Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 5, Issue 08, August -2018

EXPERIMENTAL STUDY ON FLEXURAL STRENGTHENING OF RCC BEAM BY USING CFRP

R.Aisswarya

M.E Structural Engineering

ABSTRACT :- *This project explores the flexural behaviour of carbon fiber reinforced polymer (CFRP) and Engineered cementitious composite (ECC) strengthened reinforced concrete (RC) beams. For flexural strengthening of RC beams, total 6 beams, with (150 x 300) mm rectangular cross section and of span 1900 mm are casted. The beams are designed as under – reinforced concrete beams. Four beams are strengthened with CFRP rods and ECC which are parallel to beam axis at the bottom under virgin condition and tested until failure; the remaining two beams are used as control specimens. Static responses of all beams are evaluated in terms of strength, stiffness, ductility ratio, energy absorption capacity factor, compositeness between ECC and concrete and the associated failure modes. The results shows that the strengthened beams exhibit increased flexural strength, enhanced flexural stiffness and composite action until failure.*

Keywords:- *Reinforced concrete beam, ECC,CFRP rod*

1. INTRODUCTION

The repairing and strengthening processes are aims to improve the performance of the concrete members, restore and increase the strength and stiffness of the concrete, improve the appearance of the concrete surface, increase water tightness, prevent access of corrosive materials to the reinforcing, and improve the overall durability of the concrete members.

The proper repair of deteriorating concrete structures based on the careful evaluation of the causes, consequences of the deterioration, and the repair or strength techniques, procedures, and materials used. The cost and ease of application as well as the efficiency of the repair process are major considerations in choosing the materials and techniques. A strengthened or damaged structure can retrofitted to a satisfactory level of performance at a reasonable cost by different methods. Repairing or strengthening concrete beams by applying repairing technique on the tension face of the beam. The main objective of using beneath layer is to increase the load capacity of concrete beam. Depending on the type of wrap layer used, an increase in stiffness and strength obtained. As any other strengthening or repairing technique, the design of the beneath layer should include the probable extra loads affecting on the beam and the bond between repairing material and concrete face. The compressive strength of the new concrete should be not less than that of the existing structure.

That technique can apply by several methods. Generally, the concrete beam lower face wrapped with a repairing layer bonded to the tension face of beam.

FRP can be applied to strengthen the beams, columns, and slabs of buildings and bridges. It is possible to increase the strength of structural members even after they have been severely damaged due to loading conditions. In the case of damaged reinforced concrete members, this would first require the repair of the member by removing loose debris and filling in cavities and cracks with mortar or ECC.

Two techniques are typically adopted for the strengthening of beams, relating to the strength enhancement desired: flexural strengthening or shear strengthening. In many cases it may be necessary to provide both strength enhancements. For the flexural strengthening of a beam, FRP rods are applied to the tension face of the member (the bottom face for a simply supported member with applied top loading or gravity loading). Principal tensile fibers are oriented in the beam longitudinal axis, similar to its internal flexural steel reinforcement. This increases the beam strength and its stiffness (load required to cause unit deflection), however decreases the deflection.

1.1 OBJECTIVE

The objective of this investigation is:

i. To study the structural behavior of reinforced concrete (RC) beams under static loading condition.
ii. To determine the load carrying capacity of the beam.
iii. To know the suitability of the ECC as repair materials for deteriorated RC Structures.

1.2 SCOPE

The experimental investigations are planed under:

i. To study the behavior of flexure deficient RC beams

ii. To know the practical feasibility of ECC in the construction industry

iii. To study the contribution of ECC on ultimate load carrying capacity and failure pattern of reinforced concrete beams

2. MATERIALS

2.1 ECC

A collaborative effort between US and Japanese researchers has focused on the development of high-performance elements for seismic structural applications based on a new materials technology as an Engineered Cementitious Composite (ECC) designed using micromechanical principles. ECC exhibits strain-hardening with strain capacity in excess of 1% in tension and multiple cracking properties. The excellent identical properties of ECC make it especially suitable for critical elements in seismic applications where high performance is required. Applications of ECC to energy absorption devices and damage tolerant structural elements are considered to meet the performance requirements of structures under the performance based engineering. These new structural elements with ECC are expected to reduce the seismic response and damage of structures. Objective of this research is to investigate the upgrading effects on structural performance of ECC reinforced elements. The ECC employed in this research is Polyvinyl Alcohol (PVA) fiber reinforced mortar. A tension-compression reversed cyclic test of ECC material and a structural test with six beam elements were conducted. This paper summarizes the basic mechanical properties of PVA-ECC and structural performance of the PVA-ECC reinforced beams. The micromechanics concepts, which support the development of ECC, are also briefly presented. Results of the beam test indicate that brittle failures as shear failure and bond splitting failure observed in the RC beams can be prevented by using PVA-ECC in place of the concrete. As a result, the beams with PVA-ECC indicate excellent ductile manner. The shear crack widths up to 5 % rad. in deflection angle in the beams with PVA-ECC were less than 0.3 mm, which is the maximum limit from the view of durability. Through this test, it can be clarified that ECC has much feasibility to upgrade the structural performance and damage tolerance of structural elements.

The material ingredients of engineered cementitious composite are similar to that of fiber reinforced concrete, including cement, sand, water, fiber, and a few chemical additives. Unlike the fiber reinforced concrete, the engineered cementitious composites do not include large volume of fiber. The mixing procedure of engineered cementitious composites is similar to that employed for the normal concrete. The engineered cementitious composites are economical by a reduction in the usage of fiber while maintaining the desired characteristics of strength and ductility.

The basic difference in the properties of engineered cementitious composite and fiber reinforced concrete is that afer cracking the engineered cementitious composite strain hardens while the fiber reinforced concrete does not exhibit such a behavior. In fiber reinforced concrete, the crack develops with the rupture of the fibers due to which the stress bearing capability is decreased. In addition, the engineered cementitious composites have a high fracture toughness that is similar to that of aluminium alloys, and the damage tolerance is extremely high.

2.2 Ingredients Of ECC Concrete

Engineered cementitious composite is composed of cement, sand, fly ash, water, small amount of admixtures and an optimal amount of fibers. In the mix coarse aggregates are deliberately not used because property of ECC Concrete is formation of micro cracks with large deflection. Coarse aggregates increases crack width which is contradictory to the property of ECC Concrete.

2.2.1 Cement

Cement used is Ordinary Portland cement. Numerous organic compounds used for adhering, or fastening materials, are called cements, but these are classified as adhesives, and the term cement alone means a construction material. Blast- furnace slag may also be used in some cements and the cement is called Portland slag cement (PSC). The color of the cement is due chiefly to iron oxide. In the absence of impurities, the color would be white, but neither the color nor the specific gravity is a test of quality. Ordinary Portland cement (OPC) – 53 grade (Ultratech Cement) was use.

2.2.2Silica Sand

Fine aggregate / natural sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. It is distinguished from gravel only by the size of the grains or particles, but is distinct from clays which contain organic materials. Sands that have been sorted out and separated from the organic material by the action of currents of water or by winds across arid lands are generally quite uniform in size of grains. Usually commercial sand is obtained from river beds or from sand dunes originally formed by the action of winds. The most useful commercially are silica sands, often above 98% pure. Beach sands usually have smooth, spherical to ovoid particles from the abrasive action of waves and tides and are free of organic matter. The white beach sands are largely silica but may also be of zircon, monazite, garnet, and other minerals, and are used for extracting various elements. Sand is used for making mortar and concrete and for polishing and sandblasting. Sands containing a little clay are used for making molds in foundries. Clear sands are employed for filtering water. Sand is sold by the cubic yard (0.76 m3) or ton (0.91 metric ton) but is always shipped by weight. The weight varies from 1,538 to 1,842 kg/m3, depending on the composition and size of grain. The fine aggregate obtained from river bed of Koel, clear from all sorts of organic impurities was used in this experimental program. 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 specimen.

2.2.3Super Plasticizer

Super plasticizer used is Melamine Formaldehyde Sulphonate. This is used to control rheological properties of fresh concrete. Super plasticizers are additives to fresh concrete which help in dispersing the cement uniformly in the mix. This is achieved by their deflocculating action on cement agglomerates by which water entrapped in the groups of cement grains is released and it is available for workability. Typically super plasticizer increase slump from say 5cm to about 18-20cm without addition of water. When used to achieve reduction in mixing water they can reduce water up to 15-20% and hence decrease W/C ratio by same amount. This results in increase in strength and other properties like density, water tightness. Where thin sections are to be cast super plasticizer can increase workability to pump able level and almost no compaction is required. This help in avoiding honeycombing. The permeability of concrete is a guide to its durability. Gross porosity is usually due to continuous passage in the concrete due to poor compaction or cracks which can be minimized by the use of super plasticizer, the incorporation of which provides increased workability maintaining low w/c ratio. It is reported that coefficient of permeability of cement paste reduces considerably with the reduction in w/c ratio. Thus super plasticizer can be used effectively to improve the properties of concrete and avoid defect.

2.2.4 Fly Ash

Fly ash used was pozzocrete dirk 60.And specifications provided by suppliers are given in Table 1.below. In RCC construction use of fly ash has been successful in reducing heat generation without loss of strength, increasing ultimate strength beyond 180 days, and providing additional fines for compaction. Replacement levels of primary class fly ash have ranged from 30-75% by solid volume of cementitious material. In proportioning mixes for minimum paste volumes one principal function of a fly ash is to occupy void space which would otherwise be occupied by cement or water. To occupy void space with water would obviously result in reduction in concrete strength. The fact is that even a small amount of free lime liberated from cement is sufficient to react with large volume of fly ash. The huge amount of fly ash is produce in the thermal power stations .Class F fly ash is utilized so the acquisition cost is reduced.

2.2.5 PVA Fibers

PVA fiber has suitable characteristics as reinforcing materials for cementitious composites. High modulus of elasticity, durability, tensile strength and bonding strength with concrete matrix are some of its desirable properties. PVA fiber has high strength and modulus of elasticity (25 to 40GPa) compared to other general organic fiber which widely used for cement reinforcing. Fiber elongation is about 6-10%. The tensile strength of fiber is 880-1600MPa

Fig 1.1PVA Fiber

2.2.6 Water

Water fit for drinking is generally considered fit for making concrete. Water should be free from acids, oils, alkalis, vegetables or other organic Impurities. Soft waters also produce weaker concrete. Water has two functions in a concrete mix. Firstly, it reacts chemically with the cement to form a cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Secondly, it serves as a vehicle or lubricant in the mixture of fine aggregates and cement.

3.0 MATERIAL TEST RESULT

S.No	Name of Test	Value	Codal Standard
1	Specific Gravity of Cement	3.148	3.15
2	Standard Consistency of Cement	32%	IS:4031(Part-4)-1988 Penetration 5-7mm
3	Initial Setting Time of Cement	45min	IS 12269-1987 Should not be less than 30 minitues clause 5.3
4	Test on final setting time of cement	445min	IS 12269-1987 Should not be more than 600minitues clause 5.3
5	Average Compressive strength test of cement mortar cube (28days)	$54N/mm^2$	Not less than 53 N/mm^2 as per IS 12269-1987
6	Specific gravity of FA	2.65	2.6-2.7
7	Sieve analysis of FA	FM=2.78	IS:2386(Part-1)1963 Mediumsand 2.6-2.9
8	Water absorption test on FA	0.917%	IS:2386(Part-3)1963
9	Specific gravity test for CA	2.66	FOR C.A 2.7
10	Water absorption test for CA	0.4%	5%
11	Sieve analysis of CA	FM=7.5	IS:2386(Part-1)1963
12	Impact test of CA	7.1%	Should not be > than 45% for concrete other than wearing surface and 30% for pavements as per IS 2368(Part-4)1963

3.1 MIX PROPORTION

The main objectives are to determine the most economical and practical combination of readily available materials to produce a concrete that will satisfy the performance requirements under particular conditions of use. Also to determine the proportion of ingredients that would produce a workable concrete mix that is durable and meets required strength. Mix design for each set having different combinations are carried out by using **IS:10262 - 2009**method.The mix proportion obtained for normal M30 grade concrete is **1:1.3:2.6**with a water-cement ratio of **0.45.**

3.1 Mix Design

Materials	Concrete Constitute for beam
Cement	11.05 kg
Fine aggregate	30 kg
Coarse aggregate (sand)	27 kg
Water	6 liters

3.2. CASTING AND TESTING OF SPECIMEN FOR CONTROL MIX

3.2.1 CASTING OF SPECIMEN: Cubes moulds of size 150 X 150 X 150 mm, to be used are cleaned properly with dry cloth and oil was applied before casting. The amount of cement, fine aggregate, coarse aggregate were measured based on their weight and then they were mixed on water tight platform under standard condition. Water was added gradually till all the materials has been adequately mixed together to form a uniform mix. Concrete was then filled in moulds and compacted using standard tamping rod.

After curing for required period the specimen were tested using compressive testing machine. The curing periods were was 7days, 14days and 28days.Compressive strength test was found by the following formula:

Compressive strength (N/mm^2) =

$$\frac{\text{Max } load(N)}{\text{Cross Sectional Area}(mm2)}$$

TABLE 3.2 COMPRESIVE STRENGTH IN N/mm^2

Specimen	Control concrete	
	7days	28days
1	23.86	36.12
2	24.23	32.29
3	27.65	31.45
Average	**25.25**	**33.28**

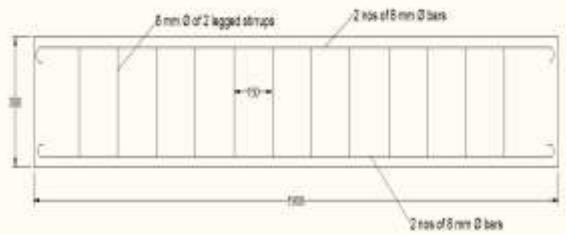
3.3 SPLIT TENSILE TEST

Cylinder specimen of size 300mm height and 150mm diameter are to be cast for the mix proportion. After curing for required period the specimen were tested using compressive testing machine. The curing periods are 7days and 28days and tested to find the split tensile of concrete and the result obtained is being tabulated below.

TABLE 3.3 CYLINDER SPLIT TENSILE STRENGTH IN N/mm^2

Specimen	Control concrete	
	7days	28days
1	2.46	3.50
2	2.49	4.0
3	2.56	4.5
Average	2.5	4.0

3.4 REINFORCEMENT DETAILS



In this project, wooden moulds that are made as a beam with a size of 1900x150x300mm and the reinforcements are provided singly at the tension zone by placing 25mm cover blocks at the bottom of the mould.

3.5 TEST SETUP

The tests were carried out in 50 T Beam Loading Frame Machine (Model:) with necessary fixtures as per ASTM C D 293(Standard test method for flexural strength of concrete using single beam with centre point loading)

with two steel rollers, on which the specimen was supported, and these rollers were mounted at a distance of 1000mm centre to centre

.

The load was applied at the top surface of the beam at a distance of 550mm from the edge. The load was divided equally between the two loading rollers.

A load cell with 50t capacity was mounted on the plate fixed at the top of the rollers

.

A sensitive dial gauge with 0.01mm least count was mounted at the center of the beam to measure mid-span deflection.

A strain gauge was fixed at the center of bottom reinforcement, which was connected to the Universal Data Acquisition and Control System which in turn connected to the computer.

The load strain behaviour was obtained automatically from the system attached.

4. RESULTS AND DISCUSSION

In this chapter the experimental results of all the control beams and strengthened beams are being compared. Their behavior throughout the test is described using mechanically obtained data on deflection behaviour and the load carrying capacity. All the beams are tested for their ultimate strengths. It was observed that the strengthened beam has good load bearing capacity.

This paper investigates NSM strengthening technique in RC beams through bending and vibration tests. The following main conclusions can be drawn:

1. NSM CFRP rods and ECC is a suitable method of strengthening for RC beams;
2. Among method's advantages there is the easy location of CFRP rods and ECC in grooves;
3. The experimental bending tests confirm the availability of NSM technique and the use of FRP rods which may increase significantly the strength of beam without delamination of CFRP rods;
4. Dynamic analysis of free vibration of beams confirmed the efficiency of strengthened beams with lower values of frequency decrease respect beam with steel reinforcement.

REFERENCES

[1] Balaguru, P.N. and Shah, S.P., Fiber Reinforced Cement Composites, McGraw Hill, 1992.
[2] Bentur, A. and Mindess, S., Fiber Reinforced Cementitious Composites, Elsevier Applied Science, 1990.
[3] IS 10262-2007 Recommended Guidelines for Concrete Mix Design
[4] IS 456-2000 Plain and Reinforced Concrete -Code of Practice
[5] IS 516-1959 Methods of Tests for Strength of Concrete
[6] M. L. Gambhir, Concrete Technology (3rd Edition), Published by The McGraw- Hill Companies, New Delhi.
[7] M. S Shetty, Concrete Technology Theory & Practice, Published by S. CHAND & Company, Ram Nagar,New Delhi
[8] FikriAlami, "Flexural Strengthening of Reinforced Concrete Beam using Glass Fiber Reinforced Polymer (GFRP)" Department of Civil Engineering – University of Lampung.
[9] Dr. Gopal Rai and Yogesh Indolia, (2011) "Fiber Reinforced Polymer Composites, a Novel Way for Strengthening Structures" National Conference on Repair and Rehabilitation of Concrete Structures.
[10] Prof. Parikh Kaushal. B., Dr. Modhera Chetan. D. (2010) "Analytical Model of Reinforced Cement Concrete Beam using Glass Fiber Reinforced Polymer" *International Journal of Advanced Engineering Technology*.

