Retrofitting of Reinforced Concrete Beams Using Rubberizedcoir Fibre Sheets

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Abstract

This paper presents retrofitting of reinforced concrete beams using Rubberized coir fiber, a natural laminate, inboth flexure and shear for which is subjected under two point loading. The main aim of this study is to rehabilitate the structurally deficient beam and to make it serviceable in both flexure and shear. The beams retrofitted with rubberized coir fibre sheets(RCFS) are used to make structure efficient and to restore stiffness and strength values greater than those of control beams. Understanding the response of these components during loading is crucial to the development of an overall efficient and safe structure. Formation of first cracks ,RCFS debonding and onset of concrete crushing are compared and discussed. Load–deflection behavior, failure modes and crack propagation patterns are studied extensively. The presence of shear straps to enhance shear strength has the dual benefit of delaying debonding of RCFS sheets used for flexural strengthening. The test results showed that thestiffness of the RCFS retrofitted beams are greatly increased compared to the control beams and also the deflection of retrofitted beams were reduced predominantly at the early stages of loading. The ultimate loads at failure of the specimen were increased. Instead of replacing the entire structure, it would be better to go for retrofitting.

Keywords: *Retrofit, Rubberized coir fibre, Stiffness.*

I. INTRODUCTION

Many existing structures all around the earth, which do not fulfill the specified requirements as it was expected for. These failures are due to aspects sudden loading like impact, fatigue, earthquake and rebar corrosion, etc. To counteract this, different types of repairing techniques are being carried out. Failure of modern engineered structures in different aspects like ground motions, deterioration of members due to ageing are strengthened and rehabilitated using recent advancements of FRP. The repair and strengthening of reinforced concrete beams, slabs, columns and beam-column joints in structural engineering applications has increased over past 20 years. Concrete structural components exists in buildings and bridges in different forms. Different types of repairing techniques were carried out in previous researches. Whereas in market, ferrocement, steel plates and fibre reinforced polymer (FRP) laminate available. Retrofitting of reinforced concrete structures using rubberized coir fiber sheets, a natural laminate for improving the structural responses like strength and maximum deflection. It is preferable for repairing or retrofitting rather than replacing completely, since it is both environmentally and economically available. With the development of structurally effective adhesive, epoxyresin, the strength improvement is remarkable. RCFS will be advantageous in using in the sense like tough, economical very high strength to weight ratio. Earlier researches shown that the application of carbon and glass fibre reinforced polymer laminates to beam can increase the stiffness and maximum load carrying capacity. The retrofitting of beams using various FRP's were done by researchers in different part of the world. The review of those literatures in the field of present study is given in summarized form.

Daniel Baggio et[1] al showed that the beams retrofitted with CFRP and anchors given better results when compared with GFRP and FRCM.YasmeenTalebObaidatet[2] al concluded that the beams retrofitted with CFRP plates had shown better results when compared with control beams in terms of stiffness, maximum load capacity and crack width greatly reduced. The increase in maximum load of retrofitted specimens reached values of about 23% for beams retrofitted in shear and of from 7 to 33% for flexure. Vishnu.H.Jariwala et[3] al showed that beams deficient in resisting torsion can be strengthened using FRP composites. Riyadh Al-Ameryet[4] al concluded that beams coupled with CFRP straps and sheets achieved significant improvement in the beam strength due to the coupling.Michael A.Colalilloet[5] al concluded that FRP retrofits greatly improved shear strength under reversed cyclic loading, attributed to the relatively elastic-like behaviour of the retrofitted specimens. In addition, retrofits with sufficient FRP strengthening to promote flexural yielding were found to improve ductility by reducing post-yield shear strength deterioration. TaraSenet[6] alshowed that JFRP,CFRP and GFRP strengthening improved the ultimate flexural strength of the RC beams by 62.5%,150% and 125%,respectively,with full wrapping technique and by 25%,50% and 37.5% respectively with strip wrapping technique. JFRP technique displayed highest deformability index and proved the jute textile FRP material has huge potential as a structural strengthening material.

Tara Senet[7] al concluded that the woven jute FRP retrofitting scheme had several advantages over carbon and glass FRP retrofitting scheme and converted brittle failure mode of beams to ductile failure mode. Unlike carbon and glass FRP retrofitting the beams did not undergo any sudden debonding or delamination or FRPrupture and depicted a complete ductile failure mode with high deflections. Non-linear finite element analysis was also conducted and the results were in good agreement with the experimentally obtained ones. Hamidreza Tahsiriet[8] al found that the applied RC jacketing can also improve the ductility; however, the FRP method cannot provide sufficient ductility. Therefore, the RC jacketing can be used in seismic zones as an alternative to the FRP method. In addition, conventional analytical methods are applied for evaluation of ultimate moment, and the results are compared with the experiments. Good agreement between the results verifies the analyses. Mohammad et[9] al showed that using CNT modified epoxy resin enhanced the ultimate load and stiffness of retrofitted beams. The enhancement efficiency highly depends on the level of dispersion of CNT, anchorage length and number of retrofitting layers.SEM characterization showed that CNTs could improve the adhesion at the concrete/epoxy interface and carbon fibre/epoxy interface leading to improvement in the load transfer and ultimate load of the strengthened beams.

Kai Liu et[10] al concluded that the rammed earth wall specimens were strengthened with the proposed retrofitting technique and loaded to failure condition under in-plane shear loading. It was observed that the lateral-load capacity and ductility of the reinforced walls were greatly increased using the proposed technique.Gonzaloet[11] al elucidated that possibility of performing the retrofitting at work place. The repaired beams showed excellent strength and deformation capacity restitution. The strengthened beams exhibited increase of load bearing capacity. The addition of fibres to the concrete played an important role in the prevention of the jacketing debonding from the beams.M.N.S.Hadi[12] showed that there are several parameters that affect the strength of the beams. The results also show that the use of FRP composites for shear strengthening provides significant static capacity increase.

With the help of above studies,In this paper,Rubberized coir fibre sheets were used for retrofitting the beams in flexure and also in shear.Also,different types of Retrofitting techniques were employed for improving the flexural and shear behavior and to increase the stiffness.

II. EXPERIMENTAL STUDY

A. Materials used for Concrete

Cement-OPC-53 grade was used.The properties of cement are specific gravity is 3.15,normalconsistency is 32%,initial setting time is about 49min and final setting time is 6hr 29 min were used.

Fine aggregates-River sand passing through 4.75mm sieve of specific gravity is 2.66,total water absorption is 1.0%,moisture content is 0.16%,and fineness modulus is 2.85 and conforming to grading zone II.

Coarse aggregates-The propertiesof crushed type coarse aggregates are specific gravity is 2.74, total water absorption is 0.6%,fineness modulus is 7.4,maximum size is 20mm and minimum size is of 12.5mm.

B. Materials used for Retrofitting

Rubberized coir fibre sheet(RCFS) was used for retrofitting the beams. The Physical appearance of the sheet is brown in colour. The weight of the sheet is 1 kg/m^2,Load taken is around 75kg/m^2 and the thickness used is 6mm.

C. Bonding Adhesive

Epoxy resin and hardener is a polymer bonding adhesive which is mixed in a ratio of 1:0.8 for better bonding efficiency. Before the application of resin, the surface of the specimen is rubbed or grinded to make the surface rough in order to provide better friction between the rubberized coir fibre sheet and the surface for better bonding purpose. A thin film of 2-3mm is applied on the surface and left undisturbed for 5 minutes. Then, the rubberized coir fibre sheets are placed for repairing.

D. Mix Design

Design mix for M25 grade concrete were arrived as per IS:10262-1999.The mix ratio was 1:1.57:2.535.The water-binder ratio is 0.45.The quantities used were cement content is 437.7kg/m^3,fine aggregate is 688.8kg/m^3,coarse aggregate is 1109.8kg/m^3 and water-197 liters.

E. Specimen Configuration

The reinforced concrete beam specimen size is 150x200 mm and length1.1m.The beams was divided into two groups. Flexure group (RF),focused on flexural behavior and for Shear group(RS),focused on shear behavior. For Flexure group(RF),two specimens are used as control beam and the four specimens are preloaded until the flexural cracks appeared and then retrofitted with RCFS. Two different lengths of RCFS are used and finally the retrofitted specimens are loaded until the failure and results are compared with the control specimens. For Shear group(RS),two specimens are used as control beam and four specimens are preloaded until the shear cracks appeared and then the specimens are retrofitted with RCFS of two different shear wrapping techniques and finally tested upto the failure. Then, the results are compared with control beam. The reinforcement details for both the groups are shown in fig.2.5a.

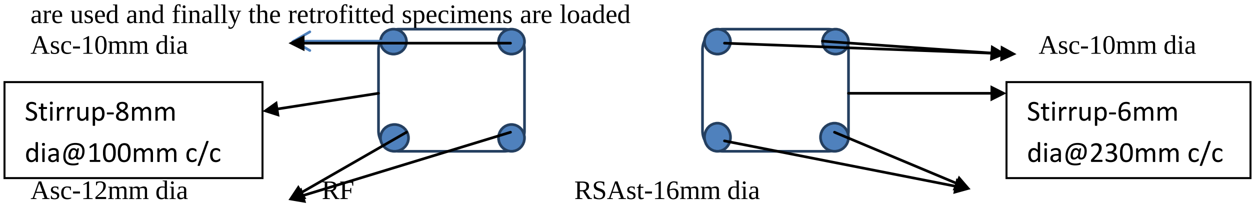
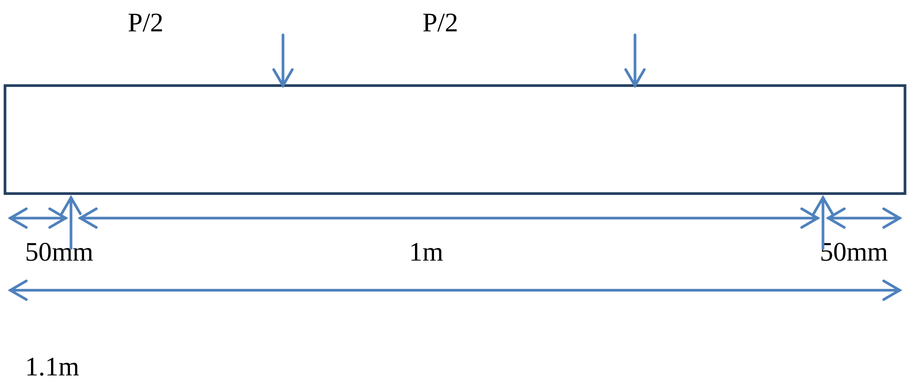


Fig.2.5a Rebar Detailing

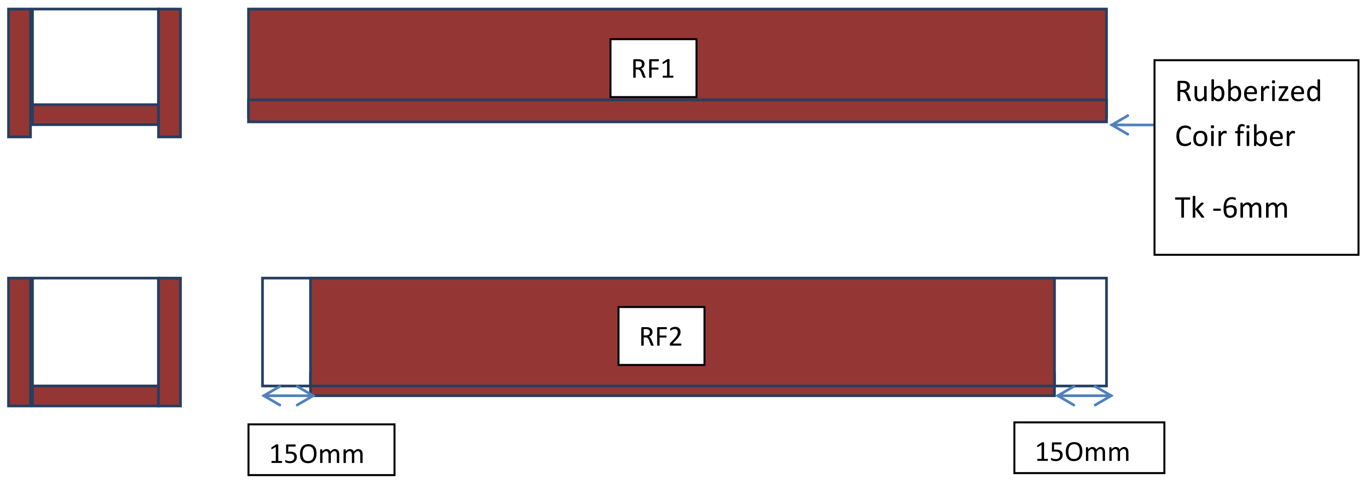
Totally,12 Reinforced concrete beam specimens were casted. As mentioned above, these 12 specimens are divided into two groups. Each group is made to share six beams each. Fig 2.5bshows the retrofitting techniques and Fig2.5c shows the schematic representation of different types of Retrofitting were employed in flexure and in shear.

Fig.2.5b. Retrofitting of Beams

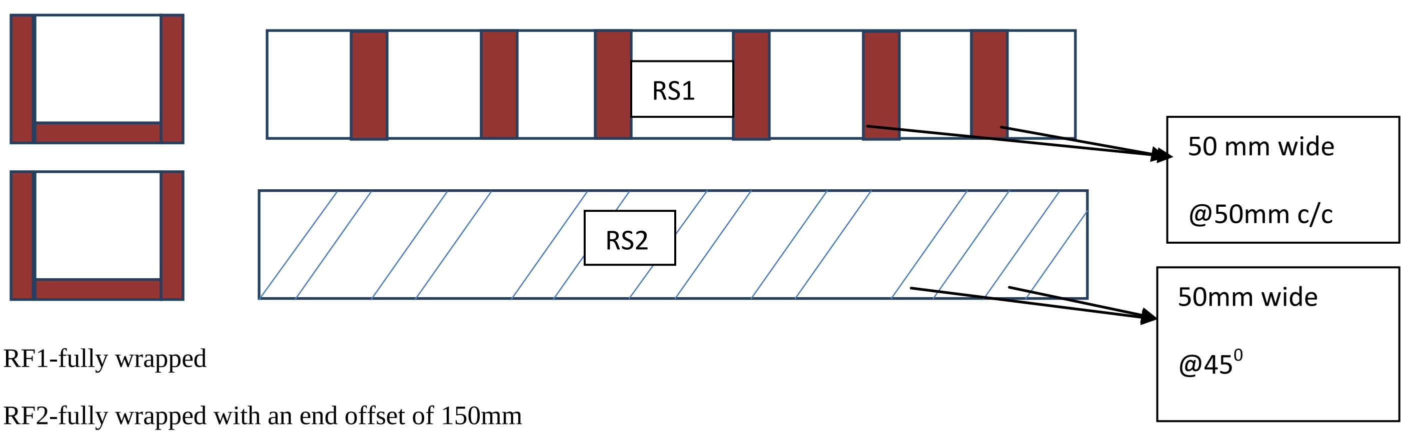
Control beam:



RF group:



RS group:



RF1-fully wrapped

RF2-fully wrapped with an end offset of 150mm

RS1-strips of 50mm size wrapped at a spacing of 50mm c/c

RS2- strips of 50mm size wrapped at an angle of 45^0

Fig.2.5c. Retrofitting Techniques

F. Compressive Strength of Cubes

The concrete cubes of size 100mmx100mmx100mmwere casted and subjected to curing for 3,7 and 28 days. After curing ages, the cubes are tested in compression testing machine which is available in Structural Engineering Laboratory to find the compressive strength for respective curing ages.

G. Test setup

Universal testing machine(UTM) with loading frame of capacity 1000kN for applying load on beam specimens to be tested under 4-point bending is shown in fig.2.6.An I-section is used for 2-point load transformation on the beams from conventional single point loading frame.The length of the specimen between the supports(i.e),the clear span is 1m with the projection of 0.1moutside the supports.The beam specimens were simply supported,with the supports and loading points consisted of pin and roller connection. The 2-point load of 5kN increment is applied at a distance of one-third of length of the beam. A dial gauge of least count 0.01mm is kept at the middle of the beam to measure the midspandeflection**.** Using the observed values, a graph is plotted for load Vs deflection curve. Cracks and their development were recorded and monitored throughout the test.

Fig. 2.7.Universal Testing Machine

In this project, the RC beam specimens were tested under the UTM of 1000kN capacity which is available in Strength of Materials laboratory.

III. RESULTS AND DISCUSSIONS

A. Compressive Strength of Cubes:

Concrete cubes of size 100 mm x 100 mm x100 mm were casted and the maximum load at failure was taken and the average compressive strength is calculated. The graph below shows the compressive strength variation.

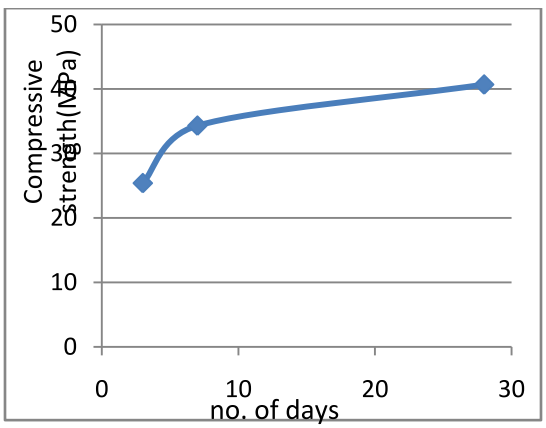


Fig.3.1 Avg. Compressive Strength Variation

B. Test Results of Beams:

1) Beams in Flexure Group(RF)

Control beam

In flexure group RF, the control beams are tested upto failure and deflection values are noted for each load increment of 5kN.Here,the ultimate failure load is depicted as 107.5 and 117.5kN.Hence the maximum load is taken into consideration for comparison. The first crack tends to form around 45kN and after reaching 90kN of load, the flexural cracks tend to increase as load increased upto the failure. The load Vs deflection curve for control beam is plotted and is shown in Fig3.2.1.The test results showed that the beam specimens in flexure group experienced the flexure failure with crushing of the concrete. Flexural cracks were initiated at the soffit of the beam exactly below the loading points. The cracks tend to propagate vertically toward the top of the beam as loads tend to increased. Simultaneously, minute shear hair cracks were developed in the shear span. As the flexural cracks propagated, the tension and compression steel bars start to yield.

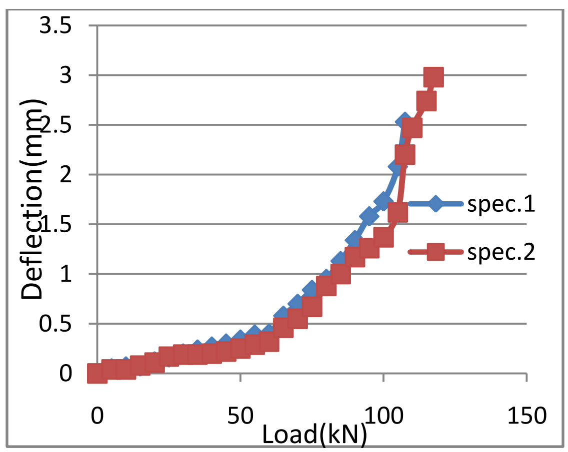
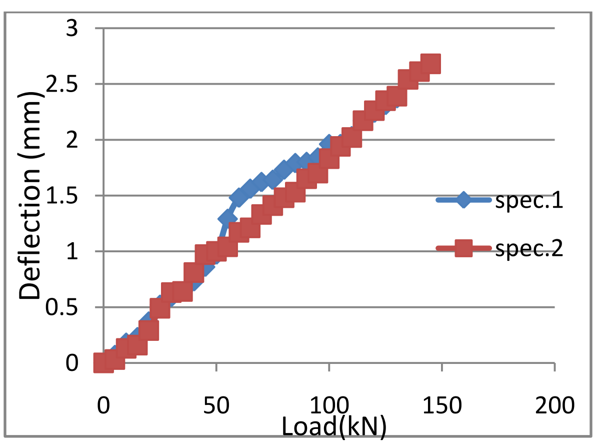


Fig.3.2.1. Load Vs Deflection Curve for Control Specimen-Flexure

2) Retrofitted beam

Before retrofitting the beams, the specimens are subjected to a preload say 30% of the failure load of control specimens. The load-deflection results from the two nominally equal beams in each series are close, which indicates that the retrofitting was performed in well-defined manner. As shown in figure the stiffness of all the beams at minimal load is nearly the same. But at the cracking stage, the stiffness of the control beam decreases notably due to cracking. But for retrofitted beams, the decrease in stiffness is less since the FRCs prevents the cracks to develop and widen. The stiffness of the beam depends on the length of the FRCS. Longer the length of the RCFS, stiffer the beam. It should be noted that when a beam subjected to preloading as mentioned before 30% of failure load, later unloaded, and then subjected to load again, the stiffness would be lesser the second time due to the damage caused in preloading. This shows that the FRCS had improved the beam and restored the stiffness to the level of control beam. The beams retrofitted with RCFS shows adequate strength improvement. The load–deflection behavior of RF1 & RF2 are shown individually and accompanied by the comparing graph between RF1&RF2 with control beam. The ultimate failure load is depicted as 145kN for RF1 which is 23% more than control beam and 137.5kN for RF2 which is 17% more than control beam.Fig.3.2.2a.below shows the load-deflection behavior of retrofitted beams. Almost all the beams experienced the brittle failure mechanism, however in this case sudden debonding of RCFS sheet from the concrete occurred without concrete splitting. This is due to the high shear stress at the ends. For RF2,the debonding occurred earlier when compared to RF1,because RF2 do not have full RCFS anchorage length. The crack propagation and final crack pattern of the beam are greatly different from that of control beam. The control beam had few flexural cracks with large width, whereas the retrofitted beam had many flexural cracks with smaller width. This indicates that the propagation of cracks was confined by FRCS laminates. The results indicate that the externally bonded FRCS has increased the stiffness and maximum load of the beam. Inaddition, the crack width and the deflection have decreased.

RF1



RF2

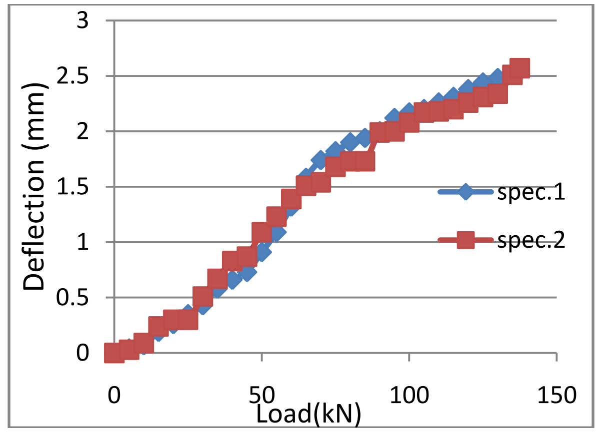


Fig.3.2.2. Load Vs Deflection Curve for Retrofitted Specimen-Flexure

Comparison of RF1 & RF2 with Control Beam-Flexure

The graph below shows the comparison of load-deflection behavior between control specimens and the retrofitted specimens, and it is clearly found that the deflection is greatly reduced for retrofitted specimens.

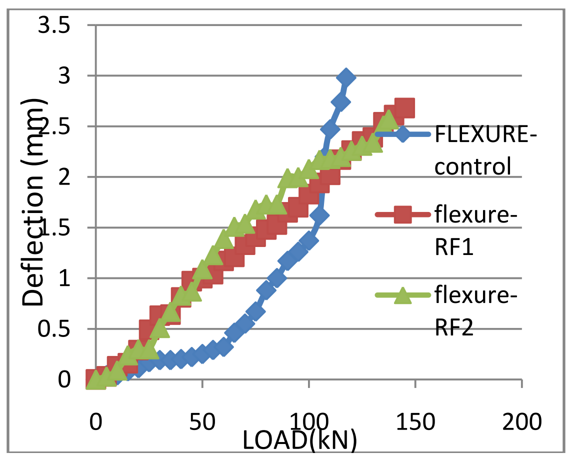


Fig.3.2.2b.Load Vs Deflection Curve Comparison forRF1&RF2 with Control Specimen

3) *Beams in Shear Group(RS)*

Control beam

In Shear group RS, the control beams are tested and the load Vs deflection curve for control beam is shown in fig. Since the beam specimens were weak in shear, the shear cracks tend to propagate at the initial stages of loading itself. The specimen clearly failed in a brittle manner with sudden destruction and has very low energy absorption before failure. Here, the ultimate failure load is depicted as 97.5 and 107.5kN.Hence the maximum load (107.5kN) is taken into consideration for comparison. The first crack tends to form around 50kN and after reaching 77.5kN of load, the shear cracks tends to increase upto the failure. In this case, as mentioned earlier the beam failed in a brittle manner and has low energy absorption before failure. The failure crack patterns shown the pure diagonal shear crack at shear spans, the failure is due to the insufficient shear steel.

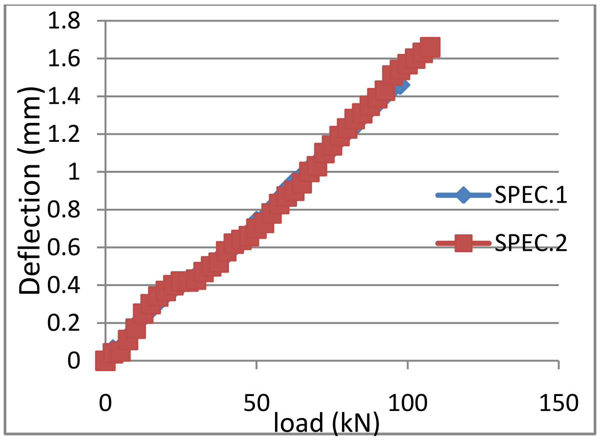
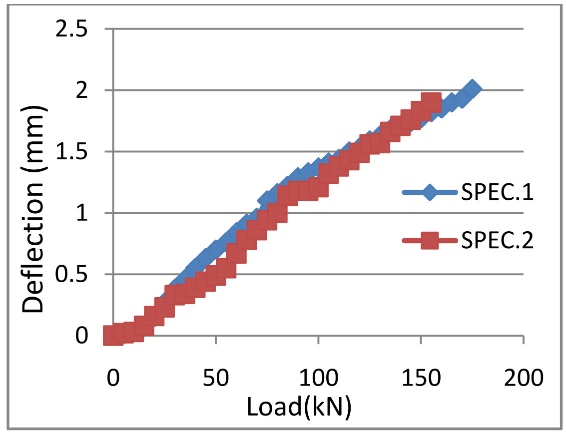


Fig.3.2.3 loadVs Deflection Curve for Control Specimen-Shear

*4) **Retrofitted Beam***

The beams retrofitted with RCFS shows adequate gain inshear strength. The debonding failure occurred for this group also. The load–deflection behavior of RS1 & RS2 are shown individually and accompanied by the comparison graph between RS1&RS2 with control beam. The ultimate failure load is depicted as 175kN for RS1 which is49% more than control beam and 195kN for RS2 which is 65% more than control beam. The crack propagation as well as deflection is greatly reduced. The control beams suffered from more softening due to crack propagation, while in retrofitted beam, the cracks are arrested by the RCFS. For RS2,the cracks were arrested greatly when compared to RS1,due to the diagonal wrapping of RCFS. Buthere, the sudden failure of the beams prevented.

RS1



RS2

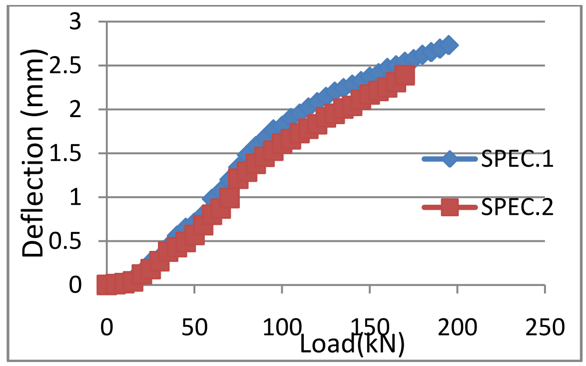


Fig.3.2.4a.Load Vs Deflection Curve for Retrofitted Specimen RS1 & RS2

Comparison of RS1 & RS2 with Control Beam-Shear

The graph below shows the comparison of load-deflection behavior between control specimens and the retrofitted specimens, and it is clearly found that the deflection is greatly reduced for retrofitted specimens.

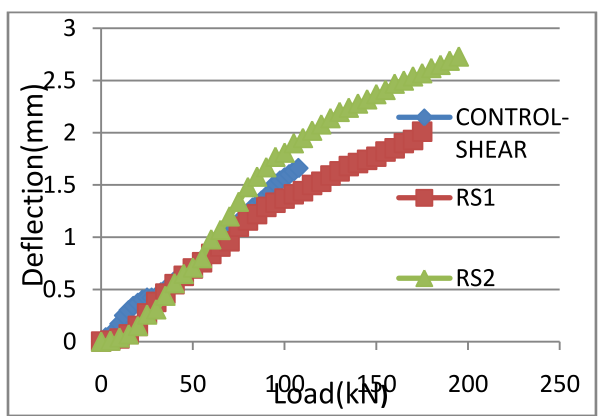


Fig.3.2.4b. Load Vs Deflection Curve Comparison of RS1 & RS2 with Control Beam

IV. CONCLUSION

This paper projects the flexural and shear behavior of reinforced concrete beams retrofitted with Rubberized coir fibre sheets after preloading. The conclusions drawn from the entire study were:

- The stiffness of the RCFS retrofitted beams are greatly increased when compared to the control beams.
- Also the deflection of retrofitted beams was reduced predominantly at the early stages of loading.
- The ultimate load atfailure of specimen was increased.
- Since,FRCS is used for retrofitting; the increase in maximum load is appreciable.The increase in ultimate load of the retrofitted specimens reached values of about 23% for specimen group RF1 and of 17% for RF2.Similarly,for RS1,the ultimate load carrying capacity comes out to an increment of 49% for RS1 and of about 65% for RS2.
- The test results showed that the complete wrapping in flexure(RF1) tends to give the maximum efficiency when compared to RF2.While in shear, inclined wrapping (RS2) showed greater results when compared with RS1.
- Instead of replacing the entire structure, it would be better to go for retrofitting.

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