Performance Evaluation of a RC Column Strengthened by Concrete Jacketing

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Abstract: In last few decades earthquake ground motions have become a critical design factor for modern structures. Recent severe earthquakes like the earthquakes in Nepal, Bhuj and Japan have forced the designers to continuously improve the structural stability of buildings also to prevent disaster in future earthquakes, the existing deficient buildings need to be retrofitted. Retrofitting can effectively raise the performance of a building against earthquake to a desired level, and to even satisfy the requirements of an upgraded design seismic code. The building need not be deteriorated or damaged. The retrofit is intended to mitigate the effect of a future earthquake. One of the methods of retrofitting in reinforced concrete buildings is concrete jacketing. The present study has investigated the effectiveness of jacketing on compressive strength and performance of column as per guidelines of IS 15988: 2013 for various mix designs. Parametric investigations were carried out to predict the experimental results for compressive strength of virgin column and jacketed column and the Results demonstrate that jacketing method used in the investigation study increases the load carrying capacity of the columns.

Index Terms - Retrofitting, Reinforced concrete jacketing, Structural capacity, Strength comparison.

I. INTRODUCTION

Reinforced concrete structures often have to face modification and improvement of their performance during their service life. The main contributing factors are Change in their use, new design standards, Construction is apparently of poor quality, Deterioration due to corrosion in the steel caused by exposure to an aggressive environment and Accident events such as earthquakes. In such circumstances there are two possible solutions: replacement or retrofitting. Full structure replacement might have determinate disadvantages such as high costs for material and labor and inconvenience due to interruption of the function of the structure e.g. traffic problems. Thus, it is often better to upgrade the structural capacity by proper retrofitting technique.

Retrofitting techniques are generally of two types a) Global and b) Local. Global Retrofitting techniques aim at overall seismic improvement of the structure that includes Base isolation, adding steel Bracing, adding an infill wall or a shear wall while the local retrofitting techniques involve reinforced concrete jacketing, steel jacketing and fiber reinforced polymer wrapping. Jacketing techniques are applied over structural members by adding a new layer of reinforced concrete or steel pates over the existing member. Gnanasekaran Kaliyaperumal and Amlan Kumar Sengupta (2009) studied jacketing method of retrofitting for beam column joint and found it very effective. Pranab Agarwal et al in 2005 suggested an effective analytical procedure for the jacketing of columns for retrofitting. Karan Shah et. al.in 2016 stated that using concrete jacket is effective method in increasing strength and stiffness in a structural member. Prathamesh Dingorkar and Ayush Srivastava in 2016 compared jacketing method and wrapping method for retrofitting and through parametric analysis found jacketing method as more effective than the wrapping method.

II. METHODOLOGY AND DESIGN

Design of Reinforced concrete Column Using IS 456: 2000. The experimental setup consists of the testing reinforced concrete column specimens with cross section of 150 mm x 150 mm with an overall length of 600 mm. Reinforcement cage was placed in casting mould by providing 20 mm covering on bottom and side face. The column was reinforced with 4 numbers of 10 mm dia. tor steel bars. The lateral ties in the specimens are 6 mm Ø 140 mm c/c.

Thus, cutting, bending and anchorage of reinforcement bars were done and reinforcement cage was prepared as per the design given in table below.

<table>
<thead>
<tr>
<th>Design of virgin specimen column as per IS: 456-2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of the Column (H) = 600 mm</td>
</tr>
<tr>
<td>Cross-Section (B x D) = (150 X 150) mm</td>
</tr>
<tr>
<td>Effective Cover= 20 mm</td>
</tr>
<tr>
<td>Grade of Concrete =20, 25 and 30 N/mm²</td>
</tr>
<tr>
<td>Grade of steel=415 N/mm²</td>
</tr>
<tr>
<td>Minimum number of longitudinal bars in rectangular column = 4 (IS 456: 2000)</td>
</tr>
<tr>
<td>No. of bars = Total Ast / Ast for one bar</td>
</tr>
<tr>
<td>Required steel area (Ast)=(Pt/100) x B x D (Pt = % of steel)</td>
</tr>
<tr>
<td>= 0.8 x 150x150/100</td>
</tr>
<tr>
<td>= 180 mm²</td>
</tr>
<tr>
<td>a) No. of bars = Total Ast / Ast for one bar</td>
</tr>
<tr>
<td>No. of bars = 4</td>
</tr>
</tbody>
</table>

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\[
4 = \frac{180}{(\pi/4) \times d^2}\] (d = dia. of steel) \hspace{1cm} (1.2)
\[
d = 7.56 \text{ mm} = 10 \text{ mm}
\]

**Lateral Ties: (IS 456: 2000)**

b) Pitch should not be more than three values

1. Least lateral dimension of column = 150 mm
2. 16 x diameter of small longitudinal bar
   \[16 \times 10 = 160 \text{ mm}\] \hspace{1cm} (1.3)
3. 300 mm c/c

Therefore, Pitch = 150 mm c/c.

c) Diameter should not be less than, whichever is greater

1. \((1/4) \times \text{diameter of largest longitudinal bar}\)
   \[= (1/4) \times 12 = 3 \text{ mm}\]
2. Provide 6 mm dia. bars

Provide 6 mm Ø 150 mm c/c.

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Design of Reinforced concrete Column Jacketing Using IS 15988: 2013

After observing the crack pattern of damaged specimen, the same was cleaned by removing the cracked portion. For developing the bond between original specimen and outer jacketed layer, surface was made rough. 8 Longitudinal reinforcement bars of 12 mm dia. at each corner and middle of the surface were tied with 6 mm lateral ties at 100 mm c/c spacing and proper covering on all sides.

In this study, column jacketing is carried out as per recommendations of Indian standard code IS 15988 (2013): Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings – Guidelines published By Bureau of Indian Standards [4]. Reinforced concrete jacketing improves column flexural strength and ductility. Closely spaced transverse reinforcement provided in the jacket improves the shear strength and ductility of the column. The procedure as per article 8.5.1.1 of the code for reinforced concrete jacketing is as follows:

**Table 2 Design of jacketed specimen column as per IS: 15988-2013**

Now, \(Pu = (0.4 \times fck \times Ac) + (0.67 \times fy \times Asc)\) \hspace{1cm} (1.4)

Thus, taking value of \(fck = 25 \text{ N/mm}^2\) (against 20 N/mm\(^2\) of actual specimen)

Assuming \(Asc = 0.8\% \text{ Ac}\) \hspace{1cm} (1.5)

Therefore, \(268 \times 103 = (0.4 \times 25 \times Ac) + (0.67 \times 415 \times (0.8\% \times Ac))\)

Where \(Asc = 0.8\% \times Ac\) \hspace{1cm} (1.6)

\(268 \times 103 = 12.224 \text{ Ac}\) or \(Ac = 21923.366 \text{ mm}^2\)

**According to 8.5.1.1 (e) of IS 15988:2013, \(Ac = 1.5A'c\)**

Therefore, \(Ac = 32885.05 \text{ mm}^2\)

Thus \(Ac = 32885.05 \text{ mm}^2\)

Assuming the cross sectional details with equal width and depth

Therefore, \(B = 181.34 \text{ mm} \text{ and } D = 181.34 \text{ mm}\)

Jacketing details of cross section:

\(B = D = (181.34 - 150) = 31.34 \text{ mm}\)

However, According to the code specified above, Minimum jacket thickness shall be 100 mm as per 8.5.1.2 (c) of IS 15988:2013

Thus, New size of the column:

\(B = 150+100 = 250 \text{ mm} \text{ Hence Consider } B = 290 \text{ mm}\)

\(D = 150+100 = 250 \text{ mm} \text{ Hence Consider } B = 290 \text{ mm}\)

New concrete area = 290 x 290 = 84100 \text{ mm}^2 > 21923.336 \text{ mm}^2 \hspace{1cm} (1.7)

**Area of steel = 672.8 \text{ mm}^2**

But according to 8.5.1.1 (e) IS 15988:2013, \(As = (4/3) \times A's\)

\(As = (4/3) \times 672.8 = 900 \text{ mm}^2\) \hspace{1cm} (1.8)

Assuming 12 mm Ø bars

**Thus number of bars = 900 \times 4 / (122 \times \pi) = 8 Bars**

**Design of Lateral Ties**

As per 8.5.1.2 (e) of IS15988: 2013, Minimum diameter of ties shall be 8 mm and not less than one-third of the longitudinal bar diameter.

Diameter of bar = 1/3 of Ø of largest longitudinal bar

\[(1/3) \times 16 = 6 \text{ mm}\]

**Spacing of ties as per 8.5.1.1 (f) of IS 15988:2013**

\(S = 100 \text{ mm c/c}\)
III. TEST SPECIMEN SETUP

![Fig. 1 Virgin Specimen without Jacketing](image1)

![Fig. 2 Specimen with jacketing layer](image2)

The specimens were fixed on Compressive testing machine (CTM). Loading was applied with the help of loading jack to damage the specimen and detailed assessment of the damaged specimen was done and the damaged zones were identified. Each damaged specimen was then jacketed with jacketing material as per the design and allowed to set. Finally again the loading was applied with the help of loading jack under Compressive Testing Machine (CTM) as shown in figure to the Strengthened specimen and again loading was applied until failure and the results were evaluated.

IV. RESULTS AND DISCUSSION

The loads and the corresponding deflections on virgin and rehabilitated specimens were plotted on graphs. These results were obtained by conducting load test on virgin specimens and rehabilitated specimens. The graphs are plotted based on loads and deflections of both the specimens

<table>
<thead>
<tr>
<th>Table 3 Specimen Details for Non-Jacketed Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO OF COLUMN</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>
Table 4: Specimen Details for Jacketed Column

<table>
<thead>
<tr>
<th>NO OF COLUMN</th>
<th>DIMENSION (MM)</th>
<th>GRADE OF CONCRETE</th>
<th>LOAD (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>290X290X600</td>
<td>M20</td>
<td>1850.03</td>
</tr>
<tr>
<td>2.</td>
<td>290X290X600</td>
<td>M20</td>
<td>1813.53</td>
</tr>
<tr>
<td>3.</td>
<td>290X290X600</td>
<td>M20</td>
<td>1955.99</td>
</tr>
<tr>
<td>4.</td>
<td>290X290X600</td>
<td>M25</td>
<td>2237.5</td>
</tr>
<tr>
<td>5.</td>
<td>290X290X600</td>
<td>M25</td>
<td>2345.39</td>
</tr>
<tr>
<td>6.</td>
<td>290X290X600</td>
<td>M25</td>
<td>2306.05</td>
</tr>
<tr>
<td>7.</td>
<td>290X290X600</td>
<td>M30</td>
<td>2887.49</td>
</tr>
<tr>
<td>8.</td>
<td>290X290X600</td>
<td>M30</td>
<td>2756.82</td>
</tr>
<tr>
<td>9.</td>
<td>290X290X600</td>
<td>M30</td>
<td>2603.57</td>
</tr>
</tbody>
</table>

Fig. 3: Specimen in the mould.
Fig. 4: Jacketing over original specimen.
Fig. 5: Testing of specimen under CTM.

FORCE VS DISPLACEMENT

Fig. 6: Load Vs Displacement for M20 grade concrete.
V. CONCLUSION

In the above study, column specimens with different grades of concrete (M20, M25, M30) were designed and casted as per IS: 456-2000 and were tested for compressive strength under Compressive testing machine (CTM) further those column specimens
were retrofitted using concrete jacketing method as per IS: 15988-2013 and were again tested for strength under Compressive testing machine (CTM) and following conclusions were carried out:

- Concrete jacketing proves to be a very effective method for retrofitting also it proves to be an easy and effective method among other retrofitting method.
- Columns for M20, M25 & M30 were casted and tested under CTM (Compression testing machine) and the results show that the strength of each specimen has increased.
- Each specimen showed an increment in strength by 4 to 6% once after failure of the actual specimen under CTM machine.
- The average strength increase of specimen of each grade is shown in the table below

<table>
<thead>
<tr>
<th>Grade of concrete</th>
<th>M20</th>
<th>M25</th>
<th>M30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non retrofitted</td>
<td>21.43</td>
<td>25.69</td>
<td>31.28</td>
</tr>
<tr>
<td>Retrofitted</td>
<td>22.27</td>
<td>27.29</td>
<td>32.80</td>
</tr>
</tbody>
</table>

Fig. 8 Strength comparison between jacketed and virgin specimen

### VI. REFERENCES

- IS:15988-2013 - Seismic evaluation and strengthening of existing reinforced concrete buildings — guidelines