RETROFITTING OF A BUILDING BY USING FERRO CEMENT AND GFRP

GULLA RAMI NAIDU [1] , A.R.NAYAK[2]

[1]M.Tech Scholar, Highway Engineering, Swami Vivekananda Engineering Collage Vizianagaram, A.P.
[2]Assistant Professor,Civil Engineering Department, Swami Vivekananda Engineering Collage Vizianagaram, A.P.

ABSTRACT :- The RCC structures constructed these days suffer damage due to a large number of factors like improper design, faulty construction, overloading, change in codal provisions, non-engineered construction, explosions, wear and tear, earthquake, fire etc. A major part of the funds used in the construction industry is being spent on repair, retrofitting and rehabilitation of such structures.

For local repair and retrofitting a large number of techniques are being used. These include injection techniques, shotcreting, removal and replacement technique, external pre-stressing, plate bonding etc. Of all the above techniques plate bonding has been found to be the most effective and a very convenient method As a substitute various authors have suggested the use of ferrocement jacketing as a more attractive option in place of FRP plate bonding due to its easy application, improved tensile strength, lesser weight, economical use, higher impermeability, and long life of the treatment.

In the present study, an effort has been made to study the effect of ferrocement jacketing on the strength of retrofitted beams. The studies have been carried out for various combination's of parameters like type of bonding agents, orientation and type of wire mesh, number of layers of wire mesh in the ferrocement jacket, initial stress level, and type of beam sections (under reinforced or balanced section). The effect of these parameters on the strength of reinforced concrete beams initially stressed in flexure to pre-determined levels, and subsequently retrofitted with jackets was investigated.

INTRODUCTION

Retrofitting is basically a process of strengthening and enhancement of the performance of deficient structural elements in a structure or structure as whole. It is different from repair or rehabilitation. Repair refers to partial improvement of degraded strength; it's only a cosmetic enhancement. Rehabilitation is a functional improvement, wherein the aim is to achieve the original strength of the structure, after it has deteriorated and suffered damage. Retrofitting means structural strengthening of the building to a pre-defined performance level irrespective of whether the structure is damaged or not. Thus, the goals of the retrofitting can be enumerated as

- Removing the weak points, where stress concentration is possible.
- Increasing the lateral load carrying capacity and stiffness of the building
- Improving the energy absorption and energy dissipation capacity of the building
- Achieving the desired performance most effectively and economically.

OBJECTIVES AND SCOPE OF THE WORK

The main objectives of the present work are follows:

- Study the effect of retrofitting on beams stressed to different levels.
- Study the effect on the maximum load, safe load and ductility of the (under reinforced and balanced) beams retrofitted with ferrocement jackets with variation in following parameters.

(a) Type of wire mesh,
(b) Number of wire mesh layers,
(c) Orientation of mesh.

- To develop a technique and methodology for designing and using ferrocement jackets for retrofitting of stressed RCC beams using conventional RCC theory.
- To compare the data, with beams retrofitted with GFRP jackets having different orientation of fibres (00, 450)

EXPERIMENTAL PROGRAM

The experimental program was designed to study the effect of various parameters on the strength of reinforced concrete beams initially stressed in flexure to pre- determined levels, and subsequently retrofitted with jackets. In total fifty two prototype beams of size 127 mm x 227 mm x 4100 mm were cast, twenty-four beams, two for each parameter, in addition to four control beams, were cast for a particular method of retrofitting.

For the purpose of investigations, of the two sets of beams, one set is retrofitted with ferrocement jacket wherein, the variation in parameters was finalized considering gaps in the available literature and on the basis of results of pilot testing carried out in the laboratory.

The other set of twenty-four beams, were retrofitted using Glass Fiber Reinforced Polymer (GFRP) jackets with fibers oriented at 00 and 450 to the longitudinal axis of the beam.

Retrofitting Using GFRP Jackets

For the purpose of investigation with GFRP jackets twenty-four prototype beams were cast. Half of these beams were designed as under reinforced sections and remaining were designed as balanced section, using limit state design theory. Four beams from each category were stressed to 60 percent, 75 percent and 90 percent of the safe load calculated from the maximum load achieved for the control beams. These beams were subsequently retrofitted using Tyfo® SEH-51 GFRP jacket to study its effect on the strength of the stressed beams. The beams were partially distressed (due to self weight only) by putting them upside down. The surface of these beams was then cleaned and dried, and cavities if any, were removed by repairing the surface with cement pasteTyfo® S epoxy was mixed in ratio of 100.0 parts of A to 42.0 parts of B by volume, and then applied on the prepared surface of the beams as well as on the GFRP sheet.

Retrofitting Using Ferrocement Jacket:-

For the second part of the investigation twenty-four prototype beams were cast. Twelve beams were designed as under reinforced sections and the other twelve were designed as balanced sections using limit state design theory. Four beams from each category i.e. balanced and under reinforced were stressed to 60 percent, 75 percent and 90 percent of safe load calculated from the test results of the control beams. The beams were partially de-stressed (due to self weight only) by putting them upside down. The surface of the stressed beams was then chipped creating grooves on surfaces of the beams and cleaned with metallic brush using potable water. One coat of cement slurry was applied on the cleaned surface as a bonding agent before placing the wire mesh cage on it without repairing the initial cracks. The cage was properly placed ensuring tight fit with the help of mild steel wire and 1:2 cement mortar with a water cement ratio of 0.4 was applied.

Effect on Strength of Beams

The average maximum load carrying capacity of the under reinforced beams as obtained from the experimental data is 22.4 kN for the control beams, where as, it is found to be 32.1 kN, 32.65 kN, and 30.5 kN for the retrofitted beams initially stressed to 60 percent, 75 percent and 90 percent of the safe load, respectively, indicating that after retrofitting, the maximum load carrying capacity increased by 33.75 percent, 36.04 percent, and 27.08. Similarly, the value of safe load (load corresponding to an allowable deflection of L/250 which is equal to 15mm) as obtained from the experimental data is 11.99 kN, 16.02 kN, 15.90 kN, and 15.13 kN for the control beam and retrofitted beams initially stressed to 60 percent, 75 percent and 90 percent of the safe load, respectively. Thus for under reinforced beams, on the same line as the maximum load carrying capacity, the safe load carrying capacity of the initially stressed beams also increases by 33.55 percent,32.55 percent, and 26.13 percent.

Effect on Deflection Ductility Ratio and Toughness of Beams:-

The ductility ratio as calculated from fitted quadri-linear curves for the under reinforced sections is found to be 2.27 for the control beam and it increases to, 2.28, 2.82, and 3.74, respectively, for the retrofitted beams initially stressed to 60 percent, 75 percent and 90 percent of the safe load indicating an increase of 0.44 percent, 24.22 percent, and 65.2 percent for the beams after retrofitting. In case of balanced sections the ductility ratio as calculated from the experimental results is found to be 1.81, 1.87, 1.87, and 2.05 for the control beam and retrofitted beams initially stressed to 60 percent, 75 percent and 90 percent of the safe load, respectively. Thus, in case of balanced section the ductility ratio increases by 3.3 percent, 3.3 percent and 13.25 percent for the 60, 75 and 90 stressed beams after retrofitting, respectively. It is also observed from the table that the ductility ratio is higher for under reinforced sections as compared to balanced sections at all levels. The area under the idealized curve for control beams and retrofitted beams was calculated to find out the toughness of the section and is also presented in the Table 4.15. It is noted from the table that the toughness of the under reinforced section increases on an average by 77.63 percent after retrofitting, whereas the corresponding increase in case of the balanced section is of the order of 57.74 percent.

Beams Retrofitted Using GFRP Jackets With Fibers At Zero Degree To The Longitudinal Axis Of Beam

Out of a total twenty-four beams cast, twelve were retrofitted using GFRP jackets with fibers oriented at zero degree to the longitudinal axis of the beam. Six of these were designed as under reinforced sections and remaining six were designed as balanced sections. Two beams from each type i.e. balanced and under reinforced were stressed to 60 percent, 75 percent and 90 percent respectively of safe load obtained from the testing of the control beams. The load deflection data obtained from the testing of the beams is plotted and presented for each beam separately in the curves.

Beams Retrofitted Using GFRP Jackets With fibers At Forty Five Degrees to the Longitudinal Axis of Beam

It is observed from the test results that under reinforced beams underwent large deflections as compared to balanced sections, as expected. The average maximum load carrying capacity is found to be 22.4 kN for under reinforced sections as compared to 38.7 kN for balanced sections.

The other beams which were subsequently stressed to 60, 75 and 90 of the safe load for the respective section, were retrofitted with GFRP having fibers at forty five degrees to the longitudinal axis, were tested to compute their load carrying capacity

It is observed from the Figures 6.3 and 6.5 that for the under reinforced beams maximum load carrying capacity of the beams obtained experimentally was 29.3 kN, 29.35 kN and 24.4 kN, respectively for the beams stressed to 60, 75 and 90 percent stress level, indicating an increase of 30.8, 31.03, and 4.86 percent, respectively. Whereas, in the case of balanced sections the corresponding value of the maximum load was 45.0 kN, 44.35 kN and 44.0 kN, indicating an increase of 16.28, 14.6 and 13.69 percent for stress levels 60, 75 and 90 percent, respectively.

Fig-1 Failure of Beam Retrofitted with GFRP Jacket with fibers at zero Degree to The Longitudinal Axis of Beam

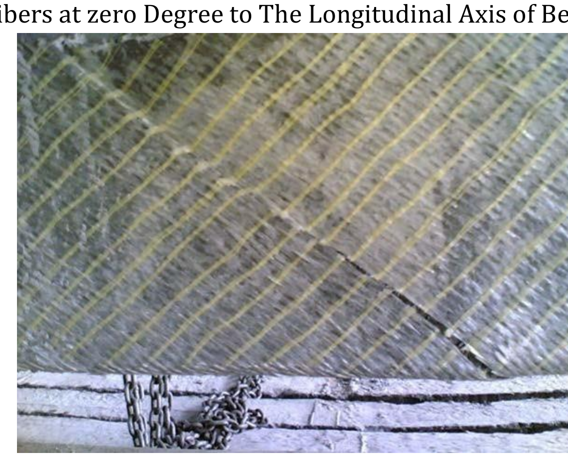

Fig-2 Failure of Beam Retrofitted with GFRP Jacket with fibers at 45 Degree to The Longitudinal Axis of Beam

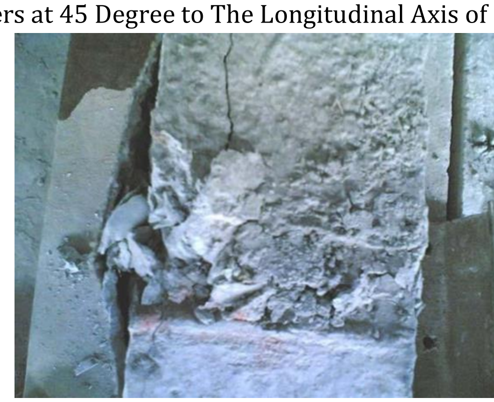

Fig-3 Crushing of Concrete in Balanced Beam Retrofitted with GFRP Jacketing

Fig-4 Debonding of GFRP Jacketing with fibers at 45 Degree to the Longitudinal Axis of Beam

CONCLUSIONS

BEAMS RETROFITTED USING GFRP JACKETS

- GFRP jackets used for retrofitting of the under reinforced beams perform better with fibres at forty-five degrees to the longitudinal axis of the beam.
- The strength of the section decreased with an increase in the initial stress level. The maximum load carrying capacity of the beams decreased due to decrease in stiffness of section with an increase in the initial stress level.
- The initially stressed beams retrofitted with GFRP jackets had a lesser safe load carrying capacity. This is attributed to the fact that, due to initial stress level the section loses its stiffness hence deflects more when reloaded after retrofitting.
- GFRP jacketing leads to an improvement in the energy absorption capacity of all the beams irrespective of the type of section and orientation of fibres in the jackets. The under reinforced sections with fibres oriented at forty-five degrees performed better within the group.

BEAMS RETROFITTED USING FERROCEMENT JACKETS

- Retrofitting of the beams with ferrocement jackets should be preferred where the strengthening of the beams is required to take care of the deficiency of the beams in flexure.
- The use of ferrocement jacketing for retrofitting of initially stressed beams helps to regain the full strength of all type of beams, even if stressed up to 90 percent of the safe load.
- Cement slurry is the most efficient bonding agent due to its low cost to strength ratio. Whereas, shear connectors with cement slurry improve the maximum load carrying capacity of the beams leading to a higher cost.
- Welded wire mesh, with forty five degree orientation to the longitudinal axis, have a significant positive effect on the load carrying capacity of the beams, whereas, zero degree orientation is most efficient due to its low cost to strength ratio. Woven wire mesh used for ferrocement jacketing of beams should be preferred over welded wire mesh due to larger improvement in the load carrying capacity, ductility ratio and energy absorption.
- The increase in the maximum load carrying capacity is higher for under reinforced beams (27-34%) as compared to balanced beams (17-20%) in case of ferrocement jackets reinforced with two layers of woven wire mesh. The corresponding increase in load carrying capacity of the beams retrofitted using ferrocement jackets reinforced with three layers of woven wire mesh, is 48- 52% and 29-35% respectively.
- The percentage increase in the safe load carrying capacity is less as compared to maximum load carrying capacity because of decrease in stiffness of the section due to initial stress.
- The percentage increase in the load carrying capacity of beams retrofitted using ferrocement jacketing, increases with increase in reinforcement in the jackets.
- The percentage increase in the load carrying capacity of beams retrofitted using ferrocement jacketing, decreases with increase in initial stress.
- The percentage increase in load carrying capacity decreases with increase in tension reinforcement in the original beam.
- The maximum load carrying capacity of the retrofitted beams is independent of the thickness of the jacket.
- Ferrocement jacketing leads to an improvement in the energy absorption capacity of all the type of beams irrespective of the type of section (under reinforced or balanced) and reinforcement in the jackets. The under reinforced sections with higher

reinforcement in the jacket performed better within the group.

- The proposed mathematical procedure devised in the study can be efficiently used to predict the maximum and safe load carrying capacities of the initially stressed retrofitted beams.

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