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Experimental Investigation of RC Beams with Rectangular Opening Strengthened by FRP Laminates

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Abstract: To provide the necessary services like water supply, sewage, power, telephone, air conditioning, and computer network, many pipes and ducts are included in today's modernistic architecture. These essential services are typically delivered in the bottom part of the beam, which is then encased with a suspended ceiling for aesthetic reasons, creating a dead area. Additionally, the structural behaviour characteristics of the beam may be compromised by the inclusion of a hole in it. In this study, a useful technique for strengthening RCC beams utilising CFRP is suggested. The aperture that is made in the beam is often either pre- or post-planned. In this work, we investigate the behaviour of RCC beams that have rectangular opening, strengthened with different FRP is studied. Five beams in total were examined, of which one was solid (i.e., had no opening), three were rectangular, added layers of CFRP and GFRP sheathing inside rectangular openings. These beams are all simply supported, and two-point loading is used to examine them. An increase in the load bearing capacity of the RCC beam strengthened with CFRP is found to be more effective. The load carrying capacity and deformation of the beams are studied in detail.

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

INTRODUCTION

In today's modernistic construction for the provision of services like water supply, sewage, power, telephone, air conditioning, and computer network, several pipelines and ducts are available. The lowest part of the beam is often where these essential services are offered. And for aesthetic reasons, these are enclosed with artificial or suspended ceilings. methods provision of openings in beams for accommodation of many service lines which are essential for computer network water supply, telephone, electricity, air-conditioning are necessary.Fig.1.1. presents the sight of the distinctive layout of multi-story high-rise structure. A "waste space/dead space" is created when the ducts and pipes are often located beneath the bottom face of the beam and visually concealed by a fall ceiling. The depth and quantity of ducts that must be accommodated determine the height of waste space that adds to the height of the overall building on each floor. A few milli metres to up to half a metre may be the depth of pipes or ducts.
As an alternative, these ducts and pipes can be installed along transverse holes in beams. The headroom is minimally reduced as a result of the current building service planning, which also yields a more affordable design.

Figure 1. The layout of pipes below the beam

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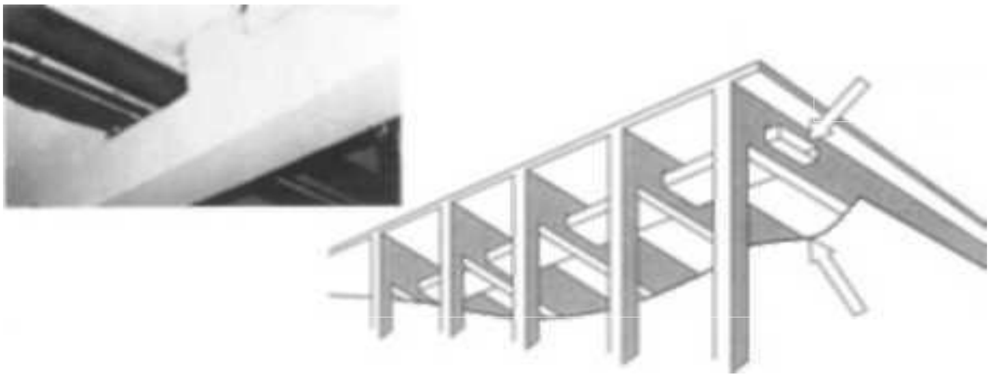
Figure 2. Substitute arrangement of pipes and service ducts



As an alternative, these ducts and pipes can be installed along transverse holes in beams. The headroom is minimally reduced as a result of the current building service planning, which also yields a more affordable design.

CLASSIFICATION OF OPENING Based on their various sizes and shapes, openings in beams can be categorised. Beams can be found in a variety of shapes, including circular, rectangular, rounded-rectangular, elliptical, diamond, trapezoidal, Rectangular and circular shapes are most often used. The aperture is seen to be large if it causes the beam to behave differently from a typical beam.

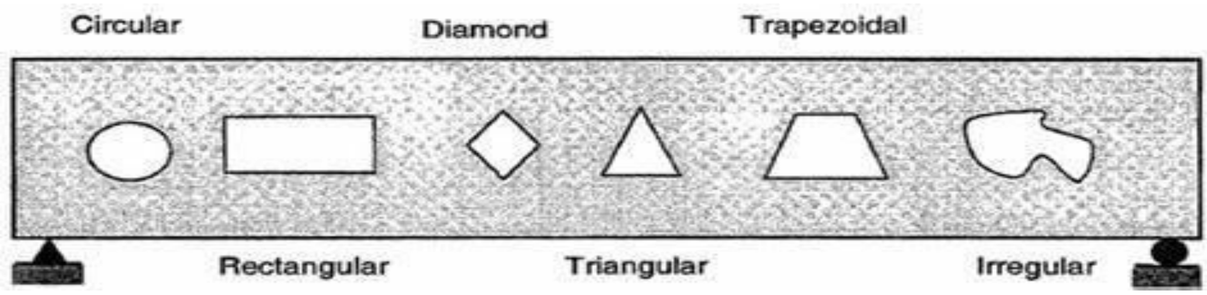


Figure 3.Different shapes of openings

Objective of project

➢ To investigate how rectangular beam transverse holes affect the first cracking load
to forecast how load deflection would behave for beams that have and don't have cut apertures

➢ To compare the flexural strength of opening beams with different FRP linings that have been core cut

MATERIAL PROPERTIES AND METHODOLOGY

MATERIALS

The following materials have been used in the present experimental work:

1. Cement
2.Aggregates
- Fine aggregates
- Coarse aggregates

3.Steel reinforcement
4.Water
5.Carbon fiber reinforced plastic (CFRP)
6.Epoxy resin
- Araldite LY556 (Resin)
- Hardener HY (Hardener)

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Properties		
Aggregate impact value	18.77%	Max 46%
Specific gravity	2.90	2.6-2.8
Elongation index	19.77%	----
Flakiness index	25.12%	----

Table 1. Physical property of 20mm downsize aggregate

fig 4. steel reinforcment

In the fe-500 grade was used as reinforcement for the current experimental work. All five 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

EXPERIMENTAL WORK

MIX DESIGN (M20)

OBTAINED RATIO = CEMENT: FINE AGGREGATE: COARSE AGGREGATE

FOR M20 GRADE = 387.2 :802.94 :1059.45

=1 :1.5 :3

MATERIALS CALCULATION

Volume of Beam = 1.6x.23x.3=.1104m^3

Dry volume = .1104 x 1.54 = .17m^3

Cement = (1/5.5 x0.17) x1440 = 43.2 kg x 10 =432 kg

Sand = (1.5/5.5 x.17)x 1600 =73.6 kg x 10 = 736 kg

Coarse aggregate = (3/5.5 x .17) x 1450 = 133.4 kg x 10 = 1334 kg

4.2.2.CASTING OF SPECIMEN

A beam size of 1600mm*230mm*300mm was chosen after a careful assessment of the literature.

Fig6. Wooden shuttering

fig7. arrangment of main bars and stirrups

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fig 8.arrangment of main bars and stirrups

fig.9. Gunny bag wet curing of beams

Core cutting in beams

Core cutting in concrete is a method used for creating openings for pipes, wires, ventilating or air conditioning vents to fit through. Core drilling is basically another way of saying the cutter is making precise, circular holes. To make holes of 2 to 12-inch diameters and up to 2 meters of depth, the core-cutting method can be used. Rectangular opening size is about 150mm*100mm

Fig 10.Rectangular opening by core cutting method

CARBON FIBER REINFORCED POLYMER (CFRP)

In this project, CFRP sheets were employed to reinforce the beams' opening region. Carbon fibre sheets and epoxy resin are combined to create CFRP, a carbon fibre composite sheathing system. Carbon fibres are available in the form of thin sheets known as mats. Epoxy resin when hardened or cured, produce a wide range of strengths

CFRP sheet

Araldite sample

application of epoxy resin

Fig 11

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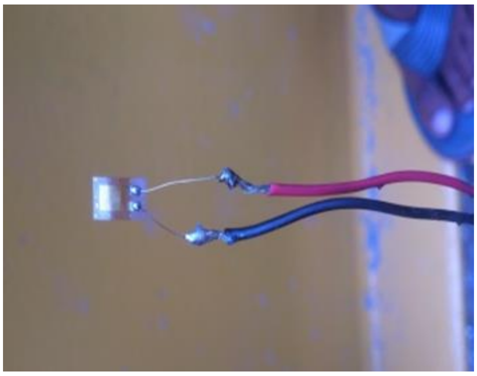
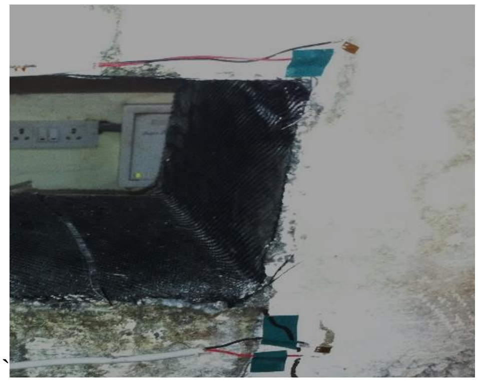
LOADING FRAME

50 ton capacity loading frame was used for testing of beam samples.

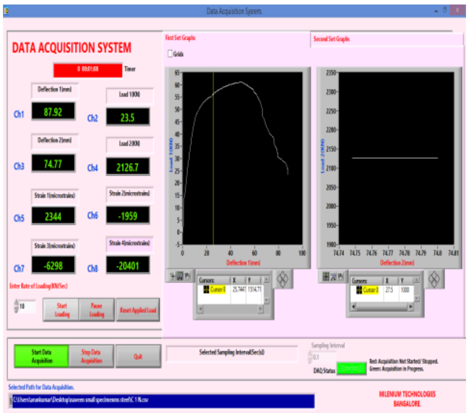
Fig 12.Loading frame

To determine the centre deflection of the beam, a 200 kN load cell was employed with an LVDT (linear variable differential transformer) with a 0.1mm sensitivity. Strain gauges with a 350Ω and 1.9 gauge factor were utilised, and the loading was applied at a slow rate of 10kN/sec. The top and bottom regions of the opening had strain gauges glued on them, and the strain values were recorded. The configurations are displayed below. Hydraulic jacks were used to gradually apply load in increments until the specimen failed.





strain gauges



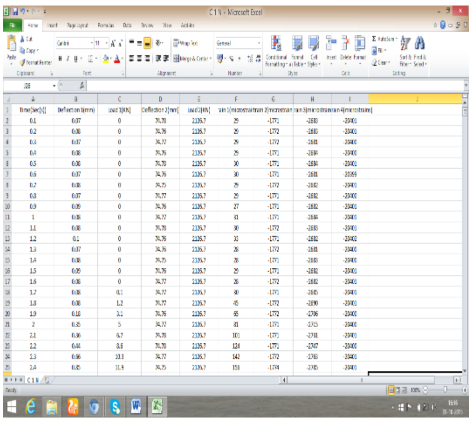


Fig13. Display from software

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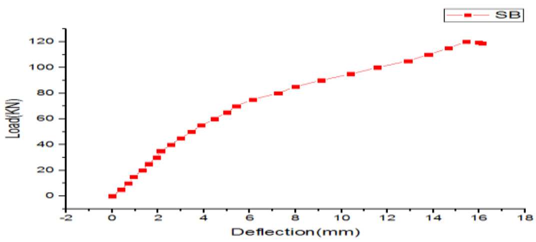
RESULT AND DISCUSSION

Failure of SB

Failure of rectangular Beam

Sl No	Load in kN	Deflection(mm)	Remark
1	0	0	
2	5	0.39	
3	10	0.69	
4	15	0.93	
5	20	1.3	
6	25	1.57	
7	30	1.86	Initial crack
8	35	2.1	
9	40	2.56	
10	45	2.98	
11	50	3.26	Steel yield
12	55	3.88	
13	60	4.46	
14	65	4.99	
15	70	5.4	
16	75	6.11	
17	80	7.22	
18	85	7.98	
19	90	9.11	
20	95	10.4	
21	100	11.56	
22	105	12.89	
23	110	13.78	
24	125	14.65	
25	138.25	15.44	Peak load
26	121.45	16.12	
27	118.77	16.28	

Sl No	Load in kN	Deflection(mm)	Remark
1	0	0	
2	5	0.51	
3	10	1.01	
4	15	1.42	
5	20	1.82	
6	25	2.23	
7	30	2.68	
8	35	3.23	
9	40	3.92	
10	41.2	4.21	
11	45	4.82	Initial crack
12	50	5.56	
13	55	6.83	Steel yield
14	60	7.47	
15	65	8.36	
16	70	9.16	
17	77	10.44	
18	81.35	12.1	
19	79	12.6	



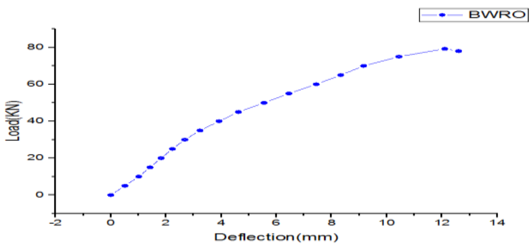


Fig 16 Load vs deflection curves

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Sl No	Load in kN	Deflection(mm)	Remark
1	0	0	
2	5	0.22	
3	10	0.45	
4	15	0.73	
5	20	1.04	
6	25	1.51	
7	30	1.94	
8	35	2.47	
9	40	2.85	
10	45	3.21	
11	48.22	3.53	
12	50	3.86	First crack
13	55	4.36	
15	56.86	4.77	
16	60	4.86	Steel yield
17	65	5.57	
18	70	6.19	
19	75	6.52	
20	80	7.42	
21	85	7.98	
22	90	8.98	
23	94	10.22	
24	98.47	11.13	
25	97.42	11.78	

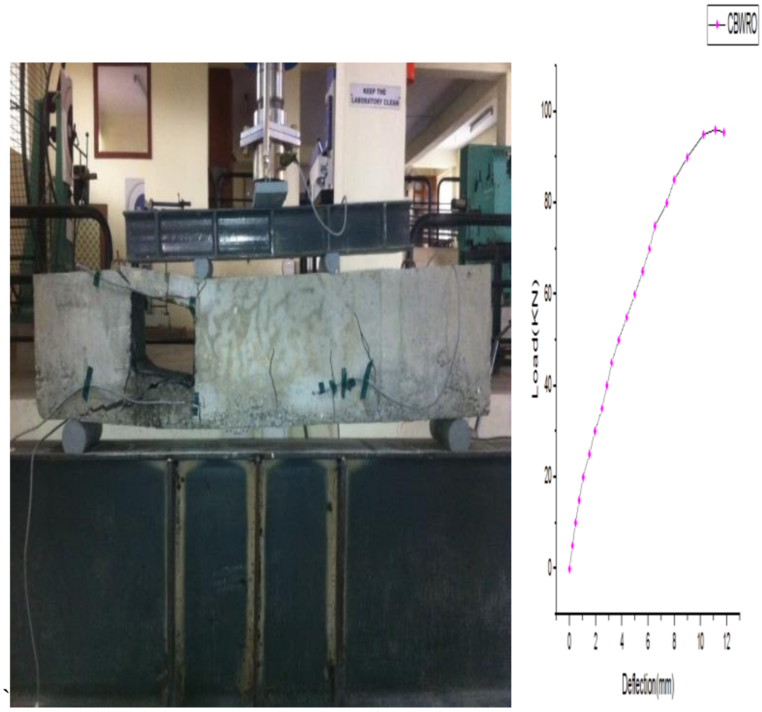

Fig 17 Failure of CARBON FIBER REONFORCED rectangular Beam

Table 5.5. Comparison of peak load

Sl no	Beam name	Peak load(KN)
1	SB	138.25
2	BWRO	81.35
3	CBWRO	98.47

Table 5.6.percentage of concrete saved

Sl no	Beam type	Volume(m^3)	% concrete saved
1	Solid beam	0.097	-
2	Rectangular opening	0.083	9.68

CONCLUSION

- The presence of an opening does not affect the appearance of the first fracture on beams.
- Additionally, the presence of openings has no bearing on the spread of cracks.
- Before shear cracks in a solid beam take time to emerge, shear cracks will start to appear at the edges of gaps.
- The opening region needs extra reinforcements, and there should be adequate clear cover from the top of the beam to the opening surface..

SCOPE FOR FUTURE STUDY

- The opening's size and placement can be adjusted and tested..
- Reinforcement patterns are modifiable and testable.
- It is possible to use openings of various forms.
- For additional reinforcing around openings, mild steel might be used.
- The exact same experimental results can be studied and modelled in software.

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