

# **Experimental Study on Strengthening of Openings in R.C Beams using BFRP Fabric**

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**ABSTRACT:** Openings in beams are provided mainly for the passage of ducts pipes and ducts which are essential to accommodate services like water supply, air-conditioning, electricity, telephone, and computer network. These openings are mainly designed to reduce weight and height of the structure. The transverse openings in beams causes stress concentrations near the openings which affects the overall stability of the structure. To overcome the instability of openings, this work studies experimentally the incorporation of external strengthening of circular openings with singular and double openings at shear zone using BFRP (Basalt fiber reinforced polymer) wrapping system inside and around openings. The effect of BFRP sheets with different openings has been studied in terms of initial crack load, ultimate failure load, cracking pattern and deflection. Effect of single and double circular openings having same area is studied. And it was found that beams with double circular opening is better than beams with singular circular opening. Hence circular openings can be used for passage of ducts, pipes etc. than rectangular openings.

**KEYWORDS:** Transverse opening, External Strengthening, Wrapping system, Basalt Fiber Reinforced Polymer, Cracks, Deflection.

## **I. INTRODUCTION**

Openings are provided for the passage of ducts and pipes. And these ducts and pipes are accommodated underneath the soffit of the beam and for aesthetic appearance, are covered by a suspended ceiling, thus creating a dead space. The height of this dead space adds to the overall height of the building depending on the number and depth of ducts. Hence the provision of the transverse openings enables to reduce the height of the structure, especially with regard to tall building construction, thus leading to a highly economical design. The transverse openings in beams are a source of potential weakness. An opening creates discontinuity in the normal flow of stresses which results in leading to stress concentration at edges of the opening and leading to early cracking of concrete. To avoid this special reinforcement enclosing the opening should be provided in the form of external or internal reinforcement. Internal reinforcements are steel bars provided along with the main reinforcements during casting. External reinforcements are applied externally around opening in the form of jacketing of composite materials like glass fibre or carbon fibre reinforced polymer called GFRP or CFRP.

FRP composite materials like are an excellent option for external reinforcement when compared to other repairing material because of their superior properties such as high specific stiffness and specific strength, ease of installation, possibility of application without disturbing the existing functionality of the structure, non-corrosive and nonmagnetic nature of the materials along with its resistance to chemicals.

## **II. RELATED WORK**

M.A. Mansur [9] gave an idea about beams containing transverse openings through the web and are subjected to combined bending and shear. H.A. Abdalla, A.M. Torkey [10] studied Design against cracking at openings in reinforced concrete beams strengthened with composite sheets and found out that it increases load carrying capacity of beam. Nishitha Nair and Kavitha.P.E [11] studied the effect of openings with various position in deep beams using strut

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and tie model approach both experimentally and analytically and concluded that ultimate load obtained from the finite element software has only 5% variation compared to experimental. Khaled Fawzy, Mahmoud M. Hashem [12] studied the strengthening effect of different schemes of CFRP sheets on the behaviour of RC beams with large web opening under pure torsion and concluded that CFRP sheets increased the stability of beam. Mithun Kumar, Shivaraj Mangalgi, et al [1] studied the behaviour of RCC Beam with circular opening Strengthened by CFRP and GFRP sheets around and inside openings and it was found that ultimate load carrying capacity increases when it is strengthened. Rakesh Diggikar, Shivaraj Mangalgi et al [2] S.C. Chin, N. Shafiq et al [3] strengthening of RC beams containing large Opening at flexure with CFRP laminates and was found large opening at flexure reduces the beam capacity and stiffness, and increases cracking and deflection. S.C. Chin, N. Shafiq et al [4] studied Reinforced Concrete (RC) beams with large square openings placed in the shear region, at a distance “0.5d” and “d” away from the support, strengthened by Carbon Fiber Reinforced Polymer (CFRP) laminates. Sharda P. Siddh, [5] developed analytical models for calculating the deflections due to uniformly applied transverse loads. Tiago Miguel Cameira Neto [6] provided guidance on determining the design resistance of composite beams with large web openings. Subhajit mondal, Bandyapadhyaya et al [7] discussed the use of GFRP for strengthenig purpose and its rehabilitation. Nageh ,Ali Imohamed et al [8] studied the efficiency of internal strengthening R.C beams with rectangular openings in shear zone by using steel plates. External strengthening by using external steel plates or external CFRP laminates will be a satisfactory method in the case if it is required to provide new opening in existing beams.

The objective of this paper is to experimentally calculate load carrying capacity and deflection of the beams with circular openings provided at shear zone and beam strengthened around and inside the opening using BFRP sheets, to determine the number of openings that can be provided in beams and to study the crack patterns of the beams experimentally.

### III. RESEARCH SIGNIFICANCE

Openings adversely affects the overall stability of the structure. To overcome the instability of openings, this work studies the incorporation of external strengthening of circular openings with singular and double opening at shear zone using BFRP (Basalt fiber reinforced polymer) wrapping system inside and around opening.

### IV. MATERIALS USED

#### a) Cement

Ordinary Portland cement of 53 grade is used.

Table-1 Test results of cement

Test conducted	Result
Specific gravity	3.15
Standard Consistency, %	38
Initial setting time, min	35
Fineness, %	2

#### b) Aggregate

M Sand as fine aggregate and coarse aggregate of 20mm size is used.

Table -2 Test results of aggregates

Test conducted	Result
Specific Gravity of Fine Aggregate	2.73
Specific Gravity of coarse Aggregate	2.81

#### c) Water

Ordinary potable water was used for mixing.

#### d) Basalt fabrics

Unidirectional BFRP sheets of thickness 0.3mm is used for the experimental study.

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Table -3 Properties of BFRP

Fiber thickness	0.3mm
Sheet width	1000mm
Tensile Strength	986.4 Mpa
Modulus of Elasticity	64000 Mpa
Percentage elongation	4.3%
Density	1.36g/cc
Poisson's Ratio	0.26

**e) Epoxy resin**

Araldite AW106 with Hardener HV 953 IN is used as epoxy resin in order to bind FRP sheets to concrete.

**f) Mix proportion**

A mix M30 grade was designed as per IS 10262:2009 and the same was used to prepare the test specimens. The design mix proportion is shown in Table 4.

Table -4 Mix proportion for M30

Cement	Fine aggregate	Coarse aggregate	Water Cement ratio
1	1.44	2.66	0.43

Compressive strength test on concrete cubes of 150mmx150mmx150mm size were conducted. Slump obtained was 110 mm after conducting slump tests. The compressive strength of hardened concrete was found to be 34.5 N/mm<sup>2</sup>.

Table -5 Test results on hardened concrete

Seven day strength	22MPa
Twenty eight day strength	34.5MPa

## V. EXPERIMENTAL INVESTIGATION

**a) General**

The experimental study consists of casting of eighteen rectangular reinforced concrete beams including beams with and without opening. Circular openings are provided at the shear zone. All the beams casted are tested to failure. The beams are indicated by the label BC1,BCO1, BCO2BFCO1, BFCO2.Each having same longitudinal and transverse steel reinforcement. All beams had the same geometrical dimensions. The behaviour of beams with circular and rectangular opening (keeping area constant) under strengthening using BFRP is carried out. Four beams with circular opening is provided using the technique of form work extrusion. Four beams are strengthened with BFRP sheets and the other one without opening is unstrengthened. These beams are tested under three point loading in the loading frame, the ultimate failure load of the beam and deflection have been recorded and results were compared with the control beam without opening and control beam with rectangular and circular opening.

- B00:Control specimen without opening.
- BCO1: Beam with one circular opening without strengthening.
- BCO2: Beam with two circular opening without strengthening.
- BFCO1: Beam with one circular opening with strengthening.
- BFCO2: Beam with two circular opening with strengthening.

**b) Beam Dimensions**

Beams of length 1m,width 0.15m,depth 0.25m having single and double circular opening having following opening dimensions adopted are as follows:

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## Opening Dimensions

Openings are provided as per SP 34.

1) circular opening (dia)

Single circular =94.40(mm) , Doublecircular=66.75(mm)

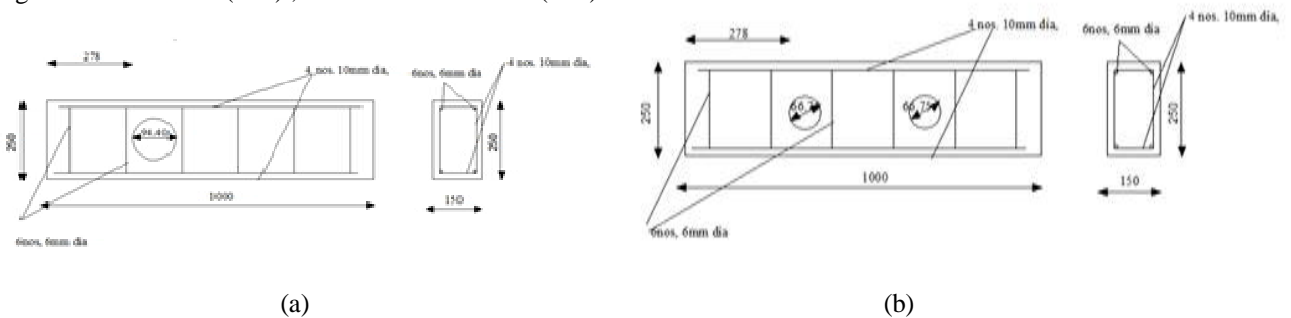


Fig.1.Specimens(a) Beam with one circular opening(b)Beam with two circular opening (area similar to one opening)

## c) Reinforcement Detailing

High-Yield Strength Deformed bars of 10 mm diameter are used for the longitudinal reinforcement and 6 mm diameter bars are used as stirrups. The tension as well as compression reinforcement consists of 2 no's 10 mm diameter HYSD bars.

## d) Mixing, Compaction and Curing of concrete

Thorough hand mixing is done. Compaction is done with the help of tamping rod in all the specimens and care is taken to avoid displacement of the reinforcement cage inside the form work. Then the surface of the concrete is levelled and smoothed by metal trowel . Curing is done to prevent the loss of water which is essential for the process of hydration and hence for hardening.

## e) Test setup

All the specimens were tested for flexural strength under three point loading control beams ,beams with circular and rectangular opening,beams strengthened with BFRP were tested in universal testing machine having capacity 1000kN.The specimens were arranged with simply supported conditions,centred over bearing blocks adjusted over an effective span of 760mm.the load was applied at midpoint of the beam specimen,increased at a uniform rate till the ultimate failure.Deflection of the beam was measured by a dial gauge placed at mid span.For each load increment the deflection and crack were observed and tabulated.The test setup for the flexural test is shown in figure 2.



Fig.2. Flexural test setup

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### f) Testing Of Beams, Test Results and Observation

All the beams casted are tested one by one. Eight with FRP and ten without FRP which is taken as the control Beam and non strengthened beam .All of them are tested in the UTM. The gradual increase in load and the deformation in the dial gauge reading are taken throughout the test. The dial gauge reading shows the deformation. The load at which the first visible crack developed is recorded as the cracking load. Then the load is applied till the ultimate failure of the beam. The deflections for the beams with and without BFRP are recorded with respect to increase of load and are tabulated in table 6 and the first crack load and ultimate load is shown in table 7 of test results and observation.



Fig.3.crack pattern(a)strengthened beam with one cicular opening(b) strengthened beam with two circular opening (c)unstrengthened beam with one cicular opening(d) unstrengthened beam with two circular opening.

Table-6 Load Deflection values of beam specimen

Load(kN)	Deflection in mm				
	B00	BCO1	BCO2	BFCO1	BFCO2
10	1.05	0.7	0.65	0.5	0.36
20	1.2	0.8	0.76	0.68	0.66
30	1.4	1.05	1.56	0.98	0.98
40	1.56	1.2	1.72	1.06	1.56
50	2.1	1.4	1.98	1.36	1.6
60	2.5	1.75	2.45	1.6	1.96
70	2.7	2.46	2.89	2.02	2.46
80	3.1	2.78	3.25	2.48	2.75
90	3.26	3.36	3.82	3.06	3.3
100	3.5	3.42	4.96	3.36	3.5
110	3.75	5.06	5.06	3.68	3.96
120	4.21		5.86	5.16	4.26
130	4.56				4.96
140	4.9				
149	4.78				

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Table-7 Beam test results

Specimen	B00	BCO1	BCO2	BFCO1	BFCO2
Firstcrack Load(kN)	55	48	50	72	76
Ultimate Load(kN)	149	107	112	121	125

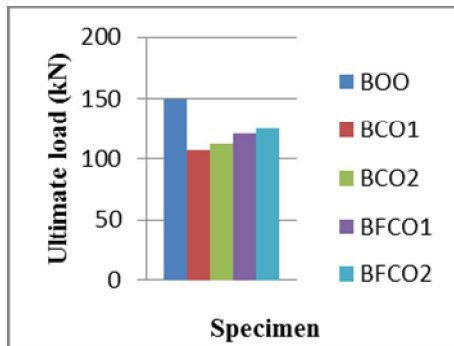


Fig.4. Ultimate load graph

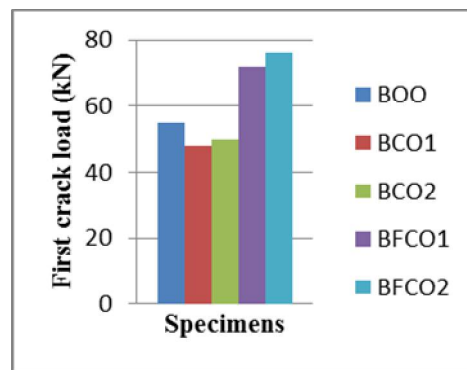


Fig.5. First crack load graph

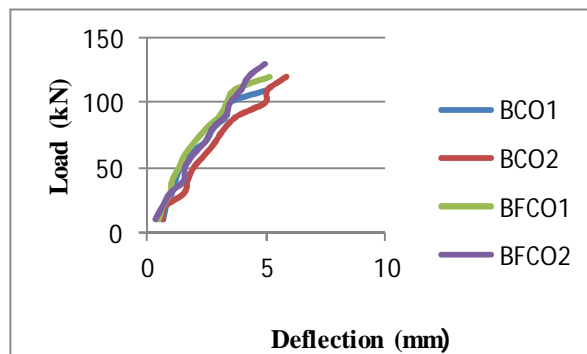


Fig.6. Load deflection graph of unstrengthened beam

Here from figure 4 its clear that two opening strengthened with BFRP takes comparatively more load than that of unstrengthened beams with single opening and from figure 5 its clear that first crack loads in beams wrapped with BFRP sheets in two openings occurred at a higher load.and it was find that beams wrapped in two openings gives better results. Figure 6 shows Load deflection graph of unstrengthened beam .

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## VI. CONCLUSION

Based on the experimental investigation of strengthening of RC beams with openings using externally bonded unidirectional BFRP composites, the following conclusions are drawn:

1. The initial cracks in the strengthened beams (BFCO1,BFCO2,) are formed at a higher load compared to the ones in the control beams (BCO1,BCO2,)
2. Formation of crack gets delayed due to the use of BFRP sheets .
3. The load carrying capacity of the strengthened beams mainly BFCO2 is found to be greater than that of the control beams, thus the externally bonded BFRP composites enhances the load carrying capacity.
4. Among the two types of failure (shear failure and flexural failure )in beams, shear failure was observed during experimental testing
5. From the overall study, it can be concluded that the strengthening with BFRP around and inside circular opening having two openings having same area is more efficient than single circular opening and openings having same area.

## REFERENCES

- [1] Mithun Kumar, Shivaraj Mangalagi, Rajendrakumar Harsoor, "Behavior of R.C.C beam with circular opening Strengthened by CFRP and GFRP sheets" , IJRET, Vol.11,pp.1-34,2012.
- [2] Rakesh Diggikar, Shivaraj Mangalagi, Rajendrakumar Harsoor, "Behavior of r.c.c. beam with rectangular opening Strengthened by CFRP and GFRP sheets " ,IJRET,Vol.4,pp.45-74,2012.
- [3] S.C. Chin, N. Shafiq and M.F. Nuruddin, , "Strengthening of RC Beams with Large Openings in Shear by CFRP Laminates: 2D Nonlinear FE Analysis ,IJCEE,Vol.7, pp.67-98,2012
- [4] S.C. Chin, N. Shafiq and M.F. Nuruddin,," Strengthening of RC Beams Containing Large Opening at Flexure with CFRP laminates " , IJCE, , Vol:5, pp.1-24,2012.
- [5] Sharda P. Siddh, Prof. P.D. Pachpor,"Finite Element Analysis of steel beam with web opening of different shapes" IJSAT (ISSN 2221-8386) Volume 1 ,pp.1-15,2012.
- [6] Tiago Miguel Cameira Neto," Analysis and Design of Composite Beams with Web Openings" Architecture and Georesources, Instituto Superior Técnico, Lisbon University, Vol 5,pp.7-67,2011
- [7] Subhajit mondal, Bandyapadhy j.n,chandra pal gautam , "strengthening and rehabilitation of reinforced concrete beams with Opening", International journal of civil and structural engineering ,Vol 2, pp.6-34, 2012.
- [8] Nageh ,Ali mohamed, Ahmed mohamed farag , "Efficiency of internal strengthening R.C beams with rectangular openings in shear zone by using steel plates", journal of engineering sciences, assiut university, Vol. 38, pp. 929-947, 2012
- [9] M.A. Mansur " Design of reinforced concrete beams with web openings "Structural Engineering and Construction Conference (APSEC 2006),Vol.6,pp. 5 – 6 , 2011.
- [10] H.A. Abdalla , A.M. Torkey , H.A. Haggag , A.F. Abu-Amira , "Design against cracking at openings in reinforced concrete beams strengthened with composite sheets", Vol.3,pp. 197–204,2012.
- [11] Nishitha Nair, Kavitha P.E, " Effect of openings in deep beams using strut and tie model method "International Journal of Technical Research and Applications, Vol 3,pp.4-56, 2015.
- [12] Khaled Fawzy "Strengthening of Opening R.C. Beams in Shear Using Bonded External Reinforcements"International Journal of Engineering Science and Innovative Technology (IJESIT), Vol 4, pp.5-67,,2015.