 3400 m/s, gives medium grade rating of concrete quality. The deflection is 5-12mm in X and Y direction for the base shear of 1210 KN. Push over analysis for earthquake stability of the structure shows immediate occupancy.

It is summarized from visual inspection and NDT testing those reinforced concrete elements inside the building are not majorly affected externally by the fire. Comparison of color and texture shows that the elements experienced less than 600° C temperature. RC members were 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. No cracks found on concrete surface. The concrete to steel bond is determined to be in good condition. Strength of concrete in affected area as shown by NDT estimates appears to be higher than unaffected area. This is due to hardening of surface. But compression test on core cut samples show 2 % drop in strength. Observation on beam said to be directly caught in fire for portion of exposed cover show that even the binding wire was not affected by fire, ruling out possibility of damage to R/F bars. As a overall conclusion it can be stated that strength of concrete is unaffected by the fire. Age of structure being more than 50 years, it is considered that it has served the useful service life. Being located in seismic zone IV, it is necessary to take precautionary measure for strengthening of some of the members, especially those showing NDT results in poor class.

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