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STRENGTHENING OF RC BEAM WRAPPED WITH KEVLAR FIBER

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ABSTRACT

Over the asset's life cycle, sustainability involves the preservation of infrastructure against any sort of deterioration. Localized damage received under high loading situations such as earthquakes, hurricanes, or tsunamis can cause reinforced concrete (RC) infrastructure to deteriorate. Furthermore, factors such as rebar corrosion or age may cause an RC column's capacity to deteriorate or decline, needing prompt reinforcement to either prolong or guarantee its intended life is not limited. Strengthening existing members to carry maximum loads or meet particular serviceability standards is one way to improve the qualities of reinforced concrete beams. The emergence of sophisticated composite materials, notably adhesive-bonded Kevlar fibre as externally bonded retrofit materials, has provided several benefits in structural engineering (i.e., corrosion-free, excellent strength to weight ratio, ease for site handling, flexibility to conform to any shape). The use of Kevlar fiber laminates in the structural repair and retrofitting of reinforced concrete members becomes a great deal of research work nowadays. This research work deals with the performance of reinforced concrete beams laminated with Kevlar fabric layers by an epoxy bonding agent under a two-point concentrated loading system. The study focus the effect of Kevlar fiber laminates improving the strength of the reinforced concrete beam will be investigated.

Keywords: beam wrapped

1. INTRODUCTION

Problems with reinforced concrete cause structures to degrade. Natural disasters such as earthquakes have repeatedly proved the sensitivity of existing structures to seismic impacts, emphasising the importance of rehabilitation of degraded structures in seismically active areas. As a result, one of the most critical tasks in civil engineering is retrofitting and reinforcing existing reinforced concrete structures. An engineer is frequently confronted with issues relating to retrofitting and strengthening an old building. As an example, how to build a robust structure. Because concrete is the world's most widely used man-made construction material. It's made by combining cementing materials, water, aggregates, and occasionally admixtures in the proper proportions. Concrete has a great compressive strength, is inexpensive, and has good flexibility. And how to modify the use of a structure, design code rules, and seismic retrofitting are some of the factors that contribute to the necessity for existing structure rehabilitation retrofitting. If upgrading is a possible option, complete replacement of the current structure may not be a cost-effective choice and may become a financial burden. Repair and rehabilitation are the most prevalent remedies in such situations.

The main objectives of this study are,

1. To study the mechanical properties of conventional concrete structure and compare with Kevlar fibre wrapped concrete beam.
2. To determine the flexural strength of Kevlar fibre reinforced concrete beam.
3. To compare the flexural behaviour of Kevlar fibre reinforced concrete beams with conventional concrete structure.

2. BACKGROUND

Fasil Mohi ud din (2017) The study's major goal is to determine the mechanical qualities and compatibility of fibre so that it may be utilised in concrete to improve its properties and durability. The specific tensile strength of both K29 and K49 is 8 times more than that of steel, making it both strong and light. It does not melt, unlike other plastics, and can withstand temperatures of up to 450°C (800°F). Kevlar can be ignited, however as the heat source is removed, the burning normally stops. Kevlar is unaffected by extremely low temperatures, according to proven research. Kevlar can endure temperatures as low as -196ºC (-320ºF).

Dheeraj kumar and Shivani Bhardwaj (2018) Retrofitting is the process of modifying an existing structure to make it more resistant to seismic activity, ground motion, and other natural disasters. Many existing reinforced concrete structures across the world are in desperate need of rehabitation owing to a variety of factors such as corrosion, a lack of detailing, and a failure of bonding between the bean-column junctions, among others. However, for structural wrapping, Aramid Kevlar Fiber Fabric Stripes Reinforcement (AKFFR) and synthetic steel fibre (SSF) are used. Our structure's materials are extremely sturdy and resistant to seismic action. This research looked at the behaviour of concrete beams after they were retrofitted with synthetic steel fibres and Aramid Kevlar fibres (AKFFR) and other materials.

Manoj Kumar Meena and Dr.Rakesh Patel (2018) The deflection of rectangular Beam reinforced by FRP laminated with CFRP, GFRP, and KEVLAR is compared using FEM software Ansys14.5 to examine the deflection of rectangular Beam reinforced by FRP laminated with CFRP, GFRP, and KEVLAR based on deformation and stresses. When compared to non-FRP material, CFRP, and GFRP laminated beams, KEVLAR provides higher structural strength. The analytical concrete Beam model KEVLAR offered higher strength to the structure (Beam) and was more successful in reducing deformation than without FRP Beam, GFRP, and CFRP reinforced material.

Shubham Chaudhary and Abhilesh Kant Sharma (2019) Fiber Kevlar is made up with technological advancements and the development of newer materials, the strength characteristics of very fine kevlar fibres when fibres are added to the concrete mix, it can also add the tensile loading capacity of the composite system of such newer materials must be investigated before it is put to practical use. The compressive strength, flexural strength, and split tensile strength of concretes all increased as the kevlar fibre content in concrete increased.

R.Arun Vidhiyagar and S.Karthiga (2019) Natural FRPs are used to wrap structures due of their excellent durability and environmental friendliness. The highest confining pressure that FRP can exert has a big impact on confinement strength. When compared to standard specimens, the load-carrying capacity rises with varied wrapping patterns. Natural fibres have a stronger environmental effect than synthetic fibres, and they should be supported in all structural applications.

Gajalakshmi Pandulu, Revathy Jayaseelan, and Sakthi Jeganathan (2020) In this research work, an attempt is made to study the performance of reinforced concrete and self-compacting beams laminated with various numbers of kevlar fabric layers by an epoxy bonding agent under a two-point concentrated loading system. The load-carrying capacity of weak structures will be improved by the flexural strengthening of beams with kevlar fabric which will enhance the performance of weak structures under flexural loading. Kevlar fabric-laminated beams yield lower crack width and average crack spacing. Kevlar fabric-lamination will also act as an additional concrete cover to prevent corrosion of the reinforcement of reinforced concrete beams. In this study, an attempt is made to find an effective solution to strengthen existing old and weak buildings by kevlar fabric laminates.

Kowsalyad and Dr. Ashok Kumar (2020) The behaviour of beam-column junctions that were externally wrapped with aramid fibre was tested to failure in this experiment. Through two opposed cantilever moment arms, a horizontal moment is transferred to the joints of the beam-column. Aramid fibre is a type of synthetic fibre that is resistant to heat. Because the chain molecules are strongly aligned along the fibre axis, the strength of the chemical connection may be utilised. The aramid fibre was tested to failure in this experiment to investigate the behaviour of beam-column junctions that were externally wrapped with aramid fibre. Through two opposed cantilever moment arms, a horizontal moment is transferred to the joints of the beam-column. Aramid fibre is a type of synthetic fibre that is resistant to heat. Because the chain molecules are strongly aligned along the fibre axis, the strength of the chemical bond may be utilised in these fibres.

Sai Mounika and Rajesh Boorla (2021) The production of Kevlar Fiber reinforced composites in various orientations is studied in this study. The components are made in accordance with ASTM specifications. ASTM D3039 is used for tensile specimens, D7264 for flexural specimens, and D785 for hardness specimens. Tensile strength, flexural strength, and hardness values are important mechanical properties to evaluate with the objective of – Fibers orientation along the length of the component, perpendicular to the length of the component, Fibers with mixed orientation i.e. combination of along the length and perpendicular to length.

A variety of technologies are used to improve the seismic resistance and load-bearing capacity of existing reinforced concrete structures. Structure's durability can be increased by using the right strengthening strategy. Fiber wrapping is a complex technology for structural element repair, retrofit, and maintenance. It protects reinforcing concrete structures from corrosion while also increasing their strength. GFRP, CFRP, and Kevlar fibers have been used to layer the beams. Reinforcing laminated beams in existing buildings, according to the majority of the literature, is a viable option. KEVLAR fiber provides the structure (beam) additional strength and is found to be more effective than other materials. In the absence of an FRP Beam, GFRP and CFRP reinforced materials are used to reduce distortion. In this research focus to determine the flexural strength of Kevlar fibers laminated beams with M30 grade of concrete. The Kevlar fabric on concrete beams will improve their flexural behaviour. The experimental investigation done by the wrapping system and a two-point loading test on regulated and strengthened beams must be performed.

3. MATRIAL PROPERTIES

3.1 Cement

All of the examples were cast with ordinary Portland cement (53 grade). The use of high-strength cement is required to generate high-performance concrete. For standard consistency pastes, different kinds of cement require varied amounts of water. Varied kinds of cement will result in different rates of strength growth in concrete. The most crucial factor in producing high-quality concrete is choosing the right brand and kind of cement. Because the type of cement used impacts the rate of hydration, the strength of the concrete at an early age can be significantly impacted. It's also crucial to make sure that the chemical and mineral admixtures are compatible with cement.

Table 1: Properties of cement

S.no	Properties	Test results
1	Normal consistency	0.32
2	Initial setting time	50min
3	Final setting time	320min
4	Specific gravity	3.15
5	Fineness	5%

3.2 Fine Aggregates

Sand is a finely split rocky material and mineral particles that make up a natural granular substance. The most frequent ingredient of sand is silica (silicon dioxide, or SiO2), which is generally in the form of quartz and is the most common weathering resistant mineral due to its chemical inertness and substantial hardness. As a result, it's commonly employed as a fine aggregate in concrete. In the research, river sand that was readily accessible on the market was employed. In compliance with IS: 2386-1963, the aggregate was evaluated for physical specifications such as gradation, fineness modulus, and specific gravity. Before using the sand, it was thoroughly dried on the surface.

Table 2: Properties of Fine Aggregate

Properties	Test Results
Specific Gravity	2.65
Bulk Density Kg/M^3	1830
Porosity,%	29.67
Grading Zone	Zone II
Fineness Modulus	3.13
Water Absorption	1.02%

3.3 Coarse Aggregate

Local crushing plants provided crushed aggregates with a size of less than 12.5mm. The aggregate that only passes through a 12.5mm filter and is kept on a 10mm sieve is chosen. In line with IS: 2386-1963, the aggregates were evaluated for physical parameters such as gradation, fineness modulus, specific gravity, and bulk density. To achieve the appropriate combined grade, the separate aggregates were blended. The particular specific gravity and water absorption of the mixture are given in the table.

Table 3: Properties of Coarse Aggregate

Properties	Coarse Aggregate
Particle Shape	Angular
Particle Size	20 mm
Specific Gravity	2.68
Bulk Density	1340 kg / m^3
Fineness Modulus	4.18

3.4 Water

Concrete's strength is dependent on the presence of water. It takes around 3/10th of its weight in water to be completely hydrated. For standard concrete, a minimum water-cement ratio of 0.35 has been demonstrated. Water participates in a chemical reaction with cement, resulting in the formation of cement paste, which binds coarse and fine particles. If more water is used, segregation and bleeding occur, weakening the concrete, but the majority of the water will be absorbed. It is possible that if the water content exceeds the acceptable limits, bleeding will occur. The requisite workability is not reached if less water is utilised. The concrete must be made using potable water that is appropriate for human consumption and has a pH range of 6 to 9.

3.5 Kevlar Fiber

Kevlar is the brand name for a para-aramid fiber-based synthetic material. Kevlar is a paramid made up of long polymeric chains that run in the same direction. Stephanie Kwolek of the Du Pont Company devised it during her study. It is heat resistant and decomposes at temperatures exceeding 400 degrees Celsius. Immersion in water has no effect on the strength of para-aramid since it does not corrode or rust. Intermolecular hydrogen linkages and aromatic stacking connections between aromatic groups in nearby strands give kevlar fabric its strength. Normal static molecules in Kevlar fabric create a planar sheet-like structure, comparable to silk protein. Kevlar materials can be used to join together or to combine with other materials to make composite materials. The tensile strength of kevlar cloth can sometimes exceed 500 MPa. Table 4 lists the physical characteristics of kevlar cloth. The fundamental qualities of Kevlar fabric were examined using an ASTM D638 Universal Testing Machine (ASTM D638-14, 2014).

Table 4: Properties of Kevlar Fiber

Property(unit)	Type
Material	Kevlar fabric
Structure of fabric	Biaxial 0 ° /90 °
Weight (g/m^2)	105
Nominal thickness per layer (mm)	0.6
Maximum tensile stress (N/mm^2)	(experimental) 1812.53

4. CASTING OF BEAMS

The beam was developed using the limit state approach, and moulds measuring 150x150x700 mm were made with 2-12 mm bars on the tension side, 2-8 mm bars on the compression side, and 6 mm bars as stirrups spaced at 125 mm centre to centre. The concrete was manually mixed and planned according to IS10262-2009, with a mix ration of 1:1.7:1.9 (cement, sand, and coarse aggregate). The entire mould was lubricated first. When the bar is in place, a cover block of 20mm is utilised to provide consistent coverage to the reinforcement. The concrete mixture was poured in stages and crushed with a tamping rod and vibrator until the mould was entirely filled. The beams were then taken out of the mould.

Fig 1: Casting of beam

4.1 Bonding Procedure of Fabric to Beam

Wire brushing is used to roughen the concrete surface, which is then completely cleaned to eliminate any dirt and debris. The epoxy glue and hardener are mixed completely and applied over the concrete surface in a 1:1 ratio. As shown in fig. 7.2, the fabric is then placed on top of the epoxy resin coating, with the warp direction of the fabric running parallel to the longitudinal reinforcement of the beam. During the epoxy hardening process, a constant uniform pressure is applied to ensure good contact between the epoxy, the concrete, and the fabric. Before testing, concrete beams with fabric are allowed to cure for seven days at room temperature.

Fig 2: Epoxy - hardener and fixing of Kevlar fabric on the beam

Table 5: Summary of Beam Specimen

Beam ID	Type of specimen	Strengthening pattern
Conventional beam		-
Kevlar wrapped beam 1	Single layer Kevlar fabric	Bottom wrapped
Kevlar wrapped beam 2		Fully wrapped

5. TESTING OF THE BEAM

5.1 Flexural Strength of Concrete Prism

The flexural strength was determined using 150 x 150 x 700 mm size prisms. The flexural strength was carried out at the age of 7 and 28 days using three prisms for each mix. The specimens were tested according to BIS: 516 –1959 (reaffirmed 2004) in a UTM by placing horizontally between two roller supports. A prism specimen was cast and tested for compressive strength of M20 grades of concrete. For each mix, three prism were tested at each age and the average flexural strength was taken.

Fig 3: Flexural strength testing of prism

Table 6: Observation table for tested beam specimen

Beam notation	Type of beam	Ultimate load (kN)	Maximum deflection (mm)
B1	Conventional	71	31
B2		71.5	29
B3		72	30
B4	Bottom wrapped	80	32
B5		85	33
B6		87	39
B7	Fully Wrapped	96	34
B8		95	30
B9		97	37

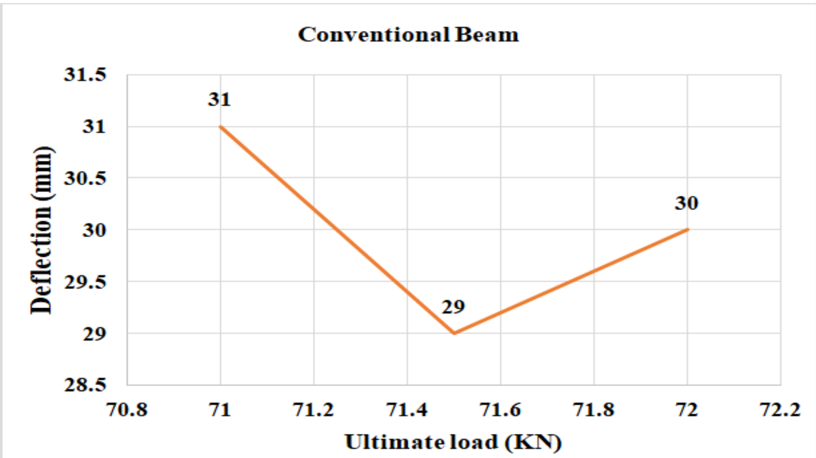

Fig 4: Load Vs Deflection for conventional beam

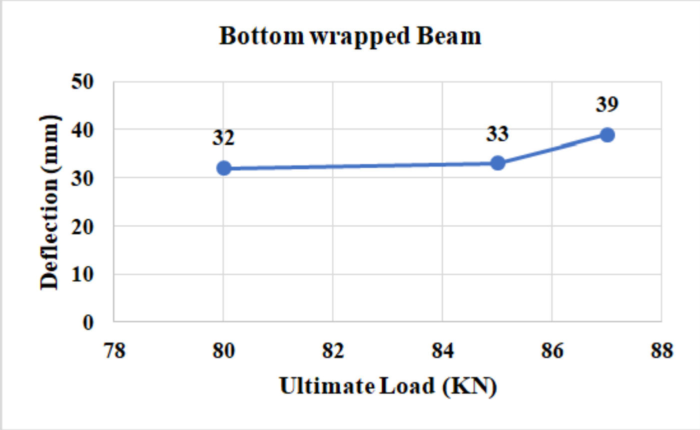

Fig 5: Load Vs Deflection for Bottom wrapped beam

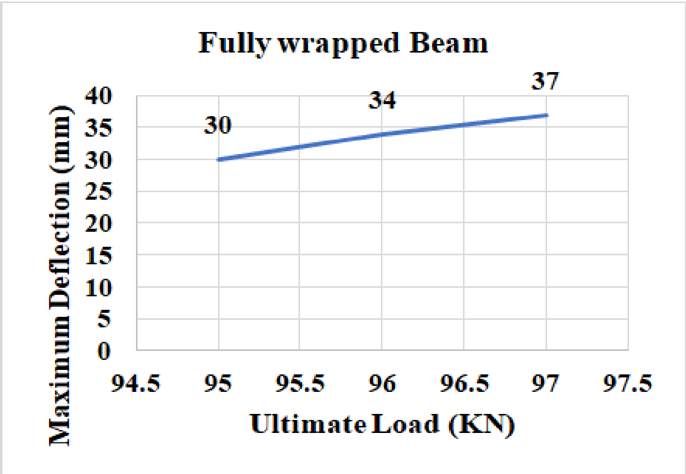

Fig 6: Load Vs Deflection for Fully wrapped beam

6. CONCLUSION

The flexural behaviour of reinforced concrete beams reinforced with Kevlar fabric was investigated in this experimental study. The following conclusions can be taken from the test results and calculated strength values: By reinforcing the beam at the soffit, initial flexural cracks develop at greater loads. The ultimate load carrying capacity of the strengthened beams KB-1 and KB-2 is significantly higher than that of standard beams CB. The final load carrying capacity of the beam is increased due to flexural strengthening, however the cracks that occurred were not visible. Because the initial cracks are not visible, the occupants regarding collapse. Despite the failure of steel and excessive deflection, the use of fully wrapped Kevlar fabric does not cause the beam to collapse suddenly. The performance of a weak structure can be improved by strengthening the beam, and this will protect many lives from sudden failure. Furthermore, no minimum concrete cover is required to keep the reinforcement from corroding. The Kevlar fabric reinforcement yields lower crack widths and crack intervals over a wide range of service loads. Additionally, the deflections of the reinforced concrete elements were clearly lower than that of non-strengthened reference elements. Finally, this method of strengthening existing old buildings' beams/structural members is effective solution.

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