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SHEAR STRENGTHENING OF REINFORCED CONCRETE BEAMS USING FRP STRIPS

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ABSTRACT:
Shear failure in reinforced concrete structures is one of the critical problems in Civil Engineering. As Shear failure is brittle in nature and identified as the most disastrous failure mode more attention is required. At present Fiber reinforced polymer (FRP) composites are widely used for strengthening. Sticking of FRP strips with epoxy resin is easy and effective in strengthening of structures. Beams, Slabs and Columns can be easily repaired rehabilitated with FRP strips putting minimum effort. I n current study beams are strengthened in shear using FRP strips. Beams (150mm x 200mm x 700mm) were casted and cured for 28 days. In order to make the beams to be fail in shear they are designed such as deficient in shear by taking the design load smaller than obtained. Then FRP two layered strips of Glass, Carbon and Basalt were sticked to beams by epoxy resin in two ways. FRP Strips 67mm, perpendicular to longitudinal axis of beam at a specified spacing and FRP Strips 34mm, perpendicular & inclined at 63.43^0 to the longitudinal axis of beam. Now beams were loaded until failure. Ultrasonic pulse velocity method is carried out during testing. Failure load, deflection curves, ultrasonic pulse velocities were obtained. For BGS-67% increase in load carrying capacity compared to control beam is 84.36%. For BGI-34% increase in load carrying capacity compared to control beam is 73.72%. For BCS-67% increase in load carrying capacity compared to control beam is 159.12%. For BCI-34% increase in load carrying capacity compared to control beam is 133.92%. For BBS-67% increase in load carrying capacity compared to control beam is 74.24%. For BBSI-34% increase in load carrying capacity compared to control beam is 80.34%. Beams with straight strips are effective in load carrying capacity compared to inclined strips. From ultrasonic pulse velocity test, it is obtained that velocity drop is more in inclined strips compared to straight strips. Out of all BCI-34 is having more velocity drop from load deflection curves straight strips BGS-67, BCS-67, BBS-67 have more displacement i.e, Ductile when compared to inclined strips BGI-34, BCI-34, BBIS-34. Among all beams BCS-67 carries a maximum load of 445.7 KN

1.0 INTRODUCTION

Earlier structures have been constructed with significant number of facilities using reinforced or pre-stressed concrete materials. During next century many of them have reached the end of their planned service life. Many natural disasters especially earthquakes made necessary to increase the safety levels of buildings etc. That leads to consequences like steel corrosion, concrete cracking and spalling is observed frequently. Many of the structures were built to carry loads are significantly smaller than the current needs. Older structures that were designed using past codes are unsafe need to be upgraded. Complete replacement of such deficit structures leads to incurring and huge amount of public money and time. Retrofitting has become important for improving their load carrying capacity and extending their service lives. Hence it is a challenge for structural engineer to evaluate and implement effective and economical repair and strengthening programs.

STRENGTHENING TEQNIQUES FOR RC BEAMS

Concrete jacketing

Involves addition of a thick layer of Reinforced Concrete (RC) in the form of a jacket, using longitudinal reinforcement and stirrups.

- To increase strength additional concrete and reinforcement is needed.
- 100 mm is the minimum allowable thickness of the jacket.
- The sizes of the sections are increased and the free available usable space becomes less.
- Huge dead mass is added.

- The stiffness of the system is highly increased.
- Requires adequate dowelling to the existing beam.

Figure: Concrete Jacketing

STEEL JACKETING

- Encasing the beam with steel plates and filling the gap with a non-shrink grout.
- Provides passive confinement to core concrete.
- Its high young's modulus causes the steel to take a large portion of the transverse load resulting sometimes in premature bending of the steel.
- General thickness of grout = 25 mm.
- Its demerits are difficulty in welding work in the field, problem of corrosion which increases the cost of maintenance.

Figure: Steel jacketing

STEEL PLATE BONDING

This method of steel plate bonding is in use for 39 years and now a days, it is using around the world. In this method epoxy adhesive is used to create bonding between mild steel plates and the soffit of the beam. There is no chance to increase its depth or its dead load practically. The method is versatile, flexible, economical and expedient. The inter-layer bond between concrete and plate effects the resulting composite system. Anchor plates are needed where the width-thickness ratio of the plate is less than 50:1 due to production of high stresses near the ends of the plates leading to premature failure. If any member affected by the corrosion then the member is not suitable to do the steel plate bonding technique.

EXTERNAL PRESTRESSING

External Pre-stressing refer to a post –tensioning method in which tendons are placed on the outside of the structural member, except deviators and at anchors. Deviators and anchorage zones have no relation with the shape of the concrete structure.

FRP COMPOSITES:

Fiber reinforced polymer (FRP), reinforcement has become increasing popular in the construction market started to use FRP for structural reinforcement, the FRP raw material costs sometimes higher but are frequently offset by reduced labor, generally in combination with other construction materials such as wood, steel, and concrete. FRP composite systems are made up of high strength continuous fibers, such as carbon or glass, embedded in a polymer resin matrix. Because of FRPs several properties are improved such high stiffness-weight ratio, flexibility in design, non-corrosiveness, high fatigue strength, and ease of application.

FRP COMPOSITES ADVANTAGES

- Non corrosive
- easily rolled which makes transportation easy
- High fatigue resistance
- High strength to weight ratio
- Time required for installation is very less

OBJECTIVES:

- To investigate the shear performance and mode of failure of RC beams after strengthening with Different FRP strips
- To study the effectiveness of these FRP reinforcement in enhancing the shear capacity of RC beams
- To investigate the FRP Strips perpendicular to longitudinal axis of beam at a specified spacing
- To investigate the FRP Strips perpendicular to longitudinal axis of beam at a specified spacing and perpendicular & inclined at 63.43^0 to the longitudinal axis of beam
- To compare different configurations of RC beams which fail in shear are casted and strengthened FRP

2.0 LITERATURE REVIEW

T. H. Patel, Dr. K. B. Parikh [1] The current paper reviews there is significant increase in the shear strength up to 50% can be achieved by bonding GFRP sheets to the sides of the RC beams. The presence of GFRP inclined strips on the beam inhibited the development of diagonal cracks. The rectangular GFRP strip were found to be effective in strengthening than the GFRP circular rods

I. A. Bukhari*, R. L. Vollum [2] The current paper reviews existing design guidelines for strengthening beams in shear with CFRP sheets. Tests showed that it is beneficial to orientate the fibres at 45^0 to longitudinal axis of beam

Amir Mofidi1 and Omar [3] The current paper reviews results of an experimental and analytical investigation of shear strengthening of RC beams with externally bonded FRP strips and sheets. Beams strengthened with wider CFRP strips achieved greater 'v_f'values than beams with narrower strips. Boding FRP strips midway between steel stirrups results in an increase in the maximum failure load and stiffness of the RC beam compared to bonding FRP strips in the same location of steel stirrups.

3.0 MATERIALS AND METHODS

CEMENT: Ordinary Portland cement of 53 grade (KCP CEMENT) confirming to IS 12269:1987 was used in this study. Properties are shown in table

Table: 3.1 Properties of Portland cement 53 grades

Type of cement	Fineness by air permeability method(m2/kg)	Setting time(min)		Compressive strength in Mpa		
OPC-53 grade	225	Initial	Final	3 days	7 days	28days
		75	125	**32**	**37.8**	**53**

WATER

Water fit for drinking is generally considered for making concrete. Water should be free from acids, oils, vegetables or other organic impurities. Soft water also produces weaker concrete; Water has two functions in a concrete mix. Firstly, it reacts chemically with the cement to form a cement paste in which the inert aggregates are held in suspension until the cement paste has hardened.

Glass fiber reinforced polymer sheet:

GFRP is a composite construction material resulting from the combination of unsaturated polyester based resin used as a binder with glass fiber. Glass Fiber Reinforced Polymers are a proven and successful alternative that have numerous advantages over traditional reinforcement methods, giving structures a longer service life.

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Figure: Glass fiber reinforced polymer sheet

Table: 3.2 properties of glass fiber

CODE	W oven pattern	Thickness(mm)	Tensile strength (Mpa)
GLASS	bi-directional	0.11	2358

Basalt fiber reinforced polymer sheet:

Basalt fiber reinforced polymer sheet is a natural material that is found in volcanic rocks. This was mainly used in crushed rock in the construction, industrial and high way engineering. Basalt can also melts (1300-1700°C) and spin it into fine fibers.

Figure: Basalt fiber reinforced polymer sheet

Table: properties of basalt fiber

CODE	W oven pattern	Thickness (mm)	Tensile strength (Mpa)
BASALT	bi-directional	0.1	2100

Carbon fiber reinforced polymer sheet:

Carbon fiber reinforced polymer (CFRP)is an extremely strong and light fiber-reinforced plastic which contains carbon fibers. CFRP has highest modulus of elasticity among all reinforcing fibers.

Table: properties of carbon fiber

CODE	W oven pattern	Thickness(mm)	Tensile strength (Mpa)
CARBON	bi-directional	0.11	3500

EPOXY RESIN:

Epoxy resins are used in the manufacture of adhesives, plastics, paints, coatings, etc; This was relatively low molecular weight pre-polymers capable of being processed under a variety of conditions. Epoxy resin is extremely strong and has great flexural strength. This epoxy resin gives low strength in cure.

Table: Proportions of ingredients in mix design

Cement	Fine aggregate	Coarse aggregate		Water
		20 mm	10 mm	
385	614	754.5	503	173.3
1 Kg	1.595Kg	2.123kg	1.45kg	0.45 lt

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Experimental procedure:

For this study, beams of size 150mmx200mmx700mm were prepared. Steel reinforcement cage consists of 4#12mm on tension side and 2#8 mm on compression side as longitudinal reinforcement and 6mm at 91.31 mm spacing as stirrups. Steel used is of Fe 415 grade.

BGS-67	Beam Glass Straight strip of 67mm width double layered
BGI-34	Beam Glass Straight and Inclined strip 34mm width double layered
BCS-67	Beam Carbon Straight strip of 67mm width double layered
BCI-34	Beam Carbon Straight and Inclined strip of 34mm width double layered
BBS-67	Beam Basalt Straight strip of 67mm width double layered
BBIS-34	Beam Glass Straight and Inclined Single layered strip of 34mm width

PREPARATION OF BEAMS

After oiling the beam moulds reinforcement cage (fig 4.3) was placed in the mould.As per the mix design concrete was prepared then beams were casted and compacted on table vibrator.After 24 hours , beams were de-moulded and immersed in water in order to cure for 28 days

Figure: Casting of beams

Mixing of chemical is must be done properly that it mixes thoroughly By using a brush epoxy was applied on surface of beams and FRP sheet was stacked and wrapped around the beams that they are kept undisturbed for 3 days for complete hardening of epoxy.

Figure: BGS-67, BGI-34

Figure: BCS-67, BCI-34

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TESTING OF CONTROL BEAM

The control beam was tested in shear under two-point loading until failure The failure load was noted. Load deflection curve was also obtained. The control beam was failed in shear as the cracks travelled diagonally from supports to load points

Figure: Failure of BGS-67, BGI-34

Figure: Failure of BCS-67, BCI-34

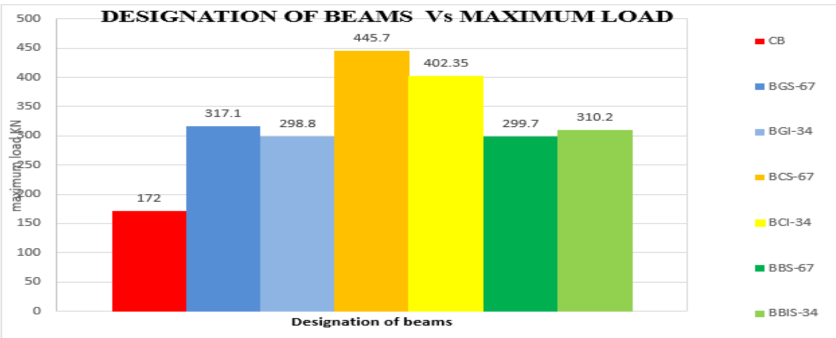
Figure: Failure of BBS-67, BBIS-34

4.0 TEST RESULTS

The failure loads and displacements at failure of the beams were noted and tabulated as below

Table: Failure loads and displacements of beams wrapped with FRP sheets.

Beam Designation	Maximum load (KN)	Displacement at maximum load (mm)
CB	172	
BGS-67	317.1	8.5
BGI-34	298.8	8.2
BCS-67	445.7	13.7
BCI-34	402.35	7.8
BBS-67	299.7	9.1
BBIS-34	310.2	8



Graph: Designation of beams Vs Maximum load

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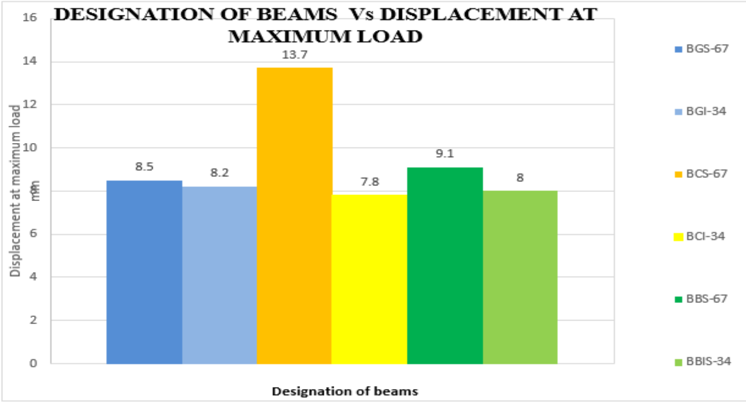

Graph: Designation of Beams Vs Displacement at Maximum Load

LOAD Vs DISPLAEMENT CURVES

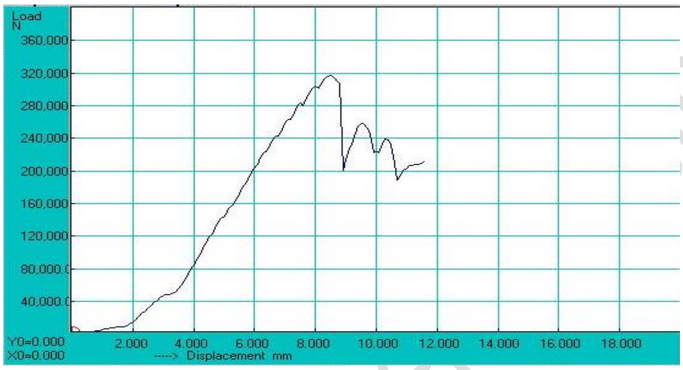

Figure: Load Vs Displacement curve for BGS-67

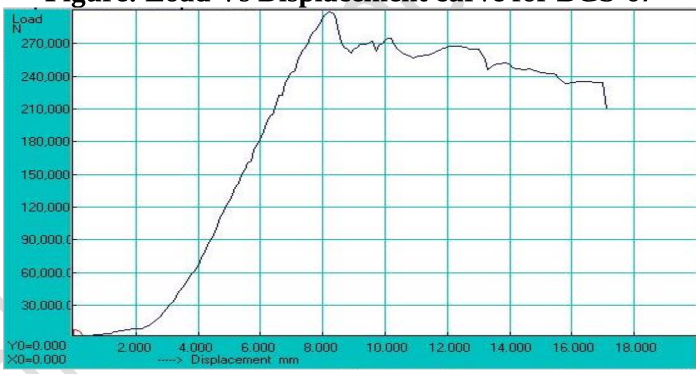

Figure: Load Vs Displacement curve for BGI-34

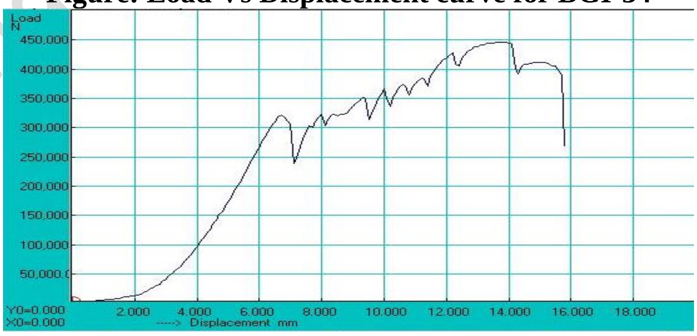

Figure: Load Vs Displacement curve for BCS-67

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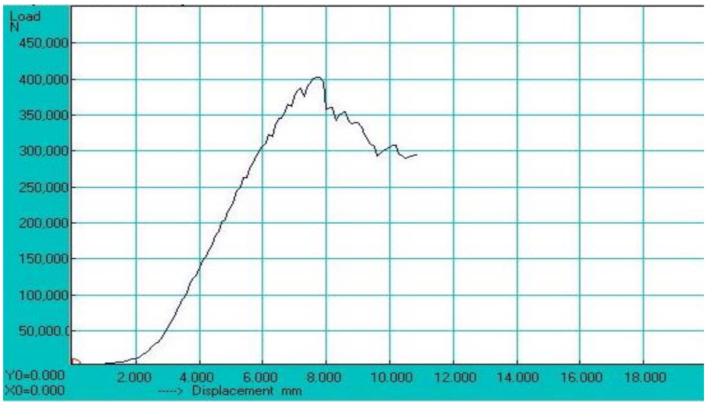

Figure: Load Vs Displacement curve for BCI-34

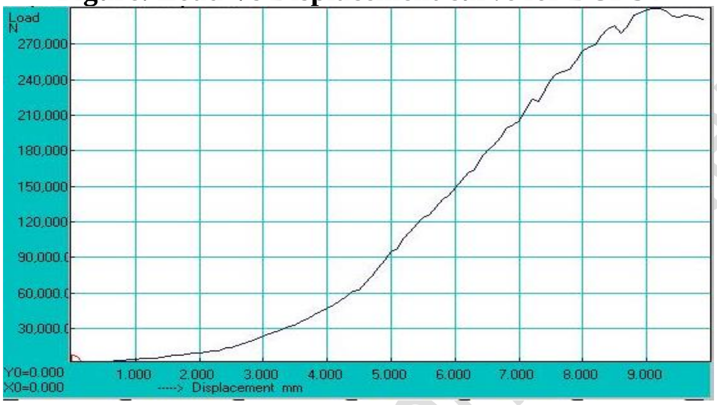

Figure: Load Vs Displacement curve for BBS-67

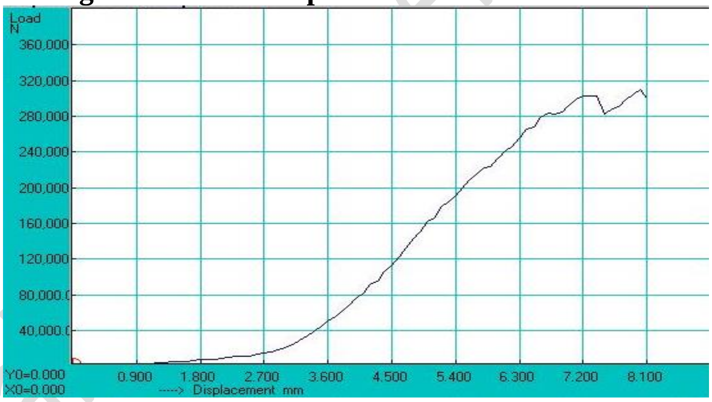

Figure: Load Vs Displacement curve for BBIS-34

CONCLUSIONS:

Following are the conclusions from the study

- Compared with control beam (CB), all FRP strengthened beams are showing increased shear carrying capacity.
- 2.Compared to the control beam (CB), the % increase in the load carrying (shear strength) capacity of BGS-67is 84.36%, BGI-34 is 73.72%, BCS-67 is159.12%, BCI-34 is 133.92%, BBS-67 is 74.24%, BBSI-34 is 80.34%.
- % Increase in load carrying capacity is more for BCS-67which is 159.12% (maximum load is 445.7KN of control beam
- Straight strips are more effective in carrying more load when compared to both Inclined & straight strips.
- For BCS-67 displacement at maximum load is13.7mm which is maximum when compared to all other beams i.e, it is more ductile.
- Beams with straight strips are more ductile, as the displacement is more, when compared to beams with both inclined and straight strips.

- From ultrasonic pulse velocity test, it is observed that velocity drop is less in case of BGI34, BGS67 and BCI-34.
- Beams with Glass FRP strips have better crack arresting property as they have less velocity drop.
- Out of all three types of FRP used CARBON is giving better results.

Shear strengthening of beams with FRP sheets is effective and easy though having some drawbacks against fire and weathering. The original strength/capacity of beam in shear can be improved.

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