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Experimental Studies on Retrofitting of RCC Beams Using GFRP

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ABSTRACT

The studies conducted on the retrofitting of RCC beams using GFRP are limited. So it is essential to study the shear carrying capacity, flexural carrying capacity and ductility of flexural deficient beams by retrofitting with GFRP. u wrapping technique was adopted for both shear deficient beams and flexural deficient beams. The number of layers of GFRP was considered as variable. The effect of increasing the number of layers of GFRP has been studied.

In this work retrofitting of RCC beam of shear deficient beam and flexural deficient beam and flexural deficient beam using GFRP lamination will be studies. Fourteen beams of size 100mm*150mm*1200mm were cast. Out of this two control beam one was used as shear deficient beam and another was used as flexural deficient beam . remaining twelve beams six beams were shear deficient used for retrofitting and six beams were flexural deficient used for retrofitting. Shear deficient control beam (SDCB) and flexural deficient control beams (FDCB) were loaded upto ultimate load in the compression testing machine of 300 tones capacity. Shear deficient and and flexural deficient beams were retrofitting using GFRP which was bonded with epoxy resin.. load deflection behavior of beam, retrofitting with different layers of stitched mat and woven roving was compared. Study of ductility of flexural deficient beams was made.

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I. INTRODUCTION

Retrofitting is a technical intervention in structural system of a building that improve resistance to earthquake by optimizing strength and ductility. Strength of a building is generated from its structural dimensions, materials, shape, and number of structural elements, etc. Ductility of a building is generated from good detailing, materials used, degree of seismic resistance, etc. Earthquake load is generated from the site seismicity, mass of structures, degree of seismic resistance etc. Due to the variety of structural conditions of building, it is hard to develop typical rules for Retrofitting. Each building has different approaches, depending on the structural deficiencies. Hence, engineers are required, to Prepare and design the retrofitting approaches. In the design of retrofitting approach, the engineer must fulfill the minimum requirements of the building codes, such as deformation, detailing strength, etc. Retrofitting of flexural concrete elements is traditionally accomplished by externally bonding steel plates to concrete. Although this technique has proved to be effective in increasing strength and stiffness of reinforced concrete elements, it has the disadvantages of being susceptible to corrosion and difficulty in installation. Recent development in the field of composite materials, together with their inherent properties, which include high specific tensile strength, good fatigue strength, corrosion resistance and ease of ease of use, make them an attractive alternative to steel plates in the field of repair and strengthening of concrete elements. Reinforced concrete structures often have to face modification and improvement of their performance during their service life. The main contributing factors are change in their use, new design standards, deterioration due to corrosion in the steel caused by exposure to an aggressive environment and accident events such as earthquakes. In such circumstances there are two possible solutions: replacement or retrofitting. Full structure replacement might have determine disadvantage such as high costs for material and labour, a stronger environmental impact and inconvenience due to interruption of the function of the structure e.g.traffic problems. When possible, it is often better to repair or upgrade the structure by retrofitting. In the last decade, the development of strong epoxy glue has led to a technique which has great potential in the field of upgrading structures. Basically the technique involves gluing steel plates or fibre reinforced polymer (FRP) plates to the surface of the concrete. The plates then act compositely with the concrete and help to carry the loads. FRP can be convenient compared to steel for a number of reasons. These materials have higher ultimate strength and lower density than steel. The installation is easier and temporary support until the adhesive gains its strength in not required due to the low weight. They can be formed on site into complicated shapes and can also be easily cut to length on site. Retrofitting reduces the vulnerability of damage of an exiting structure during a future earthquake. It aims to strengthen a structure to satisfy the requirements of the current codes for seismic design. In this respect, seismic retrofit is beyond conventional repair or even rehabilitation. The principles or seismic retrofit refer to the goals, objectives and steps. The steps encompass condition assessment of the structure, evaluation for seismic forces, selection of retrofit strategies and construction. The application include different types of buildings, industrial structures, bridges, urban transport structures, marine structures and earth retaining structures.

II. SIGNIFICANCE OF STUDY

Retrofitting of structures shall proceed as follows.

a. Identify the performance requirements for the existing structure to be retrofitted and draft on overall plan from inspection through selection of retrofitting method, design of retrofitting structure and implementation of retrofitting work.
b. Inspect the existing structure to be retrofitted.
c. Based on the results of the inspection, evaluate the performance of the structure and verify that if fulfills performance requirements.
d. If the structure does not fulfill performance requirements, and if continued use of the structure through retrofitting is desired, proceed with design of the retrofitting structure.
e. Select an appropriate retrofitting method and establish the materials to be used, structural specifications and construction method.
f. Evaluate the performance of the structure after retrofitting and verify that it will fulfill performance requirements.
g. If it is determined that the retrofitting structure will be capable of fulfilling performance requirements with the selected retrofitting and construction methods, implement the retrofitting work.

Fiber Reinforced polymer (FRP) composites are used in a wide variety of

Applications. Their mechanical properties provide unique benefits to the product they

Are moulded into. FRP composite materials possess superior mechanical properties

Including:

I. Impact resistance
II. Strength
III. Stiffness
IV. Flexibility
V. Ability to carry loads

When designing products out of FRP materials, engineers use sophisticated composite material software which calculates the known properties of the given composite. Typical tests used to measure the mechanical properties of FRP composites include:

I. Shear stiffness
II. Tensile
III. Flexible modulus
IV. Impact

The two major components of an FRP composite material is resin and reinforcement. A cured thermosetting resin without any reinforcement is glass like in nature and appearance, but often very brittle. By adding a reinforcing fiber such as carbon fiber, glass, or aramid, the properties are vastly improved. Additionally, with reinforcing fiber, a composite can have anisotropic properties. Meaning, the composite can be engineered to have different properties in different directions depending on the orientation of the fiber reinforcement. Aluminum, Steel, and other metals have isotropic properties, meaning, and equal strength in all directions. A composite material, with anisotropic properties, can have additional reinforcement in the direction of stresses, and this can create more efficient structures at lighter weights. For example, a pultruded rod having all fiberglass reinforcement in the same parallel direction could have tensile strength upwards of 150,000 PSI. As where a rod with the same area of random chopped fiber would only have tensile strength around 15,000 PSI. Another difference between FRP composites and metals is the reaction to impact. When metals receive impact, they can yield or dent. While FRP composites have no yield point and will not dent.

III. OBJECTIVE

a) To improve the load carrying capacity, of both shear deficient beams and flexural deficient beams, by retrofitting with GFRP (Stitched Mat and Woven Roving)
b) To study the load deflection behaviour for both shear deficient beams and flexural deficient beams, which are retrofitted withGFRP (Stitched Mat and Woven Roving)
c) To study the ductility of flexural deficient beams.
d) To study the effect of number of layers of Stitched Mat and Woven Roving, on the behaviour of the retrofitted beams.
e) Compare the Strength of various layers of Stitched Mat and Woven Roving, which can be wrapped on both shear deficient beams and flexural deficient beams.
f) Generate the relation between number of layers of GFRP and improvement of load carrying capacity for retrofitted beams.

SCOPE OF STUDY

The studies conducted on the Retrofitting of RCC beams using GFRP are limited. So it is essential to study the shear carrying capacity, flexural carrying capacity and ductility of flexural deficient beams by retrofitting with GFRP. The effect of increasing the number of layers of GFRP has been studied. Load carrying capacity corresponding to the number of layers of GFRP should be studied for both shear deficient beams of flexural deficient beams.

MATERIAL USED CEMENT

The cement used for the present study was Ordinary Portland Cement (Bharathi) of 53 grade

FINE AGGREGATES

River sand passing through IS 4.75mm sieve conforming to zone II of IS: 383-1970 isUsed as fine aggregates. The results of sieve analysis are given in Table 3.1 and properties of fine aggregates are given in Table 3.2.

Table 1 Sieve Analysis results of Fine Aggregates

S. No.	Sieve size (mm)	Weight Retained (g)	Cumulative weight Retained(g)	Cumulative % weight Retained	Cumulative % passing
1	4.75	0	0	0	100
2	2.38	0	0	0	100
3	1.18	99	9.9	9.9	90.1
4	0.6	234	23.4	33.3	66.7
5	0.3	503	50.3	83.6	16.4
6	0.15	144	14.4	98	2

Table 2 Properties of Fine Aggregates

Properties	Observed Values
Specific gravity	2.44
Fine modulus	2.248
Bulk density	1.6197 kg/m^3
Loose Density	1.5605 kg/m^3
Zone	III
Water Absorption	3.2%

COARSE AGGREGATES

Crushed granite, stone with a maximum size of 20mm was used as the coarse aggregates. The results of sieve analysis and properties of coase aggregates are given Table 3.3 and Table 3.4

Table 3 Sieve Analysis results of Coarse Aggregate

S. No.	Sieve size (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative % weight Retained	Cumulative % passing
1	80	0	0	0	100
2	40	0	0	0	100
3	20	2025	40.5	40.5	59.5
4	10	2887	57.74	98.24	1.76
5	4.75	88	1.76	100	0

Table 4 Properties of Coarse Aggregates

Properties	Observed Values
Specific gravity	2.81
Fine modulus	7.38
Bulk density	1.6197 kg/m^3
Loose Density	1.5305 kg/m^3
Water Absorption	3.2%

WATER

Clean potable water available in the laboratory, which satisfies drinking standards, was used for the preparation of the specimens and its subsequent curing.

REINFORCEMENT

Shear deficient beams were designed by having 3 numbers of 8 mm diameter bars in the tension zone and 2 numbers of 6mm diameter bars in the compression zone. 6mm diameter bars were used as stirrups. The spacing between the stirrups were kept at 365mm along the shear span so that beam was failed only along the shear span. Flexrual deficient beams were designed by having 2 numbers of 8mm diameter bars in the tension zone and 2 numbers of 6mm diameter bars at the compression zone. 6mm diameter bar were used as stirrups at the spacing of 175mm in the middle span of the beams were behaved as flexural deficient. Reinforcement cage for shear deficient beam and flexural deficient beam is shown in Figure 1 and 2

Fig 1 Reinforcement Cage for Shear Deficient Beam

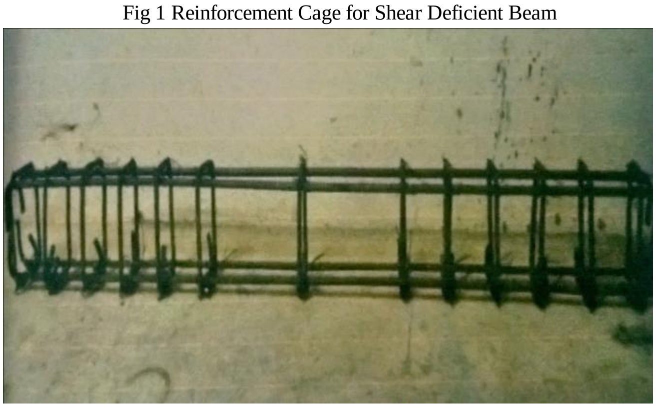

Fig 2 Reinforcement Cage for Flexural Deficient Beam

RETROFITTING OF RCC BEAM

In this study fourteen rectangular RCC beams were cast. All the beams have rectangular cross section of 1.2mx0.15mx0.10m. Out of this fourteen beams, two control beams were cast, one was used as shear deficient beam and the other was used as flexural deficient beam. Out of the remaining twelve beams, six beams were shear deficient, sued for retrofitting using GFRP and six beams were flexural deficient, used for retrofitting using GFRP. Shear deficient beams were cast by providing insufficient stirrups on the shear span so that beams failed only due to shear cracks. Flexural deficient beams were cast by providing insufficient bares on the tension zone so that beams failed only due to flexure cracks. Shear deficient control beam (SDCB) and Flexural deficient control beam (FDCB) were loaded upto ultimate load in the compression testing machine of 300 tonne capacity. In order to create distress, shear deficient beams were first loaded upto 79% of ultimate load of SDCB. Cracks developed due to this loading were filled with cement paste. The Shear deficient beams were retrofitted along the shear spans using GFRP (stitched mat and woven roving). In order to create distress, flexural deficient beams were first loaded upto 85% of ultimate load FDCB. The cracks developed due to this loading were filled with cement paste. The Flexural deficient beams were retrofitted using GFRP (stitched mat and woven roving). The GFRP was boned to the beams using epoxy U warping technique. Finally retrofitted beams were loaded upto ultimate load.

The load deflection behavior of retrofitted shear deficient beams was compared. In a similar manner in the case of retrofitted flexural deficient beams, comparison of the load deflection behavior of beams was made. A study of ductility of retr4ofitted flexural deficient beams was done. Beams failed upto 85% of the ultimate load of flexural deficient control beam (FDCB) Crecks closed with cement paste before retrofitting of flexural deficient beams Retrofitting of flexural deficient beams using stitched mat and woven roving .Beams failed upto 78% of the ultimate load of shear deficient control beam

U Wrapping technique was adopted for both shear deficient beams and flexural deficient beams. While doing the wrapping process, first the beams were washed with acetone to remove the dirt and were made clean. The surfaces of the beams were rubbed with and paper to make the surface rough. Then wrapping of GFRP on the surface of the beams were done. The wet layup or hand layup technique was adopted for wrapping purpose. In this technique surface of the beams were cleaned and applied with a layer of Duratite epoxy resin consists of a resin and a hardener the mixing proportion of which is 1:1 by volume. The resin and the hardener were taken in equal proportion by volume in a container and mixed well till a uniform mix was obtained.

This resin was then applied on the surface of the beams. GFRP was then placed on the wet resin layer. Plastic laminating rollers were then used to depress the fiber sheet into the resin, causing the fibers to get wet out by the resin and air out of the GFRP composites. Also, it ensured good contact between the epoxy, the concrete and the fabric. Then for applying the second layer, resin was applied to the surface of the existing fiber layer and the procedure was repeated. Concrete beams strengthened with glass fiber fabric were cured for 48hrs at room temperature before testing.

TESTING OF SPECIMENS

All the beams will be tested under simply supported end conditions. Two point loading is adopted for resting the specimens. The shear span to depth ratio of 2.5 to 3.0 was adopted so that the beam will fail in combined flexure and shear. The testing of the beams were done on the Bending and Compression Testing Machine of 300 tone capacity. The load was increased in stages till failure of the beam occurred. At each stage of loading deflection at the midspan was noted using dial gauge.

Fig 3 Beams failed upto 85% of the ultimate load of Flexural Deficient Control Beam (FDCB)

Fig 4 Wrapping stitched mat along the shear span of the beam

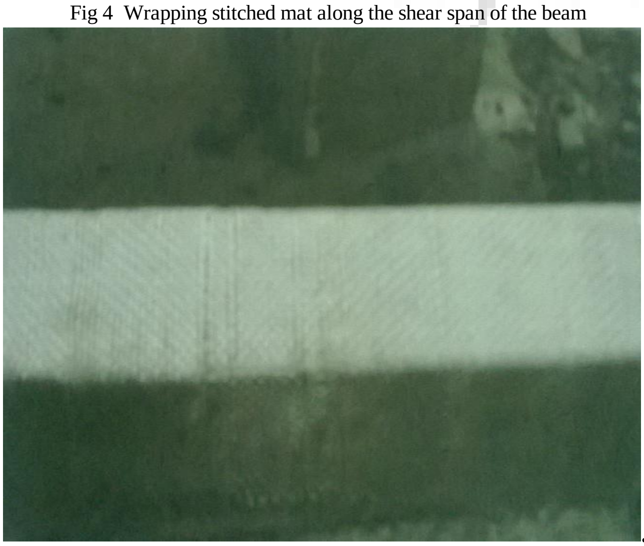

Fig 5 Wrapping Woven Roving along the flexural span of the beam

Fig 6 Experimental set up

Specimen FDCB and SDCB were designated as flexural deficient control beam and shear deficient control beam respectively. When load was applied in the FDCB, development of cracks was visible after the first crack load of 24 k.N in the case of SDCB, development of cracks was visible after the first crack load of 16kN. In SDCB flexural cracks developed first. However failure was due to diagonal shear creaks in the shear span. These test results were kept as standard for comparision of behaviour of retrofitted beams. Flexural deficient control beam (FDCB) loaded upto ultimate load is shown in Figure 3.27l. Shear deficient control beam (SDCB) loaded upto ultimate load is shown in Figure 3.28 The flexural deficient beams before retrofitting, beams were loaded upto 85% of FDCB. Then beams were retrofitted using stitched mat and woven roving.

Fig 7 Flexural deficient control beam (FDCB) loaded upto ultimate load.

Fig 8 Shear deficient control beam (SDCB) loaded upto ultimate load

RESULTS & DISCUSSIONS

LOAD DEFLECTION BEHAVIOUR THE BEAMS

Using the data obtained from the experiment, load deflection, plots were drawn. All the plots show liners behavior upto the formation of the first crack. This could be termed as the pre cracking stage. Beyond this point the slope of the curve decreases for both shear deficient deams and flexural deficient beams. Test result of retrofitted flexural deficient beams are shown in Table 4.1 Test result of retrofitted shear deficient beams are shown in Table 4.2.

Table 5 Test results of Retrofitted Flexural Deficient Beams

Specimen	Ultimate Load (kn)	Deflection Corresponding to Utimate Load (mm)
FDCB	40	10.8
FDB 1WR1	40.5	10.9
FDB 2 WR 2	44	10.3
FDB 3 WR 3	47	10.1
FDB 4 SM 1	43	10.33
FDB 5 SM 2	47	10.2
FDB 6 SM3	50	9.8

Table 6 Test results of Retrofitted Shear Deficient Beams

Specimen	Ultimate Load (kN)	Deflection Corresponding to Ultimate Load (mm)
SDCB	38	6.3
SDB 1 WR 1	38.5	6.5
SDB 2 WR 2	41	6.2
SDB 3 WR 3	43	6.1
SDB 4 SM 1	39	6.3
SDB 5 SM 2	43	6.01
SDB 6 SM 3	47	5.8

Load deflection curves were plotted for flexural deficient beams, which were loaded upt 85% of FDCB Load deflection curves for control beam and retrofitted flexural deficient beams using woven roving. It shown that improvement in flexural capacity, when number of layers of woven roving were increased in the flexural deficient retrofitted beams.

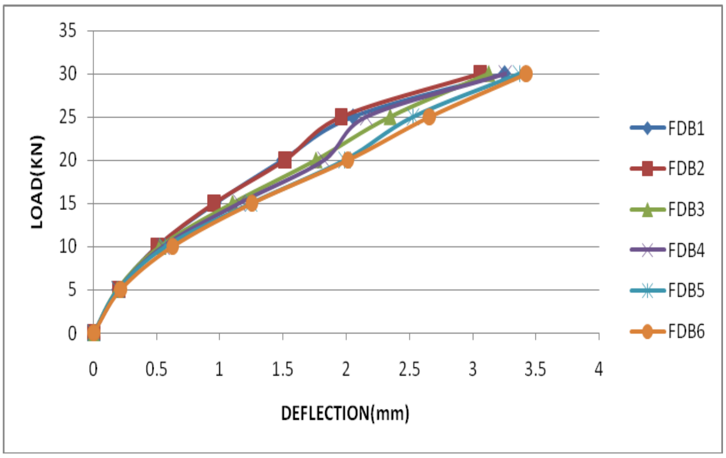

Fig 9 Load deflection curves for Pre-Retrofitted Flexural Deficient Beams loaded upto 85% of FDCB

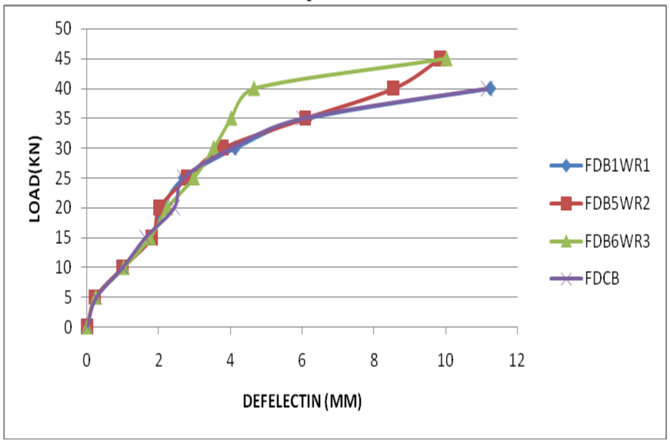

Fig 10 Load Deflection Curves for FDCB and Retrofitted Flexural Deficient Beams –Woven Roving

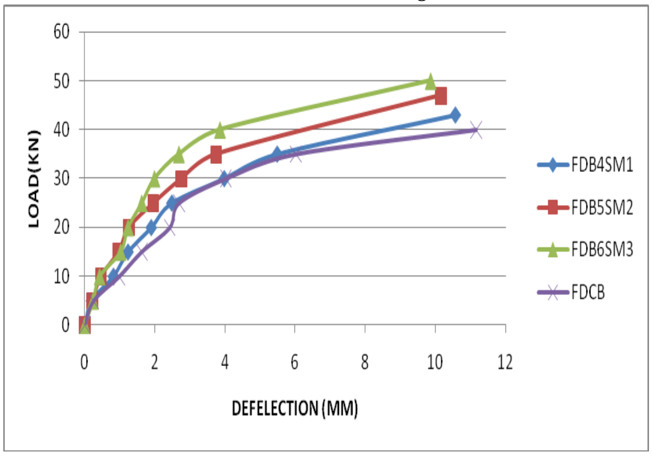

Fig 11 Load Deflection Curves for FDCB and Retrofitted Flexural Deficient Beams –Stitched Mat

Load deflection curves were plotted for retrofitted shear deficient beams loaded upto 79% of ultimate load of SDBC. Load deflection curves for control beam and retrofitted shear deficient beams using woven roving. It shows that improvement in shear capacity, when number of layers of woven roving was increased in the shear deficient beams using stitched mat is shown in Figure 4.6. It shows that improvement in shear capacity, when number of layers of stitched mat was increased in the shear deficient retrofitted beams. Similarly in case of shear deficient retrofitted beams using stitched mat, triple layer and double layer was more shear carrying capacity when compared with single layer of stitched mat.

ULTIMATE LOAD OF RETROFITTED BEAMS

The results shows that shear capacity and flexural capacity of U Wrapped specimens using stitched mat increased as the numbers of layers of mat increased. But in the case of U wrapped specimens using woven roving, double layer and triple layers have shown improvement in shear strength as well as flexural strength. The improvement in ultimate load of retrofitted shear deficient beams using stitched mat was upto 21.5% for triple layer wrap, 13.5% for triple layer wrap, 7.89% for double layer wrap and 1.25% for single layer wrap. The improvement in ultimate load of retrofitted flexural deficient beams using stitched mat was upto 25% for triple layer wrap, 17.5% for double layer wrap and 7.5% for single layer

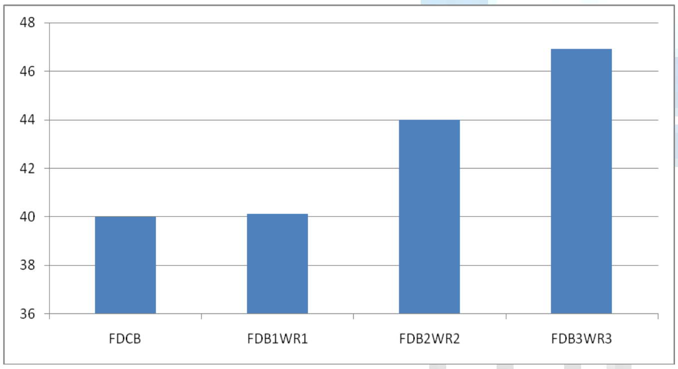

Fig 12 Comparison of FDCB and Flexural DeficientRetrofitted Beams using Woven Roving

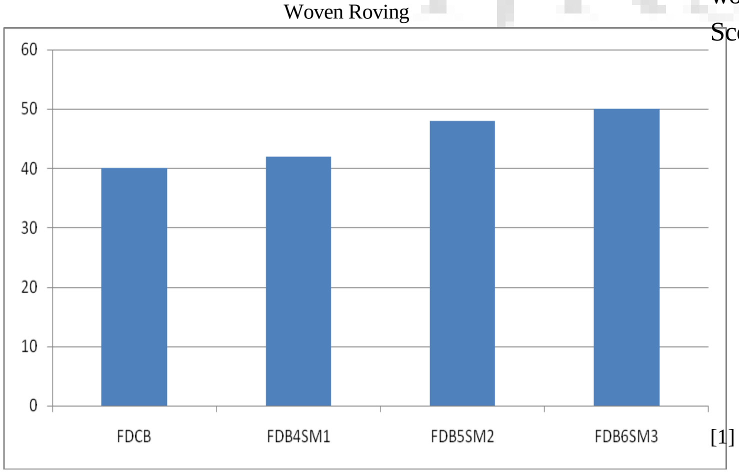

Fig 13 Comparison of FDCB and Flexural Deficient Retrofitted Beams using stitched mat

CONCLUSON

Based on the analysis of the results the following conclusion can be arrived.

i. The results shows that shear capacity and flexural capacity of U Wrapped specimens using stitched mat and woven roving increased, as the numbers of layers of the mat increased.

ii The improvement ultimate load of retrofitted flexural deficient beams using stitched mat was upto 7.5% for single layer wrap, 17.5% for double layer wrap and 25% for triple layer wrap.

iii. The improvement in ultimate load of retrofitted flexural deficient beams using woven roving was upto 1.07% for single layers wrap, 10% for double layer wrap, 17.5% for triple layer wrap.

iv. The imrprovement in ultimate load of retrofitted shear deficient beams using stitched mat was upto 2.63% for single layer wrap, 13.5% for double layer wrap and 21.5% for triple layer wrap.

v. The improvement in ultimate load of retrofitted shear deficient beams using woven roving was upto 1.25% for single layer wrap, 7.89% for double layer wrap, 13.5% for triple layer wrap.

vi. For both retrofitted shear deficient beams and retrofitted flexural deficient beams, triple layer of stitched mat and triple layer of woven roving have performed well.

vii. From this study, it is concluded that stitched mat is a more effective material for retrofitting than the woven roving.

SUGGESTION FOR FURTHER STUDY

In the present study, two types of GFRP (stitched mat and woven roving) were used for retrofitting, variable was considered as number of layers of GFRP (stitched mat and woven roving) and U wrapping technique was adopted. Scope of further studies on retrofitting is as follows.

i. Effect of retrofitting using GFRP on rectangular section of various aspect ratio and various wrapping styles can be studied.

ii. Behaviour of T-beams retrofitted with GFRP can be investigated.

iii. Investigation of the feasibility of retrofitting of shear walls can be done

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