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A STATE OF ART REVIEW ON ANALYSIS OF OPENING IN RC BEAM STRENGTHENED BY FRP USING FINITE ELEMENT APPROACH

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Abstract: To accommodate important utilities such as power, telephone, computer network, and air conditioning, modern construction structures require numerous pipes and ducts. This will produce extra void space or waste space thus, a substitute arrangement must be devised to transmit these pipes and ducts via a transverse passage of the beam, and the cost ofthe construction of structures can be decreased. Hence, strengthening a beam with an openingshould be done. These are two types of strengthening of beams: The pre-planned opening is done by steel reinforcement should be provided with proper design. When a post-planned opening occurs the beam should be reinforced with different FRP such as CFRP, GFRP, AFRP, and other materials. The different investigation has been done for reinforced structural member beams with openings. The main aim of this paper is to tell about the performance of the beam opening, analyze using the software, and design of concrete beam opening. Furthermore, various classifications of opening, different opening site suggestions, and the performance of Reinforced concrete beams with openings will be highlighted and explored. The article will also detail and explain many design methodologies, such as the ACI methodology, the AIJ approaches, and thestrut and tie method. There are different types of strengthening techniques of the beam such as Fibre Reinforced Polymer and steel plates are investigated for strengthening RC beams with openings. Finally discussed the research gaps inthe current study, future work should be done.

Keywords: Reinforced concrete beam with different shape opening, different FRPs like CFRP, GFRP, BFRP, strengthening of beams, ultimate load capacity, failure crack pattern, finite element approach, ANSYS, load versus deflection graphs, analysis of RC beams.

I. INTRODUCTION:

In today's building structures, longitudinal openings in the existing beams are typicallycreated for the movement of utility conduits and pipelines. These conduits are provided for the services like water supply pipelines, computer networks, telephone wires, and electricity. These conduits andpipes are typically located below the structural member and, these are bounded by a floating ceiling, for esthetical reasons, the height of each floor level will increase by this dead space, overall increasing the total size of the building. As a result, the web openings should be provided to minimize the structure's height, particularly in tall buildingconstruction, thus resulting in a reduction of construction cost and a highly affordable design [1].

Due to the rapid variations in the structural member's cross-section during the opening, the opening's edges of the beam are subjected to high-stress concentration, and transverse cracks in the beam can procedure. This opening in the structural member leads to producing more deflection and the strength and stiffness of the beam will reduce. In many cases, retrofitting concrete structures with FRP sheets is used to strengthen the beam it's a more cost-effective and technically superior alternative method to regain the strength and load-carrying capacity of the structural member. And it offers specific strength, reduces the density, and oxidation resistance against fatigue stress, a simple and quick method to strengthen the opening structural member [2].

II. IMPORTANCE OF RESEARCH:

The current study's major goal is to explore the structural behavior of structural member beams with opening strengthen with different FRPs, both analytically and experimentally results should compare. In this research we study the Finite

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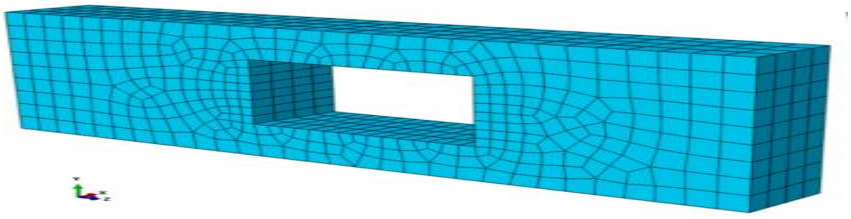
element approach is done to determine the ultimateload capacity, how much deflection in structure, stiffness of the member, ductility of the beam,and different failure forms of the structural member with openings and reinforced with FRP layers. The results of the inspected beams were compared with the characteristics of the solid RC beam to the beam with an opening and examined the productivity of the FRP, and how much strength can restore by using the different techniques.

The FEM model was developed. using the ABAQUS software. The Analytical and Experimental investigations from the various literature are checked its efficiency. The different mesh sizes were used during the modeling. Explained about how the opening position, and opening area are affected are discussed, and stiffened arrangement on the shear performance of reinforced concrete beams reinforced with different FRP layers was studied parametrically using the FEM model. The recommended mesh sizes could very well capture the empirical shear failure, as seen in fig.1. To build the web openings, many sites throughout the length of the beam were recommended. The implications of the various opening areas on load capacity andfailure pattern, on the other hand, are discussed in [3]



(a) Solid elements for concrete

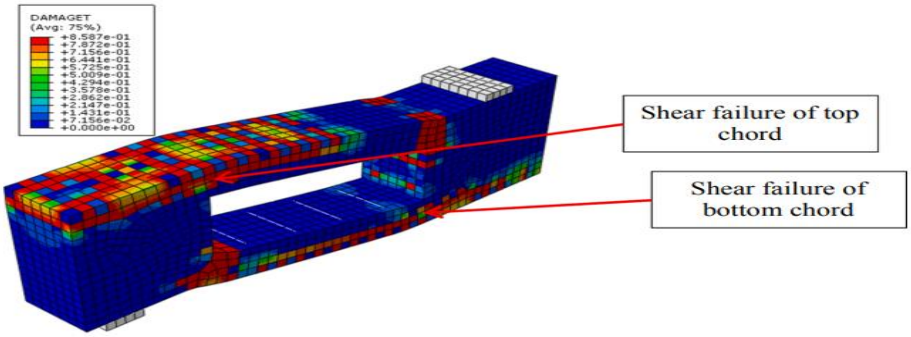


Fig. 1. Finite element method failure pattern at failure load for the specimen

III. APPLICATION OF FRP IN ENGINEERING PRACTICE:

The fiber-reinforced polymer has been used in civil engineering practice since the 1950s when(GFRP) bars were initially examined for structural purposes. It has shown good performance when paired with epoxy, it was finally considered a structural engineering element [2]. BecauseFRP is lightweight and more durable, it can be used as replacing most tensile and bending structures. There are different types of FRP used in civil engineering they are Glass Fibers, Basalt Fibers, Carbon Fibers, Aramid Fibers, and other different fibers. These frp's were employed in new construction, maintenance and rehabilitation, and architectural applications. As historic buildings age, the bar is corroded and extra retrofits are required to extend the lifespan of the structure. Most of the structures were strengthened with FRP which helps to increase the strength of the member.

IV. EXISTING LITERATURE ON OPENINGS IN RC BEAM

A) Studies on Structural member Beam With Openings Strengthened By Different FRP

Beam opening strengthened with FRP is investigated in [4] This paper investigated three different CFRP strategies used to determine which would be more effective. There are Four beams were casted in this One beam with an opening at the

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shear zone is provided. Another three beams were reinforced with CFRP techniques outside the opening, inside the beam opening, and both insideand outside the beam opening. The total length of the beam measured is 2000 mm, and the beam size is 240x300 mm. For each loading situation, the deflection vs different load levels can be tabulated and compared. They concluded that reinforcing with the FRP outside and inside the beam opening was more advantageous interms of and load bearing capacity is increased by roughly three times that of the solid structural member. Carbonfiber and glassfiber were used to reinforce the beams. Concretesheets were investigated in [5]. There were thirteen beams were modeled. the overall depth of the opening is smaller than 0.4 times the entire beam depth it is called a small rectangular opening. A sample beam with dimensions of 1800mm long, 150mm wide, and 250mm deep isconsidered. The opening was created in the dimensions of 200x100mm. And then there was the strength comparison. The ultimate strength of the structural member beam opening increased by 50%, by strengthening with CFRP sheets was observed. whereas the percentage improvement in load-carrying capability for GFRP sheets was found to be 37%. The reinforcing procedure with different FRP outside and within the beam opening proved more successful. The use of BFRP to strengthen openings in RC beams is investigated in [6] The beamsof two types of opening provided by one singular opening and double opening at the shear zone are provided and strengthened using a BFRP sheet. The influence of FRP layers with varied openings on initial crack load on the beam, breaking load, fracturing pattern in the beam, load and deflection graphs have been examined. Single and double circular openings were studied in the paper. the following opening dimensions adopted areas: Single circular opening = 94.40mm, and Double circular opening = 66.75mm, Researchers determined that BFRP reinforcement around and behind the opening was beneficial. They came to the conclusion that having two openings in the same location is more economical than having a singular annular opening in the structure. This work investigates the behaviour of a structural member beam with an opening reinforced by FRP sheets, asdescribed in [7]. In this work, there are a total of ten beams were casted, The structural member was externally strengthened by glass and carbonfiber sheets with various solidification methods. these beams were tested and had a rectangular effective length of 1800mm, cross-section thickness of 150mm, and deepness of 250mm. and It was determined that the ultimate strength of structural member beams strengthened with glassfiber sheets strength increased by 8.13 percent to 45.56 percent, and in other case member strengthened with CFRP sheets increased by 13.01 percent to 55.32 percent. The strengthening with CFRP outside and inside the member opening has the highest ultimate strength carrying capability by the strengthening schemes. Among all the strengthening techniques, this was the most effective. performance of an RCC beam member with a rectangular aperture reinforced by different FRP sheets using various approaches was investigated in [8] This experiment involved the casting of ten beams. Under two-point loading was applied for these casted beams. All of the beams tested had a cross-section with a thickness of 150mm, depth of 250mm, and 1800mmin longitudinal direction. The use of CFRP and GFRP sheets both outside and inside the beam aperture greatly increases the strength carrying capacity of the beam. The load-carrying capacity of CFRP sheets is enhanced by 50.50 percent, while that of GFRP sheets is increased by 37.41 percent. According to the research, Strengthening using carbonfiber reinforced polymer outside and within the opening is the most efficient and finest strengthening strategy.

B) ANALYTIC STUDIES ON THE PERFORMANCE OPENINGS OF RC BEAMS:

Dynamic Analysis of Opening in Reinforced concrete Beam with Using ANSYS Is Explained in [9] The dynamic behaviour of an RCC beam with rectangular, rounded-rectangular, and elliptical openings strengthened with GFRP is investigated. Seven beams were examined in all.Within rectangular, rounded-rectangular, and elliptical openings, the beams are sheathed with a layer of GFRP. All of these beams are simply supported and analyzed using ANSYS software under dynamic loads. The beam under consideration for study has dimensions of 300mm and 200 mm, with a length of 1600 mm. The opening was sheathed with 3 mm thick GFRP.The frequency response of the beams is thoroughly researched and analyzed. when the openingis strengthened with the GFRP sheet, it increases the performance of the RC beam. the application of the GFRP reduces the deflection values of rectangular openings by 30.9 percent,elliptical openings by 25.33 percent, and rounded rectangular openings by 26 percent. This study presents a discusses calculations of the shear performance of concrete beams with apertures in [3] This paper takes a look into The ABAQUS software finite element approach was used to create a nonlinear finite element model to study RC beam with web holes reinforced with various FRP layers. To create the openings, they had decided on three possible places on the concrete beam. During the validation procedure, three alternative mesh sizes are used of 30, 50, and 70 mm were employedto determine the best one. the load capacity and failure patterns, on the beam, were examined.When compared to the solid beam, this group's load capabilities were reduced by 7.3 to 66.1 percent. They concluded that reinforcing the entire length of the beam using FRP layers was more beneficial than strengthening above and below the beam opening. A reinforced concrete beam using the finite element approach is examined in [10] for two different beams with unstrengthened and strengthened members, the author utilizes the ANSYS 9 finite element program. Concrete element models of 25 X 25 X 25 mm, The results that came from the analysis were compared with the experimental and FEM simulation outcomes. The beam has a dimension of 2300 mm long-span,with a cross-section that is 250 mm tall and 100 mm wide. The beam has a variety of opening sizes. There are two ways to apply the FRP configurations F1 and F2 to strengthened beams,

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they selected the opening size of 300 X150. The ultimate capacity of the tested beams strengthened by the 2 separate configurations F1 and F2 is nearly comparable. Effects Of Opening in Reinforced Concrete Beam Is Explained In [11]. In this paper, ANSYS 10.0 finite element software was used for concrete structure member beams with different sizes of opening. The reinforced concrete beam dimensions are 100 x 250 x 250, with a model having an equal square opening of 133 mm in width. The load-deflection graph, crack pattern in the beam, and stress distribution was investigated and the behaviour of the beam opening. The reinforced concrete rectangular beams having circular openings less than 44 percent of the depth of the beam will not affect more to the load-carrying capacity, but with the beam openings greater than 44 percent of member depth, the loadcarrying capacity is reduced by 34.29 percent. The circular beam opening is stronger than the equivalent square beam opening, withan ultimate load capacity differential of 9.58 percent.

A numerical program was built to investigate the behaviour of RC beams during the opening by drilling the beam with and strengthening it with FRP sheets. [12]. The finite element approach, ANSYS 19 software was used to analyze the beam. The factors considered investigated include the opening's relative dimensions in relation to the beam's dimensions. To model andidealize the problem, A three-dimensional finite element method with constant-state loading conditions was used. The findings of this study showed that for the different openings shape of strengthening for drilled Reinforced concrete beams enhanced their load-bearing capacity, deflection graphs, and modes of failure in the structure. It was also discovered that the opening'sheight of the beam is more efficient than the length of the beam effect to the load-bearing capacity of the beam. Three finite element techniques were presented and tested using the explicit dynamic analysis approach [13]. the study offers three different Finite Element models built in ABAQUS for the replication of RC beams strengthened with an FRP for rectangular web aperture. Two are developed on the concrete severe fracture concept. and one based on the cracked ductility model of concrete. According to the findings, a FRP strengthening system approach that comprises CFRP wraps on the opening's upper and lower chords, as well as the opening's two faces, so that the ultimate strength can be increased. They recommended FE technique can be utilized to calculate the dimension and amount of FRP required based on the practical circumstances.

C) PERFORMANCE OF REINFORCED CONCRETE BEAMS WITH OPENING IN THE FLEXURAL AREA AND THE SHEAR AREA:

This report describes a study of the performance of RC beams having circular holes in the bending and shear area reinforced with various steel plates. [14]. Seven beams with varying opening diameters in the bending and shear zones were casted. Experiment work was carried out in a 400 kN loading frame. Two-point loading was applied to beams. the opening of 100 mm was provided in the bending area and at supports area respectively, When compared to the control beam, the strength of beam was lowered by 1.78 percent and 2.8 percent, correspondingly, and when the opening was strengthened with steel plates, it was reduced by 3.04 percent and 25 percent, correspondingly. Nonetheless, adding steel plates increased theductility. The beams became more ductile after the support zone apertures were reinforced withsteel plates. Even so, they caused flexural cracks, resulting in a significant loss in load-carrying strength. This study presents a fiber-reinforced FRP to the beam opening [15] Thirteen beams with openings were casted and applied using Four-point bending was used to determine whether fiber-reinforced Cfrp laminates sheets may be used as a reinforcing method to reinforce these kinds of beams. The different test parameters were checked like position, and different opening sizes in addition to the FRP sheets were all tested. Beam is strengthened by FRP around the openings to improve the shear strength of RC beams, substantially. The CFRP sheets boosted the structure's strength by 35–73%. When the predictions of theoretical techniques were compared to the experimental data, the 15% error ranged respectively. In this paper, the effects of a diagonal opening on the performance and beam strength under shear are shown and addressed in [16]. Some parameters are proposed to characterize the opening as "large" or "small" based on observable structural reaction. Two types of oblique tension failure in the beam were been found for small apertures, and a design solution based on existing codes is provided. He planned a mixture of slopingbars and full depth stirrups for large openings after assessing test evidence. The reinforcement barnecessity for crack controllers may be minimal in the case of small openings. Since theopening's sides already have full-depth stirrups to assure adequate strength, diagonally reinforcing may be performed to minimize crack propagation anywhere along the failure plane.

Carbon Fiber Reinforced Polymer laminates are used to strengthen reinforced concrete beams with large circular and square openings placed at the flexure area [17]. they examine the beam's structural behaviour at a wide opening at the bending area reducing beam strength and stiffness while increasing in cracking and deflection of the beams. The opening in the beam at the flexure point is greatly recovered by CFRP laminates, whereas a square hole only recovers 10% of the beam capacity. According to this study, CFRP can reduce severe cracking and beam deformation while increasing the beam's load strength and rigidity. Because the sharp corners of the opening are subjected to increased stress concentration, a large square hole affects structural capacity morethan a large circular opening. The cracking behaviour and flexural strength of RC shallow beams with rectangular holes are examined in this work. [18] In this experiment, they have prepared five beam specimens with the dimensions of 2200 mm x 100 mm x 150 mm. Three rectangular-

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shaped apertures were created for each beam sample, one at the mid-span of the beam and the other two at the corner of the beam at both ends. Opening in the length of the beam is supposed to vary from 110 mm to 440 mm, with the opening depth remaining constant across all specimens. As the length of the beam opening increases, so decrease the bending rigidity and toughness of the beam. With a minimal fluctuation of roughly 2.5 percent, the experimental research almost perfectly coincides with the finite element approach.This variation is caused by the slip-occurring disagreement between the concrete and steel.

V. CONCLUSION AND FUTURE PROSPECTS

The opening in the concrete beam work has been disscused in the earlier study. Based on the previous review, it is clear that earlier research has gaps that must be filled during the next effort. The major points listed below can be seen as outcomes and suggestions for upcoming studies to fill gaps in previous work.

- It is reasonable to conclude that carbon fibre reinforced polymer strengthening around and within the beam, the opening seems to be more beneficial and considered to be the finest strengthened plan in the entire research.
- It was discovered that when the distance of the circular beam opening is equal to or larger than 40% of the depth of the beam, its efficiency is reduced and cracks appear earlier. Deflection in the beams where increased where all beam openings wereprovided so strengthening in beams is required.
- The circular opening outperforms the identical square opening in terms of ultimate loadcapacity, with a 9.58 percent difference.
- According to the above research work, reinforcing the full-beam height outperformed simply by adding FRP coats above and below the beam opening and could be rated as the optimal strengthening approach.
- Future research on opening in the Reinforced concrete beam member with different FRP is needed, with a focus on determining the appropriate layered structure and depth of FRP at various loading phases, and also establishing a link between various factors including the shear span of the beam, loading mechanisms, effective length, structural concrete beam parameters, and different reinforcing methods.
- The preceding study work assists us in comprehending the performance of reinforced concrete beams with holes subjected to various loads such as seismic and dynamic loading circumstances. Reinforced the member with various FRP or steel plates by examining aspects of such member regarding the abutment end, fracture pattern, opening location, the number of reinforcing layers, strength scheme, and shear capacity of the structure is to determine. Furthermore, research on low-strength concrete members strengthened with various FRP strengthening is required.

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