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Retrofitting of Fire Affected Structural Member in Multistorey Buildings

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Abstract:
with the increased incidents of major fires in buildings; assessment, repairs and rehabilitation of fire damaged structures has become a topical interest. This is a specialized field involves expertise in many areas like concrete technology, material science and testing, structural engineering, repair materials and techniques etc. Research and developmental efforts are being carried out in this area and other related disciplines.
In this paper, 8th Storey R.C.C framed structure is considered for performing analysis and design as per relevant Indian Standards codal provisions. The modeling, linear static analysis, and design is to be performed using FE software package sap2000. For analysis the structure is subjected to fire loads in terms of temperature loading at different storey's. Due to temperature loading the strength of column is been reduced, so for re-strengthening of column retrofitting technique is to be carried out.

Keywords*: Fire, Retrofitting, Earthquake, Buildings, SAP-2000*

1. Introduction

Fire is considered one of the most serious potential risks for buildings and structures. But concrete is generally considered to have an acceptable resistance to fire in comparison with other construction materials such as wood or steel. When concrete remains exposed for long time to high temperatures, mechanical losses of its properties take place. Laboratory experiences show that in case of concrete not protected the mechanical properties decrease drastically for temperatures above 300ºC.

With the increased incidents of major fires and fire accidents in buildings; assessment, repair and rehabilitation of fire damaged structures has become a topical interest. This specialized field involves expertise in many areas like concrete technology, material science and testing, structural engineering, repair materials and techniques etc. Research and development efforts are being carried out in these related disciplines. Any structure can undergo fire accident, but because of this the structure cannot be denied neither abandoned. To make a structure functionally viable after the damage due to fire has become a challenge for the civil engineering community. The problem is where to start and how to proceed. It is vitally important that we create buildings and structure that protect both people and property as effectively as possible. Annual statistics on losses caused by fires in homes and elsewhere make for some unpleasant readings and sadly through these events we learn more about fire safety design.

In 1995-96 six large fire tests were carried out on a full-scale composite building at

The BRE Fire Research Laboratory at Cardington4. The tests made it clear that unprotected steel members could have significantly greater fire resistance within real multi-storey buildings than when tested as isolated members. This was undoubtedly due to interaction between the heated members within the fire compartment, the concrete floor slabs (both heated and unheated) and the adjacent composite frame structure. If such interactions are to be used by designers in specifying fire protection strategies, as part of an integrated limit state design process, then this cannot practically be based on testing because of the extremely high implicit costs. It is therefore becoming increasingly important that software models be developed to enable the behavior of such structures under fire conditions to be predicted with sufficient accuracy.

2. Related Work

2.1. Behavior of Reinforced Concrete Slab Subjected To Fire by Mr. C Sangluaia

The behavior of reinforced concrete slab exposed to fire is presented. Two stages of analysis is carried out using Finite Element package ABAQUS to find thermal response of structural members namely thermal analysis and structural analysis. In the first step, the distribution of the temperature over the depth during fire is determined. In the next step, the mechanical analysis is made in which these distributions are used as the temperature loads. The responses of structure depend on the type of concrete and the interactions of structural members. The RCC slab were modelled to show the role of slab thickness, percentage of reinforcement, width of slab and different boundary condition when expose to fire loading. It concludes that Temperature distribution was studied for different layers of the slab along the depth of the slab when temperature changes according to time and it was found that temperature decreases along the depth of the slab. Role of width of slab, role of rebar and role of slab thickness were also observed in this paper and it was found that

- For simply supported slab , displacement increases when width of slab increases
- Displacement decreases when percentage of steel in RCC slab increases
- Displacement Decreases When Thickness Increases

2.2. Structural Strengthening Of Damaged R.C.C. Structures With Polymer Modified Concrete By Suresh Chandra Pattanaik (2009)

Discussed some of the important properties and step by step approach for structural strengthening of damaged concrete structures with polymer modified concrete. He found in an aggressive environment like Mumbai, polymer modified concrete is very much suitable for repair and rehabilitation of damaged RCC structures because of its excellent moisture resistance properties & high early strength. Not only it strengthens the RCC structural members but also makes a highly durable repair. Though FRP has become more effective for retrofitting but polymer modified concrete is being widely used for cost effective. It observed that polymer modified concrete is a free flowing, self-leveling, self-compacting and high early strength material which is being effectively used for structural strengthening of deteriorated RCC members of column and beam in an aggressive environment. It can also be used for additional load carrying of those structural members by method of jacketing.

2.3. Seismic Jacketing Of Rc Columns For Enhanced Axial Load Carrying Performance By Keh-Chyuan Tsai and Min-Lang Lin (2002)

Conducted experiments on seismic jacketing of columns to enhance their axial load carrying capacity. They incorporated different shapes of jacketing such as circular, octagonal and square with different materials ranging from steel plates to CFRP's composites. The results showed that CFRP wrappings are effective in increasing the axial forces but is ineffective during high strain conditions. Test results also indicated that steel jacketing is more effective in increasing the axial force carrying capacity and ductility of RC columns are also increased. Octagonal shaped wrapping exhibits improved performance compared to rectangular wrapped columns. It confirmed that octagonal shaped steel and CFRP jacketing has twice as more axial load carrying capacity than normal columns.

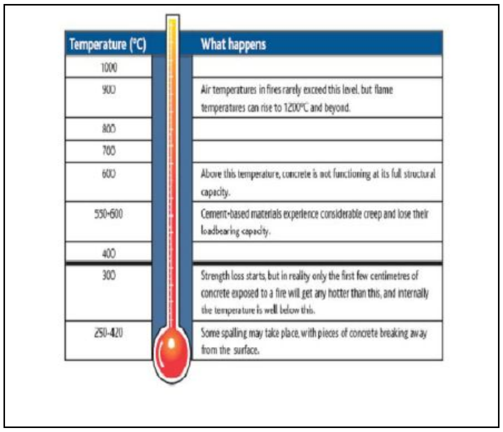
2.4. Reinforced Concrete Jacketing of Existing Structure by Teran. A And Ruiz. J (2005)

Published a study on the jacketing techniques that was widely used for repair and retrofit of the damaged structures in Mexico during the 1985 earthquake. They discussed quantitative as well as detailed applications on the use of concrete jacketing with emphasis on the connections between existing material and the new material added.

3. Terms And Definations

3.1. Effect of fire on concrete

Concrete does not burn it cannot be 'set on fire' like other materials in a building and it does not emit any toxic fumes when affected by fire. It will also not produce smoke or drip molten particles, unlike some plastics and metals, so it does not add to the fire load. For these reasons concrete is said to have a high degree of fire resistance and, in the majority of applications, concrete can be described as virtually fireproof. This excellent, performance is due in the main to concrete's constituent materials (i.e. cement aggregates) which, when chemically combined within concrete, form a material that is essentially inert and, importantly for fire safety design, has a relatively poor thermal conductivity. It is this slow rate of heat transfer that enables concrete to act as an effective fire shield not only between adjacent spaces, but also to protect itself from fire damage. The rate of increase of temperature through the cross section of a concrete element is relatively slow and so internal zones do not reach the same high temperatures as a surface exposed to flames. A standard ISO 834/BS 476 fire test on 160 mm wide x 300 mm deep concrete beams has shown that, after one hour of exposure on three sides, while a temperature of 600°C is reached at 16 mm from the surface, this value halves to just 300°C at 42 mm from the surface a temperature gradient of 300 degrees in about an inch of concrete. Even after a prolonged period, the internal temperature of concrete remains relatively low; this enables it to retain structural capacity and fire shielding properties as a separating element. Once a fire starts and the contents and/or materials in a building are burning, then the fire spreads via radiation, convection or conduction with flames reaching temperatures of between 600°C and 1200°C. Harm is caused by a combination of the effects of smoke and gases, which are emitted from burning materials, and the effects of flames and high air temperatures. The chart below shows behavior of concrete at various temperatures



Temperature (°C)	What happens
1000	
900	Air temperatures in fires rarely exceed this level, but flame temperatures can rise to 1200°C and beyond.
800	
700	
600	Above this temperature, concrete is not functioning at its full structural capacity.
550-600	Cement-based materials experience considerable creep and lose their loadbearing capacity.
400	
300	Strength loss starts, but in reality only the first few centimetres of concrete exposed to a fire will get any hotter than this, and internally the temperature is well below this.
250-420	Some spalling may take place, with pieces of concrete breaking away from the surface.

Figure 1: Behavior of concrete at various temperature

<u>3.1.1. Steps involved in retrofitting of structure</u>

A convenient way to discuss the engineering issues of evaluation and retrofit is to break down the process into steps. The first step involves the collection of information for the as-built structure. The configuration of the structural system, reinforcement detailing, material strengths, foundation system and the level of damage are recorded. In addition, data relevant to the non-structural elements (e.g. infill walls) which play a significant role and influence the seismic response of structures are also compiled. The rehabilitation objective is selected from various pairs of performance targets (i.e. supply and demand, or response and input pairs). The performance target is set according to an acceptable damage level (performance target). Building performance can be described qualitatively in terms of the safety of occupants during and after the event, the cost and feasibility of restoring the building to fire condition, the length of time the building is removed from service to effect repairs, and the economic, architectural or historic impacts on the larger community. Variations in actual performance could be associated with unknown geometry and member sizes in existing buildings, deterioration of materials, incomplete site data, and variation of ground motion that can occur within a small area and incomplete knowledge and simplifications related to modelling and analysis. In the next phase, the rehabilitation method is selected starting with the selection of an analysis procedure. The development of a preliminary rehabilitation scheme follows (using one or more rehabilitation strategies) the analysis of the building (including rehabilitation measures), and the evaluation of the analysis results.

Further, the performance and verification of the rehabilitation design are conducted. The rehabilitation design is verified to meet the requirements through an analysis of the building, including rehabilitation measures. A separate analytical evaluation is performed for each combination of building performance and seismic hazard specified in the selected rehabilitation objective. If the rehabilitation design fails to comply with the acceptance criteria for the selected objective, the interventions must be redesigned or an alternative strategy considered.

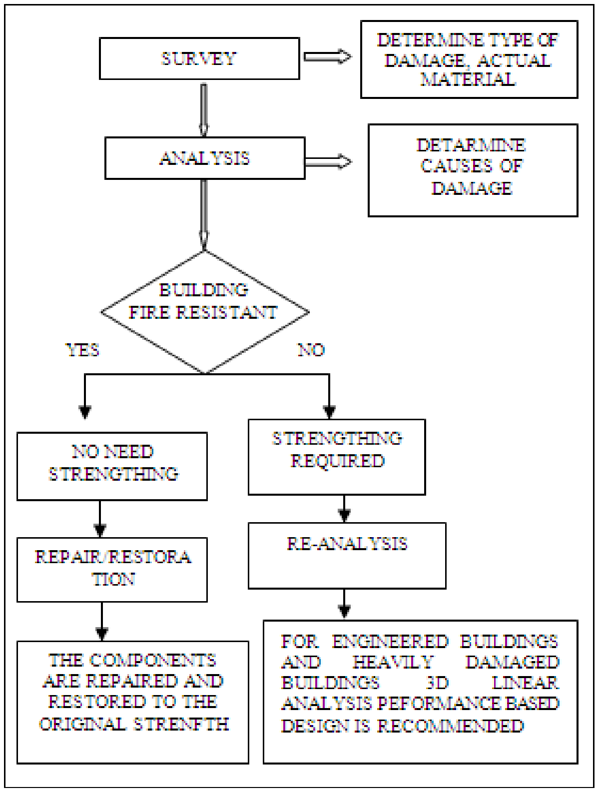


Figure 2: Steps involved in retrofitting of a structure

3.2. Methods of Retrofitting

- Concrete Jacketing.
- Steel Jacketing.
- FRP Wrapping

3.2.1. Concrete Jacketing

- Involves addition of a thick layer of Reinforced Concrete (RC) in the form of a jacket, using longitudinal reinforcement and transverse ties.
- Additional concrete and reinforcement contribute to Strength increase.
- Minimum allowable thickness of jacket = 100 mm.
- The sizes of the sections are increased and the free available
- The stiffness of the system is highly increased.
- Requires adequate dowelling to the existing column.
- Longitudinal bars need to be anchored to the foundation and should be continuous through the slab.
- Requires drilling of holes in existing column, slab, beams and footings.

3.2.2. Steel Jacketing

- Encasing the column with steel plates and Filling the gap with a non-shrink grout.
- Provides passive confinement to core concrete.
- Its resistance in axial and hoop direction can
- Neither is uncoupled nor optimized.
- Its high young's modulus causes the steel to take a large portion of the axial load resulting sometimes in premature buckling of the steel.
- General thickness of grout = 25 mm.
- Rectangular steel jackets on rectangular Columns are not generally recommended and use of an elliptical jacket is solicited.
- Since steel jacket is vulnerable to corrosion and Impact with floating materials, it is not used for Columns in river, lake and seas.

3.2.3. FRP Wrapping

- Involves wrapping of RC columns by high strength-low weight fiber wraps to provide
- Passive confinement, which increases both strength and ductility.
- FRP sheets are wrapped around the columns, with fibers oriented perpendicular to the longitudinal axis of column, and are fixed to the column using epoxy resin.
- The wrap not only provides passive confinement and increases the concrete strength, but also provides significant strength against shear.

4. Proposed Work

In this work, Study of behaviour of columns of 8 storey Rcc framed structure affected by sudden fire action in different floors. Due to the application of heavy temperature on the surface of column, the concrete will reduces its strength, to increase the column strength retrofitting technique is used. The comparison of Bending moments and Area of steel of structure before and after fire are studied. The comparative study of axial forces is done for studied.

5. Modelling And Analysis Of Structure

Following data is used in the analysis of the RC frame building models

- Type of frame: Special RC moment resisting frame fixed at the base
- Seismic zone: III
- Number of storey: 8
- Floor height: 3 m
- Foundation Depth:1.5m
- Depth of Slab: 150 mm
- Size of beam: (230 × 350) mm
- Size of column: (230 × 450) mm
- Spacing between frames: 4 m along both directions
- Live load on floor: 3 KN/m2
- Floor finish: 0.6 KN/m2
- Temperature load-400^{0}C
- Materials: M 20 concrete, Fe 415 steel and Brick infill
- Thickness of infill wall: 230 mm
- Density of concrete: 25 KN/m3
- Density of infill: 20 KN/m3
- Type of soil: Medium
- Response spectra: As per IS 1893(Part-1):2002

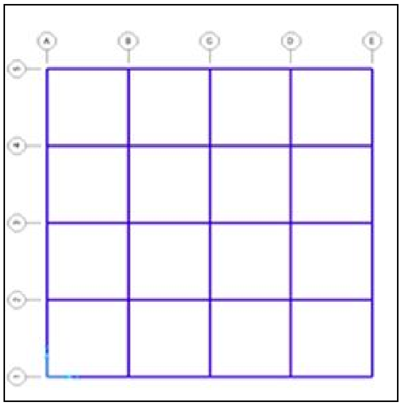


Figure 3: Plan View of Building

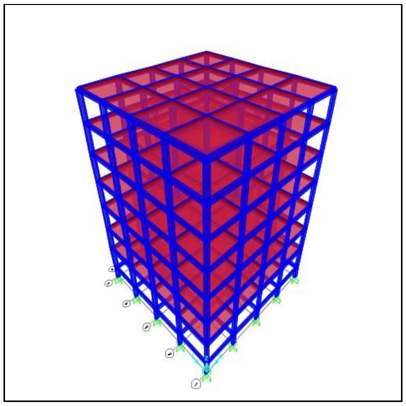
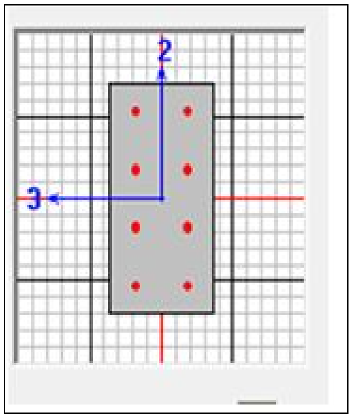


Figure 4: 3D Frame Building model



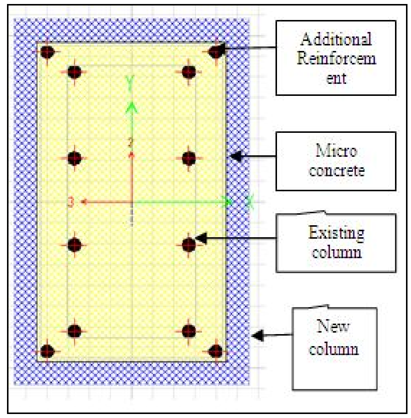


Figure 5: Sectional properties of column before fire
Figure 6: Section properties of column after retrofitting

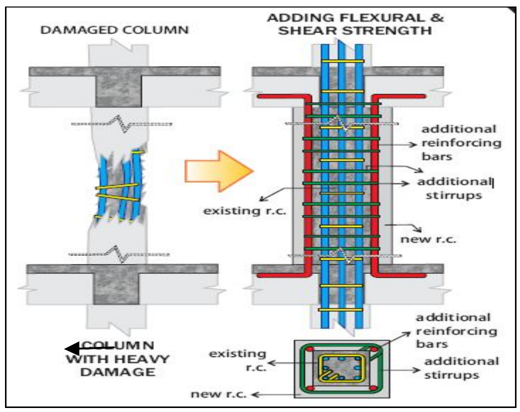
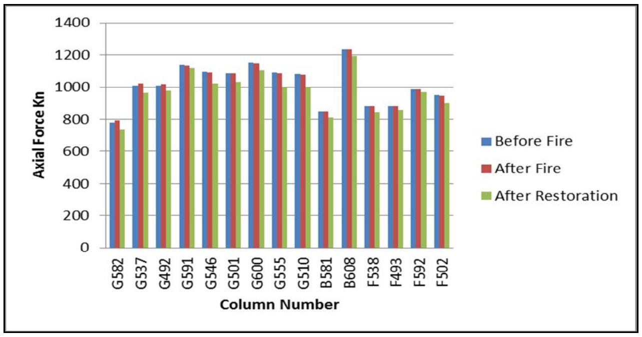


Figure 7: Retrofitting detailed

6. Results And Discussion

	Area MM^2	
Column number	**Before Fire**	**After Fire**
G582	1203.67	2696.2
G537	2331.7	3741
G492	2332.5	3737
G591	3100	4526
G546	2982.3	4389
G501	2959	4362
G600	3164	4602
G555	2959.16	4380
G510	2927.7	4348
B581	1174	1689
B608	2758.25	3094.8
F538	1572.4	2271
F493	1582.2	2336
F592	2504	2840
F502	2390.1	2873.05

Table 1: Fire consider in Ground Floor



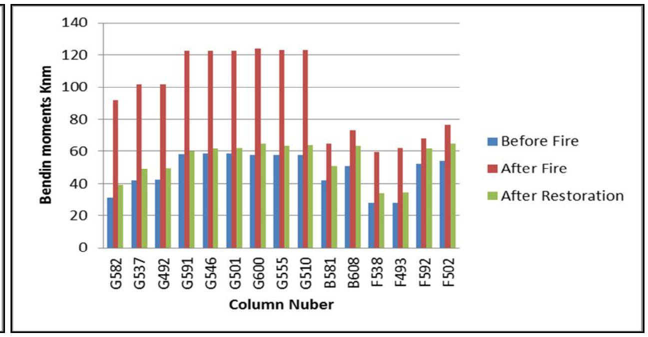
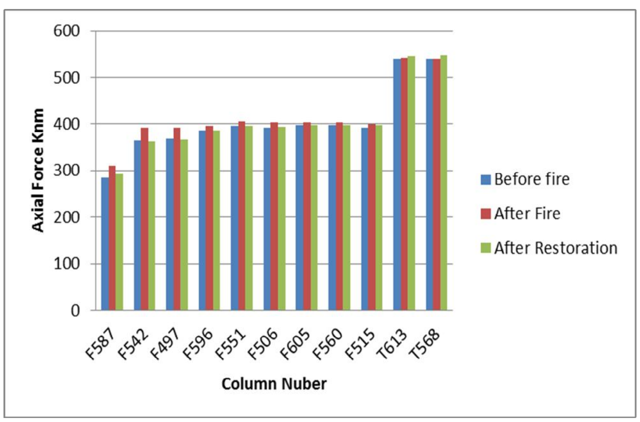


Figure 8: Graphs Showing Axial Force When Fire consider in Ground Floor
Figure 9: Graphs Showing bending moment When Fire considers in Ground Floor

Area MM^2		
Column number	**Before Fire**	**After Fire**
F587	828	993.3
F542	828	1364.54
F497	828	1427.65
F596	828	1900.48
F551	828	2092.7
F506	828	2162.22
F605	828	1980.8
F560	828	2012.98
F515	828	2040
T613	828	1600.7
T568	828	1403

Table 2: Fire consider in 4th Floor



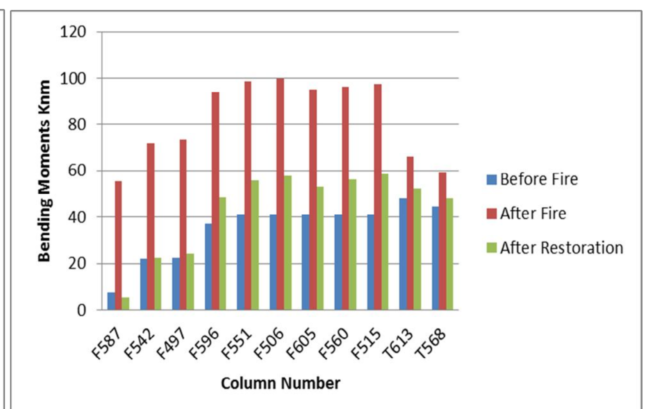
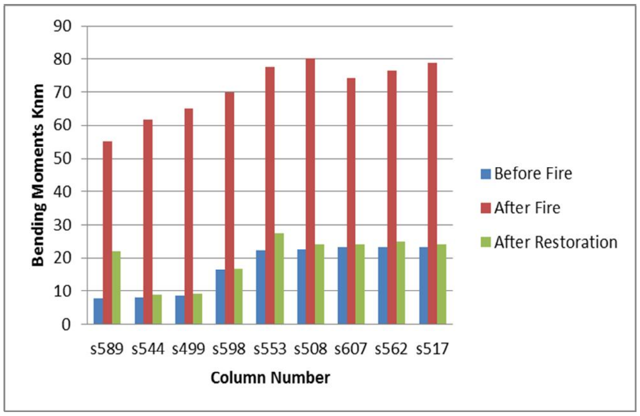


Figure 10: Graphs Showing Axial Force When Fire consider in 4th Floor
Figure 11: Graphs showing bending moments When Fire considers in 4th Floor

Area MM^2		
Column number	**Before Fire**	**After Fire**
S589	828	354.35
S544	828	881.88
S499	828	906.6
S598	828	1039
S553	828	1301.4
S508	828	376
S607	828	1197
S562	828	1277
S517	828	1344

Table 3: Fire consider in 7th Floor



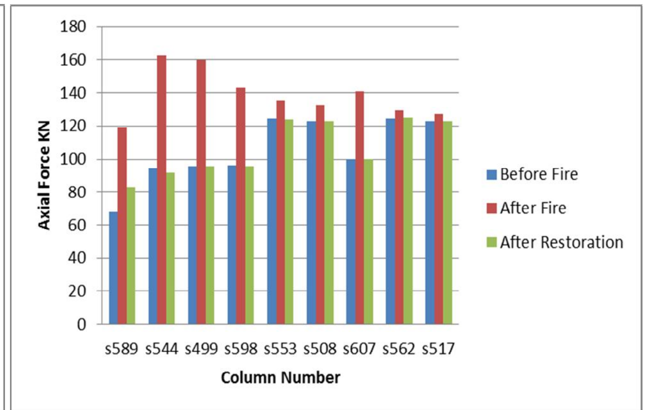


Figure 12: Graphs showing bending moments When Fire considers in 7th Floor

Figure 13: Graphs Showing Axial Force When Fire consider in 7th Floor

7. Conclusion

From the outcome of detailed studies of the building it is inferred that the effect of fire was observed to be severe in ground floor compare to results of other floors. However the effect of fire reduced in the columns of subsequent floor .Also Strength of concrete in the unaffected region Reinforced concrete columns is satisfactory from the analysis result. Whereas it is not satisfactory in severely fire affected region. This could due be due to increase in bending moment because of strength reduced in column. From the analysis it was found that the structure is safe even after the fire but retrofitting was found necessary because reinforcement damaged. After retrofitting using micro concrete, the bending moments reduced as before fire.

8. References

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