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Behavior of RC T-Beam Strengthen Using Basalt Fiber Reinforced Polymer (FRP) Sheet

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Abstract - *Fiber-reinforced polymer (FRP) application has very strong outcome to repair and to give strength to structures which has become weak structurally in their life span. The most common shape or structure of beams and girders is RC T-section in buildings and bridges. Shear failure is commonly identified as the highest disastrous failure mode as it never gives any earlier warning before failure. FRP repair systems gave an economically viable alternative to traditional repair systems and materials. In this study, experimental investigation on the flexural behavior of RC T-beams strengthened using Basalt fiber reinforced polymer (BFRP) sheets are carried out.*

Reinforced concrete T beams externally bonded with BFRP sheets were tested to failure using a symmetrical one-point static loading system. Six RC T-beams were cast for this experimental test. All of them were unable to withstand in flexure and having identical reinforcement detailing. One beam was used as a control beam and other beams were strengthened using different configurations of Basalt fiber reinforced polymer (BFRP) sheets. The effect of different amount and configuration of BFRP on ultimate load carrying capacity and failure mode of the beams were investigated. The experimental results show that externally bonded BFRP can increase the flexural capacity of the beam significantly. In addition, the results indicated that the most effective configuration was U-wrap BFRP. A series of comparative studies on deflection between the present experimental data and results from a finite element method in Ansys was made to validate the experimental results.

Keywords: T-beam, BFRP, Strengthening

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1. INTRODUCTION

The rapid deterioration of infrastructures is one of the major issues facing the concrete and bridge industry worldwide. The deterioration of these structures is mainly due to aging, poor maintenance, corrosion, aggressive environmental conditions, poor initial design or construction errors and accidental situations like earthquakes. In the past, a large number of structures were constructed using the older design codes which are structurally unsafe according to today's design standards. Since the complete replacement of such deficient structures requires an enormous amount of money and time, strengthening has become a suitable way of improving their load carrying capacity and extending their service lives. The available conventional design approaches are concrete-jacketing and steel-jacketing. The concrete-jacketing makes the existing section large hence it improves the load carrying capacity of the structure. But these techniques have several demerits such as the construction of new formworks, additional weight due to enlargement of a section, high installation cost, etc

The steel-jacketing has proven to be an effective technique to enhance the performance of structures but this method requires difficult welding work in the field and have the potential problem of corrosion which increases the cost of maintenance. Nowadays, FRP composite materials are an excellent option to be used as external reinforcement because of their high specific stiffness, high specific weight, high tensile strength, light weight, resistance to corrosion, high durability and ease of installation.

1.1 Advantages

1. Handling and installation of basalt fiber sheet are easy.
2. Requires little maintenance. And Long life.
3. Less energy required to produce FRP composite material.
4. High durability.

1.2 Disadvantages

1. Lack of experience of techniques.
2. Lack of acceptable design standard.
3. Lack of awareness.

Mostly used FRP materials are carbon and glass fibers among various types of FRPs. Though the strength of carbon fiber is very high, it is more expensive as compared to other types of fibers. Glass fiber is less expensive as compared to carbon fiber, but it was proven to be less effective and less durable against the corrosive medium. To overcome all of these disadvantages basalt fiber has been used in the research work nowadays. The cost of glass and basalt fibers is nearly the same. Basalt fiber exhibits high corrosion resistant and chemical durability towards the corrosive medium, such as salts, acid solutions, and alkalis. It has also a higher thermal ability than glass fibers.

2. OBJECTIVE

1. To study the experimental investigation of externally bonded R.C. T- Beams using BFRP sheets and study the enhancement of the strength
2. To study the effect of longitudinal BFRP sheet when externally bonded to T-beam.

2.1 Brief Review

The accelerated deterioration of infrastructure is becoming a primary challenge facing construction industries globally. The renewal policies applied to deteriorate structures comprise of complete replacement and rehabilitation. Since the complete replacement of structures involves huge investment and time, rehabilitation becomes a suitable way for the renewal of deteriorated structures. The popular retrofitting material is Fiber reinforced polymer (FRP) which has shown great promise in the rehabilitation of the existing reinforced concrete (RC) structures and strengthening of new structural members.

An extensive survey of literature concerning the objectives described in the previous chapter is presented. The major achievements and results reported in the literature are emphasized. The survey of literature has been partitioned into several sections in order of their relevance to the present study. They are as follows:

- Strengthening of Reinforced Concrete (RC) Rectangular beams
- Strengthening of Reinforced Concrete (RC) T-beams
- Strengthening of Reinforced Concrete (RC) Rectangular and T-beams with web opening

1. Gang et al. (2013a) presented an experimental study on the flexural behavior of RC beams reinforced with steel-wire continuous basalt fiber composite plates. This work explored a procedure for flexural strengthening reinforced concrete (RC) beams utilizing anew revealed steel-wire continuous basalt fiber composite plates (SBFCPs) that consists of steel wires and continuous basalt-fiber-reinforced polymer (BFRP) composites. The test results revealed that the SBFCP strengthened specimens performed superior to the unstrengthen specimen with respect to load capacity and member stiffness. A parametric study confirmed that the volumetric ratio of steel wires in the SBFCPs influence the load capacity and stiffness of specimens strengthened with SBFCPs. The results also indicated that anchorage by steel plates and bolts improves the load capacity and ductility of strengthened specimens.

2. The improvement in the shear capacity of existing reinforced concrete (RC) T-beams strengthened using externally bonded CFRP composites with different configurations was investigated by Khalifa and Nanni (2000). Six full scales, RC T-beams were cast, out of which one beam was taken as reference and the remaining beams were strengthened with different configurations of CFRP sheets considering various parameters, such as; wrapping schemes, CFRP amount, 90º/0º ply combination and CFRP end anchorage. The experimental results indicated that the shear capacity of the beams can be considerably enhanced by using externally bonded CFRP composites and U-wrap with end anchorage was found to be the most effective configuration among all. To predict the capacity of the tested beams, design Review of Literature National Institute of Technology, Rourkela Page 18 algorithms in ACI code format and Euro code format were proposed and the results showed that the proposed design approach is conservative and acceptable.

3. Ozgur (2008) carried out research work to study the strengthening of shear deficient RC T-beams with low strength concrete using CFRP composites subjected to cyclic loads. Six RC T-beams were tested up to failure under cyclic loading considering different test variables, such as; width of the CFRP straps, arrangements of straps along the shear span and anchorage techniques applied to the ends of the straps. To obtain ductile flexural behavior, shear deficient beams with low strength concrete were strengthened using CFRP straps. The test results concluded that all CFRP configurations enhanced the strength, stiffness, and energy dissipation capacity of the specimens substantially and the failure modes and ductility of the specimens fluctuated along with the CFRP strap width and arrangement

3. EXPERIMENTAL STUDY

The experimental study consists of the casting of seven reinforced concrete T beams. All the seven beams weak in flexure are cast, out of which one is taken as controlled beam and other six beams are strengthened using continuous Basalt fiber reinforced polymer (BFRP) sheets in flexure. The strengthening of the beams is done with varying configuration and layers of BFRP sheets. Experimental data on load, deflection and failure modes of each of the beams are obtained. The change in load carrying capacity and failure mode of the beams are investigated as the amount and configuration of BFRP sheets are altered.

4. CASTING OF SPECIMEN

For conducting an experiment, seven reinforced concrete T beam specimen of size as shown in the fig (Length = 1.3m, flange width = 0.350m, web width = 0.150 m, depth of the flange = 0.50m, overall depth=0.175m) and all having the same reinforcement detailing are cast. The proportion of 0.5: 1: 1.56: 3.30 for water, cement, fine aggregate, and coarse aggregate is taken. The mixing is done by using a concrete mixture. The beams are cured for 28 days. For each beam, three cubes are cast to determine the compressive strength of concrete for 28 days.

4. DETAILING OF REINFORCEMENT IN R.C. T- BEAMS

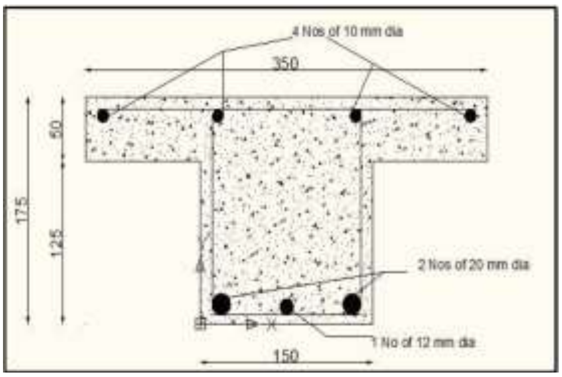

Fig -1: Reinforcement Detailing of T- Beam

Fig -2: 3D View of Reinforcement Detailing of T- Beam

5. STRENGTHENING OF BEAMS

The concrete covering is made rough using a coarse sandpaper texture and then cleaned with an air blower to remove all dirt and debris at the time of bonding of fiber. After that, the epoxy resin is mixed in accordance with the manufacturer's instructions. The mixing is sent out in a plastic container (100 parts by weight of Araldite LY 556 to 10 parts by weight of Hardener HY 951). After their uniform mixing, we can cut the fabrics according to the size then the epoxy pitch is applied to the concrete surface. Then the BFRP sheet is placed on the head of epoxy pitch coating and the pitch is squeezed over the rambling of the fabric with the roller. Air bubbles captured at the epoxy/concrete or epoxy/fabric interface are discarded. While solidification of the epoxy, a consistent uniform pressure is applied on the composite fabric surface in order to eject the excess epoxy pitch and to assure satisfying contact between the epoxy, the concrete, and the fabric. This procedure is carried out at room temperature. Concrete beams reinforced with glass fiber fabric are preserved for 24 hours at room temperature before the examination.

Fig -3: Strengthening of Beams – 1

Fig -4: Strengthening of Beams – 2

6. EXPERIMENTAL SETUP

The T-beams are tested in the loading frame of the "Structural Engineering" Laboratory of VPKBEIT, Baramati. The testing procedure for all the specimen is the same. First, the beams are cured for a period of 28 days then its surface is cleaned with the help of sandpaper for clear visibility of cracks. The one-point loading instrumentation is managed for examining of beams. This has the benefit of an abundant field of nearly uniform moment coupled with very petite shears, letting the bending capability of the central portion to be evaluated. One-point loading is conveniently given by the arrangement presented in Figure.

The load is transferred through a load cell and orbicular seating on to a spreader beam. The spreader beam is placed on rollers seated on steel plates embedded on the test member among cement in order to accommodate a smooth leveled surface. The test member is established on roller bearings acting on comparable spreader plates. The specimen is installed over the two steel rollers bearing dropping 150 mm from the ends of the beam. The outlasting 1000 mm is distributed into three equal parts of 334. One point loading pattern is done. Loading is achieved by a hydraulic jack. Lines are inscribed on the beam to be tested at center point.

7. TESTING OF BEAMS

The seven are tested one by one, six with FRP and one without FRP which is taken as the control Beam. All of them are tested in the above arrangement. The gradual increase in load and the deformation in the strain gauge reading are taken throughout the test. The dial gauge reading shows the deformation. The load where the first noticeable crack is developed is marked as cracking load. Then the load is employed till the terminal failure of the beam. The deflections at three salient points mentioned for the beams with and without GFRP are recorded with respect to increasing of load and are furnished in the table. The data decorated in this chapter have been described and reviewed in the next chapter to achieve a conclusion.

7. TEST RESULTS AND DISCUSSIONS

7.1 Load Deflection Analysis

Here the deflection of each beam at different positions is analyzed. Mid-span deflections of each beam are compared with the control beam. Also, the load-deflection behavior is compared among different wrapping designs having the equivalent reinforcement. It is noted that the behavior of the flexure deficient beams when bonded with BFRP sheets are better than the control beams. The mid-span deflections are lower when bonded externally with BFRP sheets. The use of BFRP sheet had effect in delaying the growth of crack formation. When all the wrapping schemes are considered it is found that the Beam-6 with BFRP sheet in wrapped in the web for a length of 1m in the middle part had a better load deflection behavior compared to the others strengthened beams with BFRP.

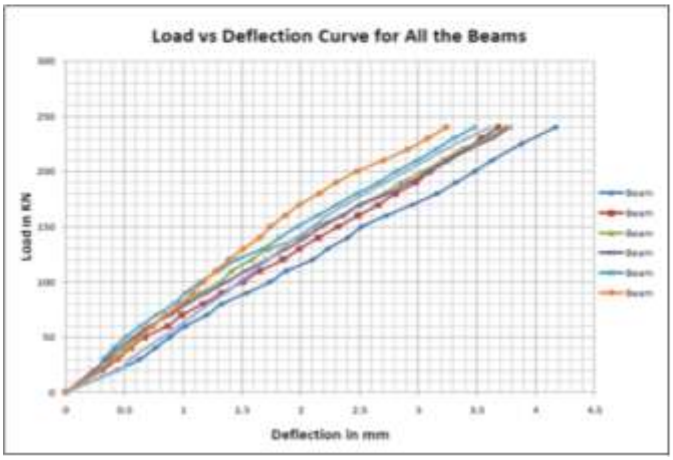

Chart -1: Load vs. Deflection Curve for All the Beams

Here all the beams are compared with respect to their deflection and load data. And it can be interpreted that beam 6 which is retrofitted with U-Jacketed single layered BFRP sheet for a length of 1 m in the middle section of the beam where most of the cracks are occurring has minimum deflection value as compared to others

7.2 Ultimate Load Carrying Capacity

The load carrying capacity of the control beams and the strengthen beam are plotted below. It is observed that beam 4 is having the max load carrying capacity.

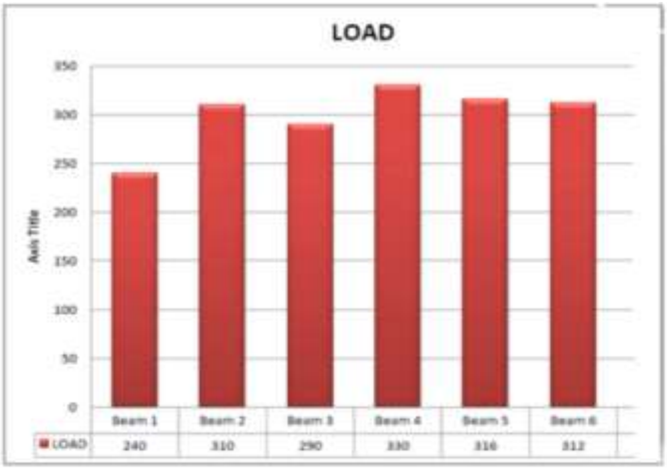

Chart -2: Ultimate Load Carrying Capacity

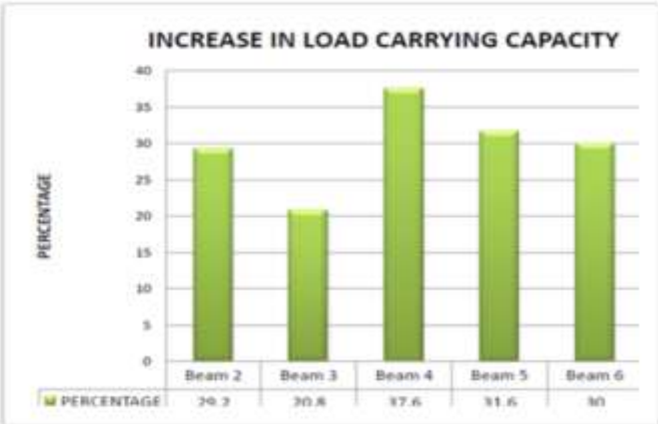

Chart -3: Percentage increase in the Ultimate Carrying capacity w.r.t Control Beam

From the above figure we can observe the amount of increase in the flexural strength for each strengthened beam with respect to the Control Beam 1.

8. CONCLUSIONS

The present experimental study is done on the flexural behavior of reinforced concrete T-beams strengthened by BFRP sheets. Six reinforced concrete (RC) T-beams weak in flexure having same reinforcement detailing are casted and tested. From the test results and calculated strength values, the following conclusions are drawn:

1. The ultimate load carrying capacity of all the strengthen beams were enhanced as compared to the Control Beam1.
2. Initial flexural cracks appear for higher loads in case of strengthened beams.
3. The load carrying capacity of the strengthened Beam 4 was found to be maximum of all the beams. It increased up to 37.5 % more than the control beam 1, 6.5% more than strengthened beam 2 and 4.4 % more than the strengthened beam 5.
4. Beam 6 which was retrofitted in the web part only for 1 m length in the center showed minimum deflection values on same loads as compared to other strengthened beams and the control beam.

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