SHEAR BEHAVIOR OF POLYMER-STRENGTHENED REINFORCED CONCRETE BEAMS WITH BASSALT FIBER

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ABSTRACT

The rapid deterioration of the infrastructures is one of the major issues facing concrete and bridge industry worldwide. The deterioration of these structures are mainly due to ageing, 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 enormous amount of money and time, strengthening has become the suitable way of improving their load carrying capacity and extending their service lives.The conventional design approaches available are concrete-jacketing and steel-jacketing. The concrete-jacketing makes the existing section large and thus improves the load carrying capacity of the structure. But these techniques have several demerits such as construction of new formworks, additional weight due to enlargement of 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 potential problem of corrosion which increases the cost of maintenance. Now-a-days, 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.

Fiber Reinforced Polymer(FRP)

FRP composites are, as the name proposes, a composition of two or more materials which, when suitably united, form a different material with properties not available from the individual ingredients.Fiber reinforced composite materials consist of fibers of high tensile strength and adhesive that binds the fibers together to produce the structural material. Commonly used fibers are aramid, basalt, carbon and glass in the civil engineering industry. The adhesive that is commonlyusedis epoxywhich protects thefibers, providingdurabilityand under theloading
condition distributes the load to the fibers. The fibers are oriented in the direction(s) that utilize them most efficiently. The successful application of FRP in different fields like aerospace, sports, recreation and automobile industries is the reason for the increase in demand of FRP. The properties of FRP composites and their versatility have resulted in significant efficiency, reliability and cost effectiveness in rehabilitation.

Among various types of FRPs, mostly used FRP materials are carbon and glass fibers.Though the strength of carbon fiber is very high, but it is more expensive as compared to other types of fibers. Glass fiber is less expensive as compared to carbon fiber, but it was proventobelesseffectiveandlessdurableagainstcorrosivemedium.Hence,toovercomeall of these disadvantages basalt fiber have been used in the present research work. The cost of glass and basalt fibers is nearly same. Basalt fiber exhibits high corrosion resistant and chemical durabilitytowards corrosive medium, such as salts, acid solutions and alkalis. Ithas also higher thermal ability as compared to glass fibers.

Strengthening using FRP

Concrete beams are the main element in structural engineering which are designed to carry both horizontal loads due to seismic or wind and vertical gravity loads. Like all otherconcrete elements they are susceptible for situations where there is an increase in structural loads. Generally reinforced concrete (RC) beams fail in two ways: flexure failure and diagonal tension (shear) failure. Flexural failure is generally preferred to shear failure as the former is ductile while the latter is brittle. A ductile failure permits stress redistribution and gives prior notice to occupants, whereas a brittle failure is sudden and thus catastrophic.

The use of external FRP reinforcement may be classified as: flexural and shear strengthening.

Flexural strengthening using FRP

Shear strengthening using FRP

When the RC beam is deficient in shear, or when its shear capacity is less than the flexural capacity after flexural strengthening, shear strengthening must be considered. It is critically important to assess the shear capacity of RC beams which are proposed to be strengthened.
To enhance the shear capacity of the beams, both composite sheets and plates can be

For flexural strengthening the laminates of FRP are used and applied with epoxy to the tension zone of the RCC members which acts as external tension reinforcements to increase the flexural strength of the RCC members.

Structural members like beams, plates and columns can be strengthened in flexure throughtheuseofFRPcompositesbondedtotheirtensionzoneusingepoxyasacommonadhesive for this purpose. The direction of fibers is kept parallel to that of the direction of high tensile stresses. Both prefabricated FRP strips and sheets are used. used,buttheformeroneis moreappreciablebecauseof theirflexiblenatureand easeofapplication and handling. Various FRP bonding schemes may be used to improve the shear capacity of RC beams. These include (1) side bonding (bonded to the sides of the beams only) (2) U jacketing (bonded to the sides and tension face of the beam) and (3) wrapping (bondedaround the whole cross section of the beam). As RC T-section is the most popular shape of beams and girders in buildings and bridges, complete wrapping is not a feasiblealternative.

Fibers may be unidirectional or bidirectional as shown in figure 1.3. The use of fibers in two directions can obviously be favourable with respect to shear resistance even if strengthening for reversed loading is not required, except for unlikely case in which one of the fiber directions is exactly parallel to the shear cracks.

In spite of the improved properties of FRP, a structure strengthened with FRP can fail too early causing debonding of the FRP. Therefore, the FRP does not achieve its full strength. In order to prevent the premature failure of the FRP composite, various anchoring systems such as U-jacketing, mechanical fastening, spike anchors and hybrid anchoring techniques are developed. Depending on the application, each type of anchor has caused some improvement in delaying premature debonding, but the problem has not been satisfactorily solved yet. Thesedrawbackshaveopenedupanewareaofresearchondevelopmentofanchorage system.

Objective

The main objectives of the present research work may be summarized as follows:

- To analyse the structural behavior of T-section RC beamsunderstaticloading condition.
- To investigate the shear behavior and modes of failureofsheardeficient RCT-beams strengthened with FRP composite sheets.
- Toexaminetheeffectofdifferentparameterssuchasnumberoflayers,bonding surface, different fiber orientation etc. on theshear capacityof theRCT-beams.
- TostudytheeffectofstrengtheningwithexternallybondedFRPontheenhancement of strength in RC T-beams with web openings of different cross-section.
- Toinvestigatetheeffectofananchorageschemeontheimprovementofshear capacity of the RC T-beams.

Based on the critical observations made from the surveyof existing literatures and to achieve the objective outlined in the previous chapter, the scope of the present research study is summarized as follows:

- To analyse the shear behavior of T-section RC beams under static loading condition.
- ToexaminetheshearbehaviourandmodesoffailureofRCsheardeficientT-beams externally strengthened with basalt fiber reinforced polymer (BFRP) sheets.
- To investigate the effect of different test parameters such as fiber amount and

distribution, bonded surface, number of layers, fiber orientation and end anchorage system on the shear capacity of RC T-beams strengthened with externally bonded BFRP composites.

- TostudythebehaviourofsheardeficientRCT-beamswithtransverseopeningsof circular, square and rectangular shapes in web portion.
- To investigate the effect of anew anchorages chemeontheshearbehaviouroftheRC T-beams.
- To compute analytically the shear capacity of the RCT-beams.

The purpose of the present research work is to study the effect of the externally bonded fiber reinforced polymer sheets on the shear capacity of the RC T-beams with and without transverse openings under static loading conditions. In this experimental programme a total of twentytwo numbers of beams are cast and tested by applying symmetrical four point static loading system up to failure. The beams are grouped into two series designated as A and B. The first series of tests, series A, dealt with the shear strengthening of the RC beams with T-shaped cross-section without transverse openings. The second series B, focused on the shear strengthening of the RC T-beams with transverse openings of different shapes. Ineach series, one of the beams is not strengthened with FRP and considered as control beam whereas other beams are strengthened with externally bonded unidirectional BFRP sheets in the shear zone of the beams.

The variables selected for the experimental works are BFRP amount and distribution (i.e., continuous wrap versus strips), bonded surface (i.e., lateral sides versus U-wrap), number of layers of BFRP, fiber orientation (i.e., 0° direction versus 90° direction versus 45^0 direction), Transverse web openings of different shape (i.e., circular versus square versus rectangular) and end anchor (i.e., U-wrap with and without end anchor).

Table3.1NominalMixProportionsof Concrete

Description	**Cement**	**Sand(Fine Aggregate)**	**Coarse Aggregate**	**Water Cement Ratio**
Mixproportioning (By weight)	1	1.67	3.33	0.55
Quantities ofmaterials foronespecimenbeam (kg)	19.64	32.79	65.38	10.8

Table3.2TestResults of Cubesafter28daysof curing

Specimen Name	Specimen ID	Average Cube Compressive Strength(MPa)
Control Beam	CB	23.1
StrengthenedBeam1	SB1	25.27
StrengthenedBeam2	SB2	24.67
StrengthenedBeam3	SB3	24.33
StrengthenedBeam4	SB4	23.36
StrengthenedBeam5	SB5	28
StrengthenedBeam6	SB6	26.81
StrengthenedBeam7	SB7	26.07
StrengthenedBeam8	SB8	24.45
StrengthenedBeam9	SB9	26.34
StrengthenedBeam10	SB10	28.33
StrengthenedBeam11	SB11	28.89
StrengthenedBeam12	SB12	28
ControlBeam1	CB1	23.55
StrengthenedBeam13	SB13	26.22
StrengthenedBeam14	SB14	28.65
ControlBeam2	CB2	26.14
StrengthenedBeam15	SB15	28.14
StrengthenedBeam16	SB16	27.26
ControlBeam3	CB3	23.26
StrengthenedBeam17	SB17	29.04
StrengthenedBeam18	SB18	25.18

The following componentmaterials areusedfor fabricatingtheBFRP plate:

I. Uni directional basalt FRP (BFRP)
II. Resin (Epoxy)
III. Catalyst(Hardener)
IV. Releasing agent (Polyvinylalcohol)

The unidirectional tensile test is conducted to determine the ultimate stress, ultimate load and modulus of elasticity of the specimens. By using diamond cutter or hex saw the specimensare cut from the plates and is polished with the help of polishing machine.

At the end of the curing period of 28 days, control beams of both the series are tested by applying load gradually up to failure. Similarly, after the curing period of 28 days, the strengthen beams are strengthened by bonding the BFRP fabrics to the concrete surface, cured Crack Behaviour and Failure Modes

CONCLUSIONS

The main objective of the present investigation is to study the contribution of basalt fiber reinforced polymer (BFRP)

The twenty two numbers of RCT-beams are tested under four pointstaticloadingsystemand their cracking behaviour and modes of failure are reported below.

Load- deflection history

In order to evaluate the effectiveness of the proposed strengthening schemes, the mid-span deflections and deflection under point loads of the shear deficient beams are measured at different load steps for the control beam and beams strengthened with BFRP sheets/strips.

Load at initial crack

The crack patterns of the beams are visualized with the progress of the load. The initialcracks are visualized for the beams which are not fully wrapped with BFRP sheets. It is observed that the initial cracks in the strengthened RC T-beams are developed at a higherload than the control

composites on the shear capacity of the T-shaped cross-section RC beams externally strengthened with BFRP composites with and without transverse web openings and also to study the effect of a new mechanical anchorage system comprising of BFRP laminated composite plates with nuts and bolts arrangement on the shear capacity of RC T-beams. Twenty two numbers of beams divided into two Series (A and B) are tested under four-point static loading system up to failure. The first series of tests, series A, discusses about the shear strengthening of the RC T-beams without transverse openings. The second series B, focuses on the shear strengthening of the RC T-beams with transverse openings of different shapes. In each series, one beam is not strengthened with BFRP and considered as control beam, whereas all other beams are strengthened with externally bonded unidirectional BFRP sheets in the shear zone of the beams. The effect of various test parameters such as fiber amount and distribution, bonded surface, number of layers, fiber orientation, different shape of transverse web openings and end anchorage on the shear capacity of RC T-beams externally strengthened with BFRP composites are investigated.

To accommodate essential services like electricity cables, natural gas pipes, water and drainage pipes, air-conditioning, telephone lines, and computer network, the transverse web openings are necessary in modern building construction.

Due to debonding failure, the full strength of the FRP is not utilized. Hence, an attempt has been taken in this study to prevent premature failure of the FRP sheets. Steel plates can be used as end anchorage to prevent the debonding, but it is susceptible to corrosion. So, the laminated composite plate is used as end anchorage in place of the steel plate in this study.

- The shear capacity of RC beams with T-shaped cross-section can be enhanced significantly by using BFRP composites as an external reinforcement.
- Strengthening with BFRP composites bonded to webs only are most susceptible to debonding with premature failure.
- The beam strengthened

with BFRP sheets is found to have more shear capacity than the beam strengthened with BFRP strips.

- Among all the BFRP strip configurations (i.e., horizontal strips, vertical strips and strips inclined at 45^0), the U-strip with 45^0 fiber orientations is moreeffective.
- Formationofcra ckgetsdelayedd uetotheuseofBF RPsheetsandals oby introduction of end anchorage.
- Amongdifferentshapes oftransversewebopenings, squareholeisfoundtobemo re effective as compared to other ones.

RecommendationsforFutureStudies

Basedonthefindingandconclusio nsofthepresentstudy,thefollowin grecommendations are made for further research in FRP shear strengthening:

- Studyof thebond mechanism betweenBFRPcomposite and concretesubstrate.
- FRPstrengtheningof RCT-beams usingcarbonandaramidcomposites.
- Strengtheningof RCT-beams usingwoven basaltfiber.
- StrengtheningofRCL-sectionbeamswithFRPcomposites.
- StrengtheningofRCL-sectionbeams withtransversewebopenings.
- Effectoftransversewebo peningsofdifferentshape andsizeontheshearbehav iour of RC L-section beams.
- Effectsof shearspan to effectivedepth ratioon theshear capacityofbeams.
- Numericalmodelling ofRCT&L-beamsstrengthenedwi thFRPsheetswithend anchorage.

REFERNCES

1) IS: 456-2000, “Plain and Reinforced Concrete - Code of Practice ”, Bureau of Indian Standards.
2) IS: 383-1970, “Specification for Coarse and Fine Aggregates from natural sources for Concrete”, Bureau of Indian Standards.
3) IS: 1786-1985, “Specification for high strength deformed steel

bars and wires for concrete reinforcement”, Bureau of Indian Standards.

4) Gang W., Jia-Wei S., Wen-Jun J., and Zhi-Shen W. (2013), “Flexural Behaviour of Concrete Beams Strengthened with New Prestressed Carbon-Basalt Hybrid Fiber Sheets”, American Society of Civil Engineers, 10.1061/(ASCE)CC.1943-5614.0000452.

5) Sahu S. (2014), “Strengthening of Reinforced Concrete Beams using Glass Fiber Reinforced Polymer (GFRP) composite”, M.Tech Thesis, NIT, Rourkela.