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Strengthening Of Beams Using Glass Fiber Reinforced Polymer

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Abstract – *All over the world the use of fibre reinforced sheet,wraps and laminates in the strengthening of beams and other concrete members is now used widely in many engineering projects.The use of FRP (FIBER REINFORCED POLYMER) is good method to strengthen and repair the structure that have become delicate over their life.FRP provide economically feasible option to previously used methods of repairs.*

Shear and flexural behavior of RC beams strengthening by the use of GFRP(glass fibre reinforced polymer)sheets are carried out experimentally. Two points concentrated static loading system is tested to failure by externally reinforced concrete beam with epoxy-bounded GFRP sheets for this experimental test two sets of beams are casted. Three beams with weak in flexure are casted in set I, from which one beam is controlled and rest two beams are strengthened by the continuous use of glass fiber reinforced polymer(GFRP) sheets in flexure. On the other hand three beams with weak in shear are also casted in SET II, from which one beam is controlled and other two beams are strengthened by the continuous use of glass fibre reinforced polymer (GFRP) Sheets in shear. The beams are strengthened with dissimilar quantity and array of GFRP sheets.

Experimental value of deflection, load and failure modes of each and every beams were obtained. The particular process and application of GFRP sheets for RC beams strengthening is also included. Failure modes and load carrying capacity of beams are investigated by the effect of numbers of GFRP layers and its orientation on ultimate.

1. INTRODUCTION

1.1 GENERAL

The upgradation of structural members and its resettlement,preservation is conceivable, is one of the most critical problems in civil engineering applications.Besides numbers of concrete structure constructed in the past years by using tradional oldesr design codes in various parts of the world are insecure structurally as compared to new design codes. As the replacement of such degraded element of structure involves lots of time and money,strengthening of structure has become the relevant way of enhancing the load carrying capacity of the structure and increasing the life of the structure. Decay of infrastructure is caused by premature failure of building and structures has lead to the investigation processes for repairing or strengthening purposes. Challenges in strengthening of concrete structures is selection of a strengthening method which will improve the strength and serviceability of the structure while addressing limitations such as budget, building operations, constructability.

- For higher loads to be placed on the structure Additional strength may be needed .This is required when higher load- carrying capacity is needed and the use of the structure changes.
- For allowing the structure to resist loads strengthening may be required. which was not expected in the original design.This may be come across when structural strengthening is needed for loads resulting from seismic forces and wind or to enhance resistance to blast loading.

The choice of the most suitable method for strengthening requires following engineering issues and include consideration of following factors :-

- Size of project (methods involving special materials and methods may be less cost-effective on small projects)
- Effect of changes in relative member stiffness;
- Accessibility;
- Environmental conditions (methods using adhesives might be unsuitable for applications in high-temperature environments, external steel methods may not be suitable in corrosive environments);
- Magnitude of strength increase

1.2 LITERATURE SURVEY

This chapter provides an introduction to the strengthening of reinforced concrete (RC), prestressed concrete and steel members using externally bonded steel plate or fiber reinforced polymer (FRP) composites sheets and plates by reviewing the most significant investigations reported in the literature. In addition, a section is devoted to the strengthening of RC members in shear utilising FRP plates and sheets. However, since the external plating and its application as a strengthening technique has only been made possible by the development of suitable adhesives, consideration is also given to the types of adhesive which may be used for external plate bonding and their requirements for this application.

2 STRUCTURAL INVESTIGATIONS

In terms of testing programmes, research and development work continued at the TRRL and at several academic institutions in the UK, most notably at the University of Sheffield. Theoretical investigations and the evaluation of suitable adhesives were allied to the extensive beam testing programmes which were undertaken.

Preliminary studies were conducted by Irwin (1975). Macdonald (1978) and Macdonald and Calder (1982) reported four point loading tests on steel plated RC beams of length 4900mm. These beams were used to provide data for the proposed strengthening of the Quinton Bridges (Raithby, 1980 and 1982), and incorporated two different epoxy adhesives, two plate thicknesses of 10.0mm and 6.5mm giving width-to-thickness (b/t) ratios of 14 and 22, and a plate lap-joint at its centre. In all cases it was found that failure of the beams occurred at one end by horizontal shear in the concrete adjacent to the steel plate, commencing at the plate end and resulting in sudden separation of the plate with the concrete still attached, up to about mid-span. The external plate was found to have a much more significant effect in terms of crack control and stiffness. The loads required to cause a crack width of 0.1mm were increased by 95%, whilst the deflections under this load were substantially reduced.

2.1 REVIEW OF EXPERIMENTAL INVESTIGATIONS

The following section reviews, on a geographical basis, experimental work reported to investigate the flexural strengthening of RC members using non-prestressed FRP plates. These studies have utilised fibrous materials in various forms, including pultruded plates, procured prepreg plates, prepreg sheets or tapes cold laminated in place, and dry fiber sheets impregnated at the time of bonding.

The following modes were observed either individually or in combination in the tests carried out at the EMPA:

- sudden, explosive, tensile failure of the CFRP laminates
- compressive failure in the concrete
- slow, continuous peeling of the laminate during loading resulting from an uneven concrete bond surface
- sudden peeling of the laminate during loading due to relative vertical displacement across a shear crack in the concrete
- horizontal shearing of the concrete in the tensile zone
- interlaminar shear within the CFRP sheet.

The CFRP plate was found to reduce the total width of cracks and produce a more even crack distribution over the length of the beam (Meier and Kaiser, 1991). Meier et al. (1992) recommended that in strengthening applications, the external CFRP should fail in tension after yielding the internal steel but before failure of the concrete in the compressive zone, since this would ensure a more ductile failure mode.

3 APPLICATIONS OF FRP STRENGTHENING

Nanni (1995) reported the findings of a visit to Japan to determine the scale of FRC use as external reinforcement.

- Strengthening of a cantilever slab of the Hata Bridge along the Kyushu Highway in order to accommodate large parapet walls which caused elevated bending moments due to the higher wind force;
- Increase of the load rating of the Tokando Highway bridge at Hiyoshikura, a reinforced concrete deck supported on steel girders, causing a 30–40% reduction of stress in the internal rebars;
- Arrest of the internal steel reinforcement corrosion of the concrete beams in the waterfront pier at the Wakayama oil refinery;
- Strengthening and stiffening of the concrete lining of the Yoshino Route tunnels on Kyushu Island
- Longitudinal strengthening of the sides and soffit of a culvert at the Fujimi Bridge in Tokyo.

4 MATERIALS

4.1CONCRETE

Concrete is a construction material composed of portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite. The cement and water form a paste which hardens by chemical reaction into a
strong, stone-like mass.

For concrete, the maximum aggregate size used was 20 mm. Nominal concrete mix of 1:1.5:3 by weight is used to achieve the strength of 20 N/mm^2. The water cement ratio 0.5 is used. Three cube specimens were cast and tested at the time of beam test (at the age of 28 days) to determine the compressive strength of concrete. The average compressive strength of the concrete was 31N/mm^2.

4.2 Cement

Cement is a material, generally in powder form, that can be made into a paste usually by the addition of water, when molded or poured, will set into a solid mass. The mostly used construction cements is portland cement. Blast-furnace slag may also be used in some cements and the cement is called portland slag cement (PSC) .The specific gravity is at leastn3.10.

4.3 Fine aggregate

The fine aggregate was passing through 4.75 mm sieve and had a specific gravity of 2.68. The grading zone of fine aggregate was zone III as per Indian Standard specifications.

4.4 Coarse aggregate

Coarse aggregate are the crushed stone is used for making concrete.The aagregate which are retained from 4.75 mm IS sieve and contain only that much of fine material as is permitted by the specifications are termed as coarse aagregate commercial stone is quarried, crushed, and graded. Much of the crushed stone used is granite, limestone, and trap rock. The last is a term used to designate basalt, gabbro, diorite, and other dark- colored, fine-grained igneous rocks. The sizes are from 0.25 to 2.5 in (0.64 to 6.35 cm), although larger sizes may be used for massive concrete aggregate. The maximum size of coarse aggregate was 20 mm and specific gravity of 2.78.

4.5 Water

Water which is safe for drinking is generally considered good for concrete.The water used for the mixing and curing of concrete should be free from injurious amount of deleterious materials.

4.6 REINFORCEMENT

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The longitudinal reinforcements used were high-yield strength deformed bars of 12 mm diameter. The stirrups were made from mild steel bars with 6 mm diameter. The yield
strength of steel reinforcements used in this experimental program was determined by performing the standard tensile test on the three specimens of each bar. The average proof stress at 0.2 % strain of 12 mm ϕ bars was 437 N/mm^2 and that of 6 mm ϕ bars was 240 N/mm^2.

4.7 FIBER REINFORCED POLYMER (FRP)

Continuous fiber-reinforced materials with polymeric matrix (FRP) can be considered as composite, heterogeneous, and anisotropic materials with a prevalent linear elastic behavior up to failure. They are widely used for strengthening of civil structures. There are many advantages of using FRPs: lightweight, good mechanical properties, corrosion-resistant, etc.

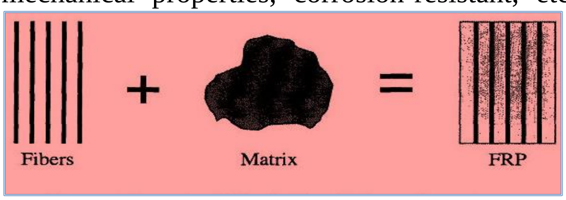

Fig. Formation of Fiber Reinforced Polymer Composite

4.7 Reinforcement materials

A great majority of materials are stronger ad stiffer in fibrous form than as bulk materials. A high fiber aspect ratio (length: diameter ratio) permits very effective transfer of load via matrix materials to the fibers, thus taking advantage of there excellent properties. Therefore, fibers are very effective and attractive reinforcement materials.

4.8 Fiber

The main functions of the fibers are to carry the load and provide stiffness, strength, thermal stability, and other structural properties in the FRP.
To perform these desirable functions, the fibers in FRP composite must have:

i) high modulus of elasticity for use as reinforcement;
ii) high ultimate strength;
iii) low variation of strength in fibers
iv) high stability of their strength during handling; and
v) high uniformity of diameter

EXPERIMENTAL STUDY

The experimental study consists of casting of two sets of reinforced concrete (RC) beams. In SET I three beams weak in flexure were casted, out of which one is controlled beam and other two beams were strengthened using continuous glass fiber reinforced polymer (GFRP) sheets in flexure. In SET II three beams weak in shear were casted, out of which one is the controlled beam and other two beams were strengthened by using continuous glass fiber reinforced polymer (GFRP) sheets in shear. The strengthening of the beams is done with varying configuration and layers of GFRP sheets. Experimental data on load, deflection and failure modes of each of the beams were obtained. The change in load carrying capacity and failure mode of the beams are investigated as the amount and configuration of GFRP sheets are altered. The following chapter describes in detail the experimental study.

Reinforcing steel

HYSD bars of 12 mm dia were used as main reinforcement. 6 mm ϕ mild steel bars were used for shear reinforcement.

5 FORM WORK

Fresh concrete, being plastic requires some kind of form work to mould it to the required shape and also to hold it till it sets. The form work has, therefore, got to be suitably designed. It should be strong enough to take the dead load and live load, during construction and also it must be rigid enough so mat any bulging, twisting or sagging due to the load if minimized, Wooden beams, mild steel sheets, wood, and several other materials can also be used. Formwork should be capable of supporting safely all vertical and lateral loads that might be applied to it until such loads can be supported by the ground.

6 MIXING OF CONCRETE

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Mixing of concrete should be done thoroughly to ensure that concrete of uniform quantity is obtained. Hand mixing is done in small works, while machine mixing is done for all big and important works. Although a machine generally does the mixing, hand mixing sometimes may be necessary. A clean surface is needed for this

1.1 warning compared to the beams strengthen only at the soffit of the beam.

1.2 By strengthening up to the neutral axis of the beam, increase in the ultimate load carrying capacity of the beam is not significant and cost involvement is almost three times compared to the beam strengthen by GFRP sheet at the soffit only.

2. SET II Beams (S1, S2 and S3)

2.1 The control beam S1 failed in shear as it was made intentionally weak in shear.

2.2 The initial cracks in the strengthen beams S2 and S3 appears at higher load compared to the un-strengthen beam S1.

2.3 After strengthening the shear zone of the beam the initial cracks appears at the flexural zone of the beam and the crack widens and propagates towards the neutral axis with increase of the load. The final failure is flexural failure which indicates that the GFRP sheets increase the shear strength of the beam. The ultimate load carrying capacity of the strengthen beam S2 is 31 % more than the controlled beam S1.

2.4 When the beam is strengthen by U-wrapping in the shear zone, the ultimate load carrying capacity is increased by 48 % compared to the control beam S1 and by 13% compared the beam S2 strengthen by bonding the GFRP sheets on the vertical sides alone in the shear zone of the beam.

2.5 When the beam is strengthen in shear, then only flexural failure takes place which gives sufficient warning compared to the brittle shear failure which is catastrophic failure of beams.

2.6 The bonding between GFRP sheet and the concrete is intact up to the failure of the beam which clearly indicates the composite action due to GFRP sheet.

Restoring or upgrading the shear strength of beams using GFRP sheet can result in increased shear strength and stiffness with no visible shear cracks. Restoring the shear strength of beams using GFRP is a highly effective technique.

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