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Reinforced Concrete Jacketed Column and Its Formwork

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Abstract: ***This study focuses on the planning and designing of a multistory building. Further, understanding the structural system of the designed building and its performance with respect to structural design forms an integral part of the study. While designing the building, certain material characteristics have been assumed and characteristics of the materials assumed in the design is verified for the suitability in the design. Assuming failure in one of the columns, retrofitting scheme have been suggested for the same, and also related tests are performed regarding the process of retrofitting by RC jacketing of short columns. A prototype of formwork system for jacketing has also been prepared for the same as an extension of this study.***

Keywords : IS 456-2000, Retrofitting, RC Jacketing, Formwork.

I. INTRODUCTION

Design of a multistory building, suiting the requirements of the site selected and study of RC jacketed column and developing a formwork for the same, forms the foundation of this paper. We started with the preparation of an architectural plan suiting the requirements of the site using AutoCAD and the structural layout was prepared using the same. The plan was then imported to the ETABS software and a model was prepared. The model was analyzed for the given loading conditions as per the Indian standard codes and the design of RCC structural components was carried out with the software. Assuming that the failure of compression member, the column (short column), was due to the fact that the desired compressive strength of concrete for column was not achieved, we chose to retrofit the column with the help of RC Jacketing and have made a prototype to replicate the same and validated the increase in strength of column achieved after retrofitting. A formwork mould has also been developed by us which is used for the experiments.

II. EXPERIMENTAL INVESTIGATION

A. Reconnaissance Survey

A reconnaissance survey was first conducted to form an architectural plan suiting the requirements needed.

Details obtained from reconnaissance Survey:

Our architectural plan and structural design is based on following basis:

- The construction area is approximately 1800sq.ft. with plot area being 8400sq.ft.
- Family size – 6 in a family.
- Space restraints – indoor and outdoor.
- Requirement of number of rooms.
- Requirement of number of utilities.
- Comfort level, material goods and their lifestyle.
- Reliability of the plan to the area and replicability of the same.
- Design is through Limit State method.

B. Concept Design

- Building is multistoried; the geometry is based on the linear form. The construction area is approximately 167.23m^2.
- Due to the prominent location of the plot and high worth, the design is set to maximize the available views to the large greens, offering the habitants a visual connection to the surrounding natural environment.
- The Residential unit is designed as 3BHK, with the unit looking into the green space all around. The house is designed in such a way that the living and dining are separated and so is the kitchen. The bedroom overlook into the living area and as such least disturbance from the utility areas.
- The building will become the center focus point of the site from the surrounding areas.

C. Analysis and design of the building

MATERIAL PROPERTIES:

Codes Referred:

1. IS: 456-2000[1] and SP: 16[2] for the design of structure.
2. IS: 875 Part-1 and Part-2 for dead loads and live loads respectively [3].
3. IS 1893:2016 [4] for seismic load.

- Concrete (IS: 456-2000):

Grade of Concrete used: M25,

Compressive Strength, f_{ck}: 25 N/mm^2,

Density of Concrete: 25kN/m^3.

Modulus of Elasticity, E_c: 5000$\sqrt{f_{ck}}$ kN/m^2.

Steel (IS: 456-2000):

- Grade of Steel: Fe500.

Yield Strength of Steel, f_y: 500N/mm^2.

Clear Cover Details:

Slab- 20mm.

Beam- 25mm.

Column- 40mm

ETABS MODELLING:

Load Input Values:

- Dead load: the unit weight of concrete (25kN/m^3) is multiplied with the volume of the RC structure (i.e. beam, column, slab etc.)

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- Superimposed Dead Load: it includes wall loads on beam and slab, and also the floor finish.
- Wall Intensity for different thickness of wall are as follows,
  a) 230mm wall- 5kN/ m^3.
  b) 200mm wall- 4.5kN/ m^3.
  c) 150mm wall- 3.5kN/ m^3.
  d) 100mm wall- 2.5kN/ m^3.
- Floor Finish for all floors- 1.35kN/m^2.
- Live Load: The live loads for different slabs is as per IS 875-part 2.

LOADS ON SLABS:
Abbreviations used:
LL= Live Load.
FF= Floor Finish.
SIDL= Super Imposed Dead Load.
SW= Self Weight of the slab.

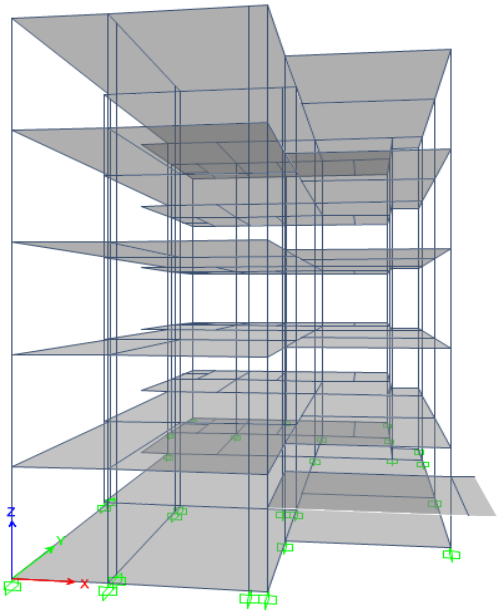

Fig. 1. 3-D model of the building (G+4 story)

Loads on Living room slab: Thickness of slab= 150 mm.
SW= 20x0.15=3.0 kN/m^2.
FF=1.35 kN/m^2.
LL=2kN/m^2.
In ETABS, following values are entered:
LL=2kN/m^2.
SIDL=1.35kN/m^2.
Loads on Dining room slab: Thickness of slab= 125 mm.
SW= 20x0.125=2.5 kN/m^2.
FF=1.35 kN/m^2.
LL=2kN/m^2.
In ETABS, following values are entered:
LL=2kN/m^2.
SIDL=1.35kN/m^2.
Loads on Bedroom slab: Thickness of slab= 125 mm.
SW= 20x0.125=2.5 kN/m^2.
FF=1.35 kN/m^2.
LL=2kN/m^2.
In ETABS, following values are entered:
LL=2kN/m^2.
SIDL=1.35kN/m^2.

Loads on Toilet slab: Thickness of slab= 125 mm; Sunk=75 mm.
SW= 20x0.125=2.5 kN/^{2}m.
FF=1.35 kN/m^2.
LL=2kN/m^2.
Sunk load=0.075x20.4=1.53 kN/m^2.
In ETABS, following values are entered:
LL=2kN/m^2.
SIDL=2.88 kN/m^2.
Loads on Staircase slab: Thickness of slab= 175 mm; Riser=150 mm: Tread=250 mm. Also, $\sqrt{150^2 + 250^2}/250$ =1.166
SW= 20x0.125x1.166=2.915 kN/m^2.
FF=1.35 kN/m^2.
LL=3 kN/m^2.
Steps=0.5x0.15x1x25=2 kN/m^2.
In ETABS, following values are entered:
LL=3kN/m^2.
SIDL=2+1.35+2.915-(20x0.125) =3.75 kN/m^2.
LOADS ON BEAM LINE:
Wall load:
Floor to floor height = 3m.
Beam size = (200x600) mm.
Assuming 230mm thick wall (main wall):
Self-weight of the beam = 0.23x0.6x20 = 2.76 kN/m^2.
Wall load = (3-0.6) x5= 12 kN/m^2.
In ETABS, wall load=12 kN/m^2.
Assuming 100mm thick wall (partition wall):
Self-weight of the beam = 0.10x0.6x20 = 1.2 kN/m^2.
Wall load = (3-0.6) x2.8= 6.72 kN/m^2.
In ETABS, wall load=6.72 kN/m^2.

D. Discussion on design check

The forces and moments obtained from the critical combination of loadings are considered for design check.
Columns:
Design check carried out for columns, considering the critical forces obtained from the analysis, the sizes and reinforcement provided for all the columns are pound to be structurally adequate to carry the present loads due to gravity loads. The columns are grouped according to their values arrived from 3D analysis of the given multi- storied structure using ETABS.
Beams:
Design check carried out for beams, considering the critical forces obtained from the analysis. The sizes and area of reinforcement provided for the existing beams are found to be structurally adequate for present level of loadings.

E. Decrease in strength of a column

We have assumed that the failure of compression member, the column (short column), was due to the fact that the desired compressive strength of concrete for one of the column was not achieved. Hence, we chose the retrofitting of the column with the help of RC Jacketing. (Given mix had to have 25N/mm² strength, but the mix has a strength of 20N/mm² in the second floor of the building.)

From ETABS, in the second floor of the column, percentage of tensile reinforcement increases from 1.46% to 1.83%.Hence, we chose the retrofitting of the column with the help of RC Jacketing to ensure that the increase in percentage of tensile reinforcement is satisfied and the structure is safe.

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F. Laboratory Tests

The following tests were conducted to simulate the conditions of site:

- Determination of characteristic strength of concrete (of second floor column which has failed as per our assumption) as per the sampling and acceptance criteria of IS 456:2000.

Fig. 2.Testing of concrete cube

The test report is annexed at the end of this section.

- Since the strength of concrete achieved is less than the specified strength (target mean strength), core sample needs to be taken to find out the actual strength of concrete. Since, we are only simulating the field conditions, we have casted three 150 mm diameter cylinders with same grade of concrete casted for cubes and we have tested the cylinder in a Compression Testing Machine as per IS 516:2018[5] and result of this test is compared as per IS 456:2000.

Fig. 3.Failure of concrete cylinder

The test report is annexed at the end of this section.

- Specified grade of Concrete is M25, 75% of M25=18.75N/mm².Achieved strength of the cylinder is less than 75% of grade of concrete specified as per IS 456:2000 Clause 17.4.3, the result is not acceptable; hence, retrofit of the column is to be done.
- Retrofit is done by the method of RC Jacketing. Shear connectors are put in place as shown in fig.4. Epoxy is used as a bonding agent between concrete used for retrofitting and original concrete. M30 grade concrete is used for retrofitting. 75mm jacketing is provided all around, i.e., 300mm diameter cylinder is casted and we have tested the cylinder in a Compression Testing Machine as per IS 516:2018 and result of this test is compared as per IS 456:2000.

Fig. 4.Reinforcement Details for jacketing along with its Shuttering.

The test report is annexed at the end of this section. The result of compression test on retrofitted specimens is discussed under the section 'discussion of test results'.

Table- I: Compressive strength of concrete at different time periods

Sl. No.	Moulds casted	Age of the Cubes	Avg. Compressive Strength in N/mm²	Standard Deviation (SD) N/mm²	Coefficient of Variations (CoV)
1.	Cube 150 x 150 x 150mm	7 Days	16.74	0.42	0.025
2.		28 Days	22.44	0.26	0.011
3.	Cylinder 150 mm diameter	28 Days	17.65	0.13	0.007
4.	Cylinder 300 mm diameter (Retrofitted)	28 Days	27.65	0.02	0.001

G. Formwork for column

Formwork was prepared by us using locally available materials such as plywood and PVC pipe for casting 150mm and 300mm diameter cylinders.

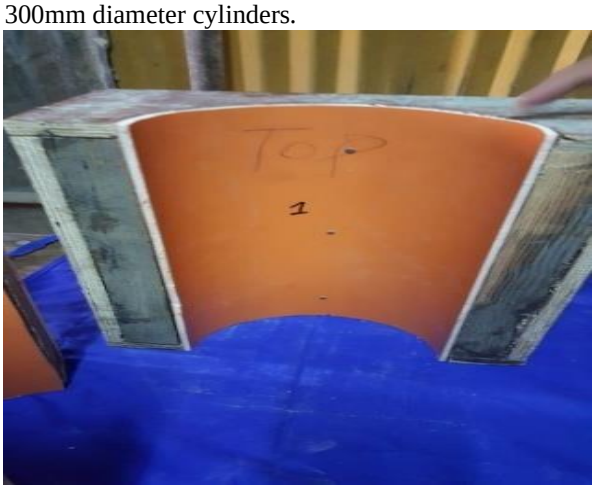

Fig. 5.Part of formwork arrangement

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III. RESULTS AND DISCUSSIONS

The following conclusions were obtained by the test of retrofitted cylinder:

- The load had to be stopped due to Compression Testing Machine not supporting load beyond 2000 kN.
- The strength achieved is more than that desired (75% of M30=22.5N/mm^2).
- Cracks have not fully propagated, thus the cylinder can still take load before failing.
- From these observations, we can say that the retrofitted scheme provided by us is satisfactory.

IV. CONCLUSIONS

The following conclusions can be drawn based on the results and observations are as:

- Materials tested have Coefficient of variations values in range of 0.001 to 0.025, hence the laboratory tests results obtained are satisfied.
- Jacketing is one of the frequently used methods to strengthen columns. With this method, strength, and stiffness of the original column is increased.
- The strength achieved through retrofitting is more than that desired.
- From the results obtained, it can state that RC Jacketing increases the strength of the column considerably and the structural element in consideration can be strengthened from this jacketing technique method.

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