A CASE STUDY ON REMEDIAL MEASURES FOR FIRE-DAMAGED STRUCTURE

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Abstract- This paper addresses solutions for buildings damaged by fire and the measures needed for their future usability. Some buildings suffer severe damage from intense fires, while others can be salvaged with a swift response. The case study focuses on Galaxy Heights, a five-story multipurpose building in Gulberg Greens, Islamabad, which, despite significant fire damage, remained usable. During the site visit, no major structural damage was observed, indicating that the building could be rehabilitated using a proposed solution that includes various strengthening chemicals, fire-resistant paint, and the installation of a proper firefighting system. The implementation of this restoration methodology successfully restored the building to its normal usage.

Keywords- Deterioration, thermal, strengthening, retrofit.

1 Introduction

Gulberg is a major construction project in Islamabad, featuring numerous residential and commercial buildings. Developed by the Intelligence Bureau Residential Housing Society, it is strategically located in the heart of Islamabad, along the Islamabad Highway Express. The project is conveniently situated, a 10-minute drive from G.T. Road and only 6 to 7 minutes from the Capital University of Sciences and Technology. Additionally, it is just 10 to 12 minutes away from the Blue Area of Islamabad [1]. During their lifespan, buildings are exposed to a range of hazards, including natural events such as earthquakes, hurricanes, and tsunamis, as well as man-made incidents like fires and explosions. These hazards pose significant risks, potentially causing partial or total collapse of buildings, rendering them inoperative. To mitigate these risks, buildings in projects like Gulberg are designed with advanced engineering techniques and materials to enhance their resilience. This includes incorporating seismic design principles, fire-resistant materials, and robust structural systems to ensure the safety and longevity of the infrastructure. Additionally, regular maintenance and inspections are conducted to identify and address any potential vulnerabilities, ensuring that the buildings remain safe and functional throughout their intended lifespan [2]. In the event of operational hazards, such damage or failure can pose a significant threat to the safety of residents and result in substantial direct and indirect financial losses. Direct losses include the cost of repairing or rebuilding damaged structures, while indirect losses encompass disruptions to daily life, business operations, and the broader economy. To mitigate these risks, it is crucial to implement comprehensive safety measures and emergency response plans. This includes advanced engineering techniques, rigorous building codes, regular maintenance, and proactive disaster preparedness programs. Ensuring the resilience and safety of buildings not only protects residents but also minimizes financial impacts and enhances community stability and economic resilience.

Therefore, structures are constructed to endure various expected risks [3]. These designs safeguard structural integrity and protection throughout the building's lifespan. Fire is one of the most dangerous hazards, and fire safety encompasses a set of methods aimed at preventing fires and mitigating their effects. Key fire safety measures include the use of fire-resistant materials, installation of smoke detectors and sprinkler systems, and the incorporation of fire escapes and emergency exits. Additionally, buildings are equipped with fire alarms and extinguishers, and regular fire drills are conducted to ensure occupants are prepared in case of an emergency. Proper planning and adherence to fire safety regulations are essential in minimizing the risk of fire-related incidents and ensuring the safety and well-being of residents and users [4], [5]. When internal stresses surpass the allowable tensile limits of concrete elements, thermal cracks and spalling can initiate within the material. The deformation characteristics under uniaxial stress of the concrete composite are distinctly manifested based on its type [6]. Fire safety also involves managing the development and consequences of accidental or intentional fires. Fire safety in structures is currently ensured by various specifications outlined in the Building Code of Conduct. Active fire protection techniques, such as sprinklers, heat and smoke detectors, are crucial for detecting, controlling, or extinguishing fires at an early stage, which is vital for life safety [7]. Passive fire protection techniques, including both structural and non-structural modules, are designed to guarantee the stability of the structure during a fire and to prevent its spread. Their primary purpose is to provide sufficient time for firefighting and rescue works and to reduce financial costs [8]. Fig. 1 provides some forms of active and passive fire protections.

This paper addresses solutions for buildings damaged by fire and the measures needed for their future usability. The objectives of this work are to evaluate the extent of fire damage, propose effective rehabilitation techniques, and ensure the restored buildings meet safety standards for future use. The case study focuses on Galaxy Heights, a five-story multipurpose building in Gulberg Greens, Islamabad, which, despite significant fire damage, remained structurally sound. During the site visit, no major structural damage was observed, indicating the building could be rehabilitated. The proposed solution includes applying various strengthening chemicals, fire-resistant paint, and installing a proper firefighting system. This restoration methodology not only restored the building to its normal usage but also enhanced its resilience against future fire incidents, ensuring long-term safety and functionality.

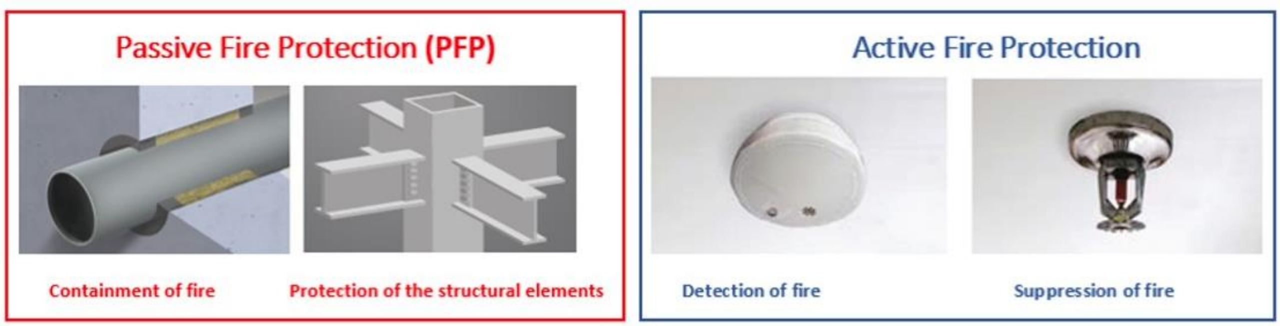

Figure 1: Active vs. passive fire protections (examples) [9]

1.1 Fire causes/reason:

For the subject building, initial observations indicated that the fire started due to a short circuit in the main distribution board of the generator. Around 7 A.M., when the Water and Power Development Authority (WAPDA) shut down electricity (load shedding), the generator activated automatically. As the generator began supplying power to the board, a short circuit occurred, igniting the fire. The fire then spread to the generator control room and eventually engulfed the entire top floor of the building. These initial observations were later confirmed by the findings of the firefighting team [7].

2 Post-Fire Observed damages

Heat transfer significantly impacts the mechanical and thermal behavior of both concrete and steel. Thermal propagation causes heat to move from one point to another, affecting the materials. When steel is exposed to high temperatures, it loses its mechanical properties and experiences additional thermal strain [10]. Compared to steel, concrete loses strength at relatively higher temperatures. Unlike steel, concrete does not melt but deteriorates and decomposes. Concrete starts losing its strength around 500-600 degrees Celsius. Upon cooling, it loses strength again, behaving like a brittle material. Exposure to direct fire damages the structural properties of concrete, and the redistribution of forces within the structure increases the probability of failure of structural members [4].

2.1 Concrete colors at different temperatures (Visual color change)

After the fire incident, the building owner engaged a company called "RK Engineering & Consulting Services, Islamabad" to assess the damage caused by the fire. The company dispatched a team of senior civil engineers to inspect the condition of Galaxy Heights and document the damage. The team made the following observations. Table 1 details the changes in concrete color over a range of fire exposure.

- Two columns of the 5th floor were found damaged by fire. (concrete covers were damaged & steel was exposed but remained undamaged)
- Two beams of the 5th floor roof were found damaged by fire. (concrete covers were damaged & steel was exposed but remained undamaged)
- 5th floor roof was burnt up to some extent
- Wooden sealing was found burnt.
- Wooden doors were burnt.
- There was some furniture on the 5th floor of the building that caught fire.

Table 1 Color changes in concrete due to temperature

Temperature Range, ^{o}C	**Concrete Color**	**Visual**	**State**
Smaller than 300	Normal	Normal	Normal
300 to 600	Pink to red	Surface crazing, cracking and aggregate pop outs	Sound but strength may be reduced
600 to 950	Whitish grey	Spalling, exposed of steel reinforcement and powdered existence	Weak
Greater than 950	Buff	Extreme spalling	Extreme/severe

3 Possible solutions to make reusable building

- Strengthening the columns, beams, and slab of the 5th floor by increasing the size of structural element. (by using strengthening chemicals in concrete + plaster) (Design change)
- Repair structural damage by using different strengthening chemicals and apply fire resistant paint with proper firefighting system installation.
- Provision of steel bracings to weak structural elements (columns, beams)
- Substitute structural element introduce (column, beam)
- Demolish the entire structure and rebuild the whole building.
- Rebuild only 5th floor of Galaxy Heights.
- Repair the damaged portion the same as it was before fire simply by ordinary concrete and plaster. (Without any epoxies, chemical use in it).

3.1 Most economical solution/purposed solution from engineering point of view

As engineering point of view keeping in experience and technical knowledge of structures and building load transfer mechanism we will go for second point, i.e., "Repair structural damage by using different strengthening chemicals, retrofit new wooden feature parts, and apply fire resistant paint with proper firefighting system installation" The main purpose of this solution is related to the building condition [8]. The structure was not in the worst condition, and it could be repaired with structural strengthening chemicals like Sikawarp-300 (structural strengthening fabrics) & Sikawarp-900C (Stitched carbon fiber fabric). In addition to this, we will go for SBR Chemical (Ressi SBR 5850) & SLR chemical (SLR-L 4601) joints in steel and concrete [8].

3.2 Solution mechanism proposed.

The recommended rehabilitation measures for the fire-damaged Galaxy Heights building in Gulberg Greens include several crucial steps. First, remove all damaged or weakened concrete and plaster from the affected areas, including columns, beams, and slabs, to ensure a clean and stable base for repairs. Next, replace weakened reinforcement and apply strengthening chemicals to improve the efficiency of bonds between steel and concrete. Use plaster mixed with chemicals containing carbon fibers, such as Sikawarp-900C, to enhance structural strength. Once the structural damage is rectified, apply fire-resistant paints to the repaired columns, beams, and slabs. Install new wooden doors treated with fire-resistant epoxies to further enhance safety. Finally, implement a comprehensive firefighting plan, ensuring that all systems, including fire alarms and sprinklers, are up to date and fully operational. These measures are designed to restore the building's structural integrity, improve fire safety, and ensure the building's future usability.

4 Conclusions

In conclusion, the assessment of the fire damage to Galaxy Heights in Gulberg Greens, Islamabad, reveals both the immediate challenges posed by the fire and the potential for effective remediation. Despite significant damage to elements such as columns, beams, and wooden features, the structural integrity of the building remained largely intact, offering hope for restoration and reuse:

- Despite fire damage, Galaxy Heights presented an opportunity for restoration, ensuring continued utilization of existing infrastructure.
- By employing advanced strengthening chemicals, refurbishing wooden features, and implementing fire-resistant coatings, structural integrity could be regained.
- The proposed solution balances effectiveness with cost-efficiency, offering a practical approach to rehabilitation.

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References

[1] A. Bayraktar, A. C. Altunişik, and M. Pehlivan, "Performance and Damages of Reinforced Concrete Buildings During the October 23 and November 9, 2011 Van, Turkey, Earthquakes," *Soil Dynamics and Earthquake Engineering*, vol. 53, pp. 49–72, Oct. 2013, doi: 10.1016/J.SOILDYN.2013.06.004.

[2] "https://policies.wsu.edu/prf/index/manuals/8-00-fire-safety/8-20-reporting-fires-fire-survival/ ".

[3] C. X. Xu, S. Peng, J. Deng, and C. Wan, "Study on Seismic Behavior of Encased Steel Jacket-Strengthened Earthquake-Damaged Composite Steel-Concrete Columns," *Journal of Building Engineering*, vol. 17, pp. 154–166, May 2018, doi: 10.1016/J.JOBE.2018.02.010.

[4] "https://www.amherst.edu/offices/enviro_health_safety/fire/report_fire ".

[5] "https://few.kp.gov.pk/page/forest_fires_analysis_report_2022/page_type/news ".

[6] M. Amran, S. S. Huang, A. M. Onaizi, G. Murali, and H. S. Abdelgader, "Fire spalling behavior of high-strength concrete: A critical review," *Constr Build Mater*, vol. 341, p. 127902, Jul. 2022, doi: 10.1016/J.CONBUILDMAT.2022.127902.

[7] D. Qin, P. K. Gao, F. Aslam, M. Sufian, and H. Alabduljabbar, "A comprehensive review on fire damage assessment of reinforced concrete structures," *Case Studies in Construction Materials*, vol. 16, p. e00843, Jun. 2022, doi: 10.1016/J.CSCM.2021.E00843.

[8] "https://www.concrete.org.uk/fingertips-nuggets.asp?cmd=display&id=895".

[9] "https://www.nullifire.com/en-gb/expert-insights/expert-advice/understanding-passive-fire-protection/".

[10] M. Shahpari, P. Bamonte, and S. Jalali Mosallam, "An experimental study on mechanical and thermal properties of structural lightweight concrete using carbon nanotubes (CNTs) and LECA aggregates after exposure to elevated temperature," *Constr Build Mater*, vol. 346, p. 128376, Sep. 2022, doi: 10.1016/J.CONBUILDMAT.2022.128376.