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HYBRID REINFORCEMENT DEVELOPED BY USING CFRP SHEET

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Abstract - *The conventional steel reinforcement replacement with CFRP sheet wrapping bars has been investigated to overcome the corrosion problem in bridge decks, marine structures and chemical plants. In addition to their excellent non-corrosive characteristics, Hybrid Reinforcements System (HRS) has high strength to weight ratio, good fatigue properties and brittle resistance. The present project work aims to study the effect of Hybrid reinforcement developed by wrapping CFRP sheet on steel rod as core material was used as tensile reinforcement in reinforced concrete beam. Eight beams, including four control beams reinforced with steel, were tested for strength, deflection, ultimate load, and failure characteristics. It was revealed that the use of the Hybrid Reinforcement resulted in remarkable increases in mainly beam ultimate load capacity as well as corrosion resistance.*

Key Words: **CFRP; Hybrid reinforcements; Beams; Strain; Corrosion; Flexural strength.**

1. INTRODUCTION

Corrosion of reinforcement is a major problem facing infrastructure in all structures. Particularly in bridge deck, marine structures, wastewater treatment facilities, chemical plants and deicing salts. Many structures in adverse environments have experienced unacceptable damages and life time reduced and affect serviceability of structural members due to the corrosion of reinforcing steel. The need for corrosion resistant in structure and rehabilitation in bar corroded structures has led to determine the alternative for steel. Because they are mostly using glass fiber reinforced polymers (GFRP) bars in strengthening and rehabilitation of RC flexural members in all construction applications. It has some important properties are high electrical insulating, heat resistance, and lowest cost. The use of GFRP Rod to strengthen the structural members started with the external bonding and this technique became popular all over the world. But GFRP bar are having disadvantage is brittle collapse, limited experience and low modulus of elasticity. To address this problem, we propose to introduce a new bar with ductile nature. Emad El-SayedEtman, et.al. (2011), "Innovative Hybrid Reinforcement for Flexural Members" [1].

(CFRP) sheet wrapping on steel rod as core material used to making Hybrid Reinforcement developed. Carbon fibers are having some properties, high tensile strength and elastic modulus. HRS is simply defining an innovative reinforcing material for corrosion resistance of marine structural elements. This reinforcement are mainly used as alterative reinforcement of structural members, due to some advantages such as resistance to corrosion under deicing salts. The HRS used in this project consists of mainly two parameters are core reinforcement and perimeter reinforcement. The core reinforcement which is made of (TMT) bars was covered with epoxy and while wet surrounded by perimeter one layers of fiber reinforcement (carbon fibers).Structural members using HRS reinforcement in external (or) internal reinforcement. In this project, they are using internal reinforcement in HRS. G. Nossoni et.al. (2014), "Rate of Reinforcement Corrosion and Stress Concentration in Concrete Columns Repair with Bonded and Un bonded FRP Wraps" [14]. This project presents tests on flexural members 4 (RC beam) reinforced with HRS, as their main reinforcement, to achieve the high strength and corrosion reduce in these beams. HRS is used to design the various material of reinforcing components to act perfectly single reinforcement system. The HRS mainly consists more variables in the project were the type core reinforcement and number of layer used in perimeter reinforcement. The present project results expected that the HRS reinforcements can increase the strength, ultimate load, deflection at ultimate load, strains and reduce corrosion.

2. EXPERIMENTAL PROGRAM

2.1. Materials used

2.1.1. Aggregates and cement

Cement is the important binding material in concrete for all construction. In this project using Pozzolanic Portland Cement (PPC) of 53 Grade and it having a specific gravity of 3.11. The river sand conforming as per code and 4.75mm sieve used to remove all unwanted particles and foreign matter. IS: 383-1987 "Indian Standard Specification for Coarse and Fine aggregates from natural sources for concrete" [18]. Fine Aggregate, Coarse Aggregate having a specific gravity 2.6 and 2.8. A maximum size of 20mm is used as coarse aggregate in concrete.

2.1.2 Water

Water is a mainly important ingredient of concrete and chemical reaction with cement. Clean potable water conforming to IS 456-2000 [16] was used.

2.1.3 Steel bar

The longitudinal reinforcements used were high-yield strength deformed bars of 10 mm diameter. The stirrups were made from TMT bars with 8 mm diameter. This bar are used to making control beams and hybrid beams.

Table 1: Properties of 10mm TMT bar

Property	Test Result
Fmax	50.99 KN
UTS	645.57 MPa
% EL	19.80 %
Yield Stress(Ys)	548.96 MPa

2.1.4 Hybrid Reinforcement

The Hybrid Reinforcement System (HRS) simply define as innovative reinforcing material of structural element and it consists more than one reinforcing material. Hybrid Reinforcement developed by using wrapped CFRP sheet on (TMT bar) used as core material CFRP sheet used in this project as one layer of perimeter. It have a high yield stress, ultimate tensile strength (UTS) and elongation compared to TMT bar.2.1 Aggregates and Cement

Fig 1. Samples of hybrid reinforcing bars

2.1.5 Silicon Carbide

Chemical compound of carbon and silicon is simply say silicon carbide. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products.

2.1.6 CFRP Sheet

Mainly used in retrofit and repair structurally deficient infrastructures such as pre stressed concrete bridge girder and aerospace industry are popularly used because its strength to weight ratio is highest among all FRPs. CFRP Sheet wrapping used in masonry columns of rehabilitation due corrosion control, earthquake resistant structures.

Properties

- alkali resistant
- low thermal conductivity
- non-magnetic
- high fatigue resistance
- high ultimate strain
- resistant to corrosion

2.1.7Matrix Materials

Fibers are cannot directly transmit loads from one to another.Bind the fibers together, transfer loads to the fibers, and damage due to handling by using matrix material. In this project are using epoxy resin and hardener. Various types of resin are there, but using Araldite MY753. Because they have many advantages are medium viscosity, corrosion resistance, mechanical and thermal properties are good, and electrical properties.

Advantages

- very good gap-filling
- good wetting
- chemical resistance
- much longer life

Table 2: Properties of epoxy resin

Property	Test Result
Viscosity at 25° C μ(cp)	12000
Density ρ ($g.cm^{-3}$)	1.16

2.1.6 Strain Gauge

A strain gauge is constructed by bonding a fine electric resistance wire or photographically etched metallic resistance foil to an electrical insulation base using appropriate bonding materials, and attaching gauge leads. They can measure the gauge parallel to the surface in which direction we want to measure the strains.

2.2. MIX DESIGN

The concrete mix has been designed for M25grade as per IS code. IS: 10262:2009 "concrete mix proportioning", Bureau of Indian Standards, New Delhi[17].The specified concrete grade involves the economical selection of relative proportions of cement, fine aggregate, coarse aggregate and water.

Table 3:Mix Proportion for M25 Grade

Constituent	Cement	Fine Aggregate	Coarse aggregate	Water
Weight/ Volume	425.73 kg/m^3	645.5 kg/m^3	1183.6 kg/m^3	191.58 lit
Proportion	1	1.51	2.77	0.45

2.3. SPECIMEN DETAILS

The present project test for 8 RC beams. All tested beams had 130-mm width, 230-mm depth and 1,400-mm length. The hybrid reinforced beams were reinforced with two numbers of 10mm hybrid reinforced bars at the bottom, and two numbers of 10 mm diameter TMT bars at the top, with the 8 mm diameter stirrups at various spacing 150 mm and 300 mm centre to centre spacing. The dimensions and details of supports common to all beams. For the four control beam, the reinforcement includes only TMT steel bars. And the four hybrid reinforcement includes two components .The reinforcement details are shown in fig.3. Three types of wrapping length in Hybrid reinforcement bar were used in total beams are described below table 1.The five strain gauges are used to measure the strains tin this project. A three strain gauge was attached to an HRS bar of the main reinforcement at the mid span and others are at 200mm spacing from the mid span of tension surface at the reinforcement, another two strain gauge was attached to a top surface of beam and bottom surface of beam at midspan. A LVDT was also mounted to measure the deflection at midspan of beam.

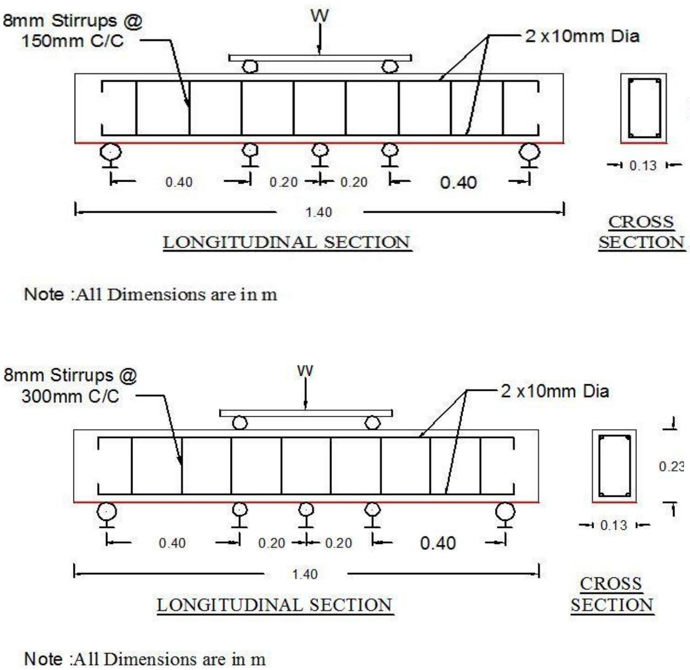

Fig 2: longitudinal profile and cross section

2.4. TEST ARRANGEMENT

The beams were tested in the Loading frame 40 Tons in capacity and test setup are show in fig 3. All beams were tested up to ultimate load, under two-point loading over a simply supported. And also used load cell on the top of beam.A concentrated load apply on a stiff steel distributor beam by displacement control was used to drive hydraulic jack, which then produces two-line loads on the beam. To measure the deflections, LVTD were placed at the centre of the beam at bottom. The load was applied in 1ton incrementally up to yield point of the beam reinforcement. The strain gauge was used for recording the strains on beam.Then the beam was tested to failure by applying the load in increments, and clearly observe all reading, such as first crack load, ultimate load, deflection and strain.

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Fig 3: Test setup

3. TEST RESULTS AND DISCUSSIONS

3.1. Mechanical properties

The average compressive strength and tensile strength at 28 days is 25 N/mm^2, 2.3 N/mm^2 .

3.2 First crack and ultimate load

The first crack load in the control beams are SB 1,SB2 ,GB3,and GB4 is 1.4KN, 2.0KN, 1.6KN and 1.9KN while for hybrid beams HCB5, HCB6 ,HCB7, and HCB8 , the first crack load forms at 1.04 KN, 1.5KN, 1.21KN, and 1.3KN, respectively. When comparing control beams to hybrid beams are having small crack, so they having high strength. Then increase in ultimate loads of beams HCB5, HCB6, HCB7 and HCB8 was 6.00KN, 6.91KN, 7.03KN, and 8.00KN, respectively, as compared to the control beam (SB1,SB2, GB3, GB4) and show in fig.4. It can be seen that in both of beams, the beam with one layers wrapping of CFRP sheet exhibits the maximum load carrying capacity when compared to other beams. This shows that the ultimate load carrying capacity increases with the Hybrid beam. The summary of test results for all beams, showing in table 4.

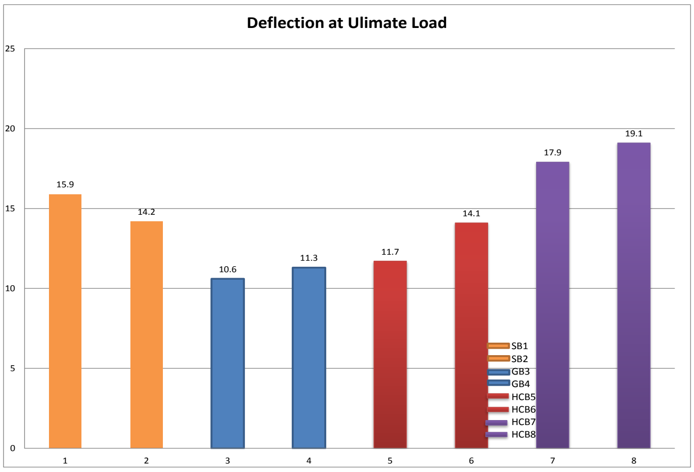

Fig.4 Deflection at ultimate load

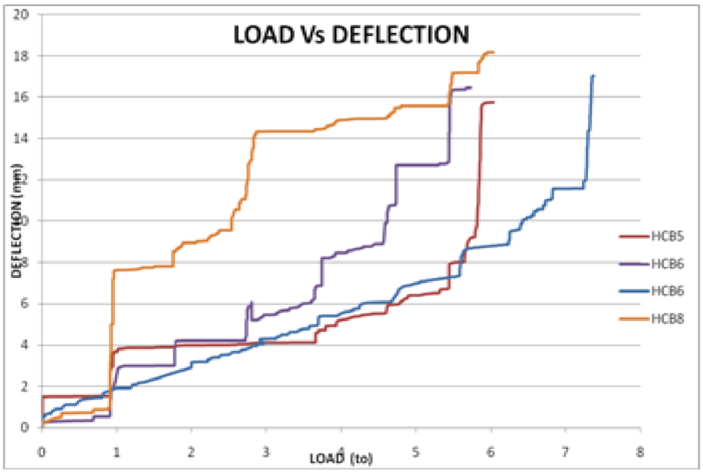

Fig.5 load-deflection response of Hybrid Reinforcement beams

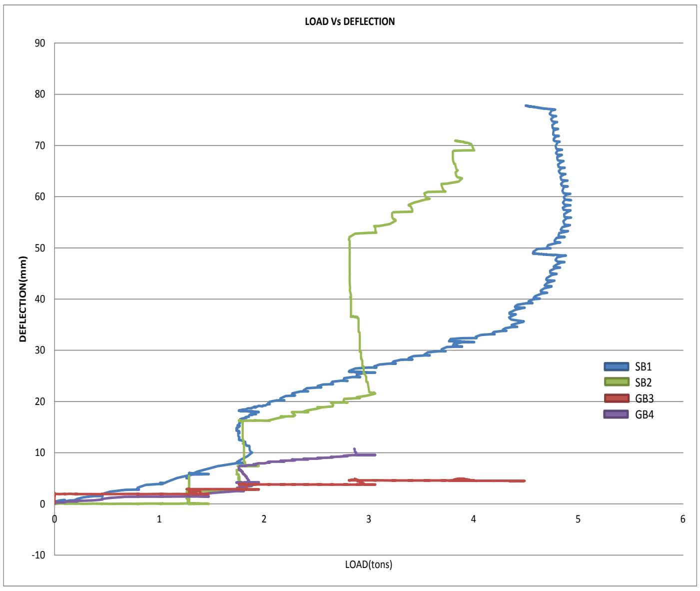

Fig6: load-deflection response of control

3.4 Load-deflection response

The load-deflection response of the (HCB5, HCB6, HCB7, HCB8) beams is compared with that of the control beam (SB1, SB2, GB3, GB4). Figure 5 and 6 represents the load-deflection response of the Hybrid Reinforcement beams, and control beam.

3.5 Failure modes

Various modes of failures are observed in Beams reinforced with HRS. The yielding of the core reinforcement in all beam observed after failures. In specimen hybrid beam, where the core reinforcement was made of TMT bar, failure was initially flexural. The vertical cracks that started on the tension face. In this cracks are continuously and finally a sudden failure occurred under the concentrated line load except specimen hybrid reinforcement that failed in a brittle manner. For the control specimen, a flexural failure mode was clearly observed in the form of deep flexural cracks that started on the extreme tension side of the beam. This failure mode was also dominated for specimens hybrid reinforced beam. When continuous crack propagation and final crushing of concrete on the compression side of the beam are, that experienced this failure mode. Fig.7 shows the failure of control beams and also Fig.8 shows the failure of hybrid beams.

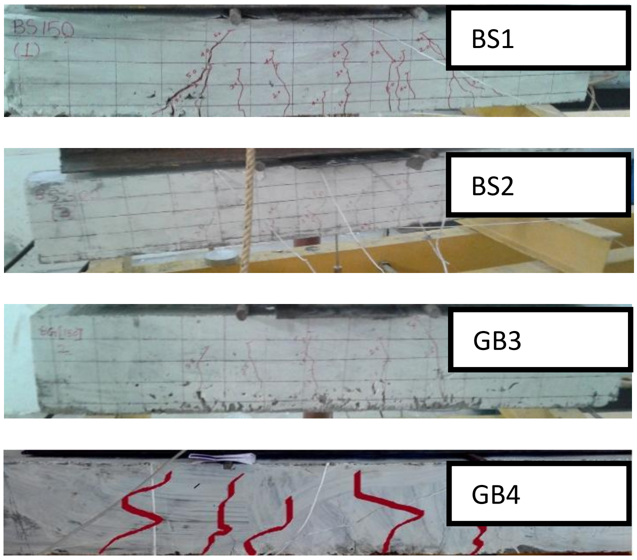

Fig 7: Failure of Control beams

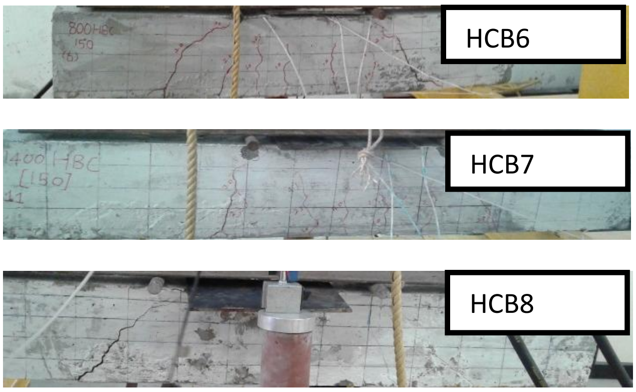

Fig 8: Failure of Hybrid Reinforcement beams

Table 4: Summary of Test Result

Beam ID	**First crack load** [KN]	**Deflection at first crack load** [mm]	**Ultimate load** [KN]	**Deflection at ultimate load** [mm]
BS1	**1.5**	**1.4**	**5.16**	**13.9**
BS2	**1.5**	**2.0**	**6.08**	**12.2**
GB3	**1.4**	**1.6**	**4.13**	**10.6**
GB4	**1.45**	**1.9**	**5.05**	**11.3**
HCB5	**1.49**	**0.8**	**6.03**	**15.8**
HCB6	**1.5**	**1.0**	**6.91**	**16.1**
HCB7	**1.21**	**1.7**	**7.31**	**17.9**
HCB8	**1.3**	**2.1**	**8.00**	**19.1**

Type Of Rods And Beam Name	Behaviour		Stirrups Spacing
Steel Rod (SB1,SB2)	Flexural		150mm
	Shear		300mm
GFRP Rod(GB3,GB4)	Flexural		150mm
	Shear		300mm
Hybrid Reinforced Rod (HCB5,HCB6,HCB7,HCB8)	Flexural	400mm Wrapping	150mm
		800mm Wrapping	150mm
		1400mm Wrapping	150mm
	Shear	1400mm Wrapping	300mm

Table 5: Reinforcement Detailing

4. CONCLUSION

Based on the presented experimental work and discussions the following conclusions are

- The use of carbon fibers in the perimeter layer of a HRS resulted in specimens with higher deflection and load capacity compare to control beam.
- The load carrying capacity of the HCB is 55% greater than BS and 93% greater than GB.
- The deflection at ultimate load of HCB is 37% greater than BS and 80% greater than GB.
- Reduce the corrosion problem in Hybrid Beam because, they have high strength, deflection.

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