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Shear Strengthening of R.C. Beams by using GFRP

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Abstract: Shear is actually a very complex problem and is not completely solved for simple reinforcement concrete beams. The current codes (American Concrete Institute (ACI), ISIS Canada and I.S.456:2000) qualify the nominal shear strength by means of a simple sum of the contributions of the concrete (Vuc) and the steel (Vus). For RC beams with externally bonded fiber reinforced fiber polymer (FRP) sheets, the Contribution of the sheets (Vuf) is added.

Shear failure is catastrophic and occurs usually without warning; thus it is desirable the beam fails in flexure rather than in shear. Many RC members are found to be deficient in shear strength and needs to be repair. Externally bonded reinforcement such as FRP provides excellent solution in this case.

The aim of the work were to check shear capacity of RC beams with different FRP orientation, to check authenticity of available analytical method to calculate shear strength of strengthened beams and to evaluate percentage increase in load carrying capacity of shear strengthened beam. The result of this research pointed out a general improvement in terms of shear capacity for the strengthened beams.

Keywords: GFRP Sheet, Shear Failure, Control Beam, Shear strengthening, Flexural strength of beam.

I. INTRODUCTION

Failure of concrete structures is one of the major problems of the construction industry today. Moreover, a large number of structures constructed in the past using older design codes in different regions of the world are structurally unsafe according to today's design codes. Since replacement of such defective structures suffer a large amount of public money and time; strengthening has become acceptable way of improving the load carrying capacity and extending their service lives.

Since the first structures were formed, whether by nature or human beings, they have been plagued by deterioration and destruction. Deterioration and destruction are the laws of nature that affect even the most modern structures. Modern structures, like skyscrapers and bridges are costly to build and construction period may sometimes be disturbing to people and society. Therefore, it is interest to have durable structures with long life and low maintenance cost. Maintenance is not only about costs but also a necessity to keep a structure at a desired performance level. The definition of performance includes load carrying capacity, durability, and function and aesthetics appearance. A structure that fulfils all demands of load carrying capacities might at the same times not satisfy durability demands or please the society's demands for aesthetics appearance. Incorrect maintenance will in most cases increase the speed of degradation process and therefore lower the performance of the structure. If the performance level becomes too low, then repair is needed to restore the structure to its original performance.

II. LITERATURE REVIEW

Khalifa A„ Gold J.W. and Ash A presented a paper on, "Contribution of Externally Bonded FRP in Shear Capacity of RC Flexural Members", Journal of Composites for Construction, November 1998. The paper reviewed researches on shear strengthening with FRP and proposed design algorithms to compute the shear contribution of FRP to shear capacity of RC flexural members. Two methods were proposed. One was based on stress level that causes tensile fracture of the FRP sheet. The stress may be less than the ultimate stress due to stress concentration and can be calculated on the basis of the effective strain in FRP. The other method was based on the delaminating of the FRP sheet from the concrete surface due to the effect of the effective bond length of the FRP.

N.F. Grace, G. A. Saved, A.K. Soliman and K.R. Saleh presented a paper on, "Strengthening RC beams using FRP Laminates", ACI Structural Journal September/October 1999. The behavior of RC beams strengthened with various types of FRP laminates is presented in this paper. The experimental program included strengthening and testing of simply supported beam of rectangular cross section. Each beam was axially loaded above its cracking load. The cracked beams were strengthened with FRP laminates and then tested until complete failure. The effects of strengthening on deflection, failure load, failure mode, and strain and beam ductility are discussed. It is concluded that, in addition to the longitudinal layers, the layer oriented in vertical direction forming a U-shape around the beam significantly reduce the deflections and increase the load carrying capacity. Furthermore, the presence of vertical FRP sheets along the entire span eliminates the rupture in flexural (horizontal) strengthening fibers. The combination of vertical and horizontal sheets, can lead a doubling of ultimate load carrying capacity of the beam.

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Ahmed Khalifa, Abdeldjelil Belarbi and Antonio Nanni presented a paper on, "Shear performance of RC members strengthened with externally bonded FRP wraps ", in the get going of 12th World conference on Earthquake Engineering, January- February 2000. This study presents the shear performance and the modes of failure of RC beams strengthened with externally bonded CFRP wraps, The variable! investigated in this research Included steel stirrups (I. a, beeras with end without stirrups), shear span to depth ratio (1,0. a/d ratio 3 versus 4), CFRP amount end distribution (i.e. continuous wrap versus strips), bonded surface (I.e. lateral sides versus U-wrap), fiber orientation (i.e.90°/0° fiber combination versus 90° direction), and end anchor (i.e. end anchor with and without end anchor).The experimental results indicated that the contribution of externally bonded FRP to the shear capacity is significant and dependent upon variables investigated.

III. METHODOLOGY

A. Design of the Beam

We designed RC beam is as per IS 456:2000. The actual length of the beam under loading is 600mm. The breadth and the depth is 150 mm each.

We tested RC beam in flexure under two point loading. The point loads are applied at middle third points.

B. Testing of the Beams

All the beams were tested under simply supported condition. The testing was done under two point loading using the Universal Testing Machine of 60 ton capacity. Each beam was instrumented with dial gauge to observe the mid-point deflection. The deflections were recorded for each incremental load of 10 kN. All the beams were tested up to the failure of beam in a single load cycle. The crack pattern was observed during the testing. The beam testing set up is shown in Fig. 1.

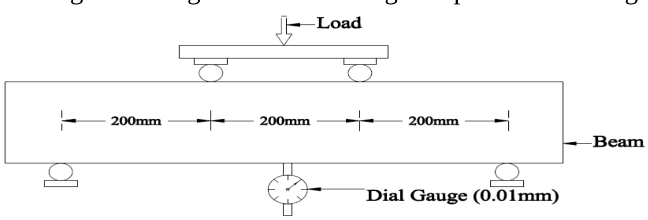

Fig. 1 Experimental Set-Up

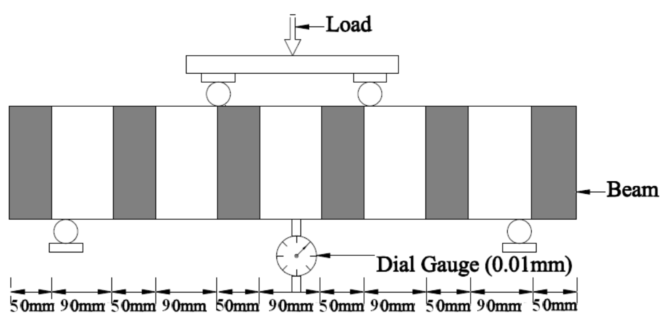

Fig. 2 Beam without shear reinforcement with FRP-50 mm Strip

IV. RESULT AND DISCUSSION

A. Control Beam

For the control beams, first shear crack was seen in the shear zone of the beam at a load of about 38 kN. The crack inclination was about 45 degree to the axis of beam. The crack was started at neutral axis of the beam and proceeds in compression zone with further increase in load. As the load increases, the inclination of the crack slightly reduced and additional shear cracks were developed. The beam finally failed in shear at the ultimate load of 45-55 kN.

It is clear from graph that, the mid span deflection increases gradually with increase in load up to the development of first shear crack. Afterword's, deflection increases at slightly higher rate.

B. Beam Strengthened with Side Bonded GFRP in Vertical Strips

In case of the beams strengthened with side bonded GFRP in vertical strips, the diagonal shear stretch of GFRP sheet was observed in shear zone. With further increase in load, the shear stretch propagated in the compression side with reduced inclination. The

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beams finally failed in shear at the ultimate load of 65-75 kN i.e. 41.24% increases as compared to control beams. After the failure, the sheets were removed to examine the cracking pattern. One larger shear crack was developed on both side of beam.

The Graph shows that the rate of deformation gets gradually increased after 40 kN i.e. the beam behaves as elastic for certain loading and afterwards it behaves as plastic. Ductility can be defined in terms of deformation as," ultimate deformation is directly proportional to the deformation at yield point". So we can say that the ductility of reinforced beam increases with GFRP wrapping is shown in Table 1.

Table I Comparison of shear strength

Beam mark	Average Ultimate Shear strength (KN)	% increase in shear strength over control Beam
Control Beam With Shear	52.5	
Control Beam Without Shear	48.5	
GFRP: 50mm side bonding without shear reinforcement	68.5	41.24

V. CONCLUSION

The following conclusions are drawn on the basis of the analytical and experimental work carried out.

A. GFRP significantly increases the ultimate shear strength of R.C. beam.

B. Ultimate of shear strength increase by, FRP in 50mm vertical strips without shear reinforcement 36.30% as compared with control beam.

C. The results shows that, the ultimate load carrying capacity of R.C. beams can be nearly doubled by using a proper vertical

D. GFRP sheets coupled with the proper epoxy.

E. The increase in amount of GFRP may result in a proportional increase in shear strength. Because, shear strength is significantly depends on the interfacial bond between GFRP and concrete.

F. GFRP strengthened RC beams exhibited greater mid-span deflections prior to the initial cracking of concrete as compared to the control beams.

G. Experimental values of ultimate load of GFRP wrapping are more than theoretical values.

H. The use of side bonded GFRP sheets in strengthening the R.C. beams reduces the deflection and increases the load carrying capacity. Cracks do occur are smaller and more evenly distributed.

VI. APPENDIX

Table II Control Beam With Shear Reinforcement

Beam 1	Beam 1	Beam 2	Beam 2	Average	
Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0	0	0	0	0	0
5	0.24	5	0.17	5	0.205
10	0.3	10	0.3	10	0.3
15	0.36	15	0.44	15	0.4
20	0.45	20	0.61	20	0.53
25	0.6	25	0.78	25	0.69
30	0.8	30	0.96	30	0.88
35	0.96	35	1.05	35	1.005
40	1.3	40	1.33	40	1.315
45	1.6	45	1.59	45	1.595
50		50	1.89	50	

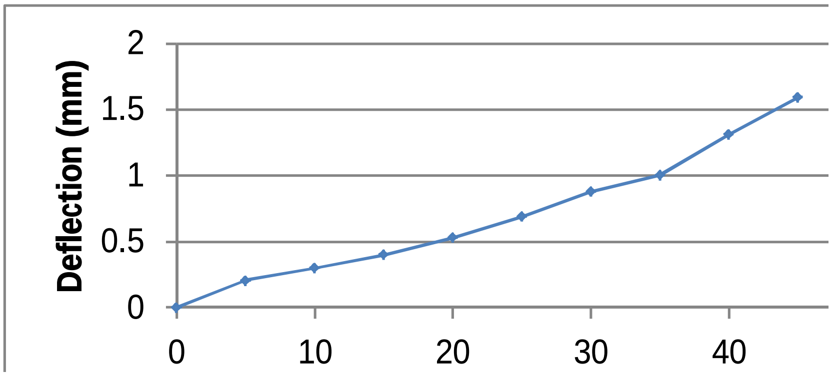

Fig. 3 Control beam with shear reinforcement

Table III Control beam without shear reinforcement

Beam 1	Beam 1	Beam 2	Beam 2	Average	
Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
0	0	0	0	0	0
5	0.12	5	0.09	5	0.105
10	0.2	10	0.15	10	0.175
15	0.34	15	0.21	15	0.275
20	0.46	20	0.29	20	0.375
25	0.59	25	0.41	25	0.5
30	0.71	30	0.55	30	0.63
35	0.85	35	0.68	35	0.765
40		40	0.81	40	

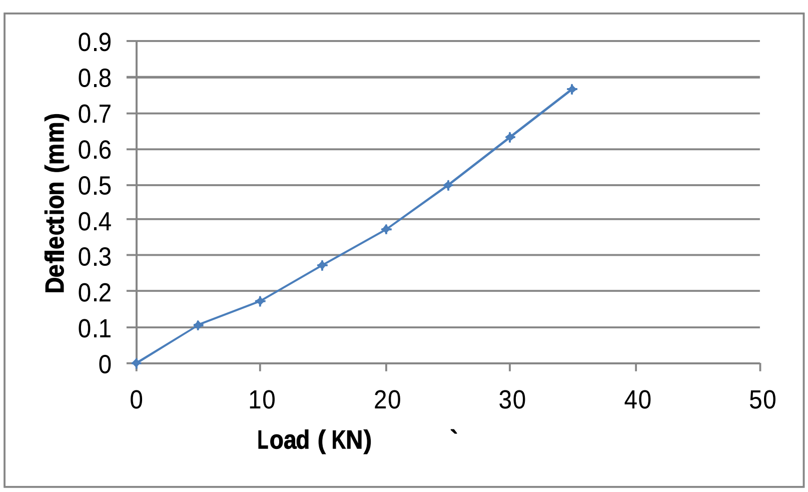

Fig. 4 Control Beam without shear reinforcement

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Table IV Beam without shear reinforcement with FRP-50 mm Strip

Beam 1	Beam 1	Beam 2	Beam 2	Average	
Load (KN)	Deflection (mm)	Load (KN)	Deflection	Load (KN)	Deflection (mm)
0	0	0	0	0	0
5	0.21	5	0.18	5	0.195
10	0.3	10	0.26	10	0.28
15	0.41	15	0.35	15	0.38
20	0.56	20	0.45	20	0.505
25	0.69	25	0.6	25	0.645
30	0.85	30	0.74	30	0.795
35	1.1	35	0.9	35	1
40	1.15	40	1.09	40	1.12
45	1.32	45	1.23	45	1.275
50	1.48	50	1.4	50	1.44
55	1.65	55	1.55	55	1.6
60	1.85	60	1.83	60	1.84
65	2.1	65	1.92	65	2.01
70	2.65	70		70	

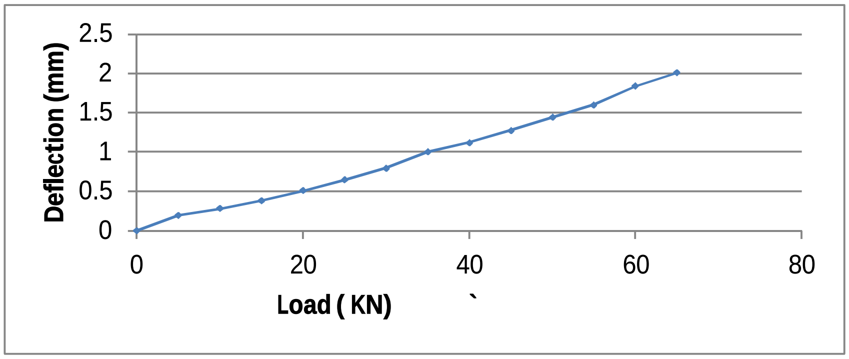

Fig. 5 Beam without shear reinforcement with FRP-50 mm Strip

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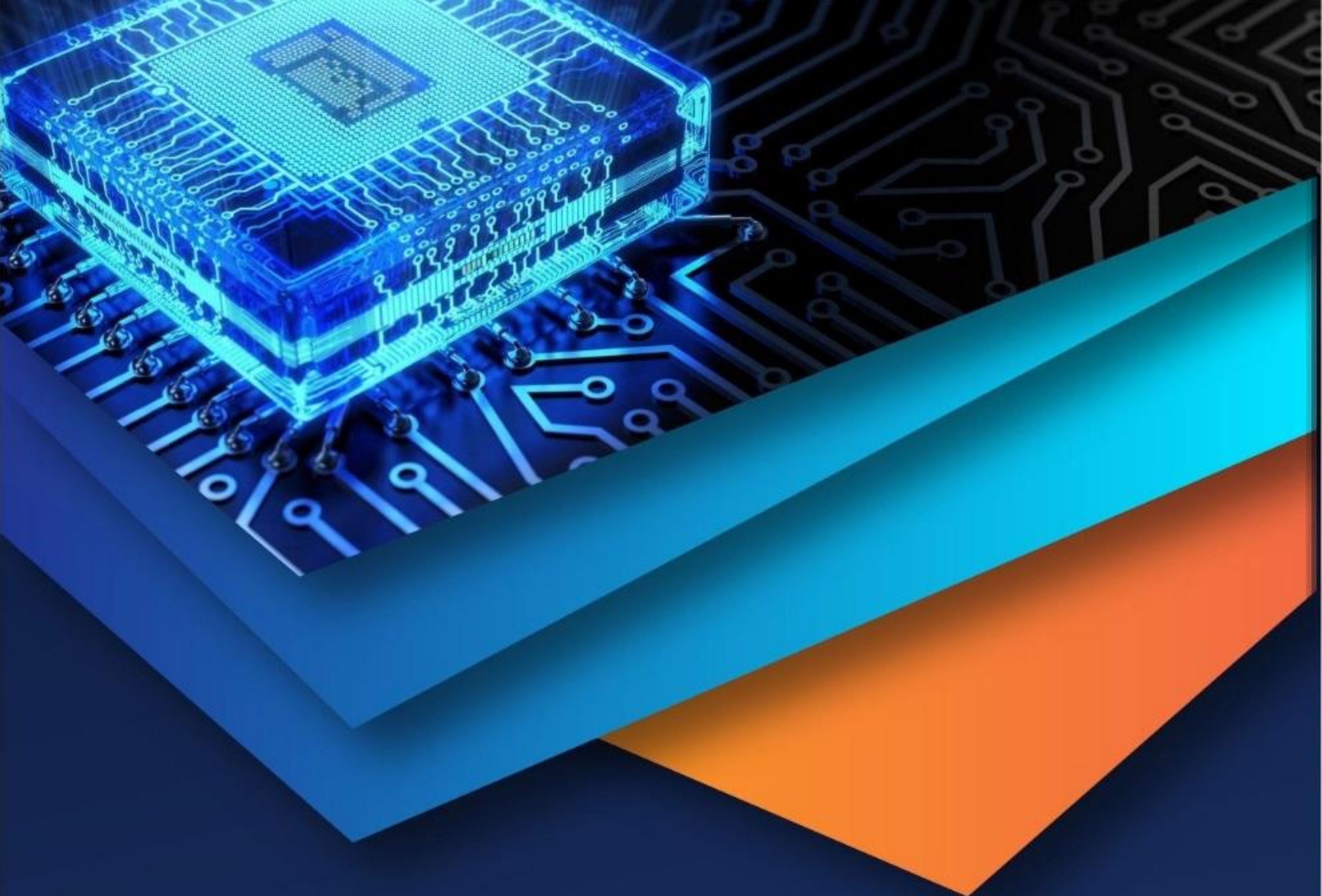

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