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SEISMIC PERFORMANCE ASSESSMENT OF RC INDUSTRIAL BUILDING AFTER RETROFITTING BEAMS AND COLUMNS

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Abstract

A numerical study is done to determine the seismic performance of G+1 industrial RC building after retrofitting beams and columns. Deterioration of building has occurred due to excess chemical spillage over structural elements. Distressed beams and columns were retrofitted using jacketing techniques. The building is located in Indian Seismic Zone IV, so there is a need to understand the global seismic behaviour of the building after retrofitting. Nonlinear static pushover analysis is carried out to and the results indicate a decrease in the storey shear values.

Keywords: Compressive Strength, Seismic Retrofitting, Push-over Analysis, Base Shear, Displacement, Jacketing

1. Introduction

The G + 1 building was constructed 15 years ago. It is an industrial production plant where due to chemical spillage, the deterioration of beams and columns has occurred. A visual inspection is done along with Non-destructive testing. The results indicated that the compressive strength decreased to 10MPa and longitudinal reinforcement corroded up to 25 percentage. The structure is located in Indian Seismic Zone IV. Since the building was industrial plant with hazardous materials, there is a need for checking the seismic safety of the structure concerning the safety of the occupants.

In the detailed report after Non-destructive Testing, it was mentioned that the distress in beams was majorly due to chemical spillage. In columns due to penetration of chemicals into the concrete substrate, large cracks were formed which lead to the corrosion of longitudinal reinforcement.

To bring the structural elements to original strength, concrete jacketing of 100mm thickness on all sides for columns and 75mm thickness on three sides were suggested. The additional longitudinal and transverse reinforcement is added in the jacketed beams and columns. A total of 6 columns and 5 beams were retrofitted. Figure 1a and 1b represent the jacketed columns and beams respectively.

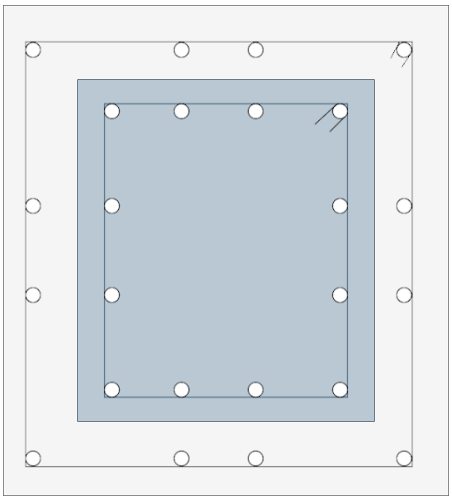

Figure 1a: Column with 100mm concrete jacket

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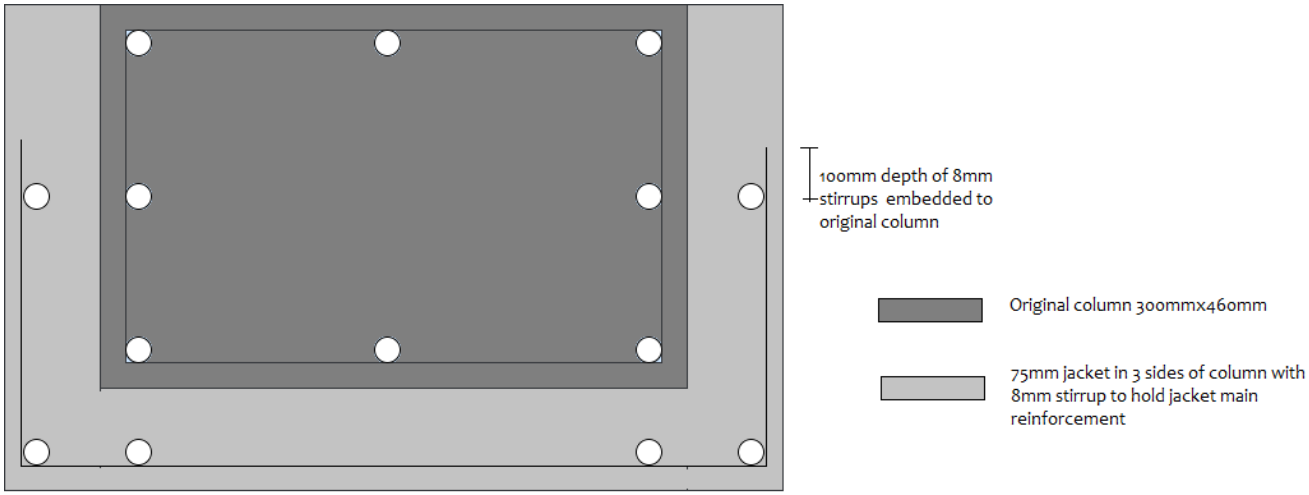

Figure 2b: Beam jacketed with 75mm on three sides

The Nonlinear static pushover (NSP) analysis predicts the seismic forces and deformation demands of the structure. For this purpose, NSP analysis is performed and the seismic safety of the industrial structure was done to check the reliability of the strengthening design of distressed structural elements.

The results indicated that after strengthening the columns and beams, the elements are able to withstand the demand.

By encasing the distressed beams and columns, the seismic stability of the structure increased which can be observed from the decrease of storey shear and deformation values after strengthening.

2. Details of existing structure

The building plan and elevation is mentioned in the below figures.

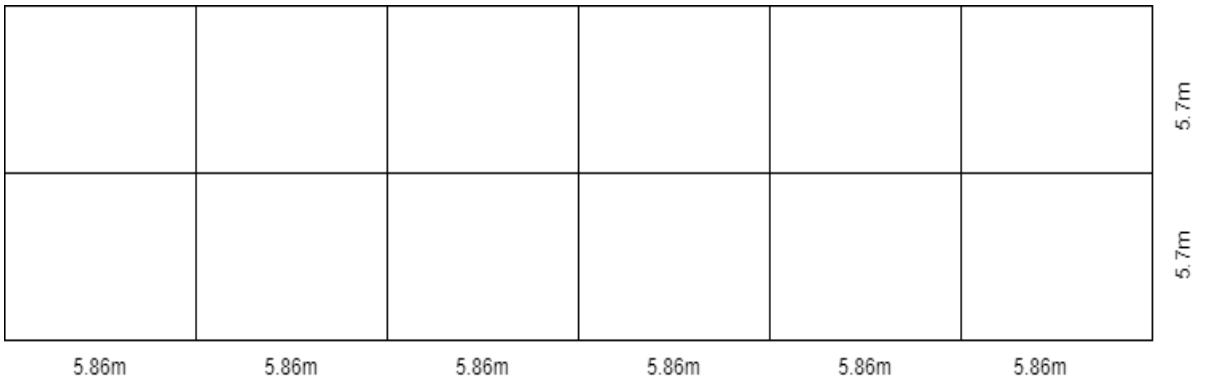

Figure 2 : Plan of the Building

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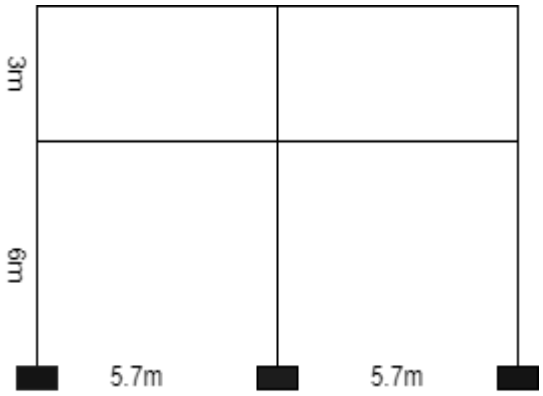

Figure 3: Elevation of Building

The existing condition of the structure is shown in the below figure 4. The results of the Non-destructive testing using rebound hammer, ultra-sonic pulse velocity and Core cutting are presented in Table1 of appendix for reference.

Figure 4: Existing condition of Columns and Beams

The height of ground floor is 6m and first floor is 3m. Plan area is 34.8 x 11.4 square meters. Live load is considered as 5 kN/m. The slab thickness is 150mm, the beams dimension is 300mmx360mm and column dimension is 400mmx480mm. The reinforcement details of beams and columns are tabulated in table of Appendix. The grade of concrete for beams is M20 and for column is M30.

3. Analysis procedure:

As the first step of analysis, Equivalent static analysis is performed. The lateral force distribution at various floors levels is represented in figure 5. To determine the lateral forces at each floor the design seismic base shear value V_b must be calculated. The total seismic weight of the building is 13745 kN. The importance factor is taken as 1.5, since the building is industrial building.

The fundamental Natural Period is 0.133 seconds. The design acceleration coefficient (Sa/g) for medium stiff soil is 2.5. The design base shear is calculated as 1237 kN.

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In the below table 1 given, W_i is the seismic weight of the building. W_i is calculated by considering full dead load and part live load acting on the structure. Since the structure is industrial type, load of the machinery is included as well along with the floor finishing load. As per the IS: 1893(Part1):2016, percentage of imposed load is calculated using Clause 7.3.1.

Table 1 – Vertical Base Shear Details

Floor	W_i	h_i	$W_ih_i^2$	$W_ih_i^2/\Sigma W_ih_i^2$	V_b	Q_i
1	13745	9	1240486	0.715	1237	884
2	13745	6	494820	0.285	1237	353

Lateral force distribution at each floor is shown in figure 5.

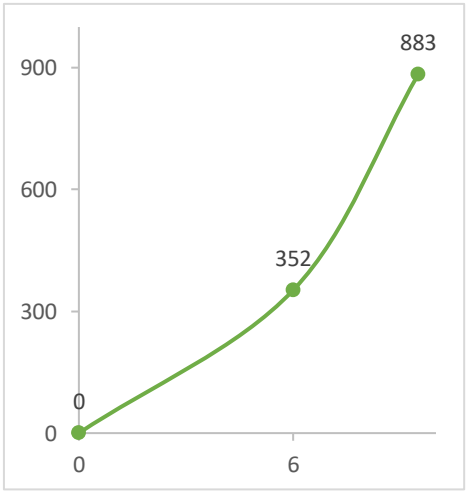

Figure 5: Loading Diagram

Non linear static pushover analysis is carried out for the structure after strengthening beams and columns. The displacements of the each floor is plotted with the storey height for strengthened building and original existing structure. The results indicate that the máximum storey displacement has decreased for retrofitted building.

Figure 6: Storey displacements Vs Storey Height for existing building and retrofitted building.

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The drift values are plotted for Push X direction and Push Y direction. The drift value of retrofitted building is less than original building in both X and Y directions.
This proves that after strengthening columns and beams, the global displacement of retrofitted structure reduced improving the seismic capacity of structure. The drift values in X and Y directions for retrofitted structure are 4mm and 10mm respectively which are less than the maximum allowable drift value of 0.4 percent of storey height i.e., 36mm.

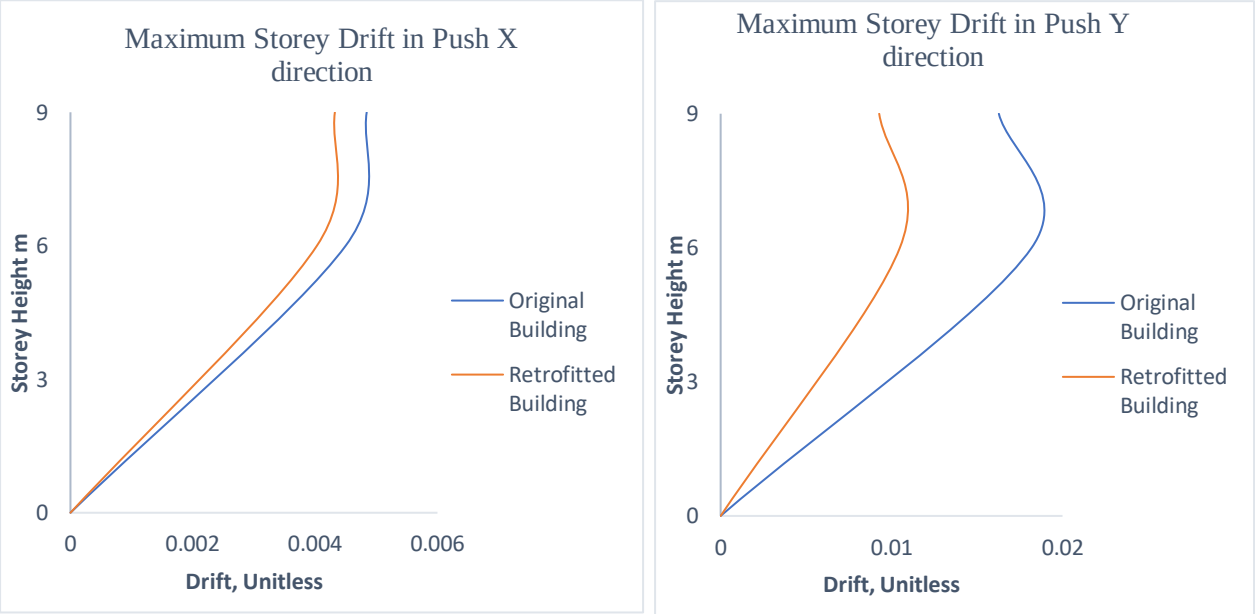

Figure 7. Maximum Storey Drift

The Base shear and roof displacement are plotted for original and retrofitted structure for X direction.

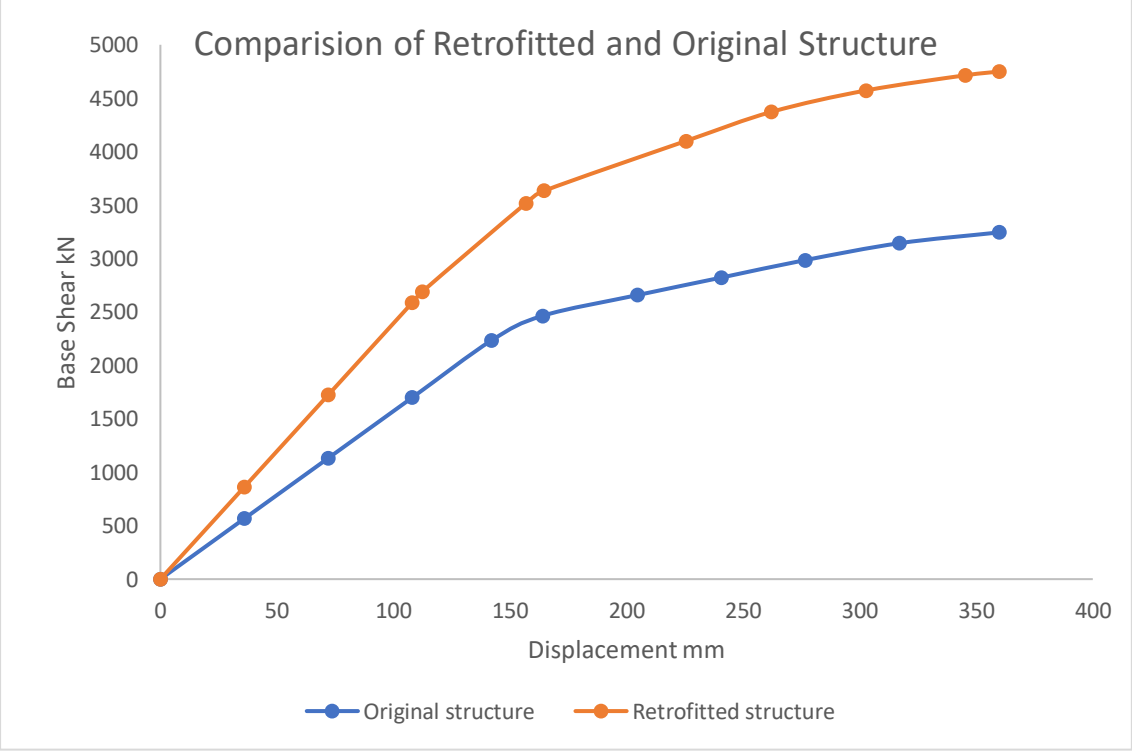

Figure 8: Pushover analysis in X direction for retrofitted and original structure.

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4. Conclusion

The distressed elements are treated using concrete jacketing for beams and columns. For beams due to accessibility three sides 100mm concrete jacket is applied and for columns 100mm concrete jacket on four sides is encased with additional longitudinal and transverse reinforcement. For economical design, concrete jacketing is used as strengthening technique. The jacketed elements are modelled in ETabs19 and Nonlinear static pushover analysis is performed. From the pushover analysis the results indicated that the after strengthening the roof displacement of retrofitted structure is reduced in X and Y direction. The pushover analysis results in X direction indicate that the base shear value is increased by 1500kN improving the seismic capacity. The drift values in Y direction are more when compared to X direction and less than the maximum allowable drift value. The overall global seismic performance of structure is affected by strengthening.

5. Appendix

Table 1 – NDT Results

S. No.	Identifications	Rebound Value (NDT)	Ultrasonic Pulse Velocity Value	Concrete Quality	Approx. Compressive Strength (N//mm2)
1	Column A1	34.5	3.78	Good	30
2	Column A2	35	3.9	Good	31
3	Column A3	25	3.1	Doubtful	16
4	Column C2	24.5	3.45	Doubtful	15.25
5	Column C3	26	3.3	Doubtful	17.5
6	Column D2	28	3.15	Doubtful	20
7	Column D3	26	3.2	Doubtful	17.5
8	Column E2	27	3.55	Doubtful	19.5
9	Column E3	35	3.96	Good	31
10	Column F2	31.25	3.83	Good	32
11	Column F3	27.5	3.5	Doubtful	19.75
12	Beam A2-A3	31.5	4	Good	25
13	Beam C1-C2	25.5	3.23	Doubtful	16.75
14	Beam C2-C3	25	3.6	Doubtful	16
15	Beam D1-D2	24	3.3	Doubtful	14.5
16	Beam D2-D3	26	3.35	Doubtful	17.5
17	Beam E1-E2	34	4.1	Good	29
18	Beam E2-E3	34	4.2	Good	29
19	Beam C2-D2	26	3.61	Doubtful	17.5
20	Beam D2-E2	23	3.14	Doubtful	13
21	Beam E2-F2	24.5	3.42	Doubtful	15.25
22	Beam E2-E3	23.5	3.5	Doubtful	13.75
23	Beam F2-G2	31.5	4.3	Good	25
24	Beam F2-F3	22	3.6	Doubtful	12

Beam Dimensions and Reinforcement Details:

Table 2 – Beam Details

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S. No.	Details	
1	Width	300 mm
2	Depth	460 mm
3	Diameter of main bar	16 mm
4	Number of bars	8
5	Concrete Cover	25 mm
6	Spacing of Ties	200 mm
7	Diameter of Ties	8 mm

Column Dimensions and Reinforcement Details:

Table 3 – Column Details

S. No.	Details	
1	Width	400 mm
2	Depth	480 mm
3	Diameter of main bar	16 mm
4	Number of bars	12
5	Concrete Cover	40 mm
6	Spacing of Ties	200 mm
7	Diameter of Ties	8 mm

Concrete Jacketing Details:

Table 4 – Column Jacketing Details

S. No.	Details	
1	Grade of Concrete	30 MPa
2	Diameter of main bar	20 mm
3	Number of bars	10
4	Spacing of Ties	200 mm c/c
5	Diameter of Ties	10 mm
6	Spacing of Shear Keys	200 mm c/c
7	Diameter of Shear Keys	10 mm

Beam Jacketing Details:

Table 5 – Beam Jacketing Details

S. No.	Details	
1	Grade of Concrete	30 MPa
2	Diameter of main bar	16 mm
3	Number of bars	5
4	Spacing of Ties	200 mm c/c
5	Diameter of Ties	8 mm
6	Spacing of Shear Keys	200 mm c/c
7	Diameter of Shear Keys	8 mm

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