AND SHEAR ZONE STRENGTHENED BY GFRP SHEET

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Abstract - In the modern building construction opening in beams are more often used to provide passage for utility duct and pipes, it also translates into substantial economic savings in the construction of multi-story building. The understanding of beams with circular openings in reinforced concrete sections and strengthening of these openings with fiber reinforcement is inadequate. In view of this, an experimental study on strengthening of post openings and pre openings in the RCC beam has been initiated.

In this thesis an experimental work is carried out to study the "Behavior of R.C.C beam with circular opening in bending and shear zone strengthened by GFRP sheets" in order to investigate the efficiency of internal strengthening with GFRP sheets.

Nine RCC beams of span 700 mm, size 150x150mm and opening diameter of 60mm were tested in the universal testing machine UTM. In the nine beams three beams were act as control beams, one without opening and two with post opening at bending and shear zone. The remaining six beams with openings, six beams were externally strengthened with GFRP sheets with different techniques i.e. strengthening with GFRP sheets around the opening, inside the opening, inside and around the opening. The beams have been tested under two point loading in the universal testing machine. Loading is applied gradually and at each increment of load, deflections at the soffit of the beams were measured. The deflections were measured at the mid span, center of the opening of the beam for every increment of loading up to failure.

The result revealed that the all six strengthening techniques increases load carrying capacity as compared to unstrengthen beam. From the overall study, it can be concluded that strengthening the beam around and inside circular opening by GFRP sheets was much more efficient in case of all the strengthening techniques, (Increased by 20.55%).

***Key Words*: Reinforced concrete beams, Beams with circular opening, GFRP, strengthening schemes, Ultimate load carrying capacity.**

1.1 INTRODUCTION

In the construction of modern buildings, many pipes and ducts are necessary to accommodate essential services like water supply, sewage, air-conditioning, electricity, telephone, and computer network. Usually, 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. 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. For small buildings, the savings thus achieved may not be significant, but for multi-storey buildings, any saving in story height multiplied by the number of stories can represent a substantial saving in total height, length of air-conditioning and electrical ducts, plumbing risers, walls and partition surfaces, and overall load on the foundation.

We knew that inclusion of openings in beams alters the simple beam behaviour to a more complex one. Due to abrupt changes in the sectional configuration, opening corners are subject to high stress concentration that may lead to cracking unacceptable from aesthetic and durability points of view. The reduced stiffness of the beam may also give rise to excessive deflection under service load and result in a considerable redistribution of internal forces and moments in a continuous beam. Unless special reinforcement is provided in sufficient quantity with proper detailing, the strength and serviceability of such a beam may be seriously affected.

Strengthening of beams provided with openings depends mainly on whether those openings are pre-planned or post-planned. In the case of pre-planned openings, both the upper and lower chords are designed and reinforced to resist the internal forces that they are subjected to two point loads. The design of such chords depends on the position of opening and the type of loading. Also, special steel reinforcement is provided around the opening edges and extended with enough length beyond the opening corners to resist the stress concentration. Both the reinforcement provided for the upper and lower chords and the special reinforcement provided around the opening are considered as internal strengthening. On the other hand in the case of post-planed opening created in an existing beam, external strengthening will be necessary for the upper and lower chords and also for the opening corners and edges to protect it against stress concent.

Quite few methods of strengthening the beams with openings, more common ones are strengthening by Carbon Fiber Reinforced Polymer Sheets (CERP Sheets). Glass Fiber Reinforced Polymer Sheets (GFRP Sheets), Aramid Fiber Reinforced Polymer Sheets (AFRP), Steel Plates and Strengthening by steel reinforcement.

Many experimental and analytical researches have been carried out on precast and pre stressed beams, T-beams, deep beams and rectangular concrete beams with web openings. The researches have provided several practical results. At the present time, many methods for analyzing reinforced concrete members are available. One of the most powerful methods is the finite element technique which spares much time and on RC rectangular beams with circular opening by simulation.

In the present experimental study of the behavior of beams with opening under different types of strengthening process using GFRP Sheets is carried out. nine beams have been casted, in that one beams have been casted without any openings, after the 28 days curing period openings are provided in eight beams by using core machine. Three beams are strengthened with GFRP sheets on bending zone and three are strengthened with GFRP sheets on shear zone. remaining two beam has not been strengthened which is comparison.

1.2 CLASSIFICATION OF OPENINGS

Transverse openings in beams may be of different shapes and sizes. Prentzas (1968), in his extensive experimental study, considered openings of circular, rectangular, diamond, triangular, trapezoidal and even irregular shapes, as shown in Fig 1. Although numerous shapes of openings are possible, circular and rectangular openings are the most common ones. Circular openings are required to accommodate service pipes, such as for plumbing and electrical supply. On the other hand, air-conditioning ducts are generally rectangular in shape, and they are accommodated in rectangular openings through beams. Sometimes the corners of a rectangular opening are rounded off with the intention of reducing possible stress concentration at sharp corners, thereby improving the cracking behaviour of the beam in service.

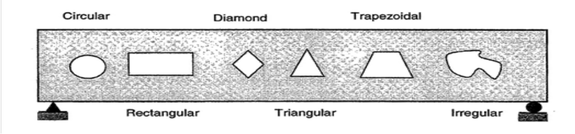

Fig. 1: Different types of openings the beam

With regard to the size of openings, many researchers use the terms small and large without any definition or clear-cut demarcation line. Mansur and Hasnat (1979) have defined openings circular, square, or nearly square in shape as small openings, whereas, according to Somes and Corley (1974), a circular opening may be considered as large when its diameter exceeds 0.25 times the depth of the beam web.

However, the authors consider that the essence of classifying an opening as either small or large lies in the structural response of the beam. When the opening is small enough to maintain the beam-type behavior or, in other words, if the usual beam theory applies, then the opening may be termed a small opening. When beam-type behavior ceases to exist due to the provision of openings, then the opening may be classified as a large opening.

1.3 GFRP

Glass fiber is isotropic in nature and high commonly utilized filament. E-Glass, S-Glass, C-Glass and AR-glass are the popular kinds of glass fibers (Table 3). High strength, well resistant to water and chemicals with low cost are the main characteristics of glass fiber. Relatively low costs compared with other types of FRPs make glass fiber the most generally applied in construction industry. Nevertheless, a comparatively low elastic modulus, low resistant to alkaline with low long-term strength due to stress rupture are the major drawbacks for glass fiber. For the situation that required better resistance to alkaline, the supposed AR-glass could be utilized

Table -1: Typical properties of GFRP

Trade Name	**Density (g/cm3)**	**Tensile Strength (MPa)**	**Modulus of Elasticity (GPa)**	**Extension to Break (%)**	**Coefficient of Thermal Expansion (10–6/_C)**
E-glass	2.5	3450	72.4	2.4	5.0
S-glass	2.5	4580	85.5	3.3	2.9
C-glass	2.5	3300	69	2.3	N/A
AR-glass	2.27	1800-3500	70-76	2.0-3.0	N/A

2. MATERIAL PROPERTIES AND ITS TEST METHODS

Test on cement

In the present work, ordinary Portland cement of 53 grade (Ultra Tech Cement Ltd.) conforming to IS: 12269-1987 has been used.

Following are the main tests conducted to know the cement properties as shown in table 2.

Table 2: Cement test results

SL. No.	**Test Conducted**	**Results Obtained**	**Requirement as per IS 12269-1987**
1.	**Normal Consistency**	33%	-
2.	**Initial settings time**	42	Shall not be less than 30 min
3.	**Final setting time**	390	Shall not be more than 600 min

4.	**Compressive strength**	58.88	Shall not be less than 53 Mpa
5.	**Specific gravity**	3.08	3.15

Test on Aggregate

The tests on fine and coarse aggregate were conducted in accordance with IS: 2386 to determine the specific gravity. The sieve analysis result indicates that, the sand confirms to zone-II. The physical properties and sieve analysis results for coarse as shown in table 3.

Table 3: Fine aggregates test results

SL. No.	**Particulars of the Test**	**Results**	**Requirement as per IS:383-1970**
1.	**Fineness Modules**	2.88	-
2.	**Specific gravity**	2.60	2.6-2.8
3.	**Zone**	ll	

Table 4: Coarse aggregate test results

SL. No.	**Particulars of the Test**	**Results**	**Requirement as per IS:383-1970**
1.	**Fineness modulus**	7.88	-
2.	**Specific gravity**	2.66	2.6-2.8

Mix proportion

For the present work concrete of Grade M20 is use.

3. EXPERIMENTAL PROGRAME

Introduction

This covers the details description of the experimental work carried out in which the beam with opening having different external strengthening techniques has been discussed along with the experimental setup and the testing method.

In the present experimental work 09 reinforced concrete beams were tested. All tested beams have a square cross section of 150mm width and 150mm depth and have a total length of 700mm and a effective span of 600mm. The first beam (BI) is made solid without any openings and thus it is considered as the control beam. 08 beams were provided with one circular opening. The dimension of the opening were same for all the 08 beams (B2 to B9). The diameter of opening is 60mm and the openings were located within the shear and bending zone of the beam. The opening location starting at a distance of 100mm from the support of the beam. The lower edge of the opening is located vertically at a distance of 40mm from the extreme bottom fiber of the beam. Therefore height of lower chord is 40mm and that of upper chord is 50mm. Figure 2 shows the dimension of beam with opening.

ALL THE DIMENSIONS ARE IN MM

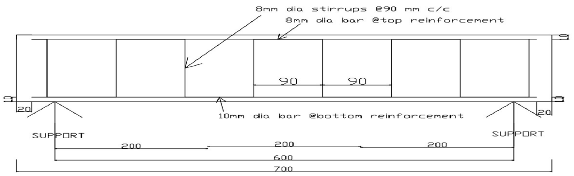

Fig 2: Dimension of beam

Quantity of materials required

The materials required for casting of each beam is shown in table 5.

Table 5: Quantity of material required for casting each beam

Cement (kg)	**Fine aggregate (kg)**	**Coarse aggregate (kg)**	**Water (lt.)**
6.351KG	10.59KG	35.061KG	3.37
1	1.5	3	w/c=0.53

Reinforcement Details

Nine reinforced concrete beams were casted (B1 to B9) using 2-#10mm as bottom reinforcement, 2-#8mm at top reinforcement and #8mm @ 90mm C/C stirrups are used as shown in figure 2 and provided post openings in eight beams after 28 days curing period and one as solid beam without any opening.

Core cutter

After completion of 28 days curing period, in eight beams openings were provided using core machine as shown in figure 3 at a distance of 100mm from support and at a distance of 50mm from the upper chord and 40mm from the lower chord. The opening diameter is 60mm.

Fig. 3: Core machine

Test set up

Universal testing machine (UTM)

All the beam specimens were tested under universal testing machine UTM of 100 tonnes capacity. A solid MS rollers of 30mm diameter and 150mm long were used for the bearing (for support) and at each of the point load for transfer of loads. An STEEL ROD roller for distribute the applied load at the centre as two point loads on the test beam.

4. TEST RESULTS AND DISCUSSIONS

CONTROL BEAM WITHOUT OPENING B1:

The test results of B1 beam as shown in table 6.

Table 6: Load-Deflection for beam-B1

Load in 'KN'	Centre	Remarks
1.215	0.15	
2.195	0.26	
4.265	0.365	
6.325	0.425	
8.105	0.5	
9.475	0.55	
11.545	0.67	
13.915	0.76	
14.785	0.81	
16.655	0.91	
18.325	0.995	
19.295	1.055	
21.165	1.11	
23.735	1.23	
25.605	1.46	
26.575	1.59	First crack
28.945	1.725	
30.185	1.815	
31.785	1.995	
33.545	2.11	
35.625	2.26	
36.595	2.41	
38.165	2.605	

40.235	2.78	
42.205	2.895	
43.375	3.015	
44.735	3.19	
45.75	3.31	
46.735	3.525	
47.575	3.71	
48.575	3.91	
49.75	4.23	
50.575	4.6	
51.575	4.88	
52.375	5.1	
53.475	5.29	
54.745	5.71	
55.785	5.995	
56.755	6.24	
57.75	6.715	Shear crack
58.755	7.4	
59.75	7.95	
60.725	8.465	
61.725	8.91	
62.775	9.23	
63.745	9.67	
64.15	10.46	
65.00	10.895	Flexure failure

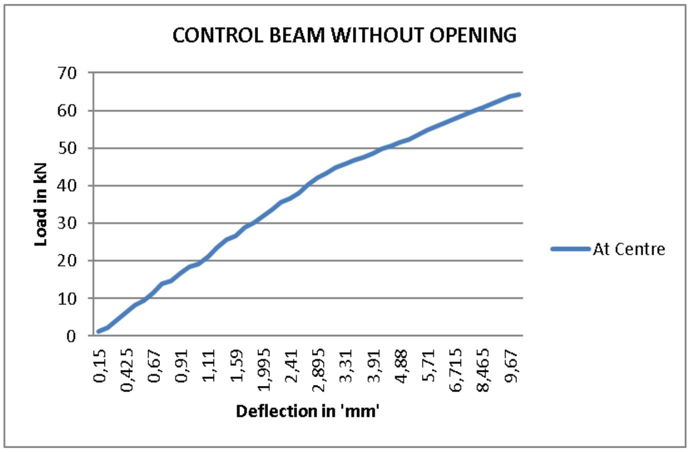

Fig. 4: Load-deflection relationship for control beam (B1)

Figure (4) shows the load deflection relationship, the beam fails at a load of 65kN and the maximum deflection observed at mid span is 10.895 mm,

CONTROL BEAM WITH OPENING SHEAR ZONE B2:

The test results of B2 beam as shown in table 7.

Table 7: Load-Deflection for beam-B2

Load in 'KN'	**Centre**	**Remarks**
3.61	0.155	
6.04	0.165	
8.47	0.200	
10.90	0.290	
12.52	0.385	
14.14	0.460	
15.76	0.520	
17.38	0.565	
19.00	0.620	First crack at opening

19.81	0.720	
20.62	0.860	
21.43	1.025	
22.24	1.150	
23.86	1.300	
25.48	1.495	
27.10	1.720	
28.72	1.945	
30.34	2.140	
31.96	2.350	
33.58	2.625	
35.20	2.960	
36.01	3.130	
36.82	3.290	
38.44	3.515	
40.06	3.795	
41.68	4.020	
43.30	4.390	
44.11	4.625	
44.92	4.910	
47.35	5.195	
49.78	5.550	Shear failure

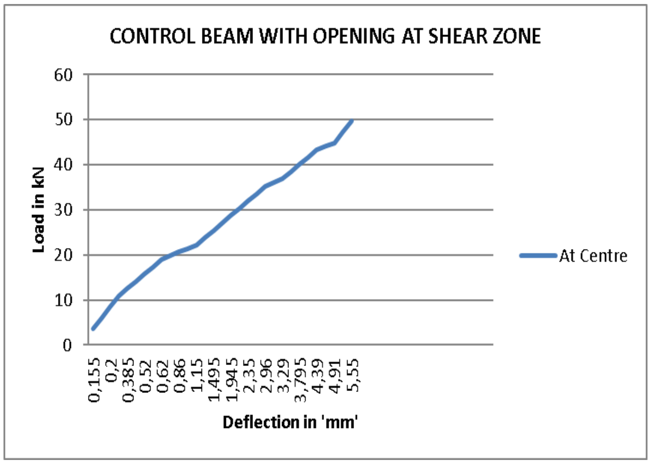

Fig. 5: Load-deflection relationship for control beam with opening (B2)

Figure (5) shows the load deflection relationship, the maximum deflection observed at failure load of 49.78 kN is 5.55 mm,

CONTROL BEAM WITH OPENING BENDING B3:

The test results of B3 beam as shown in table 8.

Table 8: Load-Deflection for beam-B3

Load in 'KN'	**Centre**	**Remarks**
3.61	0.155	
6.06	0.165	
8.47	0.200	
10.98	0.290	
12.52	0.385	
14.14	0.460	
15.76	0.520	
17.38	0.565	
19.20	0.650	First crack at opening
19.81	0.720	

20.62	0.860	
21.43	1.025	
22.24	1.150	
23.86	1.300	
25.48	1.495	
27.10	1.720	
28.72	1.945	
30.34	2.140	
31.96	2.350	
33.58	2.625	
35.20	2.960	
36.01	3.130	
36.82	3.290	
38.44	3.515	
40.06	3.795	
41.68	4.020	
43.30	4.390	
44.11	4.625	
44.92	4.910	
49.5	5.195	
50.78	5.650	Shear failure

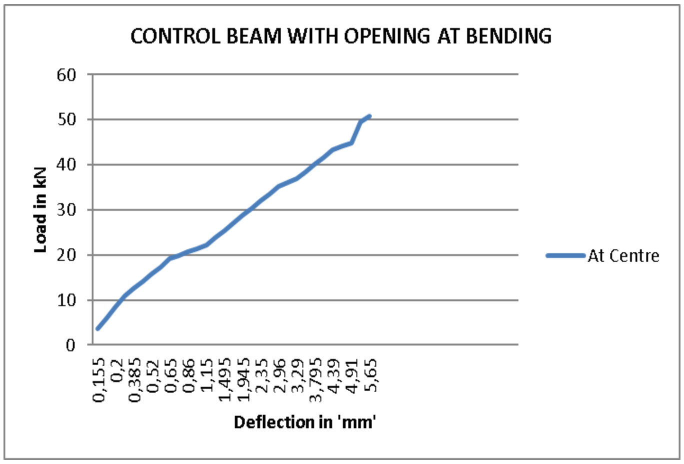

Fig. 6: Load-deflection relationship for control beam with opening (B3)

Figure (6) shows the load deflection relationship, the maximum deflection observed at failure load of 50.78 kN is 5.650 mm,

STRENGTHENED AROUND THE OPENING WITH GFRP B4:

The test results of B4 beam as shown in table 9.

Table 9: Load-Deflection for beam-B4

Load in 'KN'	**Centre**	**Remarks**
3.61	0.095	
6.04	0.195	
8.47	0.230	
10.90	0.290	
12.52	0.350	
14.14	0.405	
15.76	0.430	
17.38	0.530	
19.00	0.635	
19.81	0.700	

20.62	0.830	First crack
21.43	0.955	
22.24	1.095	
23.86	1.220	
25.48	1.380	
27.10	1.605	
28.72	1.755	
30.34	1.890	
31.96	2.200	
33.58	2.405	
35.20	2.680	
36.01	2.935	
36.82	3.100	
38.44	3.240	Crack at opening
40.06	3.530	
41.68	3.745	
43.30	4.010	
44.11	4.180	
44.92	4.355	
47.35	4.640	
49.78	4.850	
51.40	5.320	
52.21	5.790	
53.38	6.120	
54.64	6.405	
56.26	6.790	
57.058	8.110	
58.08	8.450	Shear failure

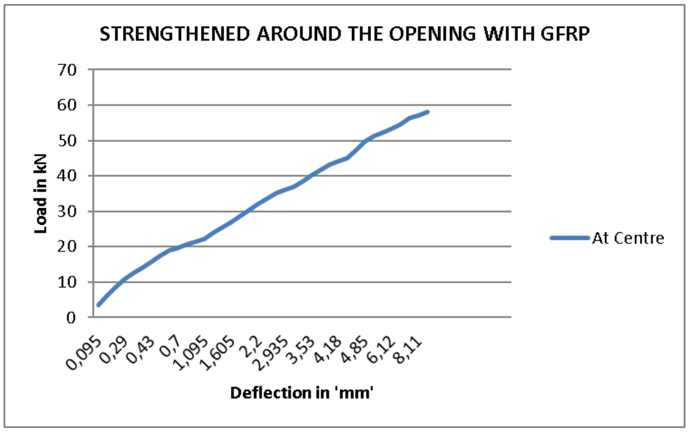

Fig. 7: Load-deflection relationship for beam strengthened outside the opening GFRP (B4)

Figure (7) shows the load deflection relationship, the maximum deflection observed at failure load of 58.08 kN at mid span is 8.450 mm,

STRENGTHENED AROUND THE OPENING WITH GFRP B7:

The test results of B4 beam as shown in table 10.

Table 10: Load-Deflection for beam-B7

Load in 'KN'	Centre	Remarks
3.61	0.095	
6.04	0.195	
8.47	0.230	
10.90	0.290	
12.52	0.350	
14.14	0.405	
15.76	0.430	
17.38	0.530	

19.00	0.635	
19.81	0.700	
21.02	0.830	First crack
21.43	0.955	
22.24	1.095	
23.86	1.220	
25.48	1.380	
27.10	1.605	
28.72	1.755	
30.34	1.890	
31.96	2.200	
33.58	2.405	
35.20	2.680	
36.01	2.935	
36.82	3.100	
38.44	3.240	Crack at opening
40.06	3.530	
41.68	3.745	
43.30	4.010	
44.11	4.180	
44.92	4.355	
47.35	4.640	
49.78	4.850	
51.40	5.320	
52.21	5.790	
53.38	6.120	
54.64	6.405	
56.26	6.790	
57.88	8.110	
58.69	8.650	
59.20	8.975	Shear failure

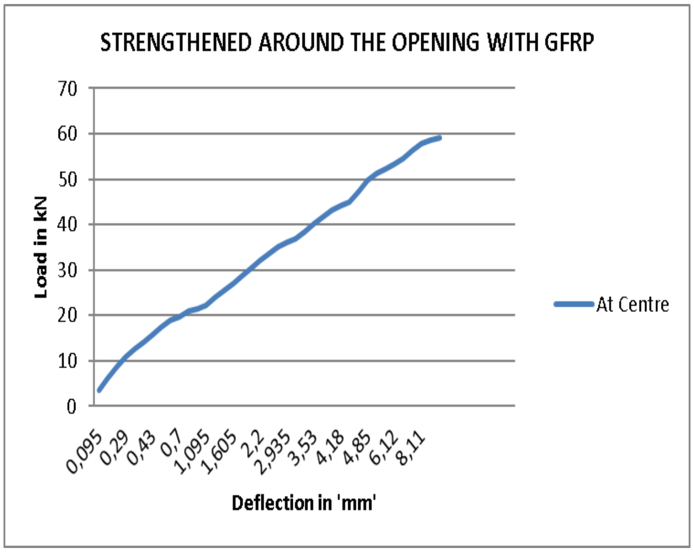

Fig. 8: Load-deflection relationship for beam strengthened outside the opening GFRP (B7)

Figure (8) shows the load deflection relationship, the maximum deflection observed at failure load of 59.2 kN at mid span is 8.975mm,

STRENGTHENED INSIDE THE OPENING WITH GFRP B5:

The test results of B5 beam as shown in table 11.

Table 11: Load-Deflection for beam-B5

Load in'KN'	**Centre**	**Remarks**
3.61	0.150	
6.04	0.215	
8.47	0.350	
10.90	0.410	

12.52	0.530	
14.14	0.700	
15.76	0.815	
17.38	0.960	
19.00	1.210	
19.81	1.370	First crack
20.62	1.510	
21.43	1.785	
22.24	1.940	
23.86	2.150	
25.48	2.415	
27.10	2.580	
28.72	2.790	
30.34	2.950	
31.96	3.175	
33.58	3.320	
35.20	3.480	
36.01	3.640	
36.82	3.800	
38.44	3.950	
40.06	4.250	
41.68	4.590	
43.30	4.880	
44.11	5.095	
44.92	5.435	
47.35	5.625	
49.78	5.890	
51.40	6.120	
52.00	6.400	Shear failure

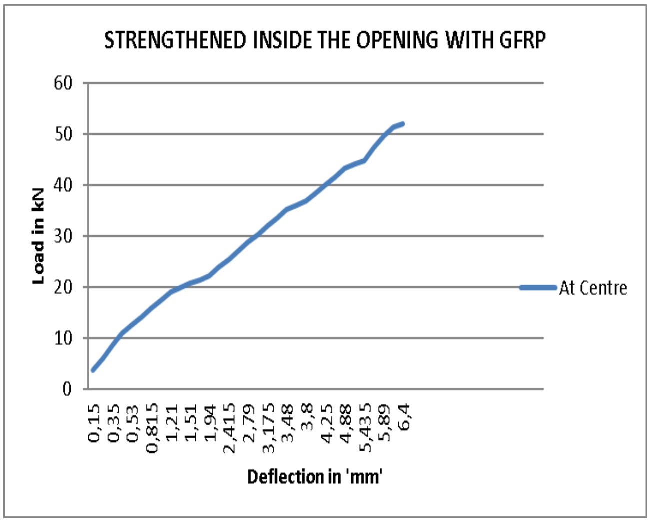

Fig. 9: Load-deflection relationship for beam strengthened inside the opening GFRP (B5)

Figure (9) shows the load deflection relationship, the maximum deflection observed at failure load of 52.00kN at mid span is 6.400 mm,

STRENGTHENED INSIDE THE OPENING WITH GFRP B8:

The test results of B8 beam as shown in table 12.

Table 12: Load-Deflection for beam-B8

Load in 'KN'	Centre	Remarks
3.61	0.150	
6.04	0.215	
8.47	0.350	
10.90	0.410	
12.52	0.530	
14.14	0.700	

15.76	0.815	
17.38	0.960	
19.00	1.210	
19.21	1.470	First crack
20.62	1.510	
21.43	1.785	
22.24	1.940	
23.86	2.150	
25.48	2.415	
27.10	2.580	
28.72	2.790	
30.34	2.950	
31.96	3.175	
33.58	3.320	
35.20	3.480	
36.01	3.640	
36.82	3.800	
38.44	3.950	
40.06	4.250	
41.68	4.590	
43.30	4.880	
44.11	5.095	
44.92	5.435	
47.35	5.625	
49.78	5.890	
51.40	6.120	
52.21	6.400	
55.00	6.950	Shear failure

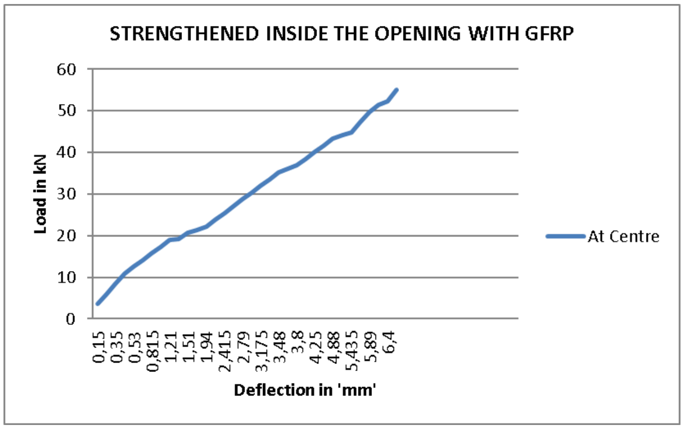

Fig 10: Load-deflection relationship for beam strengthened inside the opening GFRP (B8)

Figure (10) shows the load deflection relationship, the maximum deflection observed at failure load of 55.00 kN at mid span is 6.950 mm.

STRENGTHENED INSIDE AND AROUND THE OPENING WITH GFRP B6:

The test results of B6 beam as shown in table 13.

Table 13: Load-Deflection for beam-B6

Load in'KN'	**Centre**	**Remarks**
3.61	0.145	
6.04	0.225	
8.47	0.280	
10.90	0.340	
12.52	0.430	
14.14	0.515	
15.76	0.580	
17.38	0.680	

19.00	0.840	
19.81	0.960	
20.62	1.115	
21.43	1.190	
22.24	1.320	First crack
23.86	1.540	
25.48	1.660	
27.10	1.910	
28.72	1.975	
30.34	2.040	
31.96	2.150	
33.58	2.420	
35.20	2.700	
36.01	2.955	
36.82	3.150	
38.44	3.305	
40.06	3.510	
41.68	3.695	
43.30	4.015	
44.11	4.220	Crack at opening
44.92	4.410	
47.35	4.620	
49.78	4.835	
51.40	5.075	
52.21	5.260	
53.38	5.390	
54.64	5.720	
56.26	5.950	
57.88	6.175	
58.75	6.320	Flexure mode

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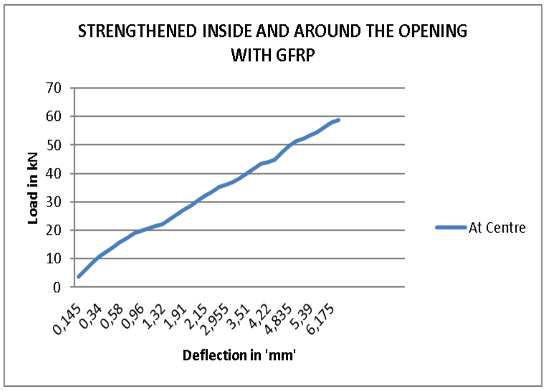

Fig. 11: Load-deflection relationship for beam strengthened inside and outside the opening GFRP (B6)

Figure (11) shows the load deflection relationship, the maximum deflection observed at failure load of 58.75 kN at mid span is 6.320 mm.

STRENGTHENED INSIDE AND AROUND THE OPENING WITH GFRP B9:

The test results of B9 beam as shown in table 14.

Table 14: Load-Deflection for beam-B9

Load in'KN'	**Centre**	**Remarks**
3.61	0.145	
6.04	0.225	
8.47	0.280	
10.90	0.340	

12.52	0.430	
14.14	0.515	
15.76	0.580	
17.38	0.680	
19.00	0.840	
19.81	0.960	
20.62	1.115	
21.43	1.190	
22.24	1.320	First crack
23.86	1.540	
25.48	1.660	
27.10	1.910	
28.72	1.975	
30.34	2.040	
31.96	2.150	
33.58	2.420	
35.20	2.700	
36.01	2.955	
36.82	3.150	
38.44	3.305	
40.06	3.510	
41.68	3.695	
43.30	4.015	
44.11	4.220	Crack at opening
44.92	4.410	
47.35	4.620	
49.78	4.835	
51.40	5.075	
52.21	5.260	
53.38	5.390	
54.64	5.720	
56.26	5.950	
57.88	6.175	
58.69	6.320	
59.50	6.595	
61.00	6.760	Flexure mode

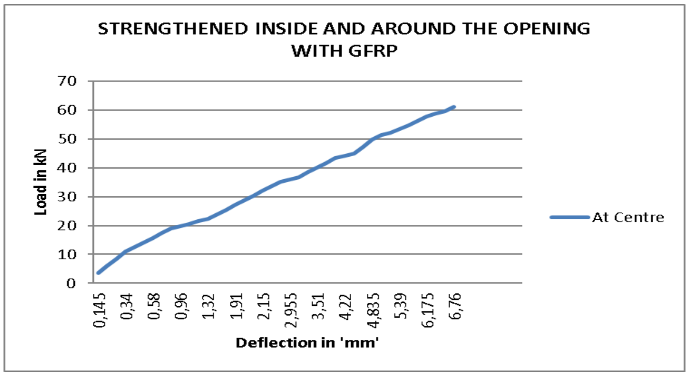

Fig. 12: Load-deflection relationship for beam strengthened inside and outside the opening GFRP (B9)

Figure (12) shows the load deflection relationship, the maximum deflection observed at failure load of 61.00kN at mid span is 6.760 mm,

Test results

The following are the test results as shown in table 15.

Table 15: Test results

Designation on Bea	**Type of Strengthene**	**Initial Crac**	**Ultimate Failur**	**Increase in loa**	**Maximum De**	**Mode of Failur**

m	**d**	**k Load in KN**	**e Load in KN**	**d carrying capacity in %**	**flection**	**e**
B1	Control beam	27.10	65	-	10.895	Flexure
B2	Non Strengthened Control beam (beam with post opening)at shear zone	19.00	*49.78	-	5.550	Shear
B3	Non Strengthened Control beam (beam with post opening)at bending zone	19.20	*50.78	-	5.650	Shear
B4	Strengthened around by GFRP at shear zone	20.62	58.08	16.67	8.450	Shear
B5	Strengthened inside by GFRP at shear zone	19.81	52.00	4.45	6.825	Shear
B6	Strengthened around and inside by GFRP at shear zone	22.24	58.75	18.1	8.150	Shear
B7	Strengthened around by GFRP at bending zone	21.02	59.2	16.91	9.430	Shear
B8	Strengthened inside by GFRP at bending zone GFRP	19.21	55.00	8.47	6.950	Shear
B9	Strengthened around and inside by GFRP at bending zone	22.24	61.00	20.55	8.220	Flexure

Discussion

The load carrying capacity and the corresponding modes of failure have been presented for all tested beams. Examining the results presented in the table 15, it is clear that the presence of an opening within the shear zone not only reduced the load carrying capacity of the beam but also reduce the stiffness of the beam. The reduction in the load carrying capacity of the beam is about 23.41 % due to presence of a 60 mm diameter circular opening within the shear zone.

The percentage of increase in load carrying capacity for the beams Strengthened around by GFRP B4 at shear zone is 16.67% as compared to non-strengthened beam B2 (control beam with circular post opening).

The percentage of increase in load carrying capacity for the beams Strengthened inside by GFRP B5 at shear zone is 4.45% as compared to non-strengthened beam B2 (control beam with circular post opening).

The percentage of increase in load carrying capacity for the beams Strengthened around and inside by GFRP B6 at shear zone is 18.01% as compared to non-strengthened beam B2 (control beam with circular post opening).

The percentage of increase in load carrying capacity for the beams Strengthened around by GFRP 7B at bending zone is 16.91% as compared to non-strengthened beam B2 (control beam with circular post opening).

The percentage of increase in load carrying capacity for the beams Strengthened around by GFRP 8B at bending zone is 8.74% as compared to non-strengthened beam B2 (control beam with circular post opening).

The percentage of increase in load carrying capacity for the beams Strengthened around by GFRP 9B at bending zone is 20.53% as compared to non-strengthened beam B2 (control beam with circular post opening).

Conclusion

1. The load carrying capacity of the beam decreases by providing an opening within the at shear zone in a reinforced concrete beam and inclusion of an opening in a reinforced concrete beam reduces its load carrying capacity by 23.41 % as compared to solid beam B1 i.e. control beam.
2. The load carrying capacity of the beam decreases by providing an opening within the at bending zone in a reinforced concrete beam and inclusion of an opening in a reinforced concrete beam reduces its load carrying capacity by 21.87 % as compared to solid beam B1 i.e. control beam.
3. The percentage of increase in load carrying capacity for the beams Strengthened around by GFRP B4 at shear zone is 16.67% as compared to non-strengthened beam B2 (control beam with circular post opening).
4. The percentage of increase in load carrying capacity for the beams Strengthened inside by GFRP B5 at shear zone is 4.45% as compared to non-strengthened beam B2 (control beam with circular post opening).
5. The percentage of increase in load carrying capacity for the beams Strengthened around and inside by GFRP B6 at shear zone is 18.01% as compared to non-strengthened beam B2 (control beam with circular post opening).
6. The percentage of increase in load carrying capacity for the beams Strengthened around by GFRP 7B at bending zone is 16.91% as compared to non-strengthened beam B2 (control beam with circular post opening).
7. The percentage of increase in load carrying capacity for the beams Strengthened around by GFRP 8B at bending zone is 8.74% as compared to non-strengthened beam B2 (control beam with circular post opening).
8. The percentage of increase in load carrying capacity for the beams Strengthened around by GFRP 9B at bending zone is 20.53% as compared to non-strengthened beam B2 (control beam with circular post opening).

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