RETROFITTING OF STRUCTURE USING REINFORCED CONCRETE STEEL JACKETING

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Abstract - *This paper aims to review the strengthening techniques of Reinforced Concrete (RC) beams using steel jacket. The structural elements with poor strength and low bearing capacity are due to seismic activity, aging, temperature conditions, and attack of fire. To restore the strength as well as the age of the entire structure, retrofitting video wrapping or jacketing technique is used. Nowadays, retrofitting is widely used in the world. The present study focuses on the performance of galvanized-iron wire mesh(GI) in the rectangular reinforced column of the weaker section which delays the crack patterns and buckling effect as lifespan increases with the three incremental intervals of 25% for each of the four columns. Further, comparing the higher percentage mesh mesh-wrapped columns with the lower percentage wrapped ones.*

Key Words: **Retrofitting, Galvanized iron wire mesh, jacketing technique, strength.**

1. INTRODUCTION

Column is the major element which carries compressive loads of the superstructure to the substructure. The failure of the column leads to destruction or performance is comparatively very low. Generally, failure occurs due to overloading, weaker cross-sectional area, dynamic loads, elastic instability, Seismic activity, fire, corroded steel, etc... To regain the strength of damaged/deficient columns can be rehabilitated by retrofitting technique. Jacketing is one of the most occurring and economical methods of retrofitting techniques in major projects. Steel Jacket, Reinforced Concrete Jacket, Fibre Reinforced and Polymer Composite are few types of Jacketing. The steel jacketing method consists of Galvanized Iron (GI) wire mesh that improves the ductility, compression strength, and good confinement to the column.

2. LITERATURE REVIEW

Muhammad N. S. Hadi et al (2011) investigated various materials such as fiberglass wire mesh (FGFM), standard aluminum fly mesh (SAFM), and Galvanized steel wire mesh of 12.7*12.7mm size (S12.7 WM). Total sixteen numbers of circular columns were loaded under eccentric, concentric, and pure bending loading. This study shows an increase in both strength and ductility of compression members with addition of these materials. Among all specimens, high load-carrying capacity was increased by wire mesh and ductility was improved by FGFM.

Azam Amir et al. mentioned about the GI Wire Mesh earlier in 2013. This study deals with the combination of FRP and Wire Mesh applied at critical sections to stabilize the existing building columns of three no's with greater seismic resistance and strength. FRP sheets were used for horizontal wraps in the first strengthening scheme and wire mesh in the 2nd strengthening scheme. Among these, high strength was achieved by FRP sheet, and ductility was increased due to FRP and wire mesh. FRP jacketing can be adopted for strengthening purposes in further retrofitting projects.

Amrul Kaish et al (2013) researched improving square jacketing technique (SJT) to restore the strength of existing RC columns. Introducing two schemes in this study to reduce the concentration of stress and cracks at corners i.e., (i) all corners were to be strengthened and (ii) reducing corner stresses. A total eight numbers of square RC columns were loaded under concentric compressive loading until failure. Among eight numbers, six numbers are retrofitted ones and the remaining two are of control specimens. Three types of jacketing techniques were used such as (a) With the addition of wire mesh of a single layer, (b) With the addition of one layer of wire mesh and the corners of column are rounded, and (c) With the addition of single layer and two more extra layers at all corners of the column.

Bishnu Gupt et al (2014)conducted tests on nine columns with two types of retrofitting methods, they are wire mesh mortar jacketing (WMM) and steel cage mortar jacketing (SCM) of three specimens each are compared with plain reinforced columns (CS). Variations in results in comparison with WMM and SCM are 1.75 and 2.28 times greater than CS. WMM got the higher Stiffness value as compared to CS. According to strength consideration SCM is preferred and WMM in absorption consideration.

Manikandeswaran et al (2015) have done experimental work on nine RC columns with two types of jacketing techniques; the Ferro cement technique and steel angles with strips. This study is aimed to achieve high load-bearing capacity as compared to RC columns. Based on this study, it was concluded that steel angles with strips improved load-bearing capacity by 40% and Ferro cement technique by 65% in comparison to RC column.

Muhammed Salih et al (2016) conducted experimental work on Ferro cement confinement in four numbers of square columns with low strength along with the addition of 0.1% of polypropylene fibers in mortar mix. Before retrofitting using Ferro cement jacketing technique, columns were loaded under ultimate load. There is an increase in the load-carrying capacity of these retrofitted columns in comparison to control specimens and no spalling of concrete cover.

3. EXPERIMENTAL PROGRAMME

3.1 MATERIAL USED

Cement

Ordinary Portland cement of 53 Grades was used for the casting of rectangular reinforced concrete columns and wire mesh confinement in the experimental work. The specific gravity of cement is 3.15.

Coarse Aggregate

A coarse aggregate of 20mm in size and a specific gravity is 2.884 was used in the experimental work.

Fine Aggregate

Fine Aggregate belongs to zone II and its specific gravity is 2.6 was used in this study.*GI Wire Mesh*

The diameter of the Galvanized Iron wire mesh was 1.3mm with spacing of 15mm X 15mm spacing.

3.2 Mix Proportion

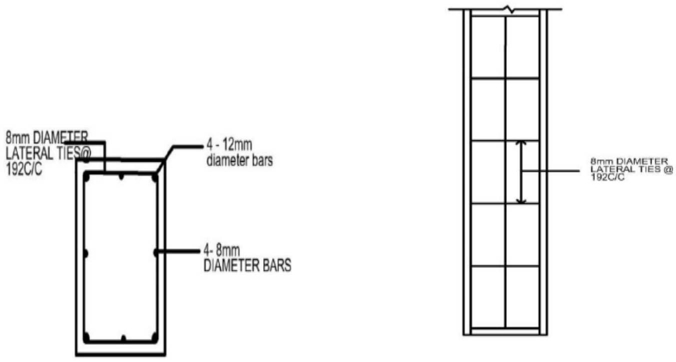
Mix was designed as per the specifications of IS: 10262-1982 to gain a target strength of 31.6 N/mm2.According to the design calculations, the cement content was 438 kg/m^3. The water-cement ratio taken from the design was 0.45.

Table 1 Mix propotion

Materials	Mix proportion	Weight (kg/m3)
Cement	**1**	**438**
Fine Aggregate	**1.53**	**673.296**
Coarse Aggregate	**2.53**	**1109.8**
Water	**0.45**	**197**

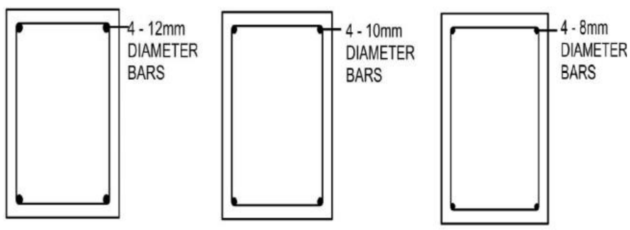
3.3 Casting of RC columns

Four rectangular reinforced concrete columns having a cross-sectional area of 230 x 300 mm^2 and length of 1000 mm were cast along with consideration of 1% of steel in design. Among all the four specimens, one is of control specimen (CS) and the other three are retrofitted specimens (RS). 4 –12mm Ø and 4 –8mm Ø longitudinal rebar and stirrups of 8mm diameter lateral ties @ 192mm c/c was used in the control specimen. The other three specimens were provided with less longitudinal reinforcement details such as 12mm, 10mm, and 8mm rebars were shown below in Figure 1 and Figure 2.



(a) (b)

Figure 1 Reinforcement Detailing of the Control Specimen



RS 1 RS 2 RS 3

Figure 2 Detailing of Retrofitted Specimens

3.4 Galvanized Iron Wire Mesh

GI wire mesh was used in the steel jacketing technique with various percentages of 25%, 50%, and 75% of wire mesh by reducing longitudinal reinforcement details. Different sizes of rebar were used such as 12, 10, and 8mm diameters in each specimen as per design considerations. After the duration of the 28-day curing period, a 20mm clear cover was chipped by chipping hammer, and then 3, 3.5, and 4 numbers of layers of wire mesh were wrapped with no gaps in between the layers around the surface of the chipped area of the specimen. To make the mesh firm it was tied to the longitudinal reinforcement with bending wires. Plastering was done for the meshed columns with a ratio of 1:2 as per the considerations. Duration of curing for retrofitted specimens was 28 days.

Figure 3

Enclosed with wire Mesh

Figure 4

Retrofitted Specimen

3.5 Testing Procedure

The column was placed such that positioning of the load cell of the loading frame is exactly to the center of the top surface of the column. Two steel caps were provided at the top and bottom ends of the column so that they restrict the spalling of the concrete during loading. Two Strain gauges were placed either in vertical or horizontal positions at the center on any of the two sides. Gauge wire and connector wires of the frame were soldered and keep them in an undisturbed position and LVDT was arranged carefully. The probe of the loading frame was connected to the load cell. The loading frame with the test setup was shown in Figure 5.

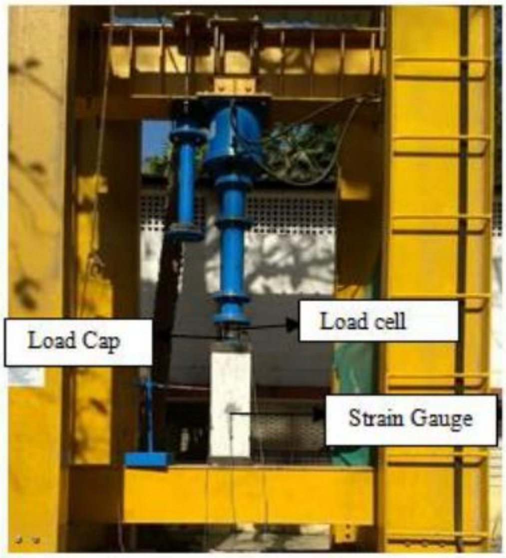


Figure 5 Test Setup of Specimen

4. RESULTS AND DISCUSSIONS

The maximum load carried by the specimens and their deflections were noted in below table 1.

Table 2 Load and Deflection of each member

Member	Load (KN)	Deflection (mm)
CS	1008.2	1.85
RS 1	1096.9	3.8
RS 2	1158.2	5.02
RS 3	1157.4	7.6

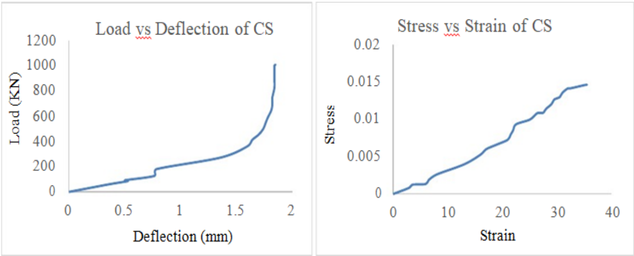
Maximum and minimum loads carried by RS2 and RS1.Confinement of 50% has more strength than that of 25% confinement.

Figure 6 Crack pattern of CS

The control specimen was axially loaded and readings of each second were recorded. As per design, the ultimate load is 960.342KN. The maximum load-bearing capacity of the member is 1008.2KN. Initial cracking have been started at the load of 994.5KN at the top end at a depth of 300mm vertically. The concentration of stress was more at the top the end of the column. Slight spalling has occurred at the top surface of the concrete member. The crack pattern can be observed in Figure 6.

From Figure .7(a) it was shown that the minimum deflection of the column is 0.35mm at a load of 58.8KN. The deflection in between loads of 86.1KN to 92.2KN and 128.1KN to 179.7KN were relatively the same and later there was a gradual increase along with the load. The maximum deflection occurred at the load of 1008.2 KN is 1.85mm.

From the figure .7(b) shows the variations between stress and strain, Initial strain occurred at 0.000852KN/mm^2. Then there is an increase in strain for about a variation of 3.5 to 6 at constant stress and is gradually increased up to the maximum of 35.5 at 0.014611 KN/mm^2.



(a) (b)

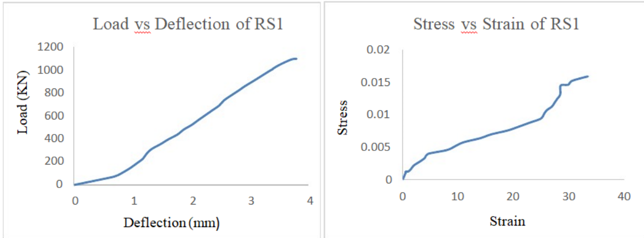
Figure 7 Retrofitted Specimens

RS1 was provided with a 25% area of wire mesh which was axially loaded up to 1096.9KN. Cracks were formed from the top end. Initial cracking started at the load of 1044.5KN. This was more ductile than the control specimen as there is less impact of stress and high load-bearing capacity and also age of the structural member was increased. Restrengthening extends the failure period by providing mesh refinement to this member.

Figure 8 Formation of cracks in RS1

In the figure. 9(a), the load and deflection curve of the retrofitted specimen-1 have been shown. From the graph, it is seen that the deflection curve has been increased with an increase of load linearly up to the ultimate load of the specimen. The minimum deflection of the specimen occurred at 0.67mm and is constant for a load of 70.3 KN.

The stress-strain curve for the retrofitted specimen1 is shown in figure. 9(b). The initial strain is occurred at a stress of 0.001018KN/mm². The curve is linearly increased with an increase in stress of 0.009389KN/mm² and suddenly increased up to the strain of 33.5.



(a) (b)

Figure 9

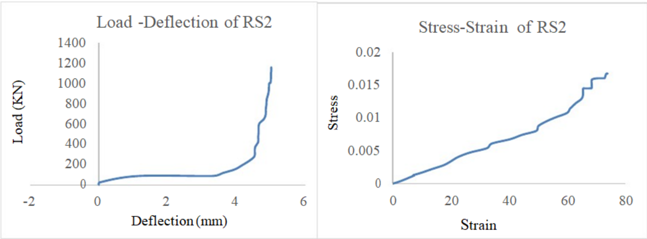
RS2 was provided with 50% of wire mesh with reduced longitudinal reinforcement. Stress concentration was higher in the top section as cracks were passed towards the center due to repeated loadings. The behavior of the specimen during the loadings was about to buckle as it exceeded its compressive strength and the member almost entered the buckling stage. Comparatively, this refinement gave good strength and high bearing capacity as compared to the control specimen and Retrofitted specimen 1.

Figure 10 Behaviour of RS 2 due to repeated loading

In the figure. 11(a), the load-deflection of retrofitted specimen-2 have been shown. Deflection started at the load of 23.9KN and was linearly increased with a deflection from 1.14mm to 3.34mm at an approximate constant load, and suddenly increased. The maximum deflection of the member at an ultimate load of 1158KN was at 5.02mm. The deflection was not as linear as RS1.

The stress-strain curve from the figure 11(b) shows that the minimum strain (i.e., 2.5) occurred at the stress of

0.000346KN/mm²and was increased with an increasing load linearly up to the load of 0.010778KN/mm². Then, the curve is rapidly increased up to a strain of 74 at stress 0.016785KN/mm².



(a) (b)

Figure 11

A column with 75% mesh confinement was placed under the loading frame for testing. After the duration of 495.4 sec, the initial crack started at the load of 1056.7 KN. The pattern of crack formation was the same as remaining specimens. The maximum capacity of the specimen to carry the load was 1157.4KN

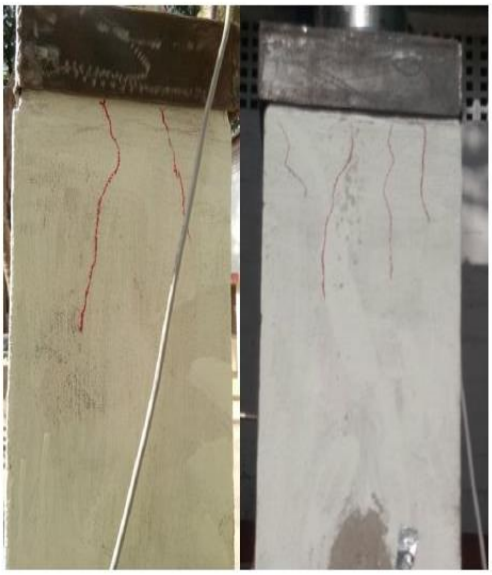
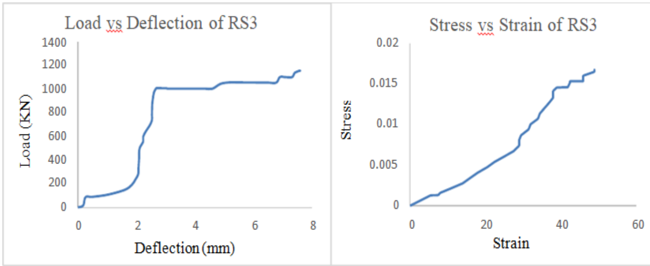


Figure 12 Crack pattern of RS3 formed at the top end

In the figure. 13(a), the Load-Deflection graph of retrofitted specimen 3 shows that the deflection initially started at the load of 15KN and deflection has increased from 0.18mm to 0.26mm at 88.3KN. The deflection is then linearly increased and reaches a level of 2.71mm at a load of 1010KN. It is then rapidly increased from 2.8mm to 7.6mm with a constant increase of load from 1009.6KN to 1157.4KN respectively. The maximum deflection of the member is at 7.6mm with a load of 1157.4KN.

In the figure. 13(b), the graph shows that the curve is linearly increased with an initial strain occurring at a stress of 0.00021KN/mm² up to the strain of 29 with the stress 0.00738KN/mm². Then there is a gradual increase in strain up to 49 along with the stress of 0.0164KN/mm².



(a) (b)

Figure 13

Figure 14 shows the load capacities of each specimen. The control specimen carried the ultimate load of 1008.2KN. Retrofitted specimens were compared with the control specimen. RS1 carried a load of 1096.9KN. RS2 and RS3 reached the ultimate load at 1158.2 and 1157.4 KN. RS2 which was with 50% mesh refinement got high strength concerning RS1 and RS3. As per my consideration, it was recommended to prefer wrapping wire mesh up to 50% was considerable as it gives strength effectively. If more than 50% of mesh refinement was used then it gives almost same strength as it.

Figure 15 shows the time at failure of specimens. RS3 took 549.8 seconds to fail it indicates that the brittle nature has reduced due to mesh and it increases the ductility of the structure as it was more ductile than CS, RS1, and RS2.

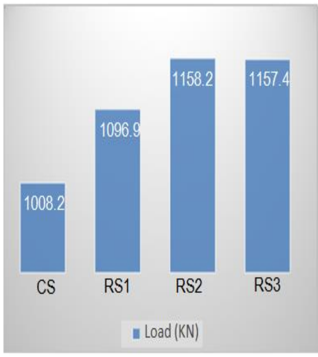


Figure 14 Load carrying capacity of specimen

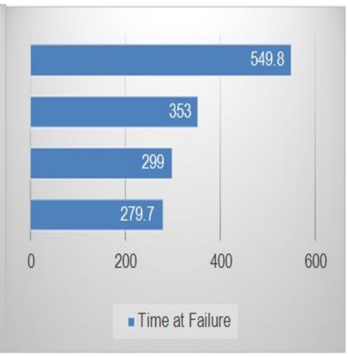


Figure 15 Duration of failure period specimen

Figure 16 consists of Stress-Strain curves. CS was strained at the lowest value of 35.5 then RS2 was strained at the highest value of 74. Stress-Strain varies along with the load i.e. if the load increases also there is an increase in strain.

From the figure 17, it shows the variations in load-deflection curves of each specimen. The curve of RS1 was linearly increased than that of all specimens. CS was suddenly increased from the load of 149.9KN and RS2 also increased from the load of 115.9KN. RS3 was more deflected than that of all specimens. Deflection depends upon the load-carrying capacity of the member if the load has increased then deflection may also increase.

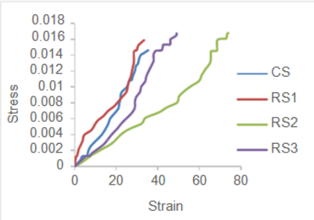


Figure 16 Stress vs Strain Curves of Specimens

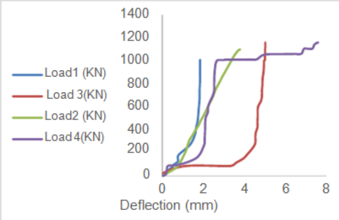


Figure 17 Load vs Deflection Curves of Specimens

5. CONCLUSIONS

- Observation from all the results of four specimens have concluded that RS2 and RS3 are 1.14 times greater than CS and RS1 is 1.08 times greater than CS.
- In comparison between retrofitted specimens, RS2 and RS3 are 1.05 times greater than that of RS1.
- RS2 and RS3 got almost the same strength as RS1 and mesh refinement of 50% was suggested for the members in future purposes.
- RS 3 took a long time to fail as it indicates a less brittle nature and more ductility nature of the member.
- RS 2 was more strained than other specimens like CS, RS1, and RS3 as it increased along with the load-carrying capacity.

6. REFERENCES

[1] Abd-ELhamed., Ezz –Eldeen M.K., H. A., “Retrofitting and Strengthening of Damaged Reinforced Concrete Columns Using Steel Angles Wrapped with Steel Wire Mesh”, International Journal of Modern Engineering Research,2014; 4(12), 16-24.

[2] Amrul Kaish A.B.M., Alam M.R., Jamil M., Wahed M.A., “Ferrocement Jacketing for Restrengthening of Square Reinforced Concrete Column under Concentric Compressive Load”, ELSEVIER, 2013; 720-728.

[3] Anagha. A.R., Shibi Varghese., “A Study on Strengthening of R.C.C Columns by Ferrocement Jacketing”, International Journal of Science Technology & Engineering, 2017; 3(11), 110-115.

[4] Azam Amir., Amjad Nasser., Orooj Azam., “Strengthening of Existing Building Column Using FRP Wrap & GI Wire Mesh”, International Journal of Scientific & Engineering Research, 2013; 4(5), 211-216.

[5] Bishnu Gupt Gautam., Lakshmipathy M., Senthil Kumaran G., “Experimental Study on Retrofitting of Square RC Short Column Subjected to Concentric Axial Loading ByJacketing” International Journal of Civil Engineering and Technology, 2014;5(8),140-147.

[6] Manikandeswaran O., Irin Mary Martin., "Comparative Study of Columns Strengthened by Steel Angles and Ferrocement Jacketing", International Journal of Research in Advent Technology, 2015; 10-11.

[7] Muhammad N.S Hadi., Hua Zhao., “Experimental Study of High-Strength Concrete Columns Confined with Different Types of Mesh under Eccentric and Concentric Load”, Journal of Materials in Civil Engineering, 2011; 23(6), 1-10.

[8] Muhammed Salih D.S., Arunkumar C., “Strengthening of Reinforced Concrete Column Using Jacketing Technique”, International Conference on Engineering Innovations and Solutions, 2016; 35-38.

[9] Tore E., Comert M., Demir C., Ilki A., Marasli M., “Seismic Retrofit of Columns Using Basalt Mesh Reinforced Sprayed GRC jacket”, GRC,2015; Dubai,1-7.

[10] Yan Xiao., ASCE M., Hui Wu., “Retrofit of Reinforced Concrete Columns Using Partially Stiffened Steel Jackets”, Journal of Structural Engineering © ASCE, 2003; 129(6), 725- 732.