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To Study the Effect of Different Strengthening Patterns Using GFRP on Shear Capacity of the Beam

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Abstract

The maintenance, rehabilitation and upgrading of structural members is perhaps one of the most crucial problems in civil engineering applications. This research study presents to Study the Effect of Different Strengthening Patterns Using GFRP (Glass Fibre Reinforced Polymer) on Shear Capacity of the Beam. Totally twelve rectangular beams having 700 mm x 150 mm x 150mm were casted. The variables considered includes three different grades of concrete i.e. M20, M30, M 40 and three different strengthening schemes were adopted (i.e. U shape vertical strip wrap "UVS", U-wrap-"U", Vertical strip at 50˚ "VS 50˚"). Shear test, using simple beam with two- point loading was adopted in UTM testing Machine to study for the performance of GFRP wrapped beams in terms of increase in shear capacity and deflection and it was compared with the blank beams. The test results show that the beams strengthened with GFRP laminates exhibit better performance. The shear strength is increased by applying different pattern of GFRP strengthening scheme. The ultimate shear strength is increased by 35%, 34% and 11% in U-shape wrapping beam in M20, M30 and M40 respectively.

1. Introduction

The maintenance, rehabilitation and upgrading of structural members is perhaps one of the most crucial problems in civil engineering applications. This research study presents to Study the Effect of Different Strengthening Patterns Using GFRP (Glass Fibre Reinforced Polymer) on Shear Capacity of the Beam. Totally twelve rectangular beams having 700 mm x 150 mm x 150mm were casted. The variables considered includes three different grades of concrete i.e. M20, M30, M 40 and three different strengthening schemes were adopted (i.e. U shape vertical strip wrap "UVS", U-wrap-"U", Vertical strip at 50˚ "VS 50˚"). Shear test, using simple beam with two-point loading was adopted in Material testing laboratory at MEFGI, Rajkot to study for the performance of GFRP wrapped beams in terms of increase in shear capacity and deflection and it was compared with the blank beams. The test results show that the beams strengthened with GFRP laminates exhibit better performance. The shear strength is increased by applying different pattern of GFRP strengthening scheme. The ultimate load increases from 7 to 35 % in various strengthening patterns in different grades of concrete.

Steel plates and FRP are bonded on the surface of concrete member with the help of epoxy resins. This is very effective technique in reducing crack widths and deflections. Surface technique is greatly increased and failure takes place within concrete. In this method thickness of adhesive is kept low because of creep effects.

FRP is more efficient than steel plates because of easy mobility. FRP Wrapping system is select as a strengthening system for this experimental study.

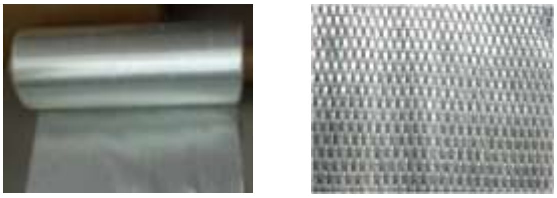
2. Materials & Method

2.1 Materials

Cement: 53 Grade Ordinary Portland Cement (OPC) Ultratech Cement conforming to IS: 12269-1987.
Sand: Locally available river sand conforming to grading zone-2 as per IS: 383-1970.
Coarse aggregate: Crushed stone coarse aggregate of maximum size 20 mm and 10 mm as per IS: 2386-1963.
Water: Water available in the college campus conforming to requirements of water for concreting and curing as per IS: 456-2000.

2.2 GFRP Sheet

Unidirectional Glass Fibre Reinforced Polymer (GFRP) sheet is used for the study. Figure 2.1(a) and Figure 2.1(b) shows the roll of GFRP sheet and its closer view respectively. Table 2.1 and Table 2.2 shows the properties of the GFRP sheet and Epoxy Resin respectively given by the manufacturer.



(a) GFRP Sheet Roll (b) Unidirectional Glass Fibre Sheet

Table: 2.1 GFRP Sheet property

Thickness per ply (t_f)	0.358 mm
Ultimate tensile strength (f_{fu}*)	2300 MPa
Rupture strain (ε_{fu}*)	0.045 mm/mm
Modulus of elasticity (E_f)	76000 N/mm^2

Table: 2.2 Properties of Epoxy Resin

Aspect	Free flowing liquid
Mixed density	1.16 kg/litre
Volume solids	100%
Mixing ratio, by weight	Part A: Part B = 100 : 34.5
Consumption	0.4 to 1.0 kg/m^2
Pot life	65 min at 30°c
Tensile Strength	45 N/mm^2

2.3 Configuration of Beams

The dimensions of beam were to be finalised of length 700 mm, breadth 150 mm and depth 150 mm. As a longitudinal reinforcement at bottom and top 2 bars of 10 mm diameter were provided. As shear reinforcement 4 ring of 6mm diameter were provided at spacing of 200 mm c/c. only 10 mm size is used for better shear failure.

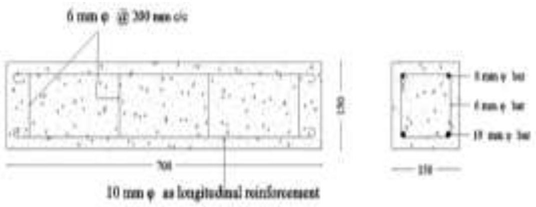


Fig 2.2: The Reinforced detailing of beam

2.4 Casting of Beams

All the specimens were casted in the Material testing Laboratory. Beams were casted as per the grades (i.e. M20, M30, M40) of mix proportions according to IS 10262-2009. Test was carried out using UTM (Universal testing machine) after 28 days of curing.

2.5 Strengthening of Beams

First of all the concrete surface was made rough using a coarse sand paper texture and cleaned with an air blower to remove all dirt and debris. After preparation of the required surface the epoxy resin was mixed in accordance with manufacturer's instructions. The material was provided by the Sika Company that is part A and part B like base and hardener and mixing ratio was 100 (Base):34.5 (hardener). First epoxy was applied to the beam surface as per given ratio. Then the glass fibre sheet was applied. Proper compaction using roller was done to ensure good contact between the epoxy, concrete and fabrics.

2.6 Beam Designations

As per the above discussion, the beams were give designations for different strengthening schemes mentioned below in table 2.3.

Table: 2.3 Wrapping Scheme

Strengthening Scheme	Designations
Blank (Control) Beam	" B "
U Shape Vertical Strip	" UVS "
U shape	" U "
Vertical Strip 50°	" VS 50° "

2.7 Detail of specimens

Table: 2.4 Detail of specimens

Grade / Designation	M 20	M 25	M30	Total
Blank " B "	1	1	1	3
" UVS "	1	1	1	3
" U "	1	1	1	3
" VS 50° "	1	1	1	3
				12

2.8 GFRP Wrapping Beams

Flexural and shear failure are main failure modes of normal RC beams. Shear strengthening is more important than flexural failure. In this experimental work three shear strengthening schemes were adopted. For strengthening "U-shape vertical strip", "shear U-wrap" and "Vertical strip with 50°"scheme were adopted. Figure 2.3 shows the GFRP wrapping different strengthening patterns of beam.

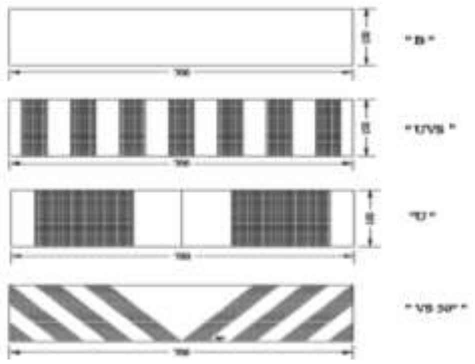


Fig.2.3 Wrapping Patterns

3. Experimental Set-Up

After the curing period of 28 days over, the beam was washed and its surface was cleaned for clear visibility of cracks. Two-point loading can be provided by the arrangement shown in figure 2.4. The load is transmitted through a load cell and spherical seating on to a spreader beam. This beam bears on rollers seated on steel plates bedded on the test member with mortar, high-strength plaster or some similar material. The test member is supported on roller bearings acting on similar spreader plates. Dial gauge was used for recording the mid span deflection of the beams.

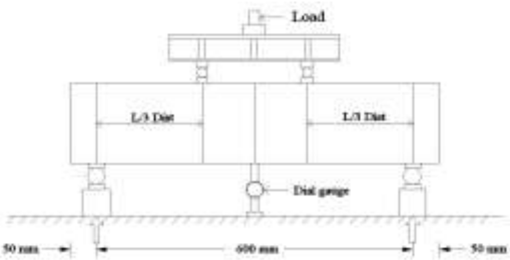


Fig.3.1 Two Point Loading Experimental Set Up

3.1 Procedure

After setting the test set-up with dial gauge check the member dimensionally, and a visual inspection made with all information carefully recorded. After setting and reading of dial gauge, the load was increased gradually, with load and deflection recorded at each stage. Loads will then normally be increased again in similar increments up to failure. Some safety precautions must be taken during testing. It is essential that deflection readings were taken up to the collapse. First Crack Load, Cracking and failure mode was checked visually and a load/deflection plot was prepared. The figure shows the experimental set up of UVS beam.

Fig.3.1 Testing of UVS Beam

4. Results & Discussion

4.1 Results

The major criteria for this study are to analyse the shear performance of RC beams. The ultimate load, first crack load and mid span deflection was measured of beam as well as for different strengthening schemes using GFRP. So the results can be classified in to three different categories named as comparison of grades, comparison of different strengthening schemes.

4.2 Comparison of Grades (M20, M30, M40)

In this experimental study M20, M30 and M40 were taken as a concrete grades. It shows the comparison between three different grades. Graphical representation of load Vs mid span deflection is shown in figure 4.1 to 4.4.

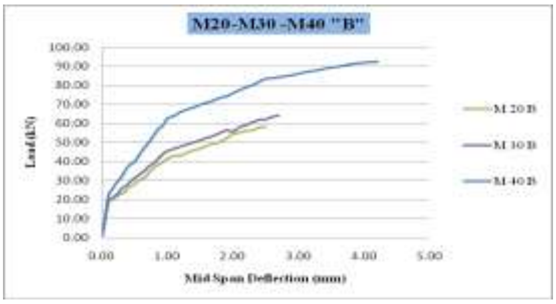


Fig 4.1 Load Vs mid span deflection of grades for "B"

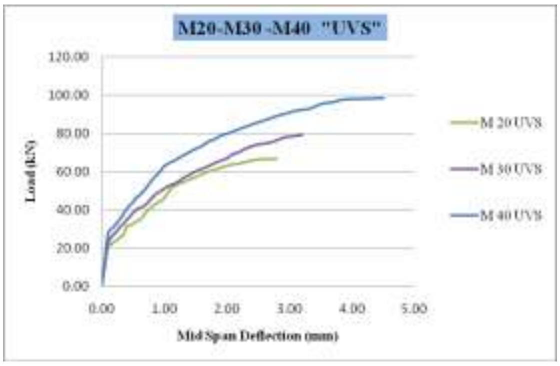


Fig 4.2 Load Vs mid span deflection of grades for "UVS"

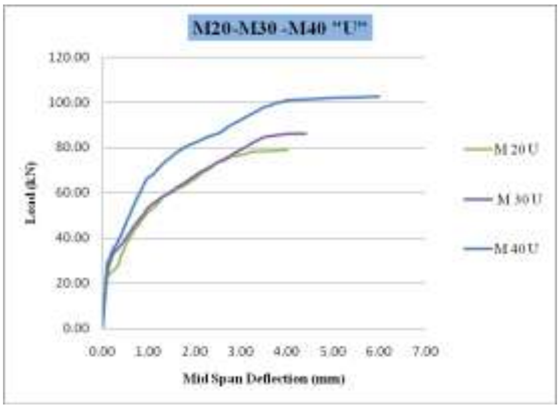


Fig 4.3 Load Vs mid span deflection of grades for "U"

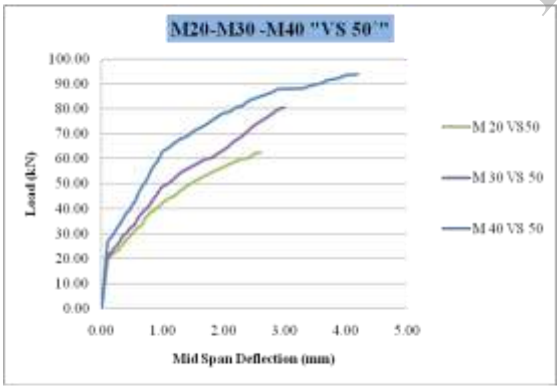


Fig 4.4 Load Vs mid span deflection of grades for "VS 50°"

In this experimental study load and deflection of all beams are recorded. The comparison shows load vs mid span deflection of four different beams like un-wrapped (Control), U-shape vertical strip (UVS), U-wrap (U) and V-shape inclined strip at 50˚ (VS 50˚). In all cases improvement in load capacity is observed and increases load bearing capacity in U wrap is higher than other two UVS and VS 50˚. Study shows that load vs deflection behaviour is not affected by strengthening patterns significantly.

4.3 Comparison of strengthening schemes

In this experimental study graphs shows comparison of different strengthening schemes. It is the comparison of un-wrapped (control) beam with externally strengthened beams that is "U-shape vertical strip wrapping", "U-shape wrapping" and "V-shape inclined strip at 50˚". Graphical presentation of load vs mid span deflection for each grade of strengthening scheme is given in figure from 4.5 to 4.7.

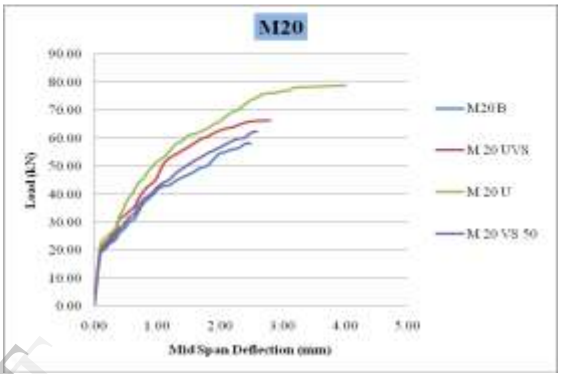


Fig 4.5 Load Vs mid span deflection of M20 grade

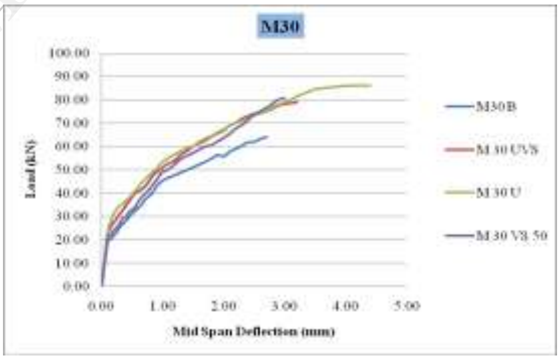


Fig 4.5 Load Vs mid span deflection of M20 grade

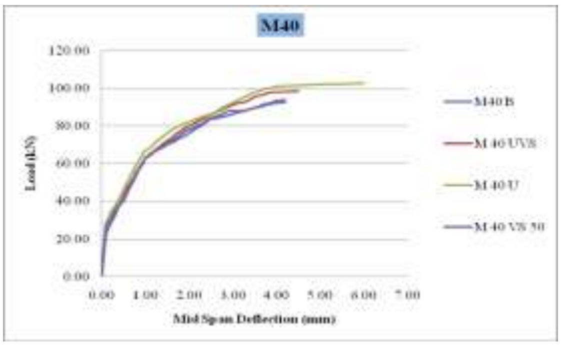


Fig 4.6 Load Vs mid span deflection of M40 grade

The graphical representation shows load deflection behaviour of different strengthening schemes. The result shows that the ultimate strength is comparatively increased with increasing grade of concrete. U-wrapping is the most effective technique for strengthening beams in shear. For each grade U-wrapped beams performed well and increases load bearing capacity. VS 50˚ is also an effective strengthening scheme in shear but it is not as satisfactory as U wrap.

4.4 Comparison of strengthening schemes

The comparison shows first crack load and its increase in percentage. It shows that U-schemes have better result in all scheme followed by UVS and VS 50˚ for all grade of concrete. The first crack load increases from 6 to 37 % in M20 grade, 9 to 40 % in M30 grade and 12 to 40 % in M40 grade of concrete. The result shows that in all beams strengthening with GFRP delays the crack formation.

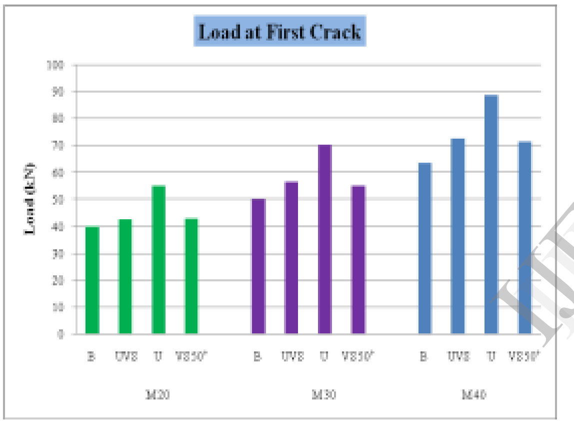


Fig 4.8 Load at Initial Crack for different grads and strengthening schemes

4.5 Comparison of Ultimate Crack Load

The comparison shows ultimate load and its increase in percentage. It shows that U-schemes have better result in all scheme followed by UVS and VS 50˚ for all grade of concrete. The ultimate load increases from 7 to 35 % in M20 grade, 25 to 34% in M30 grade and 2 to 11 % in M40 grade of concrete.

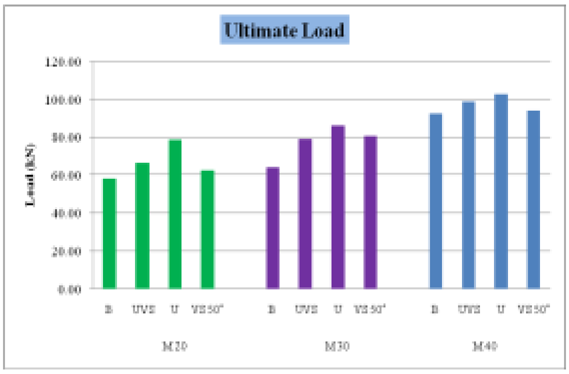


Fig 4.9 Ultimate Load for different grads and strengthening schemes

5. Conclusion

The control beam B for all grade of concrete failed in shear as it was made intentionally weak in shear.

- ✓ The ultimate load increases from 7 to 35 % in various strengthening patterns in different grades of concrete.
- ✓ In three schemes, U-wrap scheme shows highest improvement in load carrying capacity than UVS scheme and VS 50˚. VS 50˚ and UVS schemes are also showing good strength than the control beams.
- ✓ After strengthening the shear zone of the beam the initial cracks appears at the flexural zone of the beam and the crack widens and propagates towards the neutral axis with increase of the load. The final failure is flexural failure which indicates that the GFRP sheets increase the shear strength of the beam. The ultimate load carrying capacity of the strengthen U shape beam is 35 % more than the controlled beam B.
- ✓ The bonding between GFRP sheet and the concrete is intact up to the failure of the beam which clearly indicates the composite action due to GFRP sheet.
- ✓ De-lamination of GFRP sheet was observed in M40 grade after developing first crack in VS 50˚.
- ✓ Shear crack takes place in control RC beams while strengthening with GFRP it reduces the propagation of shear cracks. In most of the wrapped beam very less shear crack was formed which show that it increases the shear capacity of the beam.
- ✓ The beam strengthened with GFRP shows flexural shear failure from shear failure of the control RC beam.

5.1 Future Scope

- ✓ In this study, the shear behaviour of RC beams externally strengthened with GFRP in different strengthening scheme is studied out. The same can be examined by changing the strengthening schemes.
- ✓ In this study all beams are strengthened with single layer of GFRP sheet instead of that the same can be strengthened with double layer. The same can be studied by the use of CFRP also.
- ✓ Flexural behaviour of RC beams externally strengthened with GFRP in different strengthening scheme can be studied.
- ✓ This study can be carry forward by increasing length and width of cross-section.
- ✓ Application of FRP wrapping under conditions of damage of RC beam under acid, chemicals etc. are to be studied.

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