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# Analysis of Epoxy Coated & Glass Fiber Bamboo & Steel Reinforced Concrete Beams

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**Abstract:- Fires have become a worldwide concern, causing significant damage to multi-story reinforced concrete frame structures. Indian codal rules mandate the use of rectangular or circular ties in reinforced concrete beams based on their geometry. However, fire weakens load-bearing materials such as beams, which is a significant cause of structural damage. Construction fires in India claim the lives of 2000-3000 people each year. This study aims to assess the performance of modified Bamboo reinforcement before examining beam performance. Bamboo reinforcement is treated with epoxy and fiber mat to increase its strength, but it swells, leaving a space between concrete and reinforcement. The study involves reinforcing bamboo with steel- reinforced concrete beams, estimating their moment of resistance, and designing resistance-moment beams. Under and over- reinforced beams will be created to study their behavior, and epoxy-coated bamboo reinforced beam combinations will be tested against their MR values. The study explores the failure patterns of these beams, including reinforcement quantity, shear reinforcement, and bamboo-induced beam ductility. The need for fire prevention, repairs, and retrofitting of structures is crucial, as most structures permanently damaged by fires impact infrastructure economics. Therefore, the goal is to improve building resistance, particularly beam resistance, so structures can be used after a fire. Decreasing tie spacing increases section moment capacity at ambient temperatures, improving confinement. However, knot spacing below 100 mm has little benefit during a fire.**

***Keywords*:-** *Casting, Diamond Ring & Ties, Rebound Hammer & Ultrasonic Pulse Velocity Test, NDT, Compression Test, Resistance, Mix Design.*

## I. INTRODUCTION

Construction industries are under increasing pressure to adopt green technologies due to resource depletion and environmental concerns. Bamboo, an eco-friendly and sustainable material, is emerging as a promising alternative to traditional construction materials. With a flexural and tensile strength that outperforms steel by 20 times and low weight, bamboo has been used as a structural material since ancient times.

Bamboo reinforcement has the potential to be a low-cost solution for housing in developing countries. However, the properties of bamboo as a reinforcement material require careful assessment to ensure its effectiveness and durability. Bamboo culms are cylindrical with solid transversal diaphragms at nodes, and their strength is parallel to the fibers but weak perpendicular to them. The cross-sections of bamboo shells also vary, presenting challenges for builders, engineers, and scholars seeking to replace steel with bamboo reinforcement in concrete structures.

To address these challenges, a review of the literature comparing steel and bamboo reinforcement in concrete structures was conducted. Epoxy-coated bamboo is found to be a promising reinforcement material that strengthens the bond between bamboo and concrete, increases bamboo's acid tolerance, and improves its durability. It is also an affordable solution that can be used to prevent water-bamboo contact, keeping bamboo dry and prolonging its lifespan.

In summary, bamboo reinforcement has the potential to be a game- changer in the construction industry. With the use of epoxy-coated bamboo, builders and engineers can explore sustainable and cost- effective solutions for reinforced concrete structures.

- *Definition of Resistance*

"The property of a building element, component or assembly that prevents or retards the passage of excessive heat, hot gases or flames under conditions of use"

- *Resistance Period:*

The toughness of reinforced concrete (RC) framed beams is often overestimated due to the failure to account for the loss in confinement behavior. In this study, eight pre-stressed concrete beams were tested for resistance under various spalling scenarios, reinforcement details, and load eccentricities.

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RC is a widely used building material around the world, but its structure can rapidly break down under fire exposure. Early studies focused on the "incombustibility" and "low thermal diffusivity" of concrete to explain its resistance to fire. However, RC beams typically carry axial forces and force-induced moments, and fire alters their physical and mechanical properties, causing time-dependent creep strain and temperature-induced transient strain. Even at static axial loads, fire can deform the RC beam, resulting in a loss of stiffness and fire resistance over time.

The resistance of RC beams is influenced by various factors, including material, mechanical, structural, loading, and constructional parameters. Spalling, in particular, can significantly limit the resistance of RC beams and is a critical factor to consider.

- *Aggregates*

The strength of concrete depends significantly on the type of aggregate used. Beams made with carbonate aggregate have been found to have ten times the resistance of those made with siliceous aggregate due to the absence of tiny reactions. Additionally, carbonate aggregate has a higher specific heat over 600°C compared to siliceous aggregate, and crystalline materials have higher thermal conductivity than amorphous materials.

Cover spalling, a phenomenon where the outer layer of the concrete cover separates and falls off, is more common in high- strength concrete (HSC) beams due to their higher free moisture content, the use of lightweight aggregate, and lower concrete permeability. In contrast, siliceous aggregate has been found to produce more spalling in HSC beams, particularly in cases where the fissures are wider. Thus, the type of aggregate used in concrete can significantly impact the strength and durability of the resulting structure

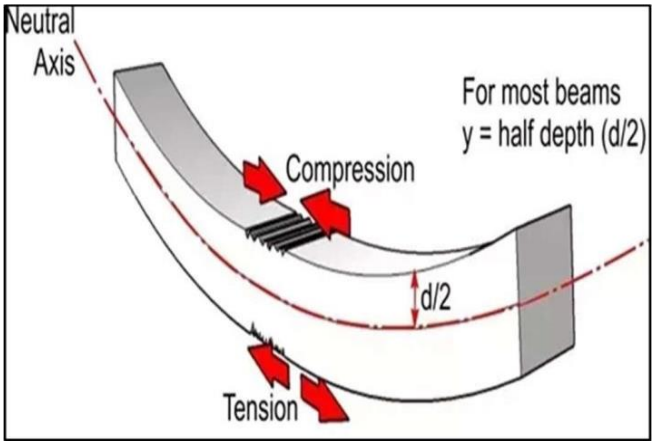

Fig1 Beam of Compression and Tension Face

Concrete structures are widely recognized for their strength and durability, and there have been relatively few reported cases of severe structural failure resulting from the collapse of individual walls, beams, or columns. However, as building designs increasingly rely on lower safety margins and higher strength concrete, this trend may change.

In the event of a fire, it is crucial to reinforce the walls of a building to limit the spread of flames and maintain the structural integrity of the overall structure. Failure to do so can lead to catastrophic consequences, as weakened walls and beams can quickly buckle and collapse under the weight of the building. Therefore, ensuring adequate fire resistance and reinforcement measures are in place is critical to protecting the safety and well- being of building occupants.

- *MaterialsCement*

The reinforced concrete beams were constructed using Type I Portland cement, which is a widely used general-purpose cement for building reinforced concrete structures. This type of cement is known for its strength, durability, and versatility, making it an excellent choice for a variety of construction applications, including the construction of reinforced concrete beams. Its high compressive strength and low shrinkage properties make it ideal for use in applications that require strong and stable concrete structures, such as bridges, buildings, and highways.

- *Aggregates*

The Beams were constructed using concrete made from carbonate aggregates. Carbonate aggregate concrete is created by using a coarse aggregate that is primarily composed of calcium carbonate or a combination of calcium and magnesium carbonate. This type of concrete is known for its excellent strength and durability, which make it ideal for use in the construction of reinforced concrete structures such as beams. The fine aggregate used in the construction of these beams was natural sand, which is a common material used in the production of concrete. The combination of carbonate aggregate and natural sand provided an excellent balance of strength, durability, and workability, making it an ideal choice for the construction of these reinforced concrete beams.

- *Reinforcement*

The use of ASTM A615-80 deformed bars for the main longitudinal bars, spirals, and ties in the reinforced concrete beams ensured that the reinforcement had sufficient yield strength. The circular beams had symmetrically inserted bars covering the spiral reinforcement, while the square beam had four longitudinal reinforcing bars covering the ties. The main reinforcing bars were welded to steel end plates.

Concrete is a ubiquitous building material in modern cities, earning them the moniker "Concrete Jungle." However, recent incidents, including accidents, arson, and terrorism, have brought attention to concrete's performance in fire. Fires can have devastating consequences, destroying lives, homes, and livelihoods. As cities continue to rely on concrete for high-rise structures, it is essential to study its fire-resistance qualities. Building fires are typically caused by human error, and once they start, they can quickly spread via radiation, convection, or conduction, generating temperatures of 600° to 1200°C. These high temperatures can damage the structural integrity and load-bearing capacity of concrete, making its resistance to fire a crucial factor in building safety.

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- *Glass Fiber Reinforced Concrete*

The use of glass fibers has a long history, but it wasn't until the development of more precise machine tooling that mass production became practical. Edward Drummond Libbey showcased a dress made of glass threads with the diameter and texture of silk fibers at the World's Columbian Exposition in 1893, which looked like it was made of silk. Glass fibers can also be found naturally occurring, such as in Pele's hair.

In the early 1930s, Games Slayter of Owens-Illinois came up with the idea of using glass wool as a thermal building insulation material, which is now referred to as "fiberglass" and sold under the brand name Fiberglas. Glass fiber is specially manufactured with a bonding agent to trap many small air cells, resulting in the low-density "glass wool" family of products. It is commonly used in products such as insulation blankets and pipe insulation.

Glass fiber has comparable mechanical properties to other types of fibers, such as polymers and carbon fiber. Glass fiber reinforced composites are utilized in the marine sector and plumbing industry because of their high specific strength and stiffness, improved damage tolerance for impact loading, and superior resistance to the environment. Although glass fiber is less rigid than carbon fiber, it is significantly less brittle and cheaper.

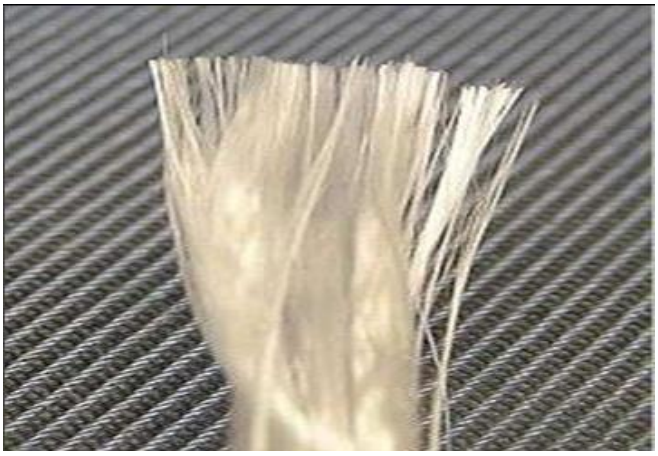

Fig 2 Glass Fiber

Fiberglass is a material commonly associated with insulation, boats, and cars such as the Corvette. However, it also has a role to play in the world of concrete. Technically, fiberglass is composed of fine glass fibers. The material used in boats or other products, though referred to as fiberglass, is actually glass fiber reinforced plastic consisting of glass fibers in a polymer matrix. By replacing the polymer with Portland cement and sand, glass fiber reinforced concrete (GFRC), also known as glass fiber reinforced cement (GRC) in the UK, is produced.

The challenge with using glass fibers as reinforcement for concrete is that glass breaks down in an alkaline environment, and there are few environments more alkaline than concrete. Alkali-silica reactivity (ASR) can cause concrete damage when reactive silica is present in the aggregate. Glass is primarily silica. GFRC from the 1940s lost strength quickly due to the alkaline environment destroying the glass. However, in the 1970s, Owens-Corning and Nippon Electric Glass (NEG) developed alkali-resistant (AR) glass fibers, leading to a surge in applications.

Glass fiber is created by extruding thin strands of silica-based glass or other formulations into many fibers with small diameters that are suitable for textile processing. The process of drawing glass into fine fibers by heating it has been known for centuries and was practiced in Egypt and Venice. Until the recent use of glass fibers for textile applications, all glass fibers were produced as staple fibers.

## II. LITERATURE REVIEW

- *Cement's Resistance, Sikar, IJETSR, Aqeel Shams SGI, March2016*

The essay by Sikar (2016) discusses the interaction between fire and reinforced concrete. It explains the concept of "Fire Rating" and how it is determined. The essay also explores the physical and chemical changes that occur in reinforced concrete when exposed to high temperatures and offers recommendations for improving its fire resistance. Additionally, the essay provides an explanation of the requirements outlined in IS 456:2000 for ensuring a specific level of fire resistance in concrete.

- *Lightweight aggregate concrete beams' axial compressive performance when restrained by transverse steel reinforcement Yu Zhang, Tao Wu, Hui Wei, and Xi Liu, 23 February 2018*

This paper presents an experimental investigation of lightweight aggregate concrete and transverse steel reinforcement beam behavior. The study evaluates twelve reinforced specimens subjected to axial compressive stress with varying transverse steel quantity and tie configuration.

- *Using the Finite Element Method, evaluate the effects of fire on reinforced concrete beams, American Journal of Engineering, 2019, SajjadSayyarRoudsari and Taher M. Abu-Lebdeh.*

This study used Finite Element (FE) ABAQUS software to analyze and experimentally validate the behavior of four different Reinforced Concrete (RC) Beams. The specimens were subjected to compressive force and fire load for 10, 15, and 20 minutes at a temperature of up to 600 degrees Celsius. Load-displacement diagrams were created, and the results showed a correlation between the experimental and FE analysis. The study found that load capacity decreased as the duration of the fire load increased.

- *An Easy Way to Calculate the Resistance of Reinforced Concrete Beams, 2019 ISSN Ataman Haksever*

In this paper, a practical method is presented for calculating the resistance time of reinforced concrete beams under uniaxial stress in fire conditions. The method does not require the use of sophisticated computer tools and has been validated through experimental studies on the fire behavior of short reinforced concrete beams.

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- *Alexandria Engineering Journal, January 2019, AneeshaBalaji, MuhamedLuquman K, Praveen Nagarajan, and T.M. Madhavan Pillai*

In this paper, the axial strength of reinforced beams exposed to fire is studied using the streamlined method described in Eurocode 2, specifically the 500 C isotherm method. The thermal analysis is performed using ANSYS, a finite element program, and the impact of different parameters on short Beams exposed to fire is measured through a series of numerical studies.

- *More effective confinement of reinforced concrete Beams, Hany A. Dahish and Ahmed M. El-Kholy, June 2019, AinShams Engineering Journal*

In this paper, a confinement configuration is proposed for short RC Beams that includes a single layer of expanded metal mesh (EMM) in addition to conventional tie reinforcement. The proposed transverse reinforcement is investigated using 16 RC Beam specimens with different volumetric ratios of ties. Another paper describes the use of a multi-objective genetic algorithm based on NSGA-II to optimize the ecological function, power output, and thermal efficiency of an irreversible regenerative Brayton heat engine model using decision-making techniques.

- *Rajesh Kumar, S.C. Kaushik, Raj Kumar, and Ranjana Hans in their article published in the Ain Shams Engineering Journal on June 9, 2019.*

In this paper, numerical methods are used to calculate the load- bearing capacity of reinforced concrete walls. The walls are composed of various segments of different heights and thicknesses, and their behavior is predicted using constitutive relationships and mechanical properties, as well as a temperature profile calculation.

- *High Performance Concrete Beam Resistance Evaluation Model, Kodur, V.K.R., Wang, T.C., Cheng, F.P., and Sultan, M.A. National Research Council, 2017*

The paper presents a computer program for calculating the resistance of high performance concrete (HPC) beams. The program uses a three-step process that includes thermal and structural analysis to calculate beam resistance.

- *Predicting the behavior of high-strength concrete beams, NRCC-43379, Feb. 2020; Kodur, V.K.R.; Wang, T.C.; Cheng, F.P*

This paper validates a computer program's numerical model for calculating the Resistance of high-performance concrete (HPC) Beams by comparing the results of full-scale Resistance tests. The study presents result and information from resistance tests performed on HPC beams and describes the three steps involved in the thermal and structural analysis for calculating beam resistance using the program. The numerical model is capable of predicting HPC beam resistance for various important parameters such as load, section dimensions, concrete strength, aggregate type, fiber reinforcement, and beam length.

- *A systematic review of reinforced concrete beam resistance Applications of Fire Engineering, September 2019, S.H. Buch and U.K. Sharma*

In this review paper, different analytical techniques and experimental findings are used to examine the equivalent resistance of RC beams. The experimental results are correlated to determine any deviation from the general results. The paper concludes with a discussion of the causes of variations in experimental results and the need for changes in theoretical methods. The paper offers insights into the understanding of RC beams' resistance behavior.

- *Without Fire Protection, Concrete-Filled Steel Tubular Beam Fire Safety Engineering Fire Science and Technology, 2019; Kenichi Ikeda1 and Yoshifumi Ohmiya*

This report presents a modeling approach for member and frame, thermal analysis during fire, and on-site planning and execution for 47 buildings based on fire tests and prior research. The report also validates the flexural element resistance provisions of the Indian standard code.

- *Songklanakarin J. Sci. Technology, Mar.–Apr. 2018, AneeshaBalaji*, Praveen Nagarajan, and Madhavan Pillai*

The paper discusses the 500°C isotherm method, a streamlined approach for determining fire rating for flexural elements. A parametric study is conducted to tailor the procedure for Indian

Conditions, and the fire ratings suggested in IS 456:2000 are compared with the strength requirements using the 500°C isotherm method. Thermal criteria obtained from a finite element model's heat transfer analysis are also used to compare them.

- *ActaPolytechnica, 1/2019, by A. Espinós, A. Hospitaler, and M.L. Romero*

In this study, it is noted that predicting the behavior of CFT beams during a fire is challenging due to the nonlinearity and inelasticity of the material properties. The demand for numerical models is high as analytical methods cannot accurately forecast their behavior. Thus, a three-dimensional numerical model is proposed in this study to investigate the actual fire behavior of CFT beams, which is expected to provide more promising outcomes.

## III. RESEARCH METHODOLOGY

- *Aim*

"To investigate a Diamond Tie Configuration in Order to Enhancethe Capacity for Strength of the Exiting Beam"

- *Objectives*

To study the improvement of Resistance of reinforced Beam byrectangular and diamond tie;

- To study the effect of different tie systems with varying spacing and cover on the behavior of reinforced concrete (RC) beams subjected to fire.
- To enhance the strength and durability of bamboo reinforcement beams by using epoxy and glass fiber
- To develop a suitable methodology for the fabrication of bamboo reinforced concrete beams, taking into account theuse of epoxy and fiber mat-wrapping.
- To explore and design different combinations of epoxy coated bamboo reinforcement beams for improved performance.
- To analyze and evaluate the various configurations of epoxy coated bamboo reinforcement beams through experimental and analytical methods.
- To compare the behavior of RC beams reinforced with rectangular and diamond ties under fire conditions.
- To investigate the effect of different concrete cover on thebehavior of RC beams subjected to fire.

➢ *Problem Statement*

The fire resistance of reinforced concrete (RC) beams is a critical concern in ensuring the safety of structures. In the event of a fire, the performance of RC beams is significantly affected by various factors, such as the type of tie system used, the spacing of the ties, and the coating applied to the reinforcement. Therefore, there is a need to investigate the behavior of RC beams subjected to fire and compare the performance of different tie systems, spacing, and coatings. Additionally, the compressive strength of various concrete covers used in RC beams needs to be evaluated to determine their effectiveness in enhancing the fire resistance of thebeams. This study aims to address these issues by analyzing and comparing the behavior of RC beams exposed to fire with different tie systems, spacing, and coatings, as well as different concrete covers, to provide valuable insights into improving the fireresistance of RC structures.

➢ *Research Work*

- *Preliminary Investigation*

Preliminary investigation- In first phase Physical properties of ingredient of concrete. In second phase Concrete mix design carried out for grade M20.

➢ *Test of Concrete for Compressive Test*

- Test specimen of size 230x230x750 is prepared for test.
- Longitudinal Reinforcement 6#12 & Transverse Reinforcement of 8@100mm, 8@150mm, 8@200mm.
- Cover for concrete is 25mm, 35mm, 45mm.
- Total 18 Beams are casted.
- 7, 14, 28, 56, 90 days curing with gunny bags or curingpond.
- After 28 days of casting Fire test will be conducted onBeam on one face of Beam or all face of Beam.
- Study the spalling area.
- Study crack pattern.
- Finding buckling load of Beam.
- NDT Test are carried of checking the strength of Beam
- Rebound hammer & Ultrasonic Pulse velocity test

➢ *Ultrasonic Pulse Velocity*

- The ultrasonic pulse velocity method could be used to establish:
- The homogeneity of the Ferrocrete,
- The presence of cracks, voids and other imperfections,
- Changes in the structure of the Ferrocrete which may occurwith time,
- The quality of the Ferrocrete in relation to standard requirements,
- The quality of one element of Ferrocrete in relation toanother and the values of the Ferrocrete.

➢ *Rebound Hammer*

The rebound hammer method could be used for:

- Assessing the likely compressive strength of Ferrocrete with the help of suitable correlations between rebound index and compressive strength.
- Assessing the uniformity of Ferrocrete,
- Assessing the quality of the Ferrocrete in relation to standard requirements

➢ *The Methodology with Respect the Set Objectives are given below:*

- The objective of this research is to enhance the performance of Bamboo reinforcement beams through the use of epoxy and fiber mat-wrapping. Prior to analyzing the performance of the beam, the modified Bamboo reinforcement material will be examined to identify effective approaches for improving its strength. This will involve the strengthening of Bamboo by wrapping it with epoxy and fiber mat. Additionally, the swelling of bamboo that creates gaps between the concrete and bamboo reinforcement, which is a disadvantage of using bamboo reinforcement, will be addressed and improved.
- The aim of this research is to develop an appropriate methodology for the fabrication of Bamboo Reinforced concrete beams. Using the modified reinforcement material and appropriate steel reinforcement, various approaches to centering and systematic methodology for scaffolding will be developed. Further processes of lapping and joining will be evolved to ensure effective fabrication.
- The objective of this research is to design different combinations of Epoxy coated Bamboo reinforced Beams. The baseline steel reinforced concrete beam design will be used as a reference, and bamboo reinforced beams will be designed based on the strength of the modified bamboo reinforcement. The moment of resistance of the bamboo reinforced beam will be estimated, and beams with various moment of resistance will be designed. Additionally, the beams with under reinforcement and over reinforcement will be designed to study the behavior of under reinforced and over reinforced beams.

- The aim of this research is to analyze the various configurations of Epoxy coated bamboo reinforced Beams. A range of epoxy coated bamboo reinforced beams will be experimentally tested to compare their performance with reference to their moment of resistancevalue. The failure patterns of these beams will also be studied, and other aspects such as the influence of reinforcement amount, the influence of shear reinforcement, and the ductility of the beam due to the ductility of bamboo will be analyzed.

## IV. EXPERIMENTAL CONSIDERATION

➢ *M20 Mix Design is 10262:2019:*

- **Step-1** Calculate Target Mean Strength of Concrete
- **Step-2** Selection of Water-Cement Ratio
- **Step-3** Estimation of Air Content
- **Step-4** Selections of Water Content and Admixture Content
- **Step-5** Estimation of Cement Content
- **Step-6** Estimation of Coarse Aggregate Proportion
- **Step-7** Mix Calculation for 1 m³

➢ *Mix Proportion by Volume*

- Cement = 318 kg/m³ Water = 197.15 Liter/m³
- Fine aggregate = 802.36 kg/m³
- Coarse aggregate 20 mm = 1162.16 x 60 %= 697.29 kg/m³
- Coarse aggregate 10 mm = 1162.16 x 40 %= 464.86 kg/m³Water-cement ratio = 0.62

➢ *Weight of Materials for 1 Bag (50 kg) Bag of Cement*

- We know that volume of 50 kg bag of cement is 0.035 m³. so ifwe divide the weight of cement by the volume of 1 bag of cement we will get a number of bags of cement required for making 1 cubic meter of concrete.
- Cement = 318 kg / 0.035 = 11.13 Nos. of Bags
- Now divide all other quantities by 11.13 to get materials quantity for 50 kg or 1 bag of cement
- Fine Aggregate (Sand) = 802.36 / 11.13 = 72.08 kg Coarse Aggregate (20 mm) = 697.29 / 11.13 = 62.64 kg
- Fine Aggregate (10 mm) = 464.86 / 11.13 = 41.76 kg
- Water = 197.15 / 11.13 = 17.71 liter.

➢ *Casting of Specimen*

Fig 3 Casting of Specimen

## V. CONCLUSION

- An UPV result with direct, semi-direct, and indirect methodsindicates that readings are below 3.5 km/sec.
- Indirect velocity will give the less pulse velocity than directmethod generally by 1km/sec.
- Reinforcement replacement and repair
- Epoxy grouting and micro concrete
- Injection grouting for concrete
- Diamond tie will improve Resistance significantly withincrease in buckling strength
- Spalling Area on the specimen of diamond tie will be less.
- Higher Concrete Cover will provide more protection fromFire.

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