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Post Fire Assessment of RCC Buildings Through Rapid Visual Screening

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Abstract

The effectiveness of rapid visual screening (RVS) in determining the fire risk of reinforced concrete (RCC) buildings is examined in this review. RVS provides a quick and practical approach to evaluate fire risks, addressing the shortcomings of traditional methods. Through a comprehensive examination of methodology, advantages, limitations, and future directions, this study aims to enhance understanding and application of RVS in fire assessment. The study employs a systematic approach to evaluate the effectiveness of RVS, analyzing its application in assessing fire vulnerability in RCC structures. Key aspects of RVS methodology, including visual inspection, identification of structural vulnerabilities, and categorization of damage, scrutinized. A case study of the Chopasani Housing Boards building in Jodhpur provides empirical evidence of RVS's utility in identifying fire-related structural vulnerabilities. The concluded, the analysis reveals that RVS effectively categorizes fire-induced damage in RCC buildings, facilitating prioritization of mitigation efforts. Damage classifications, ranging from mild to extreme, are discerned through RVS, underscoring its ability to swiftly assess structural vulnerabilities. Additionally, RVS analysis elucidates the residual strength of RCC components post-incident, providing valuable insights for retrofitting and maintenance efforts. Overall, this study highlights the pivotal role of RVS in bolstering structural fire safety measures, emphasizing its practicality, cost-effectiveness, and accessibility. However, limitations such as subjectivity and inadequate assessment of complex structures necessitate ongoing refinement and integration with advanced technologies. The findings underscore the importance of RVS in enhancing fire safety assessment practices and mitigating fire risks in urban buildings, particularly in the context of reinforced concrete structures.

Keywords: *Fire Assessment, Building Components, Reinforcement, Crack Pattern, Temperature, Residual Strength.*

1. Introduction

Rapid visual screening (RVS) plays a pivotal role in promptly evaluating the fire vulnerability of reinforced concrete (RC) structures [1], [2]. This method enables a rapid assessment of structural damage resulting from fire incidents, facilitating the identification of vulnerabilities in RCC buildings [3]. the effectiveness of RVS lies in its capability to Classify damage levels, ranging from mild to extreme, thereby offering insights into the residual strength of elements after exposure to fire [4]. This study underscores the significance of RVS in enhancing structural fire safety measures and emphasizes its role in gauging the fire risk of RCC buildings [5]. Through a case study of the Chopasani Housing Boards building in Jodhpur, Rajsthan, India, the utility of RVS is further exemplified in evaluating the impact of fire on RCC columns, beams, and stairs, thereby highlighting its importance in post-fire structural assessments.

1.1 Advantages of RVS in Fire Assessment

Time Efficiency. RVS allows for quick evaluation of multiple buildings, facilitating timely identification of fire risks. Cost Effectiveness. Compared to comprehensive fire assessments, RVS incurs lower costs in terms of manpower and resources [6]. Prioritization. By categorizing buildings based on their risk levels, RVS helps prioritize interventions and allocation of resources for fire mitigation efforts. Simplicity. RVS techniques are relatively straightforward and do not require specialized training, making them accessible to a wider range of stakeholders

1.2 Limitations of RVS

Subjectivity. RVS heavily relies on visual observations, which can introduce subjectivity and variability in the assessment process. Limited Depth. While useful for preliminary screening, RVS may not provide detailed insights into specific structural vulnerabilities or fire protection deficiencies. Inadequate for Complex Structures. Complex buildings with unique features may not be effectively assessed through RVS alone, necessitating supplementary evaluation methods [7].

1.3 Future Directions and Challenges

As technology advances, integrating RVS with digital tools such as remote sensing and artificial intelligence holds promise for enhancing its accuracy and efficiency. However, challenges such as standardization of assessment criteria, addressing subjectivity, and ensuring reliability remain areas of focus for further research and development [8].

2. Literature Review

In the realm of structural fire safety, the evaluation of buildings' vulnerability to fire hazards is crucial for ensuring the safety of occupants and mitigating potential damage. Traditional methods of fire assessment often entail extensive time and resources, prompting the development of rapid techniques such as visual screening. This literature review examines the effectiveness, methodologies, applications, and limitations of rapid visual screening (RVS) in the fire assessment of buildings, particularly focusing on reinforced concrete structures.

2.1 Effectiveness of Rapid Visual Screening

Rapid visual screening (RVS) has emerged as a valuable tool for swiftly assessing the vulnerability of buildings to fire hazards. Numerous studies have highlighted its effectiveness in quickly identifying potential fire risks and structural vulnerabilities. For instance, the work of demonstrated that RVS can efficiently evaluate the fire safety of buildings, providing valuable insights for prioritizing mitigation efforts [9].

2.2 Methodologies and Techniques.

Rapid visual screening employs a systematic approach to evaluate various aspects of a building's fire resilience. This typically involves visually inspecting key structural elements, identifying potential ignition sources, assessing fire spread pathways, and evaluating the effectiveness of fire protection systems. Researchers have proposed various methodologies and guidelines for conducting RVS, aiming to standardize the process and enhance its reliability [10].

2.3 Applications in Reinforced Concrete Structures.

Reinforced concrete (RCC) structures represent a significant portion of the built environment and are subject to fire hazards. Studies have explored the application of RVS specifically to assess the fire vulnerability of RCC buildings. By examining the performance of RCC components such as columns, beams, and slabs under fire conditions, RVS can identify potential weaknesses and prioritize structural enhancements [11].

2.4 Challenges in RVS

While RVS offers numerous benefits, it is not without limitations. One of the primary challenges is the reliance on visual inspection, which may overlook latent or non-apparent fire risks. Additionally, the subjective nature of visual assessment can introduce variability in results. Researchers continue to explore ways to mitigate these limitations, such as integrating quantitative data and advanced sensing technologies into the screening process [12].

2.5 Future Directions.

The ongoing advancement of RVS techniques holds promise for further enhancing fire safety assessment practices. Future research efforts may focus on refining methodologies, improving the integration of RVS with other assessment tools, and developing automated or semi-automated screening approaches. Additionally, there is a need for longitudinal studies to assess the long-term effectiveness of RVS in mitigating fire risks and enhancing building resilience. In conclusion, rapid visual screening (RVS) represents a valuable approach for assessing the fire vulnerability of buildings, including reinforced concrete structures. While RVS offers significant advantages in terms of efficiency and practicality, it is essential to acknowledge its limitations and continue refining methodologies to ensure reliable and comprehensive fire assessment outcomes [13].

3. Methodology of Rapid Visual Screening (Rvs)

Rapid visual screening involves a systematic visual inspection of buildings to identify potential vulnerabilities to fire hazards. The process typically includes assessing structural elements, fire protection systems, egress routes, and other critical factors influencing fire safety. RVS methodologies may vary but commonly involve the use of standardized checklists or scoring systems to quantify the level of risk. The methodology of Rapid Visual Screening (RVS) for building assessment typically involves several systematic steps to evaluate fire vulnerability. Here's an outline of the general methodology so to evaluated how much damaged occurred in structure [14]. Structure- A bakery shop at Chopasani Housing Board, Jodhpur, Rajsthan, India was subjected to fire. Following were the observations through RVS [15].

3.1. Soot Deposition Damage in a Housing Board Building

Following a fire at a bakery shop located within a housing board building, smoke from the flames penetrated various sections of the structure, resulting in damage to the occupied areas due to soot deposition. While there was no significant damage but layers of plaster and concrete were significantly impacted by the soot deposition. According to the RVS (Rapid Visual Screening) process, the building incurred losses estimated to be between 20% to 30%. Upon thorough inspection, it was determined that each column and beam [16] of the structure fell under the category of figure 1 mild damage. Subsequently, retrofitting efforts were undertaken, primarily focusing on maintenance requirements [17].

Figure 1 **Shoot Deposition in Building**

3.2. Development of Crack Patterns in an RCC Structure

Upon inspection, it was observed that certain sections of the structure sustained damage, resulting in the development of crack patterns. The structure, constructed [18] with reinforced concrete (RCC), experienced the effects of firing action, leading to elevated temperatures within the building. Consequently, cracks emerged throughout the structure as a direct consequence of this thermal impact figure 2. As per the RVS (Rapid Visual Screening) process, the total losses incurred were estimated to be between 30% to 35%. Subsequently, maintenance or retrofitting measures were deemed necessary for the affected areas.

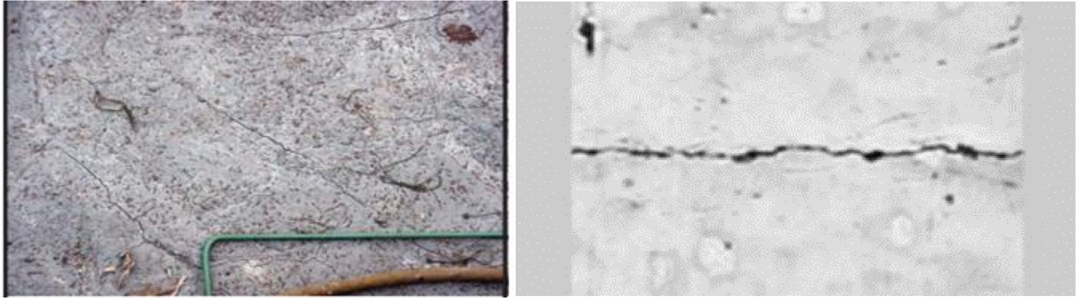

Figure 2 **Crack Pattern Visible on Roof Surface and Column Surface Due to Thermal Expansion**

3.3. Steel Behavior After Fired

After the building fire, the steel reinforcement became visible through the concrete, prompting a laboratory assessment of the affected properties. It was observed that the fire had led to alterations in key [19] characteristics such as yield strength and corrosion resistance, resulting in a decrease in steel durability. Additionally, the threads of the steel were damaged, weakening the bond between the concrete and steel figure 3. Furthermore, other characteristics, such as the Young's modulus, were evaluated by analyzing stress-strain curves up to the proportional limit. Approximately 50% of the steel in the building was lost, with the loss assessed approximately in the structure.

Figure 3 Shows the Reinforcement Visible in the Stair After the Concrete Fire

3.4. Concrete and Plaster Spalling

Spalling of concrete from column and beam slabs occurred, necessitating an evaluation of the concrete loss, including spalling concrete and plaster. This loss could [20] affect the structure's durability. Upon investigation, it was found that the approximate loss in concrete ranged from 20 to 30%, categorizing it under mild condition.

3.5. Nonstructural Fired Fire Time Duration Occurred in Building

The non-structural components of the bakery were transformed into fly ash due to the fire, resulting in significant losses. As each component of the structure experienced a different duration of fire exposure, the extent of loss varied across elements. Evaluating these losses proved challenging due to the fluctuating [21] strength of each component at different temperatures. However, a rough estimate obtained through rapid visual screening suggested a decrease of approximately 20 to 25% figure 4.

Figure 4 After the Fire, Both Structural and Non-Structural Plywood Be Seen Lying on the Floor

4. Strength Evaluation

According to ASTM E119 standards, the fire scaling ratio [22] indicates the temperature reached by a specific element at a given time. This is verified in laboratories in the USA, showcasing the element's ability to withstand fire conditions. [23] However, there is no exact declaration regarding the period of time until the element collapses, which is given by the following formula table 1.

$$T = 20 + 345\log10 (8t +1)$$

Where T – furnace temperature (oC)
t – Elapsed time (minutes) Beams and columns are tested in furnaces

Table 1 As Per ASTM E119 Relation Between Time Temperature

Time (minutes)	Temperature (oC)
0	20
10	100
20	200
30	300
40	400
50	500
60	600

Following the post-evaluation of the bakery building, the structural members, including the columns, [24] were exposed to fire for approximately 15 minutes, while beams endured around 20 minutes, and slabs endured 30 minutes of fire exposure. Non-structural elements remained unharmed for the initial 30 to 35 minutes' table 2. However, the stairs sustained fire damage around the 15-minute mark. Subsequently, all non-structural elements were consumed by fire in approximately 30 minutes, leaving residual fly ash to fall onto the floor [25].

Table 2 Residual Strength at Various Components of the Building

Element	Time (minutes)	Temperature (ºC)	Reduction factor k as Per Euro Code 2	Residual strength (k x 20MPa)
Column	15	150	.97	19.4
Beam	20	200	.95	19
Slab	30	300	.85	17
Stair	15	150	.97	19.4
Balcony /chajja	30	300	.85	17

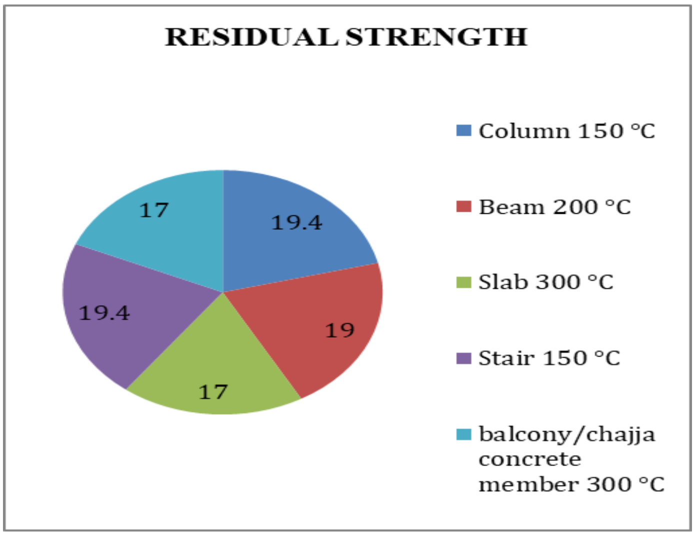

Figure 5 Illustrates the Residual Strength of Each Element at Specific Temperatures

The graph below illustrates the temperature of each element at specific times, as determined by the application of the Euro code 2. The reduction factor is used figure 5 to evaluate the strength of individual elements, revealing their residual strength following post-firing assessment [26].

Conclusions

RVS can be an effective way to determine the condition of a fire damaged building, if applied in a systematic way. A small building in Jodhpur city of Rajasthan, India was subjected to fire. The building was investigated through RVS and it was found that the damage was mainly due to soot deposition. The cover concrete of some elements was damaged which could be repaired. The time temperature curves of Eurocode 2 were used to determine the residual strength. The maximum reduction in strength of any member was 15%. Hence, the building was in a repairable condition.

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