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Analysis, Design and Seismic Retrofitting of an Existing Building

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ABSTRACT: The strengthening and enhancement of the performance of deficient structural elements or the structure as a whole is referred to as retrofitting. Retrofitting aims at structural strengthening of a building after or before an earthquake to a predefined performance. The seismic performance of a retrofitted building is superior to that of the original building. Complete reconstruction would be a costly affair. The entire redevelopment of building would cost much higher than the retrofitting cost. In the present thesis, a residential four storey building is being converted to commercial building which results in increase of live load in existing building. Hence, the building should be retrofitted with suitable technique to increase its service life. The existing building is modelled in ETABS 2016 software, and analysis is carried out with additional live loads on slab under linear static analysis method. R.C retrofitting technique enhances the axial load and moment carrying capacity in beams and column, and was concluded that the RC jacketing method is effective in strengthening RC frames in the building.

KEYWORDS: DCR value, Seismic Retrofitting, Linear static analysis, ETABS 2016

I. INTRODUCTION

Earthquake is the most disastrous, unpredictable and unpreventable natural phenomenon which causes huge damage to the structures, properties and life. Earthquake loading is highly uncertain and it depends on duration, amplitude and frequency contents of the seismic waves. Response of structures to earthquake depends on so many factors such as number of storeys, soil-structure interaction, stiffness, mass of the structure, vertical, plan and torsional irregularities and re-entrant corners etc. As per Bureau of Indian standards code 1893-Part 1 (2002), Indian plateau is divided into four seismic zones – zone II, zone III, zone IV and zone V. However, lack of experience on seismic behaviour, structures built in India over the past decade's are designed only for gravity loading and are therefore seismically deficient. Hence, some of the preventive measures should be adopted to minimize the loss ratio. One such measure which can be adopted in building structures is retrofitting. There are many retrofitting techniques which can be adopted. But in this project RC jacketing method is adopted due to its feasibility and ease in construction. In this project evaluation of seismic qualification and retrofitting of an existing structure is carried out. Analysis of the structure is done by using equivalent static method and modelling is carried out using ETABS-2016 Software. To retrofit, the structural components of the existing four storey building at Bengaluru in Zone II is taken, when a residential building is converted to commercial building. The work is carried out in following steps 1)Model 1-Analysis of existing four storey building 2)Model 2-Adding increased live load of 10KN/m² 3)Calculation of DCR value for beams and columns 4)Retrofitting of beams and columns based on DCR values.

Paper is organized as follows. Section II describes the models (model 1 and model 2) and their analysis. The results, design and discussion due to increased load are made in section III. Finally, Section IV presents conclusion.

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$$DCR = \frac{\text{demand}}{\text{capacity}}$$

If DCR values less than or equal to 1, members need not be retrofitted,

If DCR values greater than 1 are considered for retrofitting.

The columns and beams of building are checked for the DCR values in the below given table based on the bending moment values obtained from the ETABS for the two models.

Table 1: DCR values for beams

Beam No	Demand	Capacity	DCR value	Remark
B1	12.98	12.88	1.00	Retrofitting Not Required
B2	95.21	50.77	1.87	Retrofitting Required
B3	48.627	28.75	1.69	Retrofitting Required
B30	6.703	7.52	0.89	Retrofitting Not Required
B32	41.179	41.93	0.98	Retrofitting Not Required
B33	109.19	70.147	1.55	Retrofitting Required
B34	58.90	45.708	1.28	Retrofitting Required
B37	0.142	0.415	0.34	Retrofitting Not Required
B38	74.409	57.23	1.30	Retrofitting Required
B39	172.94	91.14	1.89	Retrofitting Required
B40	83.68	46.79	1.78	Retrofitting Required
B42	29.9	80.85	0.37	Retrofitting Not Required
B43	62.83	50.89	1.23	Retrofitting Required
B44	2.01	2.03	0.99	Retrofitting Not Required
B49	52.51	45.08	1.16	Retrofitting Required
B53	50.47	25.28	1.99	Retrofitting Required
B55	0.063	0.152	0.414	Retrofitting Not Required
B56	74.56	58.07	1.28	Retrofitting Required

Table 2: DCR values for columns

Column No	Demand	Capacity	DCR value	Remark
C4	12.53	9.93	1.26	Retrofitting Required
C12	4.401	2.51	1.75	Retrofitting Required
C16	5.68	5.14	1.105	Retrofitting Required
C17	12.87	9.93	1.29	Retrofitting Required
C21	61.95	35.69	1.73	Retrofitting Required
C22	79.49	29.15	2.72	Retrofitting Required
C25	58.63	35.08	1.67	Retrofitting Required
C26	46.15	37.1	1.24	Retrofitting Required
C27	52.8	26.93	1.96	Retrofitting Required
C28	51.31	35.78	1.43	Retrofitting Required

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III. RESULTS AND DISCUSSIONS

Reinforcement details of model 1 :for Beams,

Dimension of beams = 230mmX450mm

Cover to steel reinforcement (bottom) = 40mm

Main reinforcement : Top reinforcement = 2 no's of 16mm dia

Bottom reinforcement = 2 no's of 16mm dia

Shear reinforcement : at middle = 8mm dia @ 200mm c/c

At supports = 8mm dia @ 150mm c/c

Columns,

Dimension of beams = 230mmX450mm

Cover to steel reinforcement (both side) = 40mm

Main reinforcement = 6 no's 16mm dia

Shear reinforcement = 8mm dia @ 200mm c/c

Slabs,

Main reinforcement = 10mm dia @ 150mm c/c

Distribution reinforcement = 10mm dia @ 200mm c/c

Table 3: Beam reinforcement details

Critical Beams Provided Ast	Provided Ast	Ast required
B56, B49, B02, B03, B53, B34, B32, B40, B43.	402.12 mm ²	800mm ²
B33, B38, B39, B42.	402.12 mm ²	1200 mm ²

Table 4 : Column reinforcement details

Critical Column		Provided Ast	Ast required
Corner	C17, C27, C21, C16, C04	1206.37 Mm ²	2200 Mm ²
Middle	C25, C26, C22, C28, C12	1206.37mm ²	4500 Mm ²

Design of RCC Beam Jacketing as Per Is 15988:2013

Beams with reinforcement details for reinforcement of 800mm²

The beams designed for the structure are designed to resist gravity loading and are provided with a reinforcement of 2 bars with 16mm Ø at top and bottom gives 804.24mm².

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But ,when the beams are designed to resist lateral seismic forces, the reinforcement to be provided to resist the seismic forces is, 4bars of 16mm Ø at both top and bottom gives 1608.48 mm²

Reinforcement deficiency = 1608.48 – 804.24 = 804.24mm²

Provide 4 bars of 16mm dia bars gives 804.24mm²

Minimum thickness for jacketing to be provided is 100mm. Therefore, revised beam will be 430x550mm.

Provide shear reinforcement using 2 legged 8mm ϕ bars @ 150mm c/c.

Beams with reinforcement details for reinforcement of 1200mm²

The beams designed for the structure are designed to resist gravity loading and are provided with a reinforcement of 2 bars with 16mm Ø at top and bottom gives 804.24mm².

But ,when the beams are designed to resist lateral seismic forces, the reinforcement to be provided to resist the seismic forces is, 4bars of 20mm Ø at both top and bottom gives 2513.27 mm²

Reinforcement deficiency = 2513.27 – 804.24 = 1709.03mm²

Provide 4 bars of 25mm dia bars gives 1963.5mm²

Minimum thickness for jacketing to be provided is 100mm. Therefore, revised beam will be 430x550mm.

Provide shear reinforcement using 2 legged 8mm ϕ bars @ 125mm c/c.

Table 5: retrofit details for beams

BEAMS	SHEAR REINFORCEMENT PROVIDED	ADDITIONAL REINFORCEMENT PROVIDED	
		TOP REINFORCEMENT	BOTTOM REINFORCEMENT
B56	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B49	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B02	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B03	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B53	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B34	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B32	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B40	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B43	2L Ø8 @ 150 C/C	#2 Ø 16	#2 Ø 16
B33	2L Ø8 @ 125 C/C	#2 Ø 25	#2 Ø 25
B38	2L Ø8 @ 125 C/C	#2 Ø 25	#2 Ø 25
B39	2L Ø8 @ 125 C/C	#2 Ø 25	#2 Ø 25
B42	2L Ø8 @ 125 C/C	#2 Ø 25	#2 Ø 25

Design of RCC Column Jacketing as Per Is 15988:2013

Column with reinforcement details for reinforcement of 2200mm²

The columns in the building reinforcement provided are with 6 bars of 16mm ϕ = 1206.37mm².

Same building is designed to resist additional forces, reinforcement to be provided is 8 bars of 20mm ϕ = 2513.27mm²

Reinforcement deficiency = 2513.27 – 1206.37 = 1307 mm²

As per IS 15988:2013 code, Area of steel for jacketing = (4/3) As = (4/3) x 1307 = 1742.5mm²

Hence, 6 bars of 20mm dia gives 1885mm². Hence, revised jacketed section is 330x650mm

Lateral ties of 8mm at 200mm spacing are provided.

Column with reinforcement details for reinforcement of 4500mm²

The columns in the building reinforcement provided are with 6 bars of 16mm ϕ = 1206.37mm².

Same building is designed to resist additional forces, reinforcement to be provided is 12 bars of 25mm ϕ = 4908.7mm²

Reinforcement deficiency = 4908.7 – 1206.37 = 3702.33 mm²

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As per IS 15988:2013 code, Area of steel for jacketing = $(4/3) A_s = (4/3) \times 3705.36 = 4901.48 \text{mm}^2$
Hence, 10 bars of 25mm dia gives 4908.7mm^2 . Hence, revised jacketed section is 330x650mm
Lateral ties of 8mm at 200mm spacing are provided.

Table 6:retrofit details for columns

COLUMN	ADDITIONAL REINFORCEMENT PROVIDED	SHEAR REINFORCEMENT PROVIDED
C04	#6 Ø 25	2L Ø8 @ 200 C/C
C16	#6 Ø 25	2L Ø8 @ 200 C/C
C17	#6 Ø 25	2L Ø8 @ 200 C/C
C21	#6 Ø 25	2L Ø8 @ 200 C/C
C27	#10 Ø 25	2L Ø8 @ 200 C/C
C12	#10 Ø 25	2L Ø8 @ 200 C/C
C22	#10 Ø 25	2L Ø8 @ 200 C/C
C25	#10 Ø 25	2L Ø8 @ 200 C/C
C26	#10 Ø 25	2L Ø8 @ 200 C/C
C28	#10 Ø 25	2L Ø8 @ 200 C/C

IV. CONCLUSION

In this paper the study attempt is made on weakening points of structure, when the residential building is converted into commercial building. According earthquake code book IS 1893(PART-I) 2002, the analysis is made on existing building on ZONE II and soil Type-II. Due to increase of load in the existing four storey structure, the beams and columns of the building got weaken. So, beams and columns retrofitting technique is adopted to regain its strength. Apart from increase in the capacity and deformability, the shear deformation of the joint panel will be reduced significantly after retrofitting. Since slabs are parallel to earthquake forces, they need not to be strengthened. RC retrofitting technique enhances the axial load and moment carrying capacity in beams and column. Hence, it is concluded that retrofitting technique enhances the axial load and moment carrying capacity in beams and column.

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