A Study of Strengthening the Existing Beam using FRP Sheets

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***Abstract*— The rehabilitation of existing reinforced concrete (RC) bridges and building becomes necessary due to ageing, corrosion of steel reinforcement, defects in construction/design, demand in the increased service loads, and damage in case of seismic events and improvement in the design guidelines. Fibre-reinforced polymers (FRP) have emerged as promising material for rehabilitation of existing reinforced concrete structures. The rehabilitation of structures can be in the form of strengthening, repairing or retrofitting for any type of deficiencies. RC rectangular-section is the most common shape of beams and girders in buildings and bridges. In a set of experiments, all beams were subjected to a certain level of loading to create damage and then repaired with CFRP sheet with different configuration except one beam i.e. control beam and another one beam was repaired under sustain loading condition.**

Keywords—FRP; CFRP;Retrofitting;Rehabilation material

GENERAL

Reinforced concrete (RC) is an extremely popular construction material. Reinforced concrete plays a very important part in a nation's economic development. Lack of durability of Reinforced concrete structures has thus not only massive economic implications to a nation's well-being, but it is also one of the greatest threats to sustainable growth of concrete and construction industries. Deterioration in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. The deterioration is mainly due to environmental effects, which includes corrosion of steel, gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, freeze-thaw cycles, contact with chemicals and saline water and exposure to ultra-violet radiations. This problem, coupled with revisions in structural codes needed to account for the natural phenomena like earthquakes or environmental deteriorating forces, demands development of successful structural retrofit technologies.

USE OF FRP

FRP are available in many forms and are used as a structural reinforcement for the concrete structures. Some of these forms are bars, plates and sheets. The FRP sheets are more commonly used to strengthen the existing structures because of greater flexibility compared to other forms. Hence, the strengthening of such beams is needed in flexure or shear or both zones and the use of external FRP strengthening to beams may be classified as:

1. Flexural strengthening
2. Shear strengthening

REVIEW OF LITERATURE

Ghazi et al. (1994) studied the behaviour of reinforced concrete (RC) beams strengthened in shear with fibre glass plate bonding (FGPB) for structural and non-structural cracking behaviour due to a variety of reasons. Results from a study on strengthening of RC beams having deficient shear strength and showing major diagonal tension cracks have been presented. The beams with deficient shear strength were damaged to a predetermined level (the appearance of the first shear crack) and then repaired by fibre glass plate bonding (FGPB) techniques. Different shear repair schemes using FGPB to upgrade the beams shear capacity were used, i.e., FGPB repair by shear strips, by shear wings, and by U-jackets in the shear span of the beams and the results show that the increase in shear capacity by FGPB was almost identical for both strip and wing shear repairs. However, this increase was not adequate to cause beams repaired by these two schemes to fail in flexure. **Hadi (2003)** examined the strength and load carrying capacity enhancement of reinforced concrete (RC) beams; those had been tested and failed in shear. A total of sixteen sheared beam specimens with a length of 1.2m and cross-sectional area of 100 x 150 mm were retrofitted by using various types of fibre reinforced polymer (FRP) and then retested. The retrofitted beam specimens wrapped with different amounts and types of FRP were subjected to four-point static loading. Load, deflection and strain data were collected during testing the beam specimens to failure. Results of the experimental program indicate that there were 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. **Kandhan et al. (2013)** studied experimentally the damage assessment and strengthening of reinforced concrete beams. This study was attempted to obtain a possible solution to overcome the problem in simulating the exact damage and to simplify the repair methodology to be adopted. The stiffness degradation method which is widely used analytically to estimate the damage was used in this study. Two types of beams i.e. cracked and un-cracked beams strengthened with CFRP were subjected to two points loading setup. The damage beams are repaired, tested and compared with the strengthened control beam. The experimental results show that the failure of repaired concrete beam is started with delamination and continued with deboning. The un-cracked beam and un-cracked plus strengthened beam had weak and brittle performance on compare to repaired cracked beam. The strength of repair beam is directly depending on bond strength between FRP and concrete. The exact assessment of damage in RC beam is unwarranted.

OBSERVATION FROM LITERATURE

From the above information, it is, thus, clear that there lies a vast scope of research in the field of retrofitting of concrete structures especially beams using externally bonded FRP composites. In the above section it has been shown how the structural strength and stiffness can be improved by externally bonded material. The worldwide interest in the technique reflects its potential benefits and also the current importance based on economical rehabilitation and upgrading methods. Despite the growing number of field applications, there is limited number of reports on effects of different types of loading on RC beams using externally bonded FRP composites. The objective of the present work is to determine the effect of FRP on the behaviour of R.C beams.

MIX PROPORTIONN OF CONCRETE USED

Description	Cement	Sand (Fine Aggregate)	Coarse Aggregate	Water
Mix Proportion (by weight)	1	1.48	3.19	0.5
Quantities of materials for one specimen beam (kg)	16.71	24.73	53.42	8.37

RESULT OF CUBES AFTER 28 DAYS

Specimen Name	Specimen ID	Size of Cube Specimen (mm)	Average Cube Compressive Strength
Control Beam	CB	150x150x150	25.93 MPa
Strengthened Beam 1	SB1	150x150x150	26.02 MPa
Strengthened Beam 2	SB2	150x150x150	26.90 MPa
Strengthened Beam 3	SB3	150x150x150	26.77 MPa
Strengthened Beam 4	SB4	150x150x150	25.20 MPa

PROPERTIES OF CFRP USED

S.No.	Physical properties	Value
1	Tensile Strength	4000 MPa
2	Tensile Modulus	230 GPa
3	Ultimate Elongation	1.7%
4	Density	1.74 g/cm^3
5	Minimum weight per sq. yd.	0.54 Kg

PROPERTIES OF SATURANT USED

S.No.	Properties	Values
1	Mixing ratio, by weight (B:H)	100:42
2	Tensile strength	72.4 MPa
3	Tensile Modulus	3180 MPa
4	Flexural Strength	123.4 MPa
5	Flexural Modulus	3120 MPa
6	Elongation Percent	5.0%

TEST RESULTS

Beam Designation	Ultimate Load (KN)	Nature Of Failure	λ=(strengthened beam/control beam)
CB	130	Flexural Failure + Shear Failure	-
SB1	170	Fracture of CFRP + Flexural-Shear Failure + Crushing of Concrete	1.31
SB2	180	Debonding of CFRP + Shear-Flexural Failure	1.38
SB3	156	Debonding of CFRP + Shear-Flexural Failure + Crushing Of Concrete	1.2
SB4	165	Debonding + Flexural Failure	1.30

CONCLUSION

The present experimental study is done on the behavior of reinforced concrete beams strengthened by CFRP sheets. Five reinforced concrete (RC) beams having same reinforcement detailing were casted and tested. From the test results, the following conclusions are drawn:

1. The ultimate load carrying capacity of all the strengthen beams were enhanced as compared to the Control Beam CB.
2. In case of strengthened beams initial cracks appeared at higher load.
3. The load carrying capacity of the strengthened Beam 2 was found to be maximum of all the beams. It increased up to 38.46 % more than the control beam CB, 7.69% more than strengthened beam SB-1, 18.46 % more than strengthened beam SB-3 and 12.17 % more than the strengthened beam SB-4
4. Beam SB-3 which was retrofitted under sustained load in the web and sides only shows higher deflection values on same loads as compared to other strengthened beams and lower deflection value as compared to control beam.
5. The beam strengthened with a U-wrap configuration is more effective than the side-wrap configuration.
6. Strengthened beam SB-3 which was strengthened under sustained load shows less ultimate load carrying capacity as compared to strengthened beam SB-1 which is strengthened normally.

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