International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.5., Issue.3, 2017
May-June

RESEARCH ARTICLE

ISSN: 2321-7758

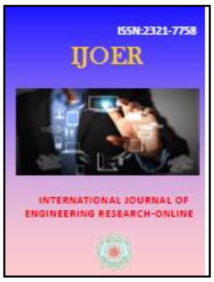
STRENGTHENING OF RC BEAMS WITH SINGLE CIRCULAR OPENING AT SHEAR ZONE USING FRP SHEETS

MUKKATHUKARIYIL SANJAY SOMAN[1], MANJU P M[2]

[1]M.Tech Student, Dept. of Civil Engineering, Sree Narayana Gurukulam College of Engineering, Ernakulam, Kerala, India

Email: sanjaysoman007@gmail.com

[2]Associate Professor, Dept. of Civil Engineering, Sree Narayana Gurukulam College of Engineering, Ernakulam, Kerala, India



ABSTRACT

Utility pipes and ducts are necessary to accommodate essential services in a building. The types of services include air-conditioning, power supply, telephone line, computer network, sewerage and water supply. It has been practiced that pipes and ducts are usually hanged below the floor beams and covered by a suspended ceiling for its aesthetic purpose. In order to reduce headroom and provide a more compact and economical design, it is now essential to pass these utility pipes and ducts through opening in a floor beam. Openings can be circular, square or rectangular in shape. Providing an opening in the web of a RC beams results to many problems in the beam behaviour including reduction in beam stiffness, excessive cracking and deflection and reduction in beam capacity. It also leads to high stress concentration at the opening corners. To overcome the above problems, the beams with openings should be strengthened. Strengthening is usually done either using external reinforcing material such as steel plates or using fiber reinforced polymer (FRP) materials. This paper hence studies the external strengthening of single circular openings at shear zone using BFRP (Basalt fiber reinforced polymer) and CFRP (Carbon fiber reinforced polymer) wrapping system inside and around openings. The effect of BFRP and CFRP sheets on shear strengthening has been studied in terms of initial crack load, ultimate failure load and cracking pattern. The load carrying capacity of strengthened beam is found to be higher than the load carrying capacity of the control beam with opening.

Keywords— Concrete, RC beams, circular opening, BFRP, CFRP, ultimate load, crack patterns

I. INTRODUCTION

In the construction of multi-storey buildings, many pipes and ducts are necessary to provide services like water supply, sewage, air-conditioning, electricity, telephone, and computer network. Normally, these pipes and ducts are placed underneath the beam soffit and for aesthetic reasons, are covered by a suspended ceiling, thus creating a dead space. Therefore the web openings enable the designer to reduce the height of the structure, especially with regard to tall building construction, thus leading to a highly economical design. Passing these ducts through transverse openings in the floor beams leads to a reduction in the dead space and results in a more compact design and thus inclusion of openings in beams alters the simple beam behaviour to a more complex one. The structural engineer is often confronted with the problem of providing convenient passage for utility services in reinforced concrete beams. In many cases, the provision of openings in such beams gives rise to excessive stresses that may be detrimental unless properly assessed and designed. Practical and experimental experiences have shown that, inclined and vertical cracks develop at the corners of the opening. Such cracks can seriously reduce the load-carrying capacity of the beam. However, as the opening represents a source of weakness, the failure plane always passes through the opening. The ultimate strength, shear strength, crack width and stiffness may also be seriously affected. Strengthening of beams with openings primarily depends whether the building services are pre-planned or post-planned. In the case of pre-planned openings, the sizes and locations of openings are known in advance during the design stage. Thus, sufficient strength and serviceability of beams with opening can be ensured before construction. Steel reinforcement provided at the upper and lower chords and diagonal reinforcement placed around the opening are considered as internal strengthening. In case of post planned, strengthening is done externally around the opening with the use of external reinforcing material, such as steel plates or by fiber reinforced polymer (FRP) materials, [10], [13]. Most of the research efforts have been made to study the flexural and shear behaviour of RC rectangular beams strengthened with fiber reinforced polymer (FRP) composites. A limited works have been reported on strengthening of RC beams with web openings. It is seen that there is a gain in shear capacity of RC beams when strengthened with FRP composites [2],[4],[11]. Most of the studies were carried out to know the effect of strengthening of R.C beams with large opening and small opening in flexure and shear by CFRP and GFRP sheets [5],[6],[7],[10]. The use of CFRP laminates with the designed strengthening configuration could significantly reduce excessive cracking and deflection and increase the ultimate capacity and stiffness of beam. [14],[16].

Hence majority of the current researches have focused only on using GFRP and CFRP composites. This paper aims to conduct studies on R C beams with single circular opening of diameter 90 mm at shear zone by externally strengthening using BFRP (Basalt fiber reinforced polymer) and CFRP (Carbon fiber reinforced polymer) of thickness 0.3 mm and width 300 mm by wrapping inside and U wrapping around the opening.

II. EXPERIMENTAL STUDY

A. Materials: Ordinary Portland cement of grade 53 was used. The size of coarse aggregates was 20 mm. The fine aggregate used was M sand conforming to zone I of IS 383:1970. The grade of concrete chosen for the study was M25. The mix design for M25 was done according to the recommendations and calculations mentioned in IS 456:2000 and IS 10262:2009. Admixture of type GLENIUM SKY 8433 produced by BASF Incorporation was added to increase the workability of concrete and to minimize the amount of water-to-cement ratio, for obtaining a desired slump range of 75 mm–125 mm for normal RCC work as per IS 456:2000, Cl.7.1. The proportioning for the mix is given in the Table I

TABLE I: CONCRETE MIX DETAILS

Mix proportion	1:1.88:3.16
Mass of cement per m^3 of concrete (kg)	387.7
Mass of coarse aggregate per m^3 of concrete (kg)	1224.91
Mass of fine aggregate per m^3 of concrete (kg)	730.62
Water-Cement ratio	0.42
Percentage of admixtures by weight of cement (%)	0.2
Slump (mm)	110

B. Test specimen: The experimental study consists of casting of rectangular reinforced concrete beams including beams with and without opening, each having same longitudinal and transverse steel reinforcement. The beams are indicated by the label CB, CO1, COCF1, and COBF1. All beams had the same geometrical dimensions. All tested beams had a rectangular cross section of 150 mm width and 250 mm depth and a effective length of 1000mm. Circular opening of size 90 mm diameter are provided at the shear zone. 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 nos 10 mm diameter HYSD bars. The details of various specimens casted are shown in Table II. The reinforcement details are shown in Fig. 1 and Fig.2.

TABLE II: TEST SPECIMENS

CB	Control beam Without opening
CO1	Beam with one circular opening without strengthening
COCF1	Beam with one circular opening with CFRP strengthening
COBF1	Beam with one circular opening with BFRP strengthening

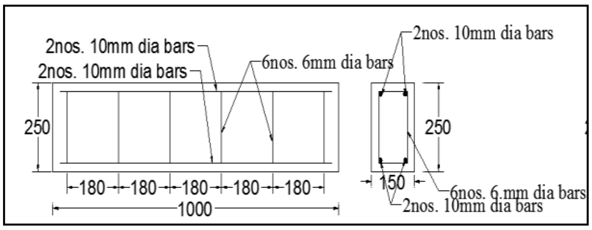


Fig. 1. Reinforcement detail of beam without opening

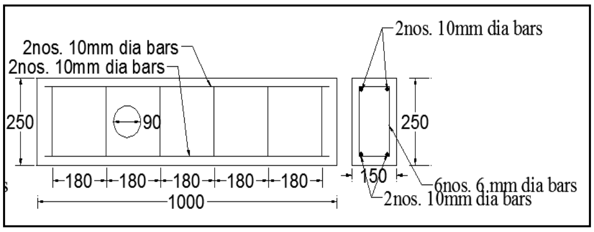


Fig. 2. Reinforcement detail of beam with opening

C. Strengthening Schemes: Strengthening was done as U- wrapping around the opening and inside the openings. FRP sheets used were Carbon fabric and basalt fabric of thickness 0.3 mm and width 300 mm. The required region of concrete is cleaned to remove all the dirt and debris particles. Araldite AW106 with Hardener HV 953 IN is used as epoxy resin in order to bind FRP sheets to concrete. The Strengthening scheme is shown in Fig. 3

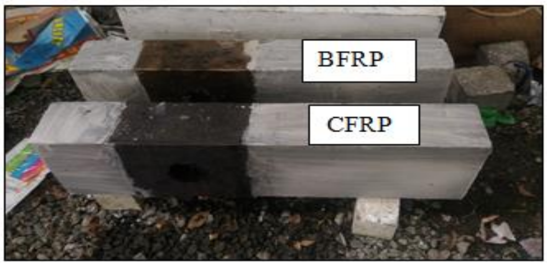


Fig. 3. Strengthening using BFRP and CFRP sheets

D. Test setup : The beam specimens were tested under four-point bending test in a universal testing machine (UTM) of capacity 1000 kN (Fig. 4). The specimens were simply supported with an effective span of 880 mm and the specimens were loaded till failure.

Fig. 4 Test Setup

III. TEST RESULTS AND DISCUSSION

A. ***Cracking load and ultimate load***: The test results are summarized in Table 2. The table shows initial crack load, ultimate failure load, and modes of failure for all the beams.

TABLE III: TEST RESULTS

Specimen	Initial crack load (kN)	Ultimate load (kN)	Mode of failure
CB	55	105	Flexure failure
CO1	43	98	Shear failure
COCF1	60	113	Flexure failure
COBF1	63	111	Flexure failure

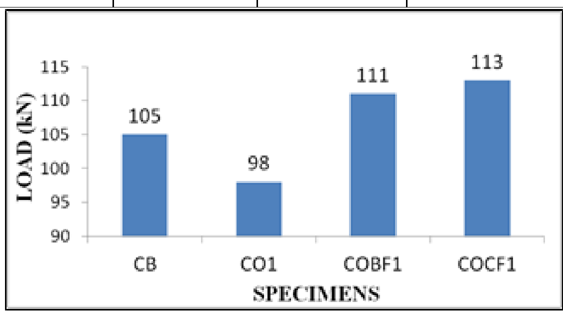


Fig. 5. Ultimate Load

From the experimental results presented in the table III, it is clear that the presence of an opening reduces the load carrying capacity of the beam . The percentage of increase in load carrying capacity for the beams strengthened with CFRP and BFRP sheets was 15.30 % and 13.26 % respectively.

B. *Crack pattern:* The crack patterns of the specimens are shown below:

Fig. 6. Crack pattern of Control beam without opening CB

Fig. 7. Crack pattern of Control beam with opening CO1

Fig. 8. Crack pattern of beam with opening strengthened using BFRP sheets

Fig. 9. Crack pattern of beam with opening strengthened using BFRP sheets

The control beam without opening failed due to flexure as shown in Fig. 6 When the opening was provided at the shear zone, the cracks formed through the opening and it failed due to shear at opening as shown in Fig. 7. When the beams with opening was strengthened with CFRP and BFRP sheets , the shear capacity increased and it failed due to flexure as shown in Fig. 8 and Fig. 9.

IV. CONCLUSION

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

- The presence of opening in RC beams reduces ultimate load carrying capacity.
- The initial cracks in the strengthened beams are formed at a higher load compared to the control beams.
- The diagonal cracks were developed due to stress concentration around the opening edges.
- The load carrying capacity of strengthened beam is found to be higher than the load carrying capacity of the control beam without opening.
- Strengthening of opening with CFRP and BFRP sheet, the load carrying capacity is more in case of CFRP wrapping.
- The percentage increase in load carrying capacity for the beams strengthened with CFRP and BFRP sheets was 15.30 % and 13.26 % respectively as compared to non-strengthened beam (control beam with circular opening).

REFERENCES

[1]. A.Ahmed, M.M.Fayyadh, S.Naganathan and K.Nasharuddin (2012), Reinforced Concrete Beams with Web Openings: A State of the Art Review, *Journal of Materials and Design*, 40, 90-102

[2]. Bashar.S.Mohammed and Omar Alanni (2014), Shear capacity of RC Beams with Web Openings Strengthened with Multi layers of CFRP, *Applied Mechanics and Materials*, 567, 494-498

[3]. Bengi Aykac, Iiker Kalkan, Sabahattin Aykac and Yusuf Emre Egriboz (2013), Flexural Behavior of RC Beams with Regular Square or Circular Web Openings, *Journal of Engineering Structures*, 56, 2165–2174

[4]. H.A.Abdalla, A.M.Torkey, H.A.Haggag and A.F.Abu-Amira (2003), Design Against Cracking at Opening in Reinforced Concrete Beams Strengthened with Composite Sheets, *Composites Structures*, 60, 197-204

[5]. Hayder Qais Majeed (2012), Experimental and Numerical Study of the Effects of Creating Openings in Existing RC Beams and Strengthening with CFRP, *Engineering and technical journal*, 30, 2550-2561

[6]. KhaledFawzy, Mahmoud.M.Hashem, Ahmed.M.Elnady (2014), Performance of RC Beams with web Opening Subjected to Pure Torsion Strengthened with CFRP, *International Journal of Engineering and Innovative Technology* , 4, 197-204

[7]. Mojtaba Hosseinia, Amir Mohammad Amiri and Peyman Beiranvand (2016), Numerical Analysis of Reinforced Concrete Beams Containing Bending and Shear Opening and Strengthened with FRP Sheet, *Engineering Solid Mechanics*, 4, 145-152

[8]. Nasr.Z.Hassan, Alaa.G.Sherif and Amal.H.Zamarawy, (2015,Oct.), Finite Element Analysis of Reinforced Concrete Beams with Opening Strengthened Using FRP. Ain Sham Engineering Journal. [online].10(011), 2090-4479. Available: http://dx.doi.org/10.1016/j.asej.2015.10.011

[9]. Rakesh Diggikar, Shivraj Mangalagi and Rajendrakumar Harsoor (2013), Behavior of R.C.C. Beam with Rectangular Opening Strengthened by CFRP and GFRP Sheets, *International Journal Of Research In Engineering And Technology,* 4, 45-74

[10]. Saeed Ahmed Al-sheikh (2014), Flexural Behaviour Of RC Beams with Opening, Concrete Research Letters, 5(2), 812-824

[11]. Sagar and Shivaraj Mangalgi (2015), Strengthening Of Preloaded RC Beams Containing Circular Opening At Shear By Using CFRP And GFRP Sheets, *International Journal of Structural and Civil Engineering Research*, 4(1), 2319-6009

[12]. Said.M.Allam (2006), Strengthening of RC beams with Large Openings in Shear Zone, *Alexandria Engineering Journal*, 44, 59-78

[13]. S.C.Chin, N.Shafiq and M.F.Nuruddin (2011), Strengthening of RC beams containing large Opening at flexure with CFRP laminates, *International Journal Of Structural Engineering,* 5 (12), 743-749

[14]. S.C.Chin, N.Shafiq and M.F.Nuruddin (2012), Strengthening of RC Beams with Large Openings in Shear by CFRP Laminates: Experiment and 2D Nonlinear Finite Element Analysis, *Research Journal of Applied Sciences, Engineering and Technology,* 4(9)1172-1180

[15]. Siew Choo Chin, Nasir Shafig and Muhd Fadhil Nuruddin (2014), FRP as Strengthening Material for Reinforced Concrete Beams with Openings-A Review, *KSCE Journal of Civil Engineering*, 4, 1-7

[16]. Subhajit Mondal, Bandyapadhya,J.N and Chandra.Pal.Gautam (2011), Strengthening and Rehabilitation of Reinforced Concrete Beams with Opening, *International journal of civil and structural engineering*, 2, 55-68

[17]. Tamer El-Maaddawy and Bilal El-Ariss (2012), Behaviour of Concrete Beams with Short Shear Span and Web Opening Strengthened in Shear with CFRP Composites, *Journal Composites For Construction*, 16(1), 47-59

[18]. Tamer El-Maaddawy and Sayed Sherif (2009), FRP Composites for Shear Strengthening of Reinforced Concrete Deep Beams with Openings, *Composites Structures*, 89, 60-69.

[19]. Vinay Chakrasali and Shaik Abdulla (2012), Shear and Flexural Behaviour of R.C.C. Beam With Circular Opening Strengthened By CFRP Sheets, *International. Journal of Engineering Research,*5, 49-52 *(PHY) Specification*, IEEE Std. 802.11, 1997.