Flexure Strengthening of Reinforced Concrete Beam by Applying Near Surface Mounted Technique

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Abstract:
The paper establishes the experimenal investigation on the performance of Reinforced concrete beams strengthened with Near Surface Mounted System. The use of near-surface mounted (NSM) steel and CFRP bars is an auspicious technology for increasing strength of flexural reinforced concrete (RC) members. A total of six specimens are cast and through static tests to assess the structural behavior of RC beams strengthened by Near-surface mounted technique. The first set are of two control beams tested and remaining beams are strengthened by deformed steel and CFRP bars of single bar in set and two bars in other set. Testing data were analyzed to investigate the performance of strengthened when compared to the unstrengthen beam.

Keywords*: : Flexure; Near Surface Mounted (NSM); Reinforced Concrete (R.C); strengthening; Fiber Reinforced Polymer (FRP).*

Introduction:

The strengthening of existing reinforced concrete (RC) structures is very important in the construction sector these days. Many reinforced concrete mounted structures found in different zones of high earthquake in India are not earthquake resistant. The surrender of partially designed structures means the seismic hazard to the resident and the matter highlights a strong religious need to restore the existing building and advance the provisions of the Seismic Code. Therefore, these structures require gradation or retrofitting, which has become one of the thrust areas in structural engineering worldwide, and various methods of reinforcement such as construction have been attempted by attaching plain steel plates. However, in order to get rid of the difficulties and some problems associated with these methods, they are intensive labor, increased size and corrosion protection.

Current research efforts include sinking on fiber reinforced polymers (FRP) to strengthen or advance the elemental property of existing reinforced concrete (RC) framed structures, without dissolving existing structural elements. Retrofitting is considered in this inspection by using externally coupled CFRP with the help of epoxy resin and hardeners.

There have been several studies based on the strengthening of structural elements that are external to the NSM system. Replacing existing structures has become a lion's share of construction activity in many countries. In large part, this is due to the aging of the infrastructure and the increasing awareness of the environment.

Some of the infrastructure is damaged by environmental impacts, including corrosion of steel, differences in temperature, UV radiation and earthquake. There are many cases of construction and design-related defects that require some correction. On the other hand, most structures need to be reinforced because the allowable loads have increased, or new codes have made the structures

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worthless. Traditional retrofitting techniques that use steel and cementitious materials do not always yield the most correct conclusion. Retrofitting with a near-surface mounted system is a relatively new technique to strengthen and repair damaged structures. Extensive research is underway in these areas for its effectiveness in increasing structural performance in terms of strength and ductility. Increase the efficiency of flexural beams by retrofitting with a Near Surface Mounted (NSM) technique. This technique is more useful in T beams and girders for strengthening of girders and T beams.

2 METHODOLOGY

Materials used

Cement:
In the present practice, Ordinary Portland Cement is used and primary tests on cement are tested. In which the specific gravity of cement is 3.15 and other physical properties of cement is conforming as per IS 12269-1987 to know the suitableness of cement which is used are in the specified range.

Fine Aggregate:
River Sand which is passing through IS 4.75mm sieve is being confirmed to the Zone III as per IS 383-1970 is commonly used as fine aggregate.

Coarse Aggregate:
Crushed stone with a maximal amount of 20 mm was being used as the aggregates.

Water:
Clean portable water available in the laboratory of university which satisfies the drinking standards was used for the preparation of specimens.

Reinforcing Steel:
The Fe500 steel is used in this research project which is used as steel rebars in the manufacturing of conventional and retrofitted beams for the purpose of flexural reinforcement i.e. main reinforcement and hanging bars and for stirrups. The diameter of bars is taken as 12mm, 10mm and 8 mm are used.

Table-I: Mechanical properties of Fe 500 steel bars

Type of steel	Yield stress	Ultimate Elongation	Tensile strength
Fe 500	540 N/mm^2	18 %	600 N/mm^2

Epoxy Adhesive:
The epoxy resin and hardener are the adhesives which are used for the purpose of bonding. Here the hardener and epoxy resin are used for the sake of bonding of CFRP with the surface of concrete. The hardener and epoxy resin were mixed thoroughly according to the ratio given by the supplier i.e. hardener: epoxy resin (1: 5). And need to mix thoroughly for 10 to 15 minutes. The detail properties of epoxy and hardener are given by manufacturer.

Table- II: Properties of epoxy resin

Property	Value
Viscosity	Thixotropic
Colour	white
Density	1.26 g/cc
Application temperature	15^0C to 40^0C
Pot life	30 minutes
Curing time	7 days

CFRP Bar:
Carbon Fiber Reinforced Polymer Bar (CFRP) is one of the composite materials comprising polymer and carbon fiber. Strength and rigidity are provided by carbon fiber, where the polymer acts as an integrated matrix, which protects and holds the fiber. These polymers are made in the form of strips, bars and sheets with the help of various production techniques such as filament winding, and hand lay-up processes. CFRP materials have very low density, high rigidity,

excellent strength, high ultimate strain and excellent fatigue resistance, corrosion and vibration resistance, as well as low thermal conductivity. They are considered to be poor electrical conductors and are paramagnetic.

CFRP offers a number of issues for infrastructure and satisfactory solutions, including bridges and buildings. Using these reinforcement bars in new concrete can eliminate problems such as potential corrosion and significantly increase the structural strength of the members. The widespread use of CFRP increases the lifespan of structures and reduces maintenance requirements. Carbon fibers are also used for reinforcement with ablative plastic and for high viscosity, high strength and lightweight structures.

Fig.: CFRP Bar

3 EXPERIMENTAL PROGRAMME

Manufacturing of beams:

Beams of long 2200 mm with the cross sectional area of 150 mm X 300 mm in the mould of proper dimensions. The reinforcement of beams bar bending as per designed dimensions and mould is greased well and reinforcement cage is placed in the mould.

Fig.: Reinforcement Cage

Concrete:

Concrete designed as per Codal provisions of IS 10262:2009 and IS 456:2000 the mix proportion of 0.45:1:1.65:3.4 and this mix was prepared, trail mix was done and tests like workability of concrete, spilt tensile strength and compressive strength were done the spilt tensile and compressive strength for nearly 28 days are 39 N/mm^2 and 4.2 N/mm^2 which are tested on Compressive Testing Machine.

Beams are casted with M30 concrete mix with Fe 500 steel and demoulded are placed on levelled surface for curing the control beam are tested after 35 days of curing.

Fig: Casting of Beam

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The other Set of beams are placed for curing for 28 days and the surface of beam cleaned and surface of tension zone of width 150 mm are grinded for level surface and groove created at tension zone of beam diamond cutting blade machine the groove is of dimension of 12mm X 12 mm of size, In which 15 mm at center of beam in tension zone for two beams having width of 150 mm. The remaining two beams are two grooves are made for spacing of 50mm to each other from center to center of groove. The length of bars of 2.1m which are used for strengthening.

The grooves cleaned grinded and cleaned by air blower. The groove is filled with epoxy for 2/3 rd. of groove and the steel bar and CFRP bar inserted in each groove and well pressed in groove and the remaining groove filled with epoxy and place the beams in shaded area for curing for a 7 days. In the process of cutting the steel, reinforcements should not be affected from cutting otherwise, it will lose all capacity. So, the reinforced concrete member should have a minimum of 20 mm cover for strengthening by this method.

All the beams are tested with the help of two point loading with equipment of loading frame which has capacity of 200 tons which is available in our laboratory. The values and graphs of cracking, ultimate load and final cracking etc. are arrived and crack widths and type of failure are identified.

Fig: Curing of Beam

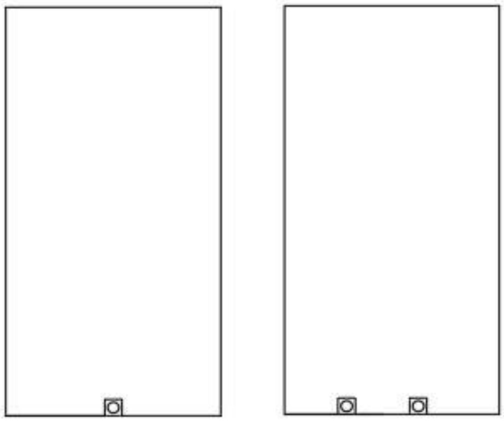

Fig : Grooves in Specimen

Fig:Cutting and Cleaning of Grooves

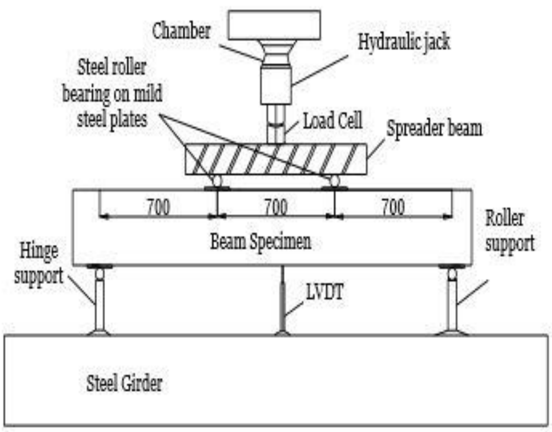

Fig. : Schematic Diagram of Test setup

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Fig: Setup of test

4. Results and Discussions

Under the testing equipment loading frame, beam specimen were tested as a two point loading. Specimens were in simply supported condition. The supports were immediately kept on a girder and the load is being applied at two distinct points that which are 700 mm away from these supports. The deflection was being measured at bottom surface of the beam by LVDT. After testing, different parameters are analyzed like mode of failure, crack pattern and load versus deflection of all specimens. From the results obtained, the comparison of traditional and strengthened specimens were analyzed.

Fig.: Crack Pattern of Beam

Table-III: Beam Narration

Beam Code	Beam description
CB 1	Control beam
CB 2	Control beam
S1	Beam strengthen with one steel rebar
S2	Beam strengthen with two steel rebars:
C1	Beam Strengthen with one CFRP bar
C2	Beam Strengthen with two CFRP bar.

Table-IV: Beam Test Report

Beam Specimen	Ultimate Load (KN)	Deflection at mid span(mm)	Type of Failure
CB 1	182	12	Shear and Flexure
CB 2	180	12	Shear and Flexure
S1	200	18	Flexure
S2	221	16.2	Flexure and Debonding
C1	192	18.5	Flexure
C2	205	17	Flexure

The parameters in which the ultimate load and deflections are obtained the control beam specimens having same ultimate load and having same mid span deflection and failures are also as shear and flexure.

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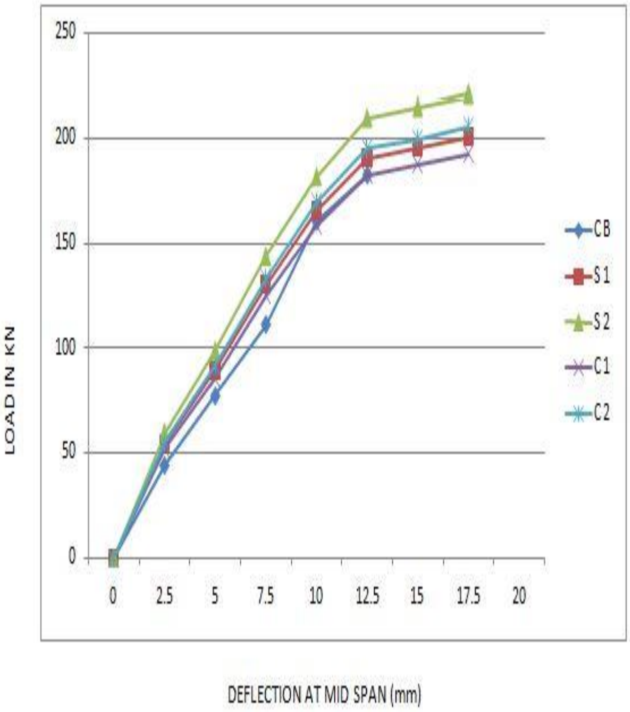

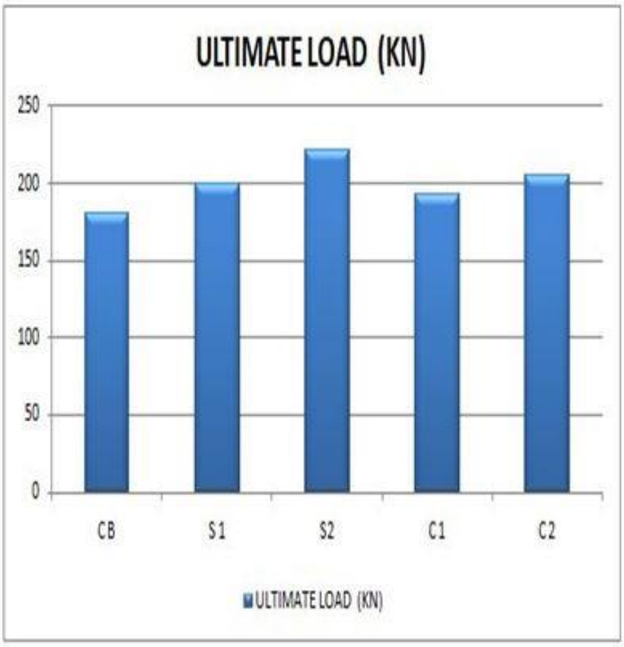

The ultimate load is obtained beam strengthen by NSM technique by two steel rebars. The mid span deflection is at the beam strengthening by one CFRP by NSM technique.

CONCLUSION

From the experimental study on aspects like control and retrofitted reinforced concrete beams using steel rebars and CFRP, the following conclusions were drawn:

I. i. Notably, the load carrying capacity of the retrofitted beams is significantly higher than that of the control beams.

II. ii. The improvement of flexural strength of retrofitted beams was being enhanced by Near Surface Mounted method.

III. iii. The perceptibility of the flexural fracture is significantly higher in the case of conventional beams compared to retrofitted beams during the initial period of load application. Some cracks were also found.

IV. iv. Retrofitting using NSM technique was being proposed to increase the flexural strength of beams.

V. v. The ultimate capacity of S1 has been significantly improved by 10.5 % higher than that of Control Beam.

VI. vi. The ultimate capacity of S2 has been significantly improved by 22.7 % higher than that of Control Beam.

VII. vii.The ultimate capacity of C1 has been significantly improved by 6% higher than that of Control Beam.

VIII. viii. The ultimate capacity of C2 has been significantly improved by 13.25 % higher than that of Control Beam.

IX. ix. Mid span deflection is more in CFRP Bar then control beam and strengthen by Steel rebar.

x. Steel rebar is more useful strengthen by NSM technique.

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