e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:04/April-2022 Impact Factor- 6.752 www.irjmets.com

STUDY ON FIRE RESISTANT DESIGN AND ENHANCEMENT PROPERTIES OF CONCRETE STRUCTURE

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ABSTRACT

Concrete has excellent fire resistance owing to its poor thermal conductivity and non-combustibility. Because concrete acts as a protective layer for steel reinforcement, reinforced cement concrete performs well in fires. Concrete structures may be damaged by fire. The extent of the damage is determined by many elements, including the maximum temperature, the length of the fire, the concrete's ingredients, and so on. Several elements influence the performance of concrete buildings in the event of a fire. These include changes in material characteristics as a result of the fire, temperature distribution among building members, type of reinforcement, and exposure length and intensity. These design methodologies often fail to forecast the genuine behavior of concrete buildings in real-world fires. When concrete is heated, it undergoes a series of complicated physicochemical processes, causing mechanical qualities such as strength and stiffness to diminish. Furthermore, spalling causes concrete chunks to break away from the surface, lowering the cross-section of an element and potentially exposing the reinforcing to high temperatures. Spalling is a harmful condition that is particularly frequent in high-strength concrete. The design technique is created by considering several critical temperature combinations. Depending on the criteria, different conclusions might be formed. The Eurocode specifies the number of prescriptive and performance-based processes for designing concrete buildings for fire resistance. This document goes through the stages involved in calculating a reinforced concrete structure's fire resistance.

Keywords: Concrete; Thermal Conductivity; Non-Flammability; Spalling; Eurocode.

I. INTRODUCTION

Reinforced concrete structural elements, in general, perform well in fire situations. This is owing to the fact that concrete's thermal conductivity is low at room temperature and decreases as the temperature rises. Concrete provides adequate protection for reinforcing steel against high temperatures encountered during a fire as long as it is not affected by significant cracking or spalling. Thermal analysis (determination of temperature distribution inside each point of structural components) and mechanical analysis are included in the full study of reinforced concrete structures under the given fire scenario (evaluation of structural response to determining temperature fields). To conduct these assessments, thorough information on a variety of temperature-dependent material characteristics (physical, thermal, and mechanical – both for structural concrete and reinforcing steel) is required. In typical design circumstances, a correctly constructed reinforced concrete structure has a certain reserve in bearing capacity:

$$R \geq Ed > Ed.fi\ (t=0)$$

Where

The load-bearing capacity is denoted by R.

According to Eurocode, Ed is a design value of an impact of activities.

The design impact of activities in fire conditions at the start of a fire is Ed.fi (t = 0).

It indicates that the structure can withstand the loads for a certain amount of time in the event of a fire, which is referred to as fire resistance. MATLAB was used as the program for the numerical analysis.

IRJMETS

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II. PROPERTIES OF FIRE

Fire is a kind of exothermic chemical process that involves the oxidation of hydrocarbons and the subsequent creation of heat. The pace at which heat is released and dispersed determines the rate at which the fire grows. The temperature, size, and dispersion of the fire are all influenced by many elements.

- The fire load
- Display of fire load (the position of fuel within the room)
- Type of fuel
- The fuel's dispersion factor and particle form
- The place where the window opens
- Air pressure, temperature, and relative humidity
- The room's measurements
- The building material's heat conductivity and diffusivity
- Radiation levels inside the compartment as well as via the windows

III. RESISTANCE OF FIRE

A structure's capacity to withstand collapse, fire spread, or another failure after exposure to a fire of a specific intensity is measured by its fire resistance. The capacity of structural components to keep their function (e.g. separation or load-bearing function) for a fire is measured by their fire resistance. The characteristics that influence fire growth and development should be used to determine fire resistance needs. These are some of them:

- Fire [fire occurrence probability, fire spread, fire duration, fire load, fire severity.
- Conditions of ventilation
- Fire extinguisher (type, size, geometry)
- The structural element's kind
- Situations requiring evacuation
- The rescue crews' safety
- Hazard to neighboring structures
- Measures to combat active fires

IV. CHEMICAL AND PHYSICAL REACTION TO FIRE ON CONCRETE STRUCTURE

When concrete is heated, it affects its microstructural, thermal, hydral, and mechanical properties. Internal fractures and the corrosion and disintegration of the cement paste are the major causes of strength loss. The cement paste's cohesiveness with the aggregates is also harmed. Understanding the various processes can help you not only understand how concrete will react in a fire, but also how to improve the material's composition for improved fire performance. When concrete cools, it undergoes reversible or irreversible physical and chemical changes. A concrete building may be considerably weakened after a fire if the alterations are irreversible, even if no visible damage exists.

Concrete Properties at Higher Temperature

The thermal and mechanical characteristics of concrete are necessary for thermal and structural calculations. As seen in fig. 1, the thermal parameters discussed include thermal conductivity, volumetric specific heat, and density. Concrete compressive strength, modulus of elasticity, shear modulus, tensile strength, and coefficient of thermal expansion are among the mechanical qualities. In normal design applications, these qualities are necessary for engineering assessments.

1. Thermodynamic characteristics

- Thermal Conductivity is a term used to describe the ability of a material to conduct heat
- It is defined as the rate of heat transmission per unit temperature through a unit thickness of the material.

2. Specific Heat in Volume

- The quantity of heat necessary to raise the temperature of a unit mass of material by 10 degrees Celsius.

3. Density

- The material's mass per unit volume.

4. Mechanical Properties

- Compressive and tensile strength, modulus of elasticity, shear modulus, and coefficient of thermal expansion are all temperature-dependent mechanical characteristics of concrete.
- The material property values are to be viewed as characteristic values. These numbers may be used in both simple and complicated calculations. Concrete and reinforcing steel mechanical properties at In EN 1992-1-1, normal temperatures are provided for normal temperature design. Equation 1 also includes design values for mechanical (strength and deformation) material parameters

$$X\, d\, fi = k\, \theta\, X\, k\, /\, \gamma\, M, fi$$

- As defined in EN 1992-1-1, X k is the characteristic value of the strength or deformation attribute for normal temperature design. k is the temperature-dependent decrease factor for a strength or deformation attribute (X k). M, fi is the fire situation's partial safety factor for the relevant material property. M, fi is set to 1 for the thermal and mechanical qualities of concrete and reinforcing steel.

V. FIRE EFFECTS ON THE STRUCTURAL MEMBER

When the temperature rises, the material properties of the members change. Concrete and steel both lose strength and stiffness as a result of this process. In reality, the whole stress-strain diagram has been altered. A thermal elevation also affects thermal attributes such as thermal conductivity and specific heat. These changes, however, are unimportant for the reinforcement since its volume is usually insufficient to impact the total temperature distribution.

VI. METHODOLOGY

The following are some various design techniques for a structure's mechanical reaction in a fire:

- Evaluation of members
- Parts of the structure are examined.
- An examination of the overall structure

A. Member Evaluation

Member Analysis, in which each member of the structure is evaluated by considering it isolated from other members, with suitable boundary conditions replacing the connection condition with other members.

B. Structure Examined

Elements of the structure will be directly considered in the evaluation using suitable boundary conditions to indicate their relationship with other parts of the structure.

C. An Examination of the Overall Structure

A global structural analysis is one in which the whole structure is assessed. The Eurocode provides the following design methods in the equation:

$$Ed, fi \leq Rd, t, fi$$

VII. SIMPLIFIED CALCULATION TECHNIQUE

Follows the same steps as normal-temperature design, but accounts for the strength loss caused by high temperatures in both concrete and steel. The ultimate load-bearing capability of a cross-section under fire circumstances is computed, and the appropriate combination of actions is then compared. The approaches primarily serve members, although they may also cover elements of buildings in specific circumstances. Although both nominal and parametric fires may be employed in the design, the standard fire curve is most often used.

METHODS OF ADVANCED CALCULATION

Advanced computational techniques allow for a more realistic structural analysis. Modeling the underlying physical behavior provides an accurate estimate of the structure's predicted behavior under fire circumstances.

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These methodologies may be used with any sort of design fire (nominal or natural), any type of analysis (member, structural component, or global analysis), and any form of the cross-section. Any possible failure modes not addressed by an advanced computation approach (e.g. local buckling or shear and bond failure) must be removed in the structure's design by proper procedures or details. The Eurocode simply explains the fundamentals of this strategy. This strategy necessitates the use of a fire engineering professional by the designer. The thermal response model and the mechanical response model are two aspects of a sophisticated calculating approach that constantly impact each other.

VIII. ANALYSIS AND RESULT

Table 1: Specimen's Ultimate Load and Corresponding Deflection

Specimen number	T1	T2	T3	T4	T5	T6	T7
Ultimate load(kN)	236.4	184.7	162.1	224.2	171.5	148.3	201.4
Fire test deflection (mm)	2.3	2.5	2.6	3.2	3.8	4.2	3.3
Static load deflection (mm)	9.4	10.5	12.4	10.3	11.3	13.4	10.7

The rise in the specimen's midspan deflection throughout the heating process and static load test can be shown in Table 1. To study the influence of temperature on the ultimate load and deflection of the specimen, one may, for example, examine specimens of T1, T2, and T3 under an identical fire load. Regardless of the temperature, the deflection increase of the specimen was greater at higher temperatures than at lower temperatures throughout the fire load and static load tests. That is, the higher the test temperature, the greater the deformation of the specimen, and the lower the stiffness of the specimen, resulting in a more flexible specimen. The test results of two groups of specimens, such as T1, T2, and T3; or T4, T5, and T6, were exhibited in Fig.1 to examine the impact of the fire load on the ultimate load and deflection of the frame specimens.

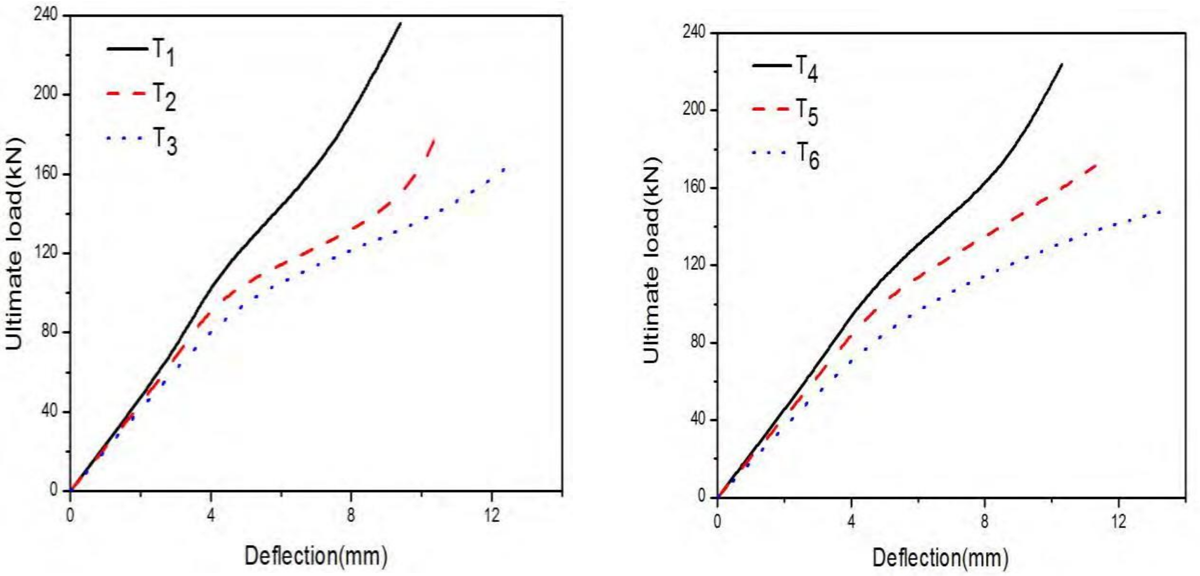

Fig 1: Different Ultimate Load vs Deflection Relationship Curves

IX. CONCLUSION

• After a fire test, the performance of a reinforced concrete frame structure changed, indicating that fire temperature and fire load had an impact on the specimen's performance. The firing temperature had a greater impact than the fire load. After a fire, the interaction between load and high temperature caused the specimen's deformation to rise, while its strength and stiffness decreased.

• The strength of the reinforced concrete frame construction was significantly reduced when exposed to high temperatures. Under 600°C, the frame structure's ultimate load was reduced by 36.9%; under 800°C, it decreased by 48 percent; and under 1000°C, the frame structure practically lost its bearing capability, decreasing 57.3 percent.

• The fire-resistant technique is a new simplified methodology based on Eurocode 2 Parts 1 and 2, which provides a basic design foundation for fire-resistant concrete buildings by taking into account numerous characteristics.

• The fire resistance of structural components is determined using a conventional fire calculation.

• The kind of structural element (e.g., pure steel or composite steel/concrete), as well as the nature and degree of fire protection, affect how quickly it heats up.

• To determine the temperature of structural components as a function of time, the heat flow to these elements must be calculated.

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