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Impact of High Temperature on Steel Reinforcement of RCC Structures

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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 that 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 topic the experience of real-life problems are presented which add immense value to this. This topic also gives a comprehensive knowledge on the overall strategy for the restoration of fire damaged buildings and presents a critical appraisal of the assessment procedures by different non-destructive techniques, specifications and execution of repair techniques. The experimentation has been done to find out the impact of the fire on reinforcement steel bars by heating the bars to 100°, 300°, 600°, and 900° centigrade of 6 samples each. The heated samples are rapidly cooled by quenching in water and normally by air cooling. The change in the mechanical properties is studied using universal testing machine (UTM) and the microscopic study of grain size and grain structure is studied by scanning electron microscope (SEM). The general conclusion is that majority of fire damaged RCC structures are repairable. But the impact of elevated temperature above 900°C on the reinforcement bars was observed that there is significant reduction in ductility when rapidly cooled by quenching. In the same case when cooled in normal atmospheric conditions the impact of temperature on ductility is not high. By heating the reinforcement bars, the mechanical properties can be changed without varying the chemical composition

INTRODUCTION

With the increasing frequency of major fires and fire-related accidents in buildings, the assessment, repair, and rehabilitation of fire-damaged structures has emerged as a subject of pressing concern. This specialized field draws upon a diverse range of expertise, including concrete technology, material science, structural engineering, and advanced repair techniques. Research and development efforts across these disciplines are actively contributing to improved methods and strategies for dealing with fire damage. While any structure is susceptible to fire incidents, it is neither practical nor sustainable to abandon fire-damaged buildings. Instead, restoring their structural integrity and making them functionally viable poses a significant challenge—and responsibility—for civil engineers. The primary dilemma lies in identifying where to begin and how to systematically address the damage. Ensuring the safety and functionality of fire-affected buildings is crucial, not only for economic reasons but also for public safety. Designing structures that effectively protect people and property from fire is an essential objective in modern construction. Unfortunately, annual statistics on fire-related losses—particularly in residential buildings—continue to be sobering. Yet, these events often serve as catalysts for improvement, offering insights that lead to better fire safety designs and standards. Fires cause substantial harm globally, with annual fatalities ranging from 1 to 2 per 100,000 people in industrialized nations, and economic losses amounting to 0.2%–0.3% of GNP. In 2000, the USA experienced over 4,000 fire-related deaths, 100,000+ injuries, and $10 billion in property damage. The UK records around 600 fire deaths yearly, mostly in homes, and fire-related business losses reach millions of pounds. Key factors influencing fire damage include building design, materials, structural integrity, fire suppression systems, and evacuation procedures. While fire safety codes aim to reduce damage, human safety remains the primary concern. Continuous updates to fire safety regulations reflect ongoing research and technological development. In terms of fire resistance concrete outperforms by a wide margin the other most popular building materials i.e. wood and steel. Fire remains one of the serious potential risks to most buildings and structures. The extensive use of concrete as a structural material has led to the need to

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fully understand the effect of fire on reinforces concrete structures. Fire has been a source of comfort and catastrophe to the human race since ancient history. Fire is a destructive force causing thousands of deaths and loss of property worth billions of dollars. Fire disasters can occur below the ground, on the ground or above the ground. Sometimes, they occur in the most unexpected or unpredictable circumstances. Considerable progress has been made in the 2 understanding of structural fire protection since the earliest attempts to implement fire safety. Fire protection activity was initiated after a great fire in London in 1666; however investigation of structural fire protection began in second half of 18th century. It is vitally important that we create buildings and structures 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. Further the advances in material technology led to the concept of fire proof structures using gypsum. Later, Metropolitan Borough Act (1844) and London Building Act (1894) brought refinement in building control regulations.

A scientific approach to research into structural fire resistance began towards the end of 19th century after the establishment of British Fire Protection Committee (BFPC). In 1932 first British Standard (BS 476:1932) related to fire was published which defined the test for fire resistance. The recent collapse of the twin-towers, World Trade Centre building in New York, USA, due to the terrorist attack and subsequent fire has renewed the interest in fire-resistant design of structures. Traditionally, the provision of fire resistance for reinforced concrete (RC) structures and components is usually treated indirectly in structural design. Most design procedures assume sufficient fire resistance, if certain criteria, mainly the distance of the reinforcing bars from the concrete surface, are kept. Building codes specify regulations for buildings designed in such a way that they exhibit an acceptable level of performance in the event of fire. Generally concrete is thought to have good fire resistance but the behavior of reinforced concrete columns under high temperature is mainly affected by the strength of the concrete, the changes of material property and explosive spalling. However, high temperatures affect the strength of the concrete by explosive spalling and so affect the integrity of the concrete structure. In recent years, many researchers studied the fire behavior of concrete columns; their studies included experimental and an analytical evaluation for reinforced concrete. Concrete is a material that has an excellent intrinsic behavior when exposed to fire, it does not burn, (non-combustible), and it has a high thermal massively, which significantly slows down the spread of heat through concrete elements. As a matter of fact, in most common fires only the outer layer of the concrete with a thickness of approximately 3 to 5 cm is damaged (Denoël, 2007). Therefore, many concrete buildings that experienced fire can be fairly simply restored and reused. An excellent example of the good behavior towards fire of concrete structures is the Windsor Tower in Madrid (Denoël, 2007).

Experience of Fires:

Fig.1.1: Fire Damaged Slab

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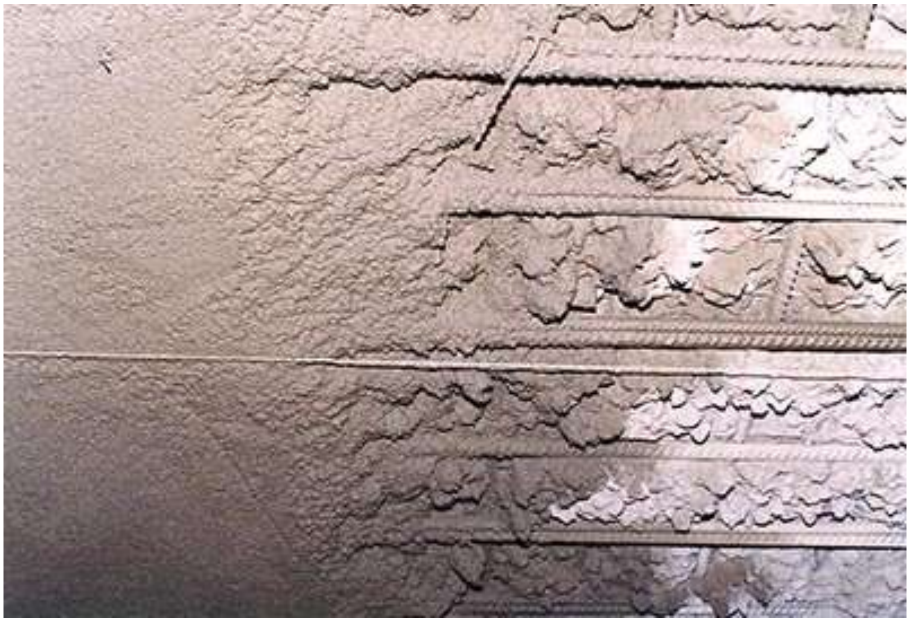

Fig 1.2: Concreting of Fire Damaged Slab

1. Most of the structures were repaired. Of those that were not, many could have been but were demolished for reasons other than the damage sustained.
2. Almost without exception, the structures performed well during and after the fire.

EXPERIMENTAL RESULTS

Fires in buildings can result from accidents, energy sources, or natural events, but most are due to human error. Once ignited, a fire spreads through radiation, convection, or conduction, with flames reaching temperatures between 600°C and 1200°C. The danger comes not only from the heat and flames but also from toxic smoke and gases released by burning materials.

Fig 1.3: Concrete Against Fire

Importance of Fire Protection In Buildings: Fire is one of the most serious events to which any building can fall victim throughout its lifetime. Not only does it pose a direct threat to the occupants through the release of harmful gases and devastating heat, but the elevated temperatures themselves also have seriously adverse effects on the structural integrity of the entire building. According to the 2002 Annual Report released by the Council of Canadian Fire Marshals and Fire Commissioners (CCFM/FC), fire was responsible for 304 deaths and almost CAN$1.5 Billion in property damage in 2002 alone. Though undesired, fires will undoubtedly continue to occur in buildings. Therefore fire protection efforts must be made to reduce the impact of such events. The primary goal of fire protection is to limit, to acceptable levels, the probability of death, injury and property loss in an unwanted fire (Buchanan, 2001).

With respect to structural design, this means providing sufficient time for the occupants to exit the building and for firefighters to extinguish the fire before any structural collapse occurs. In order to do so, numerous methods of providing 5 protection are available, often categorized by active and passive measures. Active measures refer to systems which become engaged or are used during a fire, such as alarms, sprinklers and provisions for fire fighters. Passive measures are design considerations such as adequate compartmentation in the building layout, as well as providing sufficient insulation for key structural members (Purkiss, 2007). Traditional building materials, such as steel and concrete, experience a loss in stiffness and strength with rising temperatures and therefore require insulation to slow the transfer of heat. Because of this, fire design codes typically allocate building fire ratings based on when key structural members reach the maximum acceptable temperature for that respective material.

Changes of Concrete In Fire

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 and 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 (conductivity) that enables concrete to act as an effective fire shield not only between adjacent spaces, but also to protect itself from fire damage. Concrete can be described as virtually fireproof‖x`.

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