GRD Journals | Global Research and Development Journal for Engineering | Recent Advances in Civil Engineering for Global Sustainability | March 2016
e-ISSN: 2455-5703

Performance Evaluation Study of an Innovative Material to Improve the Strength of Conventional Concrete

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Abstract

Concrete is an absolute essential material use for construction. Despite of its versatility in construction. It is known to have several limitations. It is having limited ductility and less resistance to cracking, so concrete structure suffers a large amount of distortions in strength under the effect of external forces. Some recently developed materials and technique can play virtual role in structural repair, strengthen and retrofitting of existing building, weather damaged or undamaged condition. By use of standard and innovative repair material appropriate technology, proper quality control, are the key factors for strengthen and retrofitting of concrete. The main objective of our study is to suggest best innovative material and techniques to enhance the strength of concrete. The natural calamities such as earthquake, tsunami is not in our control but solution to the damaged structure is available with engineers through retrofitting and rehabilitation technique.
Keyword- Reinforced concrete (RC), FRP, UTM

I. INTRODUCTION

Reinforced concrete (RC) is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength and/or ductility. The reinforcement is usually, though not necessarily, steel reinforcing bars and is usually embedded passively in the concrete before the concrete sets. Reinforcing schemes are generally designed to resist tensile stresses in particular regions of the concrete that might cause unacceptable cracking and/or structural failure. Modern reinforced concrete can contain varied reinforcing materials made of steel, polymers or alternate composite material in conjunction with rebar or not. Reinforced concrete may also be permanently stressed (in compression), so as to improve the behavior of the final structure under working loads.

Existing reinforced concrete structures may be structurally deficient for several reasons: substandard seismic design details, improper transverse reinforcement, flaws in structural design, and insufficient load carrying capacity. Over the last few years, there has been a worldwide increase in the use of composite materials for the rehabilitation of deficient reinforced concrete structures. One important application of this composite retrofitting technology is the use of fiber reinforced polymer (FRP) jackets or sheets to provide external confinement to reinforced concrete specimens when the existing internal transverse reinforcement is inadequate. Reinforced concrete specimens need to be laterally confined in order to ensure large deformation under load before failure and to provide an adequate load resistance capacity. In the case of a seismic event, energy dissipation allowed by a well-confined concrete core can often save lives. On the contrary, a poorly confined concrete column behaves in a brittle manner, leading to sudden and catastrophic failures.

There are considerable number of existing concrete structures in India that do not meet current design standards because of inadequate design and construction or need structural up gradation to meet new seismic design requirements because of new design standards, deterioration due to corrosion in the steel caused by exposure to an aggressive environment and accident events such as earthquakes. Inadequate performance of this type of structures is a major concern from public safety standpoint. That is why reinforced concrete structures often have to face modification and improvement of their performance during their service life. In such circumstances there are two possible solutions: replacement or retrofitting. Full structural replacement might have determinate disadvantages such as high costs for material and labor, a stronger environmental impact and inconvenience due to interruption of the function of the structure e.g. traffic problems. When possible, it is often better to repair or upgrade the structure by retrofitting. Retrofitting have become the increasingly dominant use of the material in civil engineering, and applications include increasing the load capacity of old structures that were designed to tolerate for lower service loads than they are experiencing today, seismic retrofitting, and repair of damaged structures. Concrete structures deteriorate with time, a process that becomes much faster in aggressive environmental conditions. Broadly, methods to repair them can be classified under structural repair and nonstructural repair. Structural repair is carried out by repair, renovation and retrofitting of the entire system as a whole for structural strengthening to carry additional loads or for retrofitting.

II. OBJECTIVE OF PAPER

- To improve the strength of the damaged structural element using innovative material/techniques.
- To study the change in nature of structural element after the application of innovative material/techniques.
- To compare different types of characteristics of the specimen by using graphs and charts.
- To suggest the best material this gives maximum strength at optimum cost.

III. OBJECTIVE OF RETROFITTING

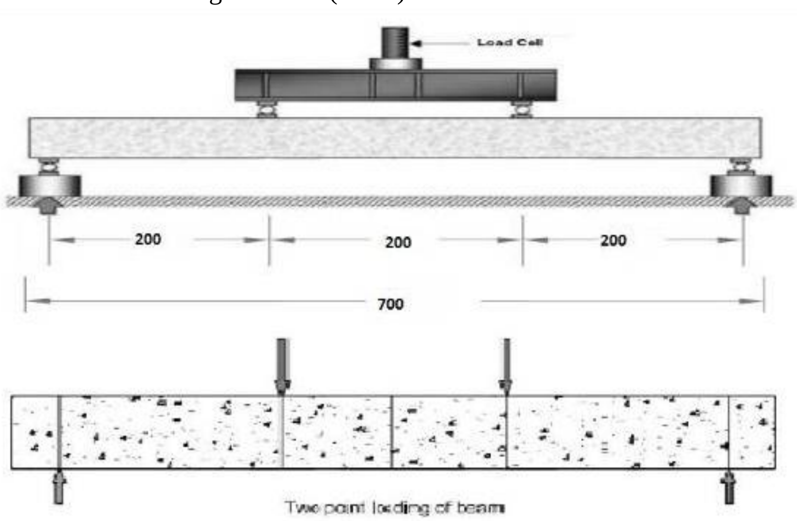
- Increasing the ductility and enhancing the energy dissipation capacity.
- Eliminating sources of weakness or those that produce concentration of stresses.
- Increasing the lateral strength and stiffness of the building.
- Enhancement of redundancy in the number of lateral load resisting elements.
- The retrofit scheme should be cost effective.
- Giving unity to the structure.
- Each retrofit strategy should consistently achieve the performance objective.

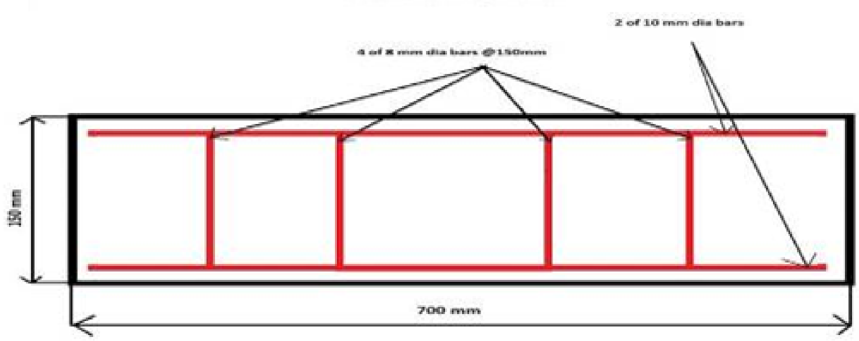
IV. METHODOLOGY AND DESIGN

- A Reinforced Concrete Cement specimen of size 150 x 150 x 700 mm is being adopted, as per the feasible laboratorial conditions.
- Firstly, round about 21 numbers of beams were casted and were kept for curing for 28 days.
- The grade of the concrete and water cement ratio was M25 and 0.5 was adopted respectively.

A. Phase1

- After the completion of the casting and curing process of specimen, load on the specimen has been applied with the help of Universal Testing Machine (UTM) to disfigure the structure.
- After the disfigured zone in the specimen has been recognized, the detailed evaluation of the in-situ quality of the material has been done.
- Graph obtained from the Universal Testing Machine (UTM) machine has been studied for the entire specimen.





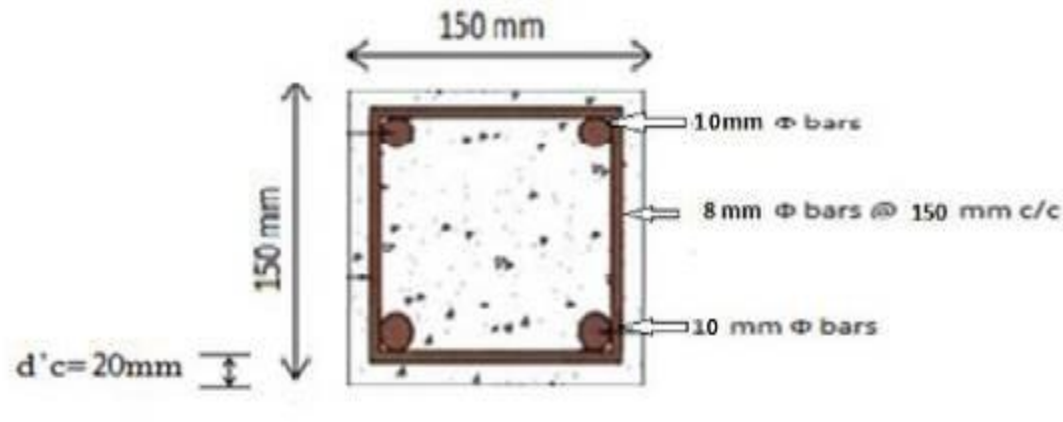


Fig. 1: Details of Concrete Specimen

B. *Casting*

- In casting process concrete is laid in a mould in a 3 layers .The casting has to be done in a definite sequence.
- A special care has to be taken for making a concrete of definite proportion of cement, sand and aggregate with proper water cement ratio.
- Mixing of concrete can be done either by hand mixing of concrete mixing machine. Most probably batch mixing is being used for mass concreting work.

C. *Casting Procedure of Specimen*

1) Step-1:- A steel reinforcement was prepared having 4 bars of 10mm ø, c/c distance of 100 mm with 4 stirrups of 8mm ø with c/c distance of 150 mm.
2) Step-2:- Mould is having dimensions 150 x 150 x 700 mm and oiling was done in the inner faces for the easy removal of the specimen.
3) Step-3:- Reinforcement cage was placed in mould by providing 20mm covering on bottom and side face.
4) Step-4:- Mixing of cement, sand and aggregate was done in the proportion of 1:1:2 with water cement ratio as 0.50 in concrete mixture machine.
5) Step-5:- Concrete was poured in the mould in three layers and properly hand compaction was done with the help of rod.
6) Step-6:- Top surface was well finished with suitable tools.
7) Step-7:- After 24 hours, specimen was placed for the curing process for 28 days.
8) Step 8:- Testing of specimen,

Fig. 2: Casting procedure of specimen

D. Results of Testing of Specimens

Sr. No.	*Dimension (mm)*	*Weight(Kg)*	*Load carried (KN)*
1	*150×150×700*	*40.87*	*104*
2	*150×150×700*	*40.86*	*101.82*
3	*150×150×700*	*41.01*	*94.57*
4	*150×150×700*	*40.66*	*96.64*
5	*150×150×700*	*39.75*	*112.27*
6	*150×150×700*	*40.35*	*93.45*
7	*150×150×700*	*40.21*	*106.396*
Average		*40.51*	*101.3*

Table 1: Testing Results

Fig. 3: Beam Testing.

V. MATERIAL

A. Carbon Fiber Fabric

– Carbon fiber fabric, designed for installation using the dry or wet application process.

1) Sika Wrap- 450 C/Sika Wrap-600 C

1) Form

Fiber Type Mid strength carbon fibers. Fabric Construction Fiber orientation: 0° (unidirectional).Warp: black carbon fibers (99% of total areal weight).Weft: white thermoplastic heat-set fibers (1% of total areal weight).

2) Uses

Strengthening of reinforced concrete, masonry, brickwork and timber elements or structures, to increase flexural and shear loading capacity for :Improved seismic performance of masonry walls, Replacing missing steel reinforcement, Increasing the strength and ductility of columns, Increasing the loading capacity of structural elements, Enabling Changes in use/alterations and refurbishment, Correcting structural design and / or construction defects, Increasing resistance to seismic movement, Improving service life and durability

3) Characteristics /Advantages

Manufactured with weft fibers to keep the fabric stable (heat-set), Multifunctional fabric for use in many different strengthening applications, Flexible and accommodating of different surface planes and geometry (Beams, columns, chimneys, piles, walls, soffits, silos etc.), Low density for minimal additional weight, cost effective in comparison to traditional strengthening techniques

4) Technical detail of Wrap-450 C

– Areal Weight: 450 g/m^2+ 15 g/m^2
– Fabric Design Thickness: 0.255 mm (based on fiber content).
– Fiber Density: 1.82 g/cm^3

5) Technical detail of Wrap-600 C

– Areal Weight: 625 g/m^2+ 35 g/m^2 (total areal weight)
  600 g/m^2+30g/m^2 (carbon fiber content)
– Fabric Design Thickness: 0.331 mm (based on fiber content).
– Fiber Density: 1.82 g/cm^3

2) 2-part epoxy impregnation resin (Sikadur 330):-

1) Form

- Appearance / Colours Resin Part. A: paste, Hardener Part B: paste
- Colour: Part A: white.Part B: black.Part A+B mixed: grey

2) Uses

Impregnation resin for Wrap method, Primer resin for the wet application system, Structural adhesive for bonding Wrap fabric reinforcement for the dry application to even surfaces.

3) Advantages /Characteristics

Easy mix and application by trowel and impregnation roller, Manufactured for manual saturation methods, excellent application behavior to vertical and overhead surfaces, Good adhesion to many substrates, High mechanical properties, No separate primer required.

3) 2-part epoxy impregnation resin (Sikadur300):-

- Appearance / Colours Resin Part. A: liquid Hardener Part B: liquid
- Colour: Part A: light-yellow to amber, Part B: pale yellow to clear liquid Part A + B mixed: light-yellow to clear liquid

1) Uses

Impregnating resin for Wrap fabric reinforcement for the wet application method, Primer resin for the wet application system

2) Advantages /Characteristics

Easy mix and application by trowel and impregnation roller, Manufactured for manual or mechanical saturation methods, Good adhesion to many substrates, High mechanical properties, Extra-long pot life.

VI. PROCEDURE FOR RETROFITTING

A. Steps for Retrofitting

1) Step 1:- Clearing the cracks formed in beam & expanding it for the Epoxy grouting.
2) Step 2:- Grouting is being done on all the beam cracks by mixture of Epoxy + Cement (1:1) (Sikadur 330) and nozzle is fitted on the suitable point for injection.
3) Step 3:- Epoxy (Sikadur 330) is injected in the cracks with the help of the pressured pump.
4) Step 4:- All the surface & edges are grinded to bolded the pointed surface.
5) Step 5:- Epoxy (Sikadur 330) is applied on the surface of about .5 to 1 mm thick.
6) Step 6:- Carbon Fiber Fabric is the Wrapped on the surface of the beam & allowed to harden of 24-36 hours.

B. Type of Wrapping

1) Type A: - Full Wrap with Sika Wrap 450 C.
2) Type B: - Wrap at 250mm from both the ends with Sika Wrap 450 C .
3) Type C: - Full Wrap with Sika Wrap 600 C.
4) Type D: - only epoxy grouting.

Fig. 4: procedure of retrofitting.

VII. RESULTS AND DISCUSSION

Sr. No.	*Type*	*Load carried (KN)*
1	*B*	*78.9*
2	*C*	*83.80*
3	*A*	*93.5*
4	*C*	*88.65*
5	*B*	*96.12*
6	*A*	*66.5*
Average		*84.57*

Table 2: results of retrofitting.

Fig. 5: testing of retrofitted beam.

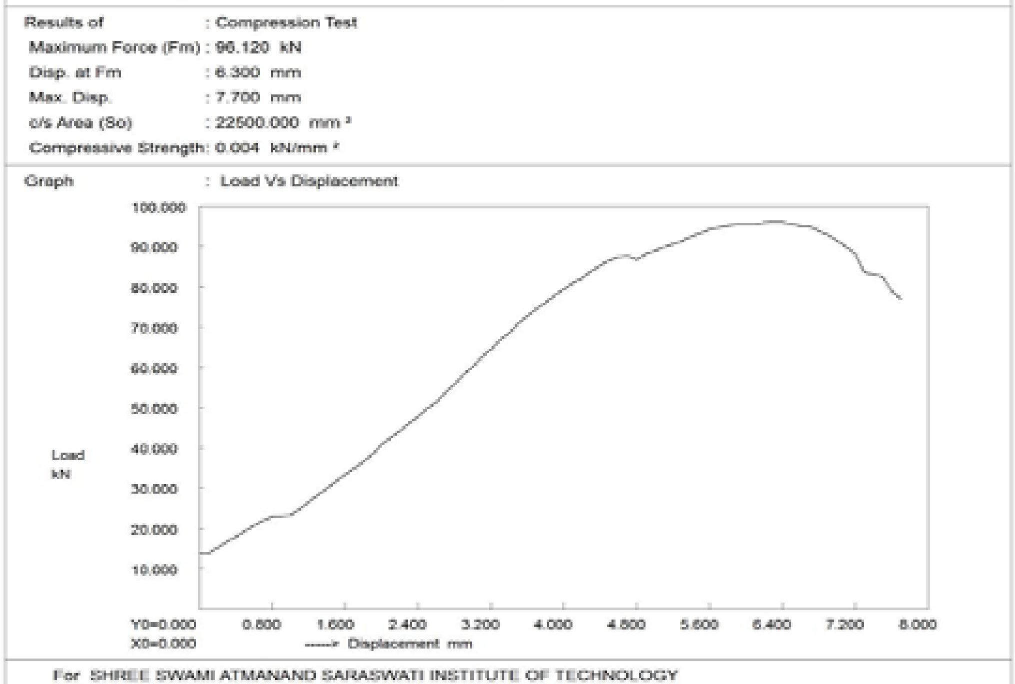


Fig. 6: Graph load Vs. Displacement of beam 5.

VIII. OBSERVATION

On observing the results of the retrofitting of beam we can conclude that there is strength improvement on the beam more than 75% of original load carrying capacity.so carbon fiber fabric a new material that can be used for the retrofitting of the structural member under specific conditions. Beam with only epoxy grouting gave lesser load carrying capacity as compare to initial loading; it gave 42% of original loading in our case.

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