Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 3, Issue 12; October-December, 2016, pp. 1042-1045

http://www.krishisanskriti.org/Publication.html

Ultimate Moment Carrying Capacity of RCC Beams Strengthened by Steel Plates–A Review

Ankush Kumar[1] and S.M. Gupta[2]

[1]PG Student, Department of Civil Engineering, National Institute of Technology Kurukshetra (136119) Haryana, India
[2]Department of Civil Engineering, National Institute of Technology Kurukshetra (136119) Haryana, India
E-mail: [1]ankushmakkar41@gmail.com, [2]smgupta@nitkkr.ac.in

Abstract—*Reinforced concrete beams in buildings and bridges are increasingly being retrofitted/strengthening by adhesively bonding steel or Fiber reinforced plates (FRP Plates). This review paper presents how bonded steel /FRP plates to the beams can substantially increase flexural stiffness, reduce cracking and structural deformations at all load levels and contribute to increase the ultimate flexural capacity. The gains in strength and stiffness are usually associated with a decrease in ductility. Also in this paper varies parameter like (the compressive strength of concrete, yield strength of web reinforcement, and longitudinal bars, the tensile reinforcement ratio, shear span to depth ratio, the strength of steel plates, the area of steel plates, the anchorage lengths of steel plates, mechanical properties of epoxy adhesive and friction coefficient between steel plate and concrete etc.) are defined with the help of various researchers on which the ultimate strength and cracking load of the retrofitted/strengthening end reinforced concrete beam bonded with steel/FRP plates.*

Keywords*: RCC Beams, Steel/FRP plates, Ultimate flexural capacity, Retrofitted/Strengthening.*

1. INTRODUCTION

The development of civil infrastructure is one of the main factors that uses the national wealth in the form of money as well as resources. The structures being constructed are required to be long lasting for the sustainable development of a nation. Unless the resources are properly used to design and develop infrastructural systems, it will create negative impact on the economy. In present days new techniques and methods are experimented in the civil engineering field to have better infrastructure. There are various new technology which are developed in civil engineering. To strengthening the various reinforced structure. Strengthening means enhancing the structural performance of an existing structure. By strengthening some selected elements, the life of the whole structure may be extended. Strengthening of a structural element can be done by adding some technology, accessory, component or feature to it. This process is termed as retrofitting. The family of reinforced concrete beams is the biggest among the structural element families in a structure in terms of number of members.

There are different technique in retrofitting such as steel jacketing, providing additional reinforcement and increasing the section dimensions, strengthening using fiber reinforced polymers etc. Each of these methods has their own importance and is opted based on the requirement and ease of application. The above techniques are expensive, require skilled labour and take more duration for application. Mild steel plates will be one of the alternatives for retrofitting the existing structure, which has high young's modulus and is ductile, malleable. They are economical in cost and easy to install. They will be available in required thickness. They can be painted along with the specimen, so that it won't appear as retrofitted specimen.

By doing strengthening or retrofitting it may involve some of the following actions:

a) Increasing the lateral strength in one or both directions by increasing column and wall areas or the number of walls and columns.

b) Giving unity to the structure, by providing a proper connection between its resisting elements, in such a way that inertia forces generated by the vibration of the building can be transmitted to the members that have the ability to resist them.

c) Eliminating features that are sources of weakness or that produce concentration of stresses in some members.

d) Avoiding the possibility of brittle modes of failure by proper reinforcement and connection of resisting members.

Thus in all previous research strengthening of reinforced beam using steel plates are done preexisting structure.

For the design of this type of beam a non- linear analysis is being used. In this non-linear analysis following assumption should be made-

1. The beams strengthened by steel plate in line with the assumption of plane-section.

2. Both of the concrete in the tensile area and adhesive layer are not involved in the work of tension after the concrete cracked at the end of beam.

3. The normal stress of concrete in the compression area is distributed as triangle before the concrete cracked at the end of beam.

4. The relative slip between the steel plate and concrete beam is ignored; an ideal elastic-plastic stress and strain relationship is adopted.

2. ANALYSIS OF EXPERIMENTAL AND THEORETICAL RESULTS (BY VARIOUS RESEARCHER)

G.Arslan, F.Sevuk, I.Ekiz (April 2006) works on a strengthening technique of a RC beam. In their research they take five reference beams (with different compressive strength) which have been loaded monotonically up to maximum load capacities in order to define the load deflection relationship of damaged beam. The damaged reference beam have been then strengthened using different steel plate configurations (as shown below) in order to obtain ten different test beams included five reference beams. These retrofitted RC beams have been tested in the same conditions and the contribution of the repairing and strengthening techniques on load carrying capacity are investigated.

3. DETAILS OF TEST BEAMS

All beams are 100 · 160 · 1970 mm with an effective depth of 135 mm and cover of 13 mm. Beams are simply supported with the distance of 1800 mm between the supports and loaded at mid-span. Fig. 1 shows the cross-sectional dimensions and steel plate's sizes (286MPa) of the various specimens. (Name given to damage beams B1 series (32.46MPa) B11, B12 and B13; B2 series (38.26MPa) B21and B22). Five beams have been strengthened with externally bonded steel plates in various manners. (Name given to retrofitted beams (B11S3, B12S1, B13S2, B21S1 and B22S21).

The beams are reinforced with two B8 bars (8 mm in diameter) in the compression zone, whereas two B12 bars (12 mm in diameter) in the tension zone. The web reinforcement consists of 6 mm diameter closed web reinforcements spaced by 160 mm Centre to center throughout the beam span.

4. RESULTS AND DISCUSSIONS

The used flexural strengthening technique has enhanced the cracking load and ultimate load. Considering the load-carrying capacity, the retrofitted beams show a considerable strength enhancement comparing that of the corresponding damaged reference beams.

There are five failure modes that must be considered when determining the strength of an RC beam strengthened with steel plate:

1. Concrete crushing in compression prior to tension reinforcement yielding;

2. Concrete crushing in compression after tension reinforcement yielding;

3. Yielding of the steel plate followed by crushing of concrete;

4. Steel plate debonding from the concrete substrate.

5. Shear peeling failure (cover delamination).

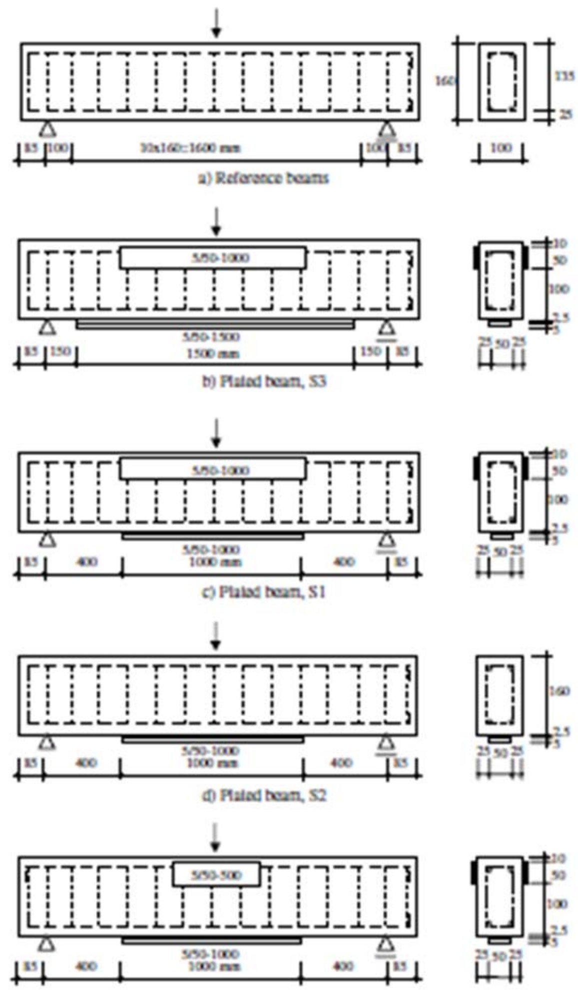


Fig. 1.1

Configuration and details of RC beams and steel plates

1. The reference beams have been exhibited a moderate amount of reserve load-carrying capacity beyond the formation of cracking. In other words, these beams demonstrate high ductile behavior and produced large deflection prior to failure which is remarkably gradual.

2. Reference beams (B11, B12 and B13) have failed in flexure by crushing of concrete in the compression zone after flexural reinforcement yielding.
3. All retrofitted beams except B22S21 have failed with shear peeling of steel plate.
4. For the same compressive strength of concrete and the same amount of vertical shear reinforcement, the load-carrying capacity increases, but the deflection capacity of the strengthened beam decreases as the steel plate ratio increased for the same level of load.
5. It has been confirm that externally bonded continues steel plates can improve the ultimate load-carrying capacities of damaged RC beams. The used flexural strengthening technique has enhanced the cracking load and ultimate load. Steel plate length has showed a significant effect on the flexural load-carrying capacity. Comparing the ultimate load, the B1 series retrofitted beams exhibit 2.36, 1.39 and 1.27 times the load of the corresponding reference beams for strengthened sample of S3, S1 and S2, respectively and B3 series have showed 1.80 and 1.65 Times the load of the corresponding reference beams for strengthened sample of S1 and S21 respectively.
6. Comparing the deflection capacities of B22S21 and B23S1, it is recommended that the length of side plate should be equal to the length of bottom plate since side plate prevents the extension of the crack, formed at the end of bottom plate, to the loading point.

Wenshan Lin (2011) have done an experimental analysis on ultimate carrying capacity and deflection of reinforced beam which are strengthened by varies size of steel plates. For the analysis he takes four beam (UR1, UR2, UR3, and UR4) for experiment purpose. Beam UR1 is an ordinary under reinforced concrete beam with no external steel plate reinforcement and sufficient shear reinforcement to ensure a ductile flexural type failure (100*150 c/s area, length 2240 and 2nos of bar with 10mm diameter in tension zone, 2nos of bar with 8mm diameter in compression zone also with a 6mm diameter bar @70mm as a shear reinforcement). Beams UR2, UR3, and UR4 are similar to Beam UR1 except that a steel plate of 1.5 mm, 3 mm, and 5 mm reinforced each beam, respectively as shown in figure 1.2

The flexural capacity of Beam UR1 is obtained from the strength theory base on the ACI code and RC beams strengthened with bonded steel plates will be predicted by strain compatibility.

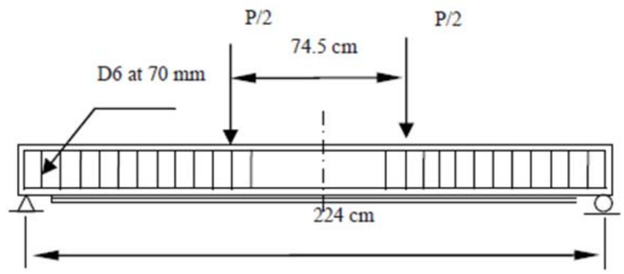


Fig. 1.2

The result of their experiment as follows-(when the load is placed symmetrically w.r.t to center @ 745mm (i.e. half value on the left of center and half value on the right)

Table 1.1

Ultimate loads of beam (IN KN)			
Beam	**Thickness**	**Experimental**	**Theoretical**
UR1	-	28.09	26.95
UR2	1.5	39.98	39.29
UR3	3.0	54.98	51.44
UR4	5.0	57.48	57.12

Load deflection of Beam UR1:

Table 1.2

Load deflection point	**I_e(cm^4)**	**P(KN)**	**Δ**
Cracking	3276	5.47	.106
Yielding of steel bars	1070	25.87	1.541
Failure of concrete	300	26.95	5.72

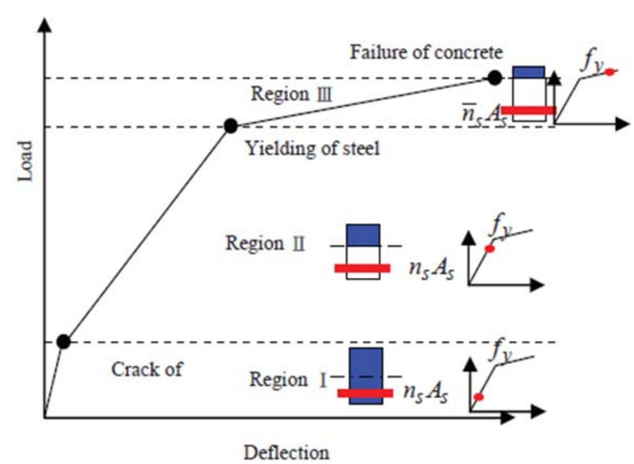
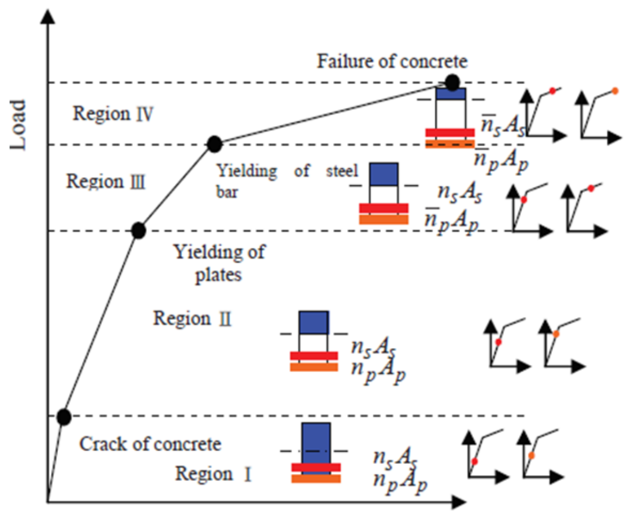


Fig. 1.3 Typical load-deflection curve of RC beam

Load deflection of Beam UR2:

Table 1.3

Load deflection point	$I_e(cm^4)$	P(KN)	Δ
Cracking	3713	6.51	.112
Yielding of steel bars	1398	36.21	1.783
Failure of concrete	498	39.29	5.030



Deflection
Fig. 1.4 Load-deflection curve of RC beam strengthened with external plate.

5. CONCLUSION

1. Comparison of calculation and test results indicate that the proposal model yields reasonable estimation.
2. Estimation of the cracking point, the yielding of both steel plate and steel bar point in the load deflection curve is attained using the elementary procedures of strength of materials. But using the secant modulus concept, the replace a secant modular ratio $n_p = E_p / E_c$ and $n_s = E_s / E_c$ with modular ration $n_p = E_p / E_c$ and $n_s = E_s / E_c$ to determine cracked transformed section.
3. When there is thickness of 1.5mm in UR2, the increase in ultimate load of beam is 42.78 % of UR1. Similarly, with the thickness of 3mm in UR3, the increase in ultimate load of beam is 95.72% of UR1 also with the thickness of 5mm in UR4, the increase in ultimate load of beam is 104.62% of UR1.
4. At failure of concrete deflection of UR1 beam is 57.20mm, but deflection of UR2 at failure of concrete is 50.30mm.

REFERENCES

[1] Wenshan Lin, "Simplified Prediction of Load Deflection Curve for RC Beam Strengthened by External Steel Plate'', IEEE structural engineering 20, 10, January 2011.

[2] G. Arslan , F. Sevuk , I. Ekiz , " Steel plate contribution to load-carrying capacity of retrofitted RC beams" Construction and Building Materials 22 (2008) 143–153.

[3] Jones R, Swamy RN, Charif A," Plate separation and anchorage of reinforced concrete beams strengthened by epoxy-bonded steel plates". Struct Eng 1988;66(5):85–94.

[4] Hazem M.F. Elbakry, Said M. Allam, "Punching strengthening of two-way slabs using external steel plates", IEEE structural engineering 13, September 2015.

[5] Jansze W, "Strengthening of RC members in bending by externally bonded steel plates", Ph.D. thesis, Delft University of Technology, Delft; 1997.

[6] Anna Liji Mathew, Raju Anumol, "Retrofitting of RC Beams Using FRP", IJERT Vol. 2 Issue 1, January- 2013.

[7] Dr. K.P. Jaya (2011), "Retrofitting and Rehabilitation of

[8] Structures", Paper presented in one day conference on, Repair, Restoration and Rehabilitation of Concrete Structures conducted by ICI-TNCC.