



NUMERICAL EVALUATION OF STRUCTURAL BEHAVIOR OF THE SIMPLY SUPPORTED FRP-RC BEAMS

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Abstract:

The main problem of steel-reinforced concrete structures is corrosion of steel reinforcements which leads to premature failure of the concrete structures. This problem costs a lot annually to rehabilitate and repair these structures. In order to improve the long-term performance of reinforced concrete structures and for preventing this corrosion problem, Fiber Reinforced Polymer (FRP) bars can be substituted of conventional steel bars for reinforcing concrete structures. This study is a numerical study to evaluate structural behavior of the simply supported concrete beams reinforced with FRP bars in comparison with steel-reinforced concrete beams

1.0 Introduction:

To evaluate effect of different width of FRP on structural behaviors of RC beams and investigate most effective height of FRP on the side surfaces of RC beams for flexural strengthening. Toward this goal, five RC beams are design and strengthened with different width of FRP, and then four-point bending tests with the simply supported beams are performed. Results of this study show that the width of strengthened FRPs on RC beams has a significant influence on structural behaviors of RC beams. Fiber reinforced polymer (FRP) is widely used for reinforcing structural members due to its high strength, light weight, and simple installation. The use of FRP materials for structural repairing presents several advantages such as the high strength to weight ratio of FRP, the ease of FRP

application on site due to little equipment needed and finally the improved durability and corrosion resistance in strengthened structures. Externally bonded FRP laminates and fabrics can be used to increase structural and flexural strength of reinforced beams and columns. In order to increase flexural strength of beams, a continuous sheet of FRP can be bonded at its bottom face. The structural behavior of flexural members with bonded FRP as external reinforcement has been extensively investigated. In all these studies, the lack of an effective anchorage of the composite plate reinforcing the RC member results in loss of the flexural design capacity of the member.

Polymers:

The linking of small molecules (monomers) to make larger molecules is a polymer. Poly-metrication requires that each small molecule have at least two reaction points or functional groups. There are two distinct major types of polymerization processes, condensation polymerization, in which the chain growth is accompanied by elimination of small molecules such as H₂O or CH₃OH, and addition polymerization, in which the polymer is formed without the loss of other materials. There are many variants and sub-classes of polymerization reactions. The polymer chains can be



classified in linear polymer chain, branched polymer chain, and cross-linked polymer chain.

Polymer composites:

The polymer composites are any of the combinations or compositions that comprise two or more materials as separate phases, at least one of which is a polymer. By combining a polymer with another material, such as glass, carbon, or another polymer, it is often possible to obtain unique combinations or levels of properties. Typical examples of synthetic polymeric composites include glass-, carbon-, or polymer-fiber-reinforced, thermoplastic or thermosetting resins, carbon-reinforced rubber, polymer blends, silica- or mica-reinforced resins, and polymer-bonded or -impregnated concrete or wood. It is also often useful to consider as composites such materials as coatings (pigment-binder combinations) and crystalline polymers (crystallites in a polymer matrix).

FRP (fibre reinforced polymer):

Fiber-reinforced polymer (FRP), also Fiber-reinforced plastic, is a composite material made of a polymer matrix reinforced with fiber the fibers are usually glass, carbon, or aramid, although other fibers such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic, and phenol formaldehyde resins are still in use. FRPs are commonly used in the aerospace, automotive, marine, and construction industries. Composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the

finished structure. Most composites have strong, stiff fibres in a matrix which is weaker and less stiff. The objective is usually to make a component which is strong and stiff, often with a low density

Reinforcing fibers for structural composites:

Principal fibers in commercial use for production of civil engineering applications, including composite-reinforced concrete, are glass, carbon, and aramid. The most common form of fiber-reinforced composites used in structural applications is called a laminate. Laminates are made by stacking a number of thin layers (laminate) of fibers and matrix and consolidating them into the desired thickness. Fiber orientation in each layer as well as the stacking sequence of the various layers can be controlled to generate a range of physical and mechanical properties. A composite can be any combination of two or more materials so long as there are distinct, recognizable regions of each material.

FRP Composites Benefits:

- Prefabrication of deck panels
- Manufacturing in a plant to ensure quality
- Minimizes installation on site
- High strength
- Lightweight
- Reduces installation time
- Reduces the number of trucks to carry products to site as more products can be transported per truck
- Lighter duty equipment needed to lift and place panels

Strengthening using FRP

Concrete beams are the main element in structural engineering which are designed to carry both horizontal loads due to seismic or wind and vertical gravity loads.



Like all other concrete elements they are susceptible for situations where there is an increase in structural loads. Generally reinforced concrete (RC) beams fail in two ways: flexure failure and diagonal tension failure. Flexural failure is generally preferred to structural failure as the former is ductile while the latter is brittle.

Advantages Of FRP:

FRP materials have higher ultimate strength and lower density as compared to steel. When these properties are taken together they lead to fiber composites having a strength/weight ratio higher than steel plate in some cases. The lower weight of FRP makes installation and handling significantly easier than steel. These properties are particularly important when installation is done in cramped locations. Other works like works on soffits of bridges and building floor slabs are carried out from man-access platforms rather than from full scaffolding

2.0 Literature review:

Papakonstantinou et al. (2001) these researchers conducted tests of un strengthened beams and strengthened beams using glass fiber-reinforced composites. The reported failure mode for all their tests consisted of steel fatigue fracture. It should be pointed out, however, that for all the strengthened beams in their study the FRP laminates extended past the supports so FRP deboning was restrained by clamping from support plates near the beam ends.

Pinkerton, L., and Till, R. D. (2003) the infrared detection technology was used to record the FRP-concrete interfacial fatigue behaviors. The results demonstrated that the fatigue development by RC beams strengthened with FRP was divided into three typical stages: rapid increase, stable-

change, and uncontrollable propagation. The period of stable-change accounted for more than 99% of the fatigue lifetime. The average bending stiffness and the average FRP fatigue strain of the stable-change phase obtained under certain fatigue load were close to those obtained under the same monotonic load.

MuktarNuhuDanraka1, H. MahirMahmod (2017) Excessive fatigue deterioration is usually experienced when Reinforced Concrete structural elements are subjected to loadings. This emphasizes the desire to strengthen as well as improve the fatigue performance and extend the fatigue life of RC structural components particularly beams. During the last few decades, strengthening of concrete structural elements by fibre-reinforced polymer (FRP) has become a widely used technique where high strength is needed for carrying heavy loads or repairing is done due to fatigue cracking, failure modes and or corrosion. This paper reviews various aspects of RC beams strengthened with FRP

3.0 Methodology:

Reinforced concrete (RC) (also called reinforced cement concrete or RCC) is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength or ductility. The reinforcement is usually, though not necessarily, steel reinforcing bars (rebar) and is usually embedded passively in the concrete before the concrete sets. Reinforcing schemes are generally designed to resist tensile stresses in particular regions of the concrete that might cause unacceptable cracking and/or structural failure

FRP-strengthened reinforced concrete beam:

In this study a single span simply supported beam strengthened with FRP composites is considered. Details of a typical beam used for the modeling and analysis in this study are shown in Fig. .

The flexural analysis of concrete sections with externally bonded tensile FRP reinforcement is based on the following assumptions:

- Plane sections remain plane at all time and strain distribution of elements in cross section is linearly on height.
- There is no slip between the steel or FRP reinforcement and concrete.

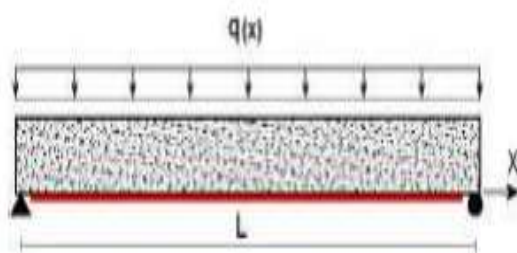


Figure: Simply supported reinforced concrete beam strengthened using FRP sheets

Fatigue Performance of RC Beams:

A quite number of studies conducted by as well as have all reported significant improvement in fatigue resistance and capability of RC beams after retrofitting (strengthening) with externally bonded laminates of FRP. Reported that usage of laminates to strengthen beams with FRP results in greater fatigue strength of almost thrice that of un strengthened beam under equal loading condition and interval. Tremendous improvement in fatigue performance was also reported in cases where serious impairment had occurred prior to retrofitting of the RC beams They also noted that strengthening technique using FRP laminates is envisaged to improve fatigue performance as strength

and stiffness is increased while the crack propagation is reduced thus leading to a reduction in stress build up in the reinforcement and applied fatigue loading under service in order to investigate fatigue efficiency of RC beams retrofitted with FRP

Materials:

Concrete is a mixture of coarse (stone or brick chips) and fine (generally sand or crushed stone) aggregates with a paste of binder material (usually Portland cement) and water. When cement is mixed with a small amount of water, it hydrates to form microscopic opaque crystal lattices encapsulating and locking the aggregate into a rigid structure.

Mate rials	De nsit y (kg /m3)	Elas tic Mo dul us (M Pa)	Poi son 's rati o	Fc 28 (M Pa)	Fy (M Pa)	Elem ent Used
Conc rete	240 0	191 63	0.1 7	15	-	SOL ID65
Reinf orcin g Steel	785 0	210 000	0.2 7	-	41 5	BEA M18 8

Physical characteristics give reinforced concrete its special properties:

The coefficient of thermal expansion of concrete is similar to that of steel, eliminating large internal stresses due to differences in thermal expansion or contraction When the cement paste within the concrete hardens, this conforms to the surface details of the steel, permitting any

stress to be transmitted efficiently between the different materials. Usually steel bars are roughened or corrugated to further improve the bond or cohesion between the concrete and steel.

Beam Dimensions:

As per clause 29 of IS 456:2000 the beam dimensions were finalized as follows:

Length (L) = 1.2 m

Width (b) = 0.15 m Depth (D) = 0.46 m

Effective span (l) = 0.9 m

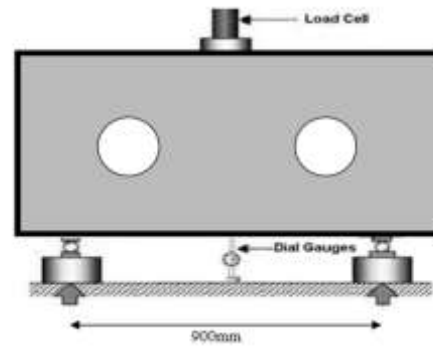
It has been tested after 28 days with three points loading



Figure: Reinforcement cage

Experimental Setup:

The beams with holes are tested in the loading frame of the the testing procedure for the all the specimen is same. First the beams are cured for a period of 28 days then its surface is cleaned with the help of sand paper to make the cracks clearly visible after testing. One point loading arrangement is used for testing of beams. The load is transmitted through a load cell and spherical seating directly at the midpoint of the beam. The specimens placed over the two steel rollers bearing leaving 150 mm from the Ends of the beam one dial gauge is used for recording the deflection of the beam and is placed at the center of the beam



Model view of Rc beam

4.0 Results:

the structural behavior of the strengthened beam. A quarter of the full beam was used for modeling by taking advantage of the symmetry of the beam and loadings. solid65, was used to model the concrete studied comparison on the behavior and performance of bond between concrete and materials of FRP in different systems of bonding which included near surface mounted, fiber anchored, externally bonded as well as hybrid bonded FRP systems.

Result of the specimens:

beam layer specimens	Ultimate stress (MPa)	Ultimate Load (N)	Young's modulus (MPa)
2(closely spaced)	172.79	6200	6829.9
4(closely spaced)	209.09	9200	7788.5
2(largely spaced)	268.6	30890	6158
4(largely spaced)	271.48	31221	6224.02

Beam 1 is taken as the control beam which is weak in structural . In Beam1 no strengthening is done. Three point loading

is applied on the beam and at the each increment of the load, deflection values at $L/2$ are taken with the help of dial gauge. Using this load and deflection data, load vs. deflection curve is plotted. At the load of 90 KN first crack appeared. Later with the increase in loading values the crack propagated further

Beam – 2 double layer U- wrap:



Figure: U-wrap FRP wrapped at Beam 2

Beam-2 is strengthened using double layer u-wrap of FRP(closely spaced). Three point loading is applied on the beam and at the each increment of the load, deflection values at $L/2$ are taken with the help of dial gauge. Using this load and deflection data, load vs. deflection curve is plotted. At the load of 190 KN initial hairline cracks appeared. Later with the increase in loading values the crack propagated further.

Geometry and loading conditions:

Simply supported beam is considered having and overall length of 1200 mm with effective length of 900 mm. Size of the beam is 150 x 460 mm. Figure the control beam with boundary conditions used in the analysis. Single point loading is applied at the midpoint of the beam. To get the accuracy of results mesh size considered as 25 mm as edge length

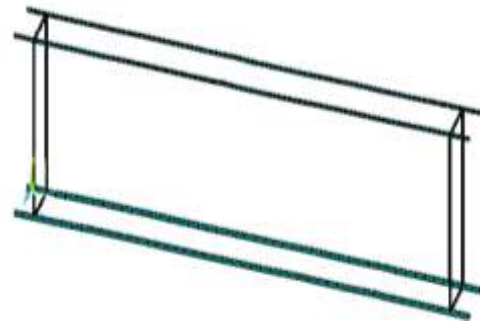


Figure: reinforcement model beam

Conclusion:

The present experimental study is done on the structural behavior of reinforced concrete deep beams containing openings strengthened. Three reinforced concrete (RC) beams containing openings weak in structural having same reinforcement detailing are casted and tested under three point loading. From the calculated strength values, the following conclusions are drawn:

The load carrying capacity of the strengthened beam 3 which was strengthened using four layer u-wrap FRP (closely spaced) was found to be higher when compared to beam 2 which was strengthened using double layer u-wrap FRP. Using FRP strengthen RC beams improves the fatigue performance of retrofitted beams by extending the strength and lifetime of the beams. The failure in the beams is mostly influenced by fracture of reinforcing bars

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