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An experimental investigation of RCC beams with rounded rectangular opening strengthened by different FRP laminates

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Abstract: This paper presents the review of studies performed to investigate the behaviour of Reinforced Concrete (RC) beams containing rounded rectangular kind of opening. Fibre-reinforced polymers (FRP) have emerged as promising material for rehabilitation of existing reinforced concrete structures. The rehabilitation of structures can be in the form of strengthening, repairing or retrofitting for any type of deficiencies. RC rectangular-section is the most common shape of beams and girders in buildings and bridges. In this experimental study 5 beams were casted, one beam without opening as a control beam and the remaining beams were provided with opening. These beams were tested under four-point loading. From the test results, its concluded that the presence of an aperture does not affect the appearance of the first fracture on beams. By allowing a hole in the beam, on average 7% of concrete may be saved, thus lowering the weight of the beam and the stress it places on the foundation. And from Load vs deflection curve it can be observed that beams sheathed with CFRP behaves similar to that of reference/solid beam.

Keywords: RC beam, opening, CFRP, Flexure strength.

1.INTRODUCTION

Openings in beams must be provided in today's sophisticated building techniques in order to accommodate the numerous service lines needed for computer networks, including water supply, telephone, power, and air conditioning. Fig. depicts the view of a multi-story high-rise building's unusual design. As an alternative, these ducts and pipes can be installed along beams' transverse holes. The current planning of building services results in a little reduction in headroom and a further cost-effective design. When compared to total cost, the savings might not be significant for small structures. However, by adding apertures to beams, their behaviour completely changes in both static and dynamic conditions. As a result, more attention should be taken to evaluate and design these types of beams, which are now beyond the purview of the major building design standards.

Although beams may be made in a variety of forms, the rectangular and circular designs are the most often used. In order to accommodate service pipes for things like plumbing and electrical supplies, circular apertures are useful. Corners of rectangular apertures can be rounded off to lessen stress concentration at edges and increase the service life of beams by minimizing fractures.

OBJECTIVES OF STUDY

- To study the influence of transverse openings in rectangular beam for the first cracking load
- To predict load-deflection behaviour of beams with and without core-cut openings
- To analyse comparative flexural strength of core cut opening beams core-cut for different FRP lining.

2.MATERIALS USED

CEMENT: In this experiment OPC 53 grade was used. Ultra-Tech brand cement was used for all the mixes. Fresh and lumps free cement with a specific gravity 2.95 was used. The design strength for 28 days is a minimum of 53MPa.It sets quicker then OPC 43 and has quite low initial setting time.

FINE AGGREGATE : M-Sand is artificial sand produced from crushing hard stones into small sized angular shaped particles ,washed and finely graded to be used as construction aggregate .It is superior alternative to river sand for

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construction purposes .The M-sand used in this study has specific gravity of 2.58 with particles size smaller than 2.63 mm used as fine aggregate.

COARSE AGGREGATE: In construction, coarse aggregates are larger-sized filler materials. The particles that retain on a 4.75 mm sieve are known as coarse aggregates. The primary sources of coarse aggregate are dolomite aggregates, crushed gravel or stone, and natural rock disintegration. Coarse aggregate used in this study has specific gravity of 2.59 and size less then 20mm.

WATER : Water used for the experimentation was taken from the laboratory.

CARBON FIBER REINFORCED PLASTIC(CFRP) : CFRP sheets have been used in this project to strengthen the opening region of the beams. CFRP is a carbon-fibre composite sheathing system were carbon fibre sheets are used in combination with epoxy resin. Carbon fibres are obtainable as thin sheets called mats.

4.METHODOLOGY

In this experiment total of 5 rectangular beams were casted ,1 control beam and 4 beams with opening and laminated with CFRP sheet. Concrete of M-25 grade was designed on the guidelines of IS10262-2009 and mix proportion of 1:1.5:3 was selected.Beams with dimension of 1600 X 230 X 300 mm were casted curing with gunny bags for 28 days. Clear cover or spacers of 25 mm was provided to beam for uniform spacing of bar. As-perldesign calculation, concrete mix was decanted in layer and compacted with the help of mechanical vibrator needle(20mm), All 5 beams have bottom reinforcements that are 2-10 mm in diameter and top reinforcements that are 2-8 mm in diameter. Additionally, stirrups have 6 mm steel reinforcements around the openings.

Mix proportion obtained for the concrete mix is :

Cement	F.A	C.A	Water
383.2	800.94	1049.45	198.3
Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3
1	1.5	3	0.45

Steel quantity required :

	TOTAL LENGTH (m) (8mm)	TOTAL LENGTH (m) (8mm)	TOTAL LENGTH (m) (10mm)
Total length (m)	3.26	4.78	3.26
Weight/m Length (kg/m)	0.39	0.39	0.616
Total weight (kg)	1.27	1.86	2
10% extra for wastage (kg)	0.12	0.18	0.2
Grand total Weight (kg)	1.4	2.04	2.2

PROCEDURE FOR TEST BEAMS :

Testing of beams were carried out on a precession 50 ton capacity loading frame and 20 ton load cells were used for testing. Two roller supports were provided at a distance for 100mm apart from the edge of beam. Two point loads were applied transversely to beam.

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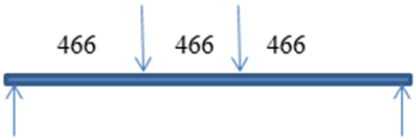
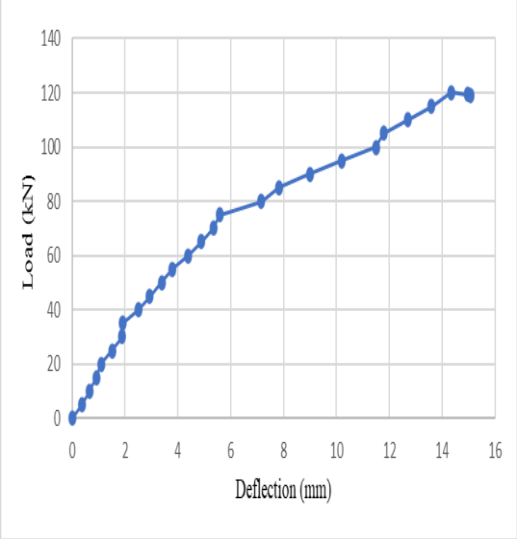


Fig :.loading setup

5.RESULTS

5.1 CONTROL BEAM/REFERANCE BEAM(SB) (B-1)

The control beam or reference beam or solid beam is designated as B1 for convenience. As beam was loaded cracks started to propagate through the center portion the beam and first crack appeared on beam at 35 kN. The ultimate failure-0f beam occurred at a load of 120.12 kN. all the load and deflection values are noted and tabulated ,load-deflection graph has been plotted



Fig; Load vs deflection curve for B1

Fig: Failure of B1

5.2 BEAM WITH ROUNDED RECTANGULAR OPENING (B-2)

The beam with circular opening was tested and for convenience it is abbreviated as B2 the initial crack appeared at 41.2 kN thought the initial crack appeared along the edges of the beam the crack propagation did not continue in this zone, major cracks were observed in flexural zone , the beam failed at a peak load of 79.22 kN.

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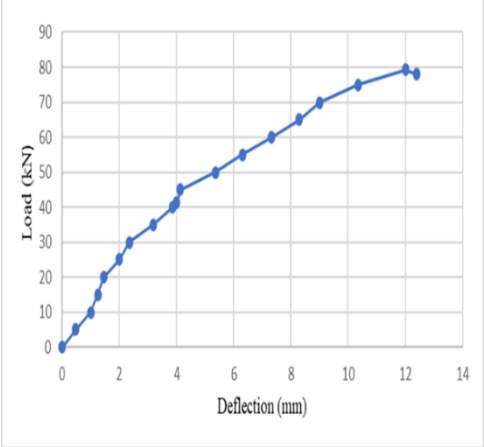

Fig:Load vs deflection curve for B2

Fig: Failure of B2

5.3 BEAM WITH ROUNDED-RECTANGULAR OPENING(B-3)

The beam with rounded-circular opening were tested and for convenience it is abbreviated as B-3.. The initial cracks appeared around the openings and first crack appeared at a load of 22.16 kN and the peak load of B-2 is 82.22kN.

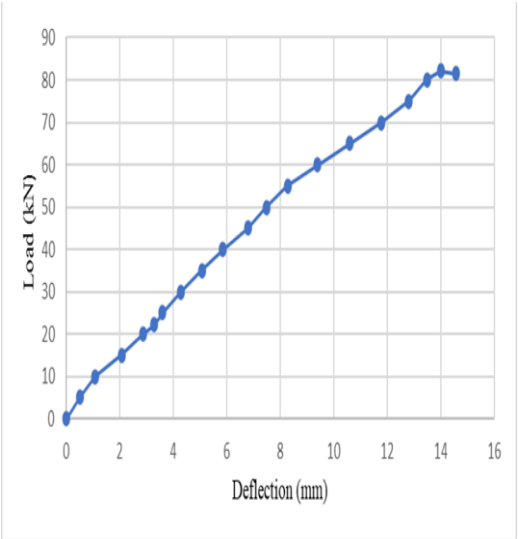

Fig:Load vs deflection curve for B3

5.4 BEAM WITH ROUNDED RECTANGULAR OPENING (B4)

The beam with elliptical opening was tested and for convenience it is abbreviated as B4. In this beam initial cracks were observed at opening area but final failure occurred due to propagation of large cracks in flexure region of beam. The initial crack appeared at 26.49kN and peak load of beam was 84.88kN .

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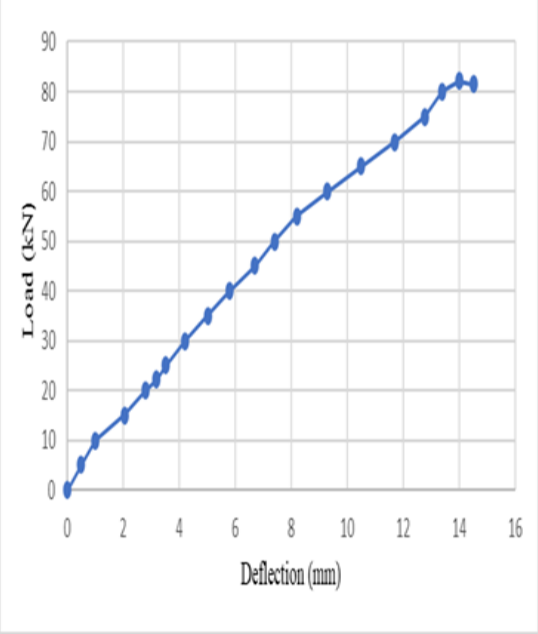

Fig:Load vs deflection curve for B4

5.5 BEAM WITH ROUNDED RECTANGULAR OPENING (B5)

The beam with circular opening were sheathed for strengthening purpose and was tested, for convenience it is abbreviated as B5.It was observed in this beam that there was about 15kN more load carrying capacity than that of beam without CFRP, initial cracks appeared at a load of 48.22kN and peak load was 96.17 kN.

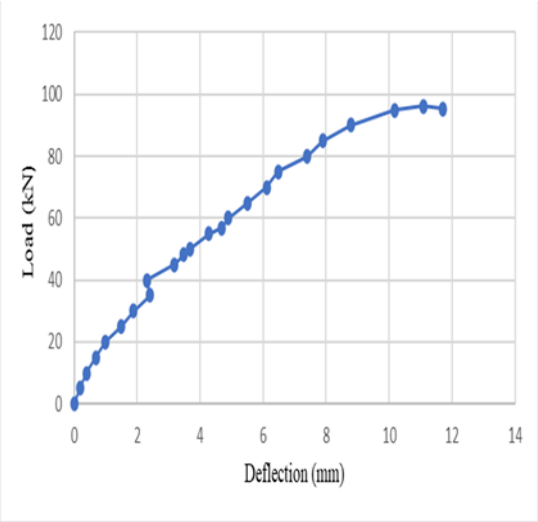

Fig:Load vs deflection curve for B4

From the graphs it can be observed that beams sheathed with CFRP laminates behave similar to solid beam and has almost same load carrying capacity as reference beam.

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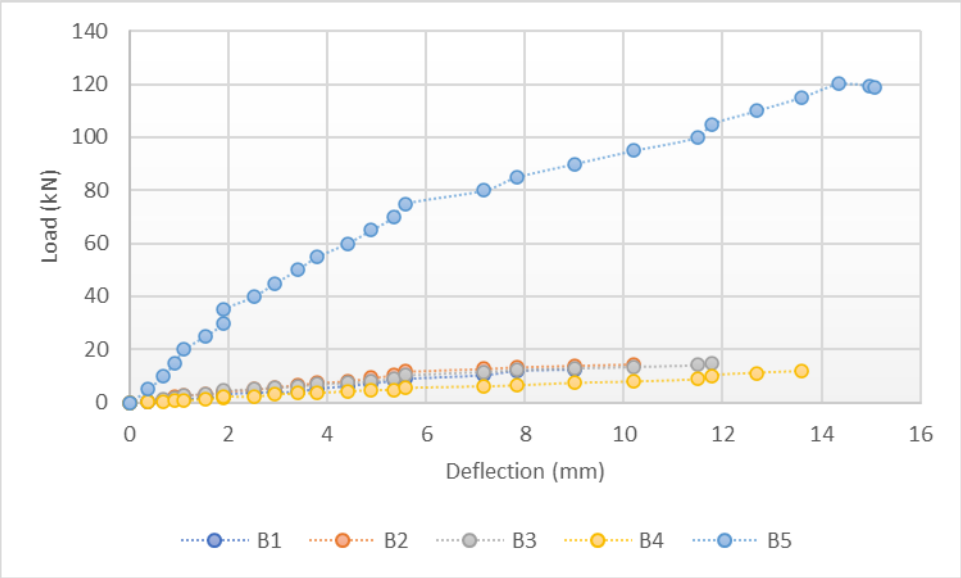
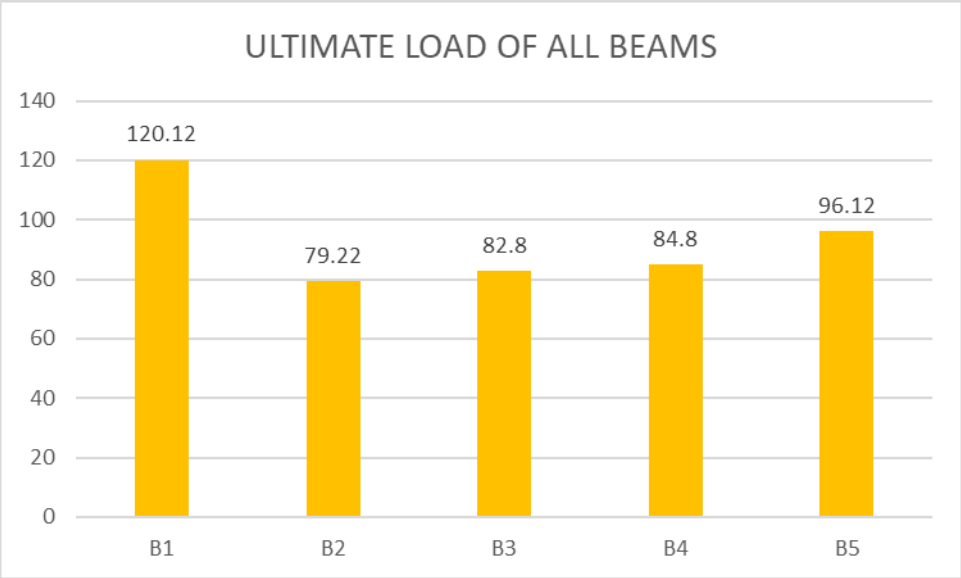


5.6 COMPARISON OF PEAK LOADS



6.CONCLUSION AND SCOPE FOR FUTURE STUDY

From the test results obtained and observations made the foll0wing conclusion were drawn

- The presence of an aperture does not affect the appearance of the first fracture on beams.
- Additionally, the presence of openings does not affect how fractures spread.
- Shear fractures along the perimeter of apertures will start to show up before they do in a solid beam.
- In contrast to rounded rectangular and elliptical openings, the fracture propagation rate is much quicker in beams with rectangular openings.
- A significant component is the presence of extra reinforcements at the entrance, and from the top of the beam to the opening surface, there should be a suitable transparent cover.
- A rectangular-shaped beam has the lowest load bearing capability, according to the experimental investigation.
- It can be observed that beams sheathed with CFRP laminates have higher load carrying capacity.
- From Load vs deflection curve it can be observed that beams sheathed with CFRP behaves similar to that of reference/solid beam(SB).

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- For beams with sheathing CFRP laminates, rounded rectangular opening has high load carrying capacity compared to other shapes of opening .
- On an average 7% of concrete can be saved by providing opening in beam, which will ultimately reduce its weight and load on foundation.
- It is evident that beams with CFRP laminate sheathing have greater load bearing capability.
- It can be seen from the load-deflection curve that CFRP-sheathed beams behave similarly to reference/solid beams (SB).
- Comparatively to other types of aperture, rounded rectangular openings for CFRP laminated beams have a good load bearing capability.

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