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Experimental Investigation of RC Beams With Opening By GFRP Laminates-A Review

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Abstract: This paper presents the influence of wide web apertures in the shear zone on the response Un-strengthened and upgraded reinforced concrete (RC) beams is investigated experimentally and numerically in this work. Web openings in reinforced concrete (RC) beams are typically required for the transit of utility ducts. The use of externally bonded fibre reinforced polymer (FRP) sheets, strips, or steel plates for strengthening reinforced concrete (RC) beams is a new and convenient method for reducing beam strength caused by such openings. The use of GLASS FIBER REINFORCED POLYMER (GFRP) to strengthen and rehabilitate structures is explored in this paper. While there have been a few finite element (FE) approaches to forecasting the behaviour of such RC beams, they have been quite limited. In light of this, three different FE models for the simulation of RC beams with a FRP-strengthened rectangular web opening were constructed using ABAQUS In this study, two models based on the brittle cracking model of concrete.

Keywords: GFRP laminates, opening in beams, RC beams, strengthening methods

1.INTROUDUCTION

Utility pipes and ducts are required to accommodate vital services in old buildings with solid slab systems. Air conditioning, power supply, telephone connection, computer network, sewerage, and water supply are among these services. Pipes and ducts are used in practice. For aesthetic reasons, it is frequently hung below the floor timbers and covered by a suspended ceiling. These holes come in a variety of forms and sizes, including circular, square, and rectangular. The presence of an opening in a reinforced concrete beam's web causes a slew of issues. Reduced beam stiffness, excessive cracking, and excessive deflection are examples of changes in beam behaviour and a weakening of the beam. When the overall cross-sectional dimension of a beam is reduced, the simple beam behaviour is transformed into a more complex one. Many elements influence the structural effect of an opening, including boundary conditions, tension and compression reinforcement, opening location, and load kinds. (GFRP) GLASS FIBER REINFORCED POLYMER sheets are employed in the opening zone of beams in this study to strengthen and repair them.

1.1 EFFECT OF OPENING IN BEAMS ON SERVICIABILITY

EFFECT ON STIFFNESS AND DEFLECTION

After cracking, openings have a considerable impact on beam stiffness, and each increase in hole size leads to a direct reduction in beam stiffness. The location of the opening, on the other hand, has no discernible effect on the beam's stiffness.

If the size and location of apertures in beams are not taken into account, the deflection will rise.

1.2 STRENGTH EFFECT OF OPENING IN BEAM

EFFECT ON ULTIMATE STRENGTH

The final strength of the beams is reduced by increasing the size of the apertures and shifting them farther from the centre stub of the beam. When compared to beams without openings, the ultimate strength of beams with openings near the beam supports to avoid the failure plane is reduced by more than ten percent. This could be because one or more stirrups have been removed, lowering the capacity to carry a large amount of applied shear. To Re-Establish structural integrity, several methods such as externally bonded fibre reinforced polymer plate, grouting with non-shrinking cement, or any other method can be utilised the ultimate strength of the elements when openings are drilled to evaluate the performance of old structures.

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II.LITERATURE REVIEW

Subhajit Mondal(1), Creating a crack around the aperture in the beam reduces stiffness and leads to a more complicated structural reaction. The use of GLASS FIBER REINFORCED POLYMER (GFRP) to strengthen and rehabilitate structures is explored in this paper. Ten beams are examined in this experiment, one solid as a reference beam and the other nine characterised as beams with openings, strengthened beams, and rehabilitated beams. The impact of FRP on deflection pattern, cracking, strain in the immediate vicinity, initial crack load, and ultimate failure load is examined. This research may aid the designer in providing adequate openings in the beams without compromising their carrying capacity as well as understanding the behaviour of retrofitted beams.

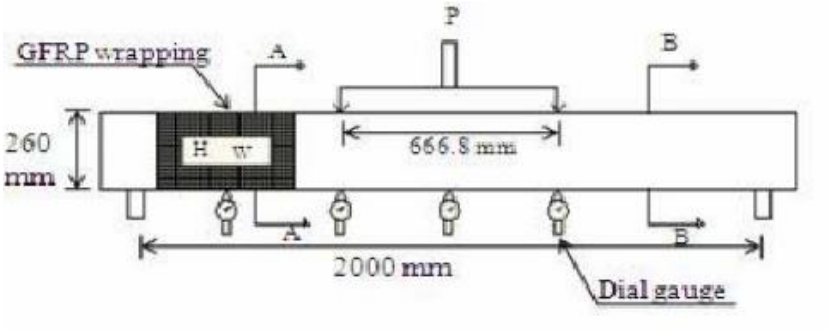

Figure: Experimental Set up

In the first group of three beams, the opening is 100 mm wide x 100 mm, in the second group of three beams, 200 mm x 100 mm, and in the third group of three beams, 300 mm x 100 mm. width of opening 100, 200 and 300 mm, The height of each opening is fixed at 100mm.each of the three groups second beams has an opening, which is reinforced using isotropic GFRP lamination at the opening zone. Two Point loads with a 1 tone increment are applied to all ten beams at a distance of one third of the span from the two supports. Initial cracks in the flexural zone, rather than cracks around the opening, can be seen when FRP is wrapped around the opening of beams with 200mm and 300 mm opening widths. Beams wrapped in FRP show debonding of the FRP layer, causing them to tear along diagonal.

Rakesh Diggikar(2),Work carried on R.C.C. Beam with rectangular opening strengthened by GFRP sheets. total of Ten beams were cast, one without an opening (solid beam) and one with a rectangular post opening, and these two were used as comparison beams. The opening size 300*100mm, the height of each opening is fixed at 100 mm. the remaining eight beams were reinforced with (GFRP) sheets using various strengthening techniques. all around the opening, all within the opening, all inside and around the opening, and double layer all around the opening. in the loading frame, these beams were evaluated under Two Point loading. On such beams, GFRP sheets with various strengthening strategies were investigated in terms of first crack load, ultimate failure load, and cracking pattern. The results of the analysis aid practising engineers in providing an opening in the beams without diminishing their load-bearing capability. The maximum load carrying capacity of R.C.C. beams with openings enhanced with GFRP sheets was raised by 3.74 to 37.41% in various designs. When a rectangular post opening is included in a beam, its weight carrying capacity is reduced by 45.70 percent when compared to a solid beam, such as a control beam. to make it more flexible the cracks were diagonal generated as a result of the accumulation of stress around the entrance edges.

Mithun Kumar(3),This paper presents Ten beams were cast in this experiment, All of the beams that were tested had a rectangular cross section with a 150mm width and 250mm depth, as well as an effective length of 1800mm. opening size 100mm diameter .one with no opening (i.e. solid beam) and one with a round post opening, both of which were used as control beams. GLASS FIBRE REINFORCED POLYMER (GFRP) sheets with varied strengthening schemes, such as around the opening, within the opening, inside and around the opening, and double layer around the opening, were used to reinforce the other eight beams. These beams were simply supported and tested in a loading frame with less than two points of loading. The load-carrying capability, load-deflection behaviour, and cracking patterns of such beams were investigated. The ultimate load carrying capability of the R.C.C. beam strengthened with GFRP sheets of various schemes was enhanced in the range of the test findings. The load carrying capacity of the beam is reduced by 37.57 percent when compared to a solid beam (control beam), decrease in stiffness and the development of diagonal cracks due to stress concentration around the aperture.

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Siew Choo Chin(4), Deep beams of reinforced concrete (RC) are commonly employed in tall buildings, especially at transfer floors, warehouses, and other industrial facilities. The significant stress concentrations are plainly seen at the cut's corners and beneath the loading locations. The researchers tested ten continuous deep RC beams with openings up to the point of collapse. Thirteen (13) deep beams were cast and tested using the four-point bending method.

Beam specimens had an 80 x 500 mm cross-section and a total length of 1200 mm. The apertures have a square form to them. Regardless of the shear span-to-overall depth ratio, two types of failure modes were identified due to the influence of the size and placement of web apertures. Under two-point symmetric top loads, the beams were tested to failure. The reduction of concrete area in the high shear zone reduces beam shear strength dramatically and causes significant serviceability issues. The size of the opening, its placement, and the presence of GFRP sheets were all factors in the test. Assist us in analysing the debonding behaviour of strengthening materials and possible mitigating strategies.

Bashir H. Osman(5), Alternative reinforcing processes for shear-strengthening beams include steel plate and FRP laminate. A point load was applied to a high-strength RC beam with a wide rectangular aperture. the opening size 300 *100mm and 300mm opening from support. The behaviour of reinforced concrete Beams with small square opening under increasing loads was studied using a nonlinear finite element approach. The effects of section reduction owing to openings on the load-carrying capability of the beams are explored, as well as crucial design elements such as opening locations and the presence of web reinforcement. The shear strength of deep beams is less affected by concrete strength, according to the findings. The final shear collapse was caused by diagonal cracks linking the four corners of the opening to the loading and support locations. The first form involves enclosing the opening with FRP, while the second involves placing FRP diagonally across the beam. The original performance is almost totally recovered when FRP laminates diagonally to the beam's axis of the opening throughout the entire beam's depth.

Nasr Z. Hassan(6), Under static load, the reinforced concrete beams were modelled in the ANSYS V12 programme. The finite element programme ANSYS V12 was used to evaluate fifty-seven beams. The results of the analysis were compared to fifteen experimental beams. The opening width and height of the beams are 200 * 100 mm and 300*100 mm, respectively. The opening's midline is 225, 300, 350, and 400 mm away from the near support. The use of FIBER Reinforced Polymer to strengthen all beams with openings resulted in six distinct schemes around the opening (FRP). The inclusion of a rectangular opening reduces the cracking and ultimate strengths of RC beams, as well as their stiffness. Tensile pressures caused the fiber laminates to debond from the concrete beam, which caused the beam to fail. Strengthening beams at the opening zone with FRP sheets can improve overall rigidity and reclaim some of the stiffness lost during the opening process. When using one layer of GFRP laminates, the failure loads are mostly affected by the strengthening scheme, with spacing "S" having a minor impact.

Tarek Almusallam(7), Examine the behaviour of reinforced concrete (RC) beams reinforced with fibre reinforced polymer (FRP) with big rectangular web holes in the flexure zone. there is a web aperture with a depth of 225 mm and a length of 450 mm. were used in the test programme. Seven RC beams, divided into two groups, were put to the test. Two unstrengthened beams (one solid with no opening and one with a wide rectangular web opening in the pure flexure zone) were evaluated under four-point bending in the first group. Five beams were tested under center point loading in the second group. the web opening is small $\ell o \leq hc$ where ℓo is the length of the opening. the web opening is large $\ell o >$ hc. They were made up of one solid reference beam and four beams with big rectangular webs that opened in the maximum moment region. Two of the four beams with openings were left un-strengthened, while the other two were reinforced using two distinct FRP techniques. The decision to use GFRP instead of CFRP was made to avoid the problem of galvanic corrosion that can occur when metals are coupled to CFRP This strengthening technology can now be used safely in the field. Finite Element Modeling was used to complete the project. The FE modelling utilised in this study was found to be adequate for determining the flexural strength of unstrengthened and FRP-strengthened RC beams having web holes in the flexure zone. This illustrates the validity of the modelling approach, which may be applied in future study on the usage of FRP for RC structural members with confidence. If the depth of the top chord is greater than or equal to the depth of the concrete stress block at ultimate state, the ultimate capacity of RC beams with openings in the pure flexure zone is unaffected by the opening.

Hussein M. Elsanadedy(8), The influence of wide rectangular web openings in the shear zone on the response of un-strengthened and upgraded reinforced concrete (RC) beams is investigated experimentally and numerically in this work. The opening size and strengthening strategy were the parameters that were investigated.

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Seven RC beams with section dimensions of 200* 450 mm were evaluated under four-point bending in the experimental programme. A control beam with no opening was utilised to make comparisons with the other beams. The remaining six beams were split into two groups, each consisting of three RC beams. Beams with two rectangular holes of 225 mm depth and 450 mm length were created in the first group. The opening length was enlarged to 675 mm in the second group, situated near supports, and one reference specimen with no opening (solid beam). Two specimens were unstrengthened and four specimens were strengthened with two fibre reinforced polymer (FRP) strengthening schemes out of the six beams with openings. Two thicknesses (0°/90°) of carbon FRP (CFRP) sheets were used to reinforce beams. The second concept, on the other hand, was a hybrid system made up of glass FRP (GFRP) sheets anchored by bolted steel plates. these were used to validate the numerical models and the results of the finite element (FE) analysis.

X.F. Nie(9), in this paper demonstrated the viability of employing externally bonded FRP to compensate for the strength loss of beams caused by web openings, whereas finite element (FE) methodologies for forecasting the behaviour of such RC beams have been limited. The beam measured 500 mm in height, 250 mm in breadth, 100 mm in flange thickness, 1450 mm in total flange width, and 3300 mm in clear span., a shear span of 1650 mm.

This work presents three different FE models created using ABAQUS for the simulation of RC beams with FRP-strengthened rectangular web opening. models are based on the concrete brittle cracking model, while one is based on the concrete damaged plasticity model. The most appropriate FE technique is chosen by comparing their predictions with test data collected from the available literature. The brittle cracking model is designed for simulations of structures whose behaviour is dominated by the tensile and shear behaviour of concrete. hence the compressive behaviour of concrete is considered to be linear elastic. The static structural response of RC beams with a FRP-strengthened rectangular aperture can be simulated using the proposed dynamic analysis approach with the main elements appropriately established. The brittle cracking model with the modulus of concrete is recommended for use in such simulations because it can produce the best predictions of load deflection curves of current test beams.

Rania Salih(10), Using an external bonded approach, this study evaluates the cyclic loading response of reinforced concrete beams with web holes and shear-flexure strengthened Glass fibre reinforced polymer (GFRP) sheets. When the ratio of the diameter of the opening to the overall beam depth (d/D) is less than 40% for circular web openings, it is characterised as a "small" opening; when the ratio d/D is larger than 50%, it is classified as a "big" opening. Six rectangular RC beams with simple supports were cast, with a total length of 2000 mm and a clear span of 1700 mm, six rectangular simply supported RC beams (140 mm wide and 250 mm deep) with an effective depth of 220 mm were cast. two layers of GFRP composite in the shape of a U-jacket the thickness was set to 0.35 mm nominally. One of the tested beams was left open, while the other five had apertures in various positions. One of the tested beams was left open, while the other five had apertures in various positions. The strengthened area was calculated based on the GFRP's minimum effective length. It is possible to examine crack patterns and failure modes. The reaction of RC components to hysteretic pinching under reversed cyclic stresses is studied. To create and develop models, the commercial software ABAQUS was utilised.

III.CONCLUSION

The importance of the study in the strengthening of the RC beam with opening utilising GFRP laminate in the strengthening system provides an economical and various solutions for prolonging the service life of reinforced concrete beams that have been opened. The study that has already been done was reviewed in this paper. The opening in the RC rectangle and T-Beam sections are strengthened in shear with GFRP laminate, steel plate, and integrated steel plate joints, there hasn't been much research done on CFRP sheets under seismic loading. The goal of the suggested research is to improve the knowledge of reinforced concrete beams. Strengthening beams at the opening zone with FRP sheets can improve overall rigidity and reclaim some of the stiffness lost during the opening process.

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