Seismic Retrofitting of Reinforced Concrete Structures

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Abstract - *Earthquake around the world is one of the reasons responsible for the destruction to life and property in large numbers. In order to mitigate such hazards, it is important to incorporate norms that will enhance the seismic performance of the structures. Earthquake loads are required to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated. Seismic Retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. In this project our aim is to analyze an existing building using STAAD Pro v8i, with and without the provision of seismic retrofitting. The structure is analyzed in STAAD Pro v8i and the bending moment was chosen as the criteria for selecting the weak member. RC jacketing was selected as the retrofitting technique employed to the weak member andlater the member in the structure was compared with the bending moment value before and after providing retrofitting. It was determined that RC jacketing strengthened the structure, which was vulnerable to seismic activity.*

(Key words: Seismic activity, Retrofitting, RC jacketing, STAAD Pro v8i)

1. INTRODUCTION

1.1 GENERAL BACKGROUND

In recent times, reinforced concrete buildings have become common in India, particularly in towns and cities. Reinforced concrete (or simply *RC*) consists of two primary materials, namely concrete with reinforcing steelbars. Concrete is made of sand, crushed stone (called aggregates) and cement, all mixed with pre-determined amount of water. Concrete can be moulded into any desired shape, and steel bars can be bent into many shapes. Thus, structures of complex shapes are possible with RC.A typical RC building is made of horizontal members (beams and slabs) and vertical members (columns and walls), and supported by foundationsthat rest on ground. The system comprising of RC columns and connecting beams is called a RC Frame. The RC frame participates in resisting the earthquake forces. Earthquake shaking generates inertia forces in the building, which are proportional to the building mass. Since most of the building mass is present at floor levels, earthquake-induced inertia forces primarily develop at the floor levels. These forces travel downwards – through slab and beams to columns and walls, and then to the foundations from where they are dispersed to the ground. As inertia forces accumulate downwards from the top of the building, the columns and walls at lower storeys experience higher earthquake-induced forces and are therefore designed to be stronger than those in storeys above.

Seismic analysis is a subset of structural analysis and is the calculation of the response of a building (or non building) structure to earthquakes. It is part of the process of structural design earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. A Seismic Retrofit provides existing structures with more resistance to seismic activity due to earthquakes. In buildings, this process typically includes strengthening weak connections found in roof to wall connections, continuity ties, shear walls and the roof diaphragm. It is of critical importance that the structures that need seismic retrofitting are identified correctly, and an optimal retrofitting is conducted in a cost effective fashion. Once the decision is made, seismic retrofitting can be performed through several methods with various objectives such as increasing the load, deformation, and/or energy dissipation capacity of the structure. Conventional retrofitting methods include addition of new structural elements to the system and enlarging the existing members.

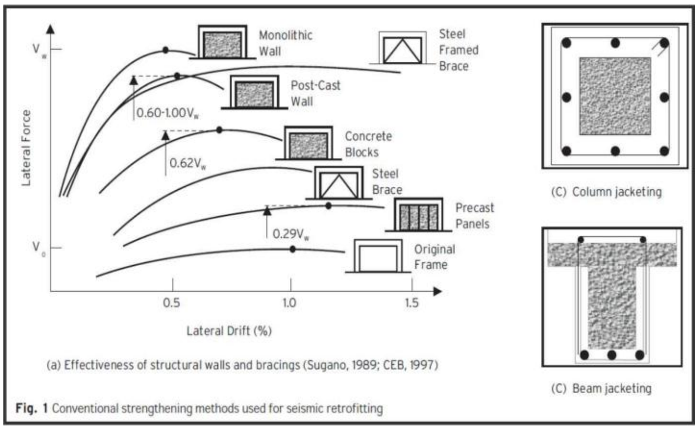

Fig.1.1 Conventional strengthening methods used for seismic retrofitting

Addition of shear walls and bracings shown in Fig. 1.1(a) is the most popular strengthening method due to its effectiveness, relative ease, and lower overall project cost compared to column and beam jacketing shown in Fig. 1.1(b) and (c), respectively. Relative effectiveness of various wall and bracing configurations are compared in Fig. 1.1(a). From this figure, it is seen that post-cast shear walls and steel braced frames are the most effective strengthening techniques.

Most retrofitting techniques will result an increase in stiffness and slightly increase in mass which causes in return a shorter period. Shortening in period of vibration often results an increase in strength and ductility of retrofitted structure. Thus, a proposed retrofit scheme can be said to be successful if it results an increase in strength and ductility capacity of the structure which is greater than the demands imposed by earthquakes.

1.2 OBJECTIVES

- To study the seismic response of a building.
- To introduce Retrofitting techniques to an existing building.
- To analyse the effectiveness of RC jacketing as a retrofitting technique.
- To analyse the building after introducing Retrofitting.
- To compare the response of the building to seismic activity with and without Retrofitting.

1.3 SCOPE

- To ensure the safety and security of a building, employees, structure functionality, machinery and inventory.
- Essential to reduce hazard and losses from structural elements.
- Predominantly concerned with structural improvement to reduce seismic hazard.
- Important buildings must be strengthened whose services are assumed to be essential just after an earthquake like hospitals.

2. LITERATURE REVIEW

2.1 STUDY OF PREVIOUS LITERATURES

Giuseppe Oliveto and Massimo Marletta, 2005 studied the seismic retrofitting of reinforced concrete buildings not designed to withstand seismic action is considered. The study was based on the scenario in Italy. The paper proceeds with an illustrative description of the seismic action and then addresses the problem of evaluating the seismic resistance and vulnerability of engineering structures. The application of the methodology presented to reinforced concrete buildings in Eastern Sicily clarifies the concepts discussed. In particular, the concept of seismic resistance, seismic vulnerability and seismic over-resistance become easily understood from the journal. The paper then considers the retrofitting of buildings vulnerable to earthquakes and briefly describes the main traditional and innovative methods of seismic retrofitting.[1]

N. Lakshmanan, 2006 gathered the available information particularly on the nonlinear behaviour, and the various approaches available to evaluate the seismic safety of buildings. It was emphasized that the existing procedure is grossly approximate, and hence improving sections of the approach to high levels of accuracy would not necessarily lead to a better result. The need for evaluating the various repair strategies for use in the improvement of the seismic performance of reinforced concrete structures has been highlighted. The behaviour of repaired beams and beam-column joints has been discussed.[2]

Komal Bedi, 2013 explained about different techniques of Retrofitting. Retrofitting is defined as a general term consisting of treatments including, preservation, rehabilitation and construction. It is saidthat the section of appropriate treatment strategy is a great challenge involved in the retrofit process and must be determined individually for each project. Seismic retrofitting techniques are Structure level Retrofit, Addition of structural RC walls, Use of steel bracing, Seismic isolation etc. Recent retrofitting techniques such as Concrete Jacketing, Steel Jacketing etc are also pointed out in this journal.[3]

Sumit Bharadwaj et.al, 2015 explained that retrofit in structures is done to increase the survivability functionality. At present day, retrofitting has a very lucrative market in the developed and as well as developing countries. It provides a number of ways to improve the damaged structure and allows expanding the lifespan of a structure, increasing its functioning and safety. Retrofitting mainly depends upon the modern technology and the unique ideas of the engineers and may vary from place to place.[4]

Sameh A, 2016 studied seismic vulnerability of RC buildings in Egypt. It has been said that seismic provisions were not provided in Egypt and hence the buildings where vulnerable to seismic activity. Two buildings one provided with seismic provisions and the other without seismic provisions were taken into account. The final conclusion was that seismic provisions are a necessary to be checked and provided. Even though Egypt is considered a region of moderate seismicity, in order to avoid the future risk Seismic analysis was carried out.[5]

Pranay Ranjan et.al, 2016 gave emphasise to the design of RC, FRP and SFRC Jacketing of failed columns of an existing building. These three retrofitting techniques are mainly dealt in this journal and that too for existing columns. Jacketing of columns consists of added concrete with longitudinal and transverse reinforcement around the existing columns. This type of strengthening improves the axial and shear strength of columns while the flexural strength of column and strength of the beam-column joints remain the same. It is also observed that the jacketing of columns is not successful for improving the ductility. A major advantage of column jacketing is that it improves the lateral load capacity of the building in a reasonably uniform and distributed way and hence avoiding the concentration of stiffness as in the case of shear walls. A four storey building in Patna, Bihar is considered in this journal which doesn't show any seismic vulnerability. The building is assumed to be provided with additional two storeys and thus additional loads may lead to seismic vulnerability. Three designs with RC, FRP, and SFRC Jacketing techniques are carried out along with cost evaluation.IS 15988:2013, Seismic Evaluation and Strengthening of Existing Reinforced Concrete Buildings – Guidelines, Bureau of Indian Standards, New Delhi, 2013 is the code followed in this journal.[6]

3. MODELING AND ANALYSIS

3.1 SOFTWARE'S USED

3.1.1 STAAD Pro v8i

STAADPro v8i is a structural analysis and design software application originally developed by Research Engineers International in 1997. In late 2005, Research Engineers International was bought by Bentley Systems. STAAD Pro v8i is one of the most widely used structural analysis and design software products worldwide. It supports over 90 international steel, concrete, timber &aluminium design codes. It can make use of various forms of analysis from the traditional static analysis to more recent analysis methods like p-delta analysis, geometric non-linear analysis, Pushover analysis (Static-Non Linear Analysis) or a buckling analysis. It can also make use of various forms of dynamic analysis methods from time history analysis to response spectrum analysis.

3.1.2Auto CAD 2010

Auto CAD is a CAD (Computer Aided Design or Computer Aided Drafting) software application for 2D and 3D design and drafting, developed and sold by Autodesk, Inc. It is a vector graphics drawing programme. It uses primitive entities-such as lines, poly-lines, circles, arcs and text-as the foundation for the complex objects. Auto CAD's native file format, DWG, and to a lesser extent, its interchange file format, DXF has become the standards for interchange of CAD data. All the drawings for reference were done by making use of Auto CAD 2010.

3.2 Loads and Load Combinations

The various loads considered for the analysis were:

i. Dead Loads as per IS: 875 (Part I) – 1987

These are self-weights of the structure to be designed. The dimensions of the cross section are to be assumed initially which enable to estimate the dead load from the known unit weights of the structure. The values of the unit weights of the materials are specified in IS 875:1987(Part- I).Dead load includes self-weight of columns, beams, slabs, brick walls, floor finish etc. The self-weight of the columns, beams and slabs were taken automatically by the software.

ii. Live Loads as per IS: 875 (Part II) – 1987

They are also known as imposed loads and consist of all loads other than the dead loads of the structure. The values of the imposed loads depend on the functional requirement of the structure. Commercial buildings will have comparatively higher values of the imposed loads than those of the residential buildings.

iii. Earthquake Loads as per IS: 1893 (Part I) – 2002

Dynamic forces on multi-storeyed buildings are best computed through a detailed vibration analysis. Detailed dynamic analysis or modal analysis or pseudo-static analysis should be carried out depending on the importance of the problem. Earthquake shaking is random and time variant. But, most design codes represent the earthquake-induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force. This force is called as the Seismic Design Base Shear VB and remains the primary quantity involved in the force-based earthquake-resistant design of buildings. Instead, the earthquake demand is estimated only based on concepts of the probability of evidence, and the design of earthquake effects is termed as earthquake-resistant design against the probable value of the demand.

The Design Base Shear, Vb is taken as per the Indian Seismic Code IS 1893 (Part 1) – 2002.

Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements for the following buildings:

Base Shear, Vb = W*Ah (3.1)

W = 8540.84 kN

Fundamental natural period, Ta = 0.09 h/ $d^{0.5}$ (3.2)

Ta = 0.422 sec X direction = 0.463 sec Z direction

As per IS 1893(Part 1) - 2002 fig 2 & table 3,

Spectral acceleration coefficient, Sa/G= 2.5

As per IS 1893(Part 1) - table 2,

Zone factor, Z = 0.16(Moderate)

As per IS 1893(Part 1) -2002 table 6,

Importance factor, I = 1

As per IS 1893(Part 1) - 2002 table2,

Response reduction factor, R = 5

$$Ah = \frac{Z}{2} * \frac{I}{R} * \frac{Sa}{g} = 0.04 \quad (3.3)$$

Base shear force, Vb = 341.63 kN.

iv. Load Combinations

Design of the structures would have become highly expensive in order to maintain either serviceability and safety if all types of forces would have acted on all structures at all times. Accordingly the concept of characteristic loads has been accepted to ensure at least 95 percent of the cases, the characteristic loads considered will be higher than the actual loads on the structure. However the characteristic loads are to be calculated on the basis of average/mean load of some logical combinations of all loads mentioned above.

IS 456:2000 and IS 1893(Part-1):2002 stipulates the combination of the loads to be considered in the design of the structures.

3.2.4 Member Property Specification

The properties of various frame member sections such as cross sectional dimensions of the slab; beams, columns etc are given;

i. Slab

Thickness of the slab up to 7m = 130 mm

Thickness of the slab from 7 to 18m =120mm

ii. Beam

The dimensions of the beams are 200mm *400mm

iii. Column

The dimensions of the columns are 300mm *400mm

3.3 STAAD Pro v8i MODELLING

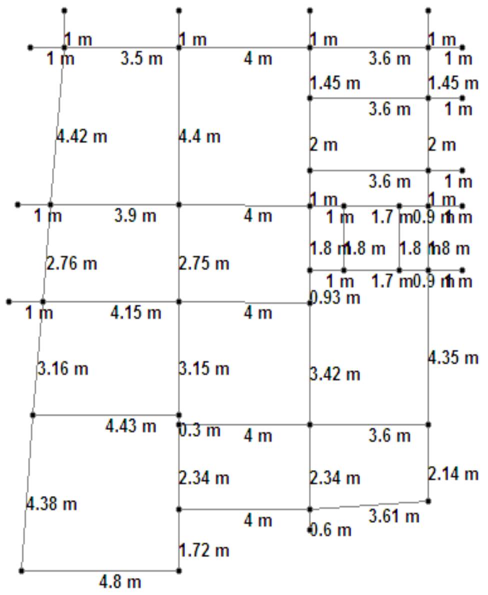

Fig.3.1 Plan of multi-storeyed building

Fig.3.1 shows the plan of the multi-storied building. This was obtained by providing co-ordinates in STAAD Pro v8i.

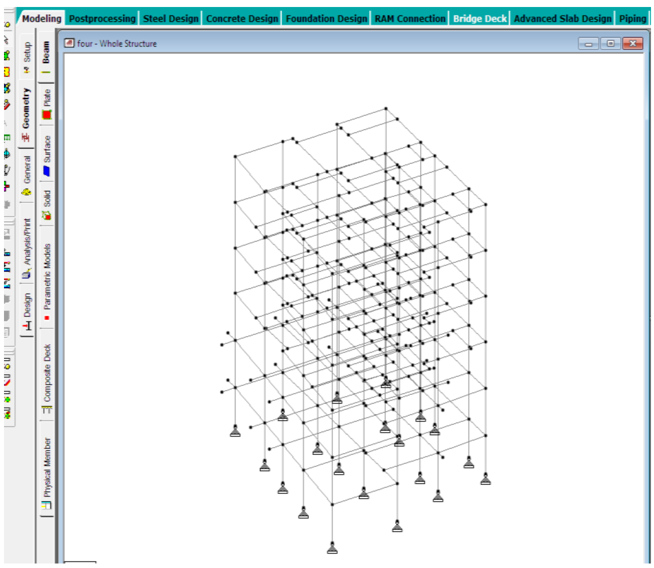

Fig.3.2 Model with Nodes and Supports

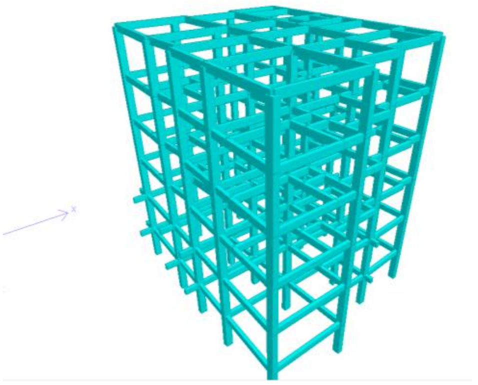

Fig.3.4 Rendered view of the Model before Retrofitting

Fig.3.4 shows the 3D view of Multi-storied building. The dimensions of the beams are 200mm*400mm. The dimensions of the columns are 300mm*400mm.

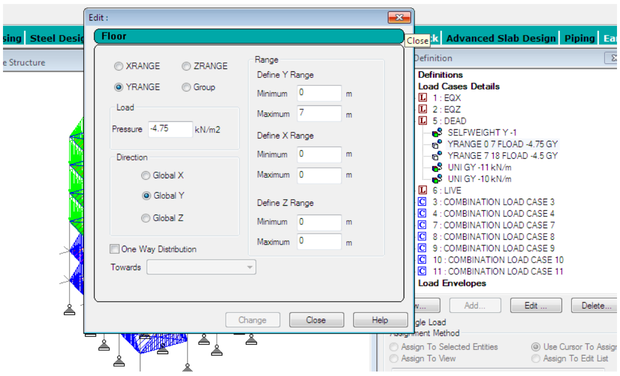

Figure.3.5 Floor Load

Fig.3.5 shows the floor load applied to the bottom storeys(0 to7m).

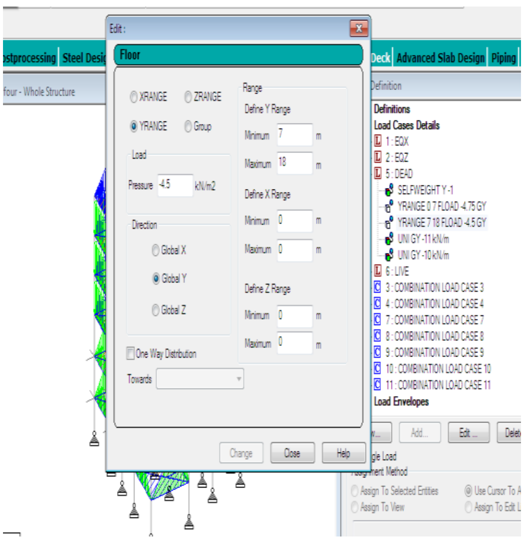

Fig.3.6 Floor load

Fig.3.5 & 3.6 shows the floor load applied. As plates are not provided, it is necessary to consider the slab load. Floor load provided is the summation of self weight of the slab and floor finish.. Assuming the floor finish to be 1.5kN/m².Slab thickness is 130mm till 7m and it varies to 120mm from 7 to 18m.

Self weight of slab = 0.130*25*1 = 3.253N/m²

Floor finish = 1.5kN/m²

Total floor load = 3.25+1.5 = 4.75kN/m²

As so from 7 to 18m height, Floor load = 4.5kN/m²

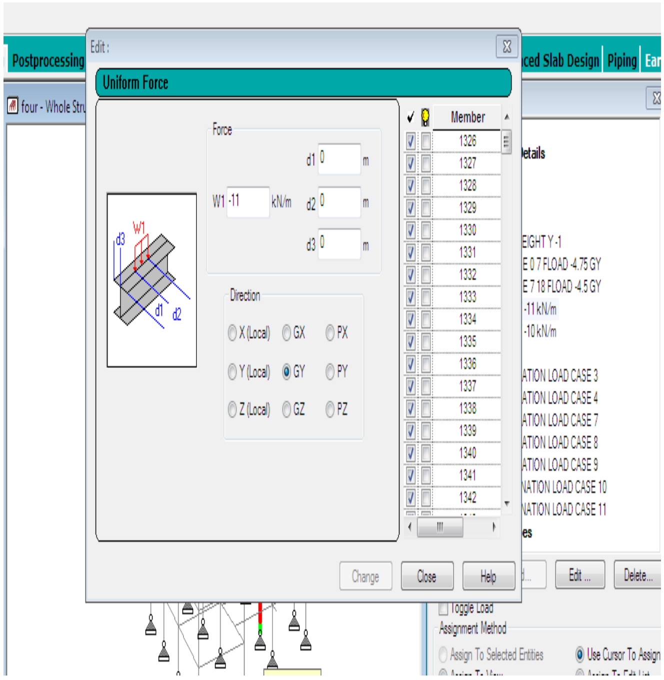

Fig.3.7 Wall load as UDL

Fig.3.7 shows the wall load coming on the frame. The thickness of wall is 20cm and height of wall is 3m. In framed structure dead load of bricks will act on the beams. And it will be expressed in terms of kN/m, which is as a UDL.

Considering 20cm thickness of brick, including plastering. Height of wall neglecting beam depth 2.6m. Density of engineering bricks as per IS 875 PART 1 = 21.20kN/m³. Load will be,

21.20kN/m³ *20m*2.6m= 11kN/m.

3.4 STAAD Pro v8i ANALYSIS

Beam	L/C	Section	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kN-m	Moment-Y kN-m	Moment-Z kN-m
1625	8	0.000	1380.510	90.341	11.696	-0.000	-28.914	230.302
1625	8	0.083	1383.161	90.341	11.696	-0.000	-26.488	211.156
1625	8	0.167	1385.812	90.341	11.696	-0.000	-24.066	191.997
1625	10	0.000	1201.445	73.755	12.851	-0.000	-31.867	187.940
1625	8	0.250	1388.462	90.341	11.696	-0.000	-21.647	172.827
1625	10	0.083	1203.566	73.755	12.851	-0.000	-29.197	172.315
1625	10	0.167	1205.686	73.755	12.851	-0.000	-26.531	156.680
1625	8	0.333	1391.113	90.341	11.696	-0.000	-19.232	153.646
1625	1	0.000	318.519	58.286	-6.041	-0.000	15.287	148.798
1130	8	0.000	823.321	95.099	-2.433	-0.505	3.959	147.720
1625	10	0.250	1207.807	73.755	12.851	-0.000	-23.868	141.035
1625	1	0.083	318.519	58.286	-6.041	-0.000	14.009	136.427
1625	8	0.417	1393.764	90.341	11.696	-0.000	-16.820	134.456
1130	10	0.000	813.372	84.521	-2.434	-0.405	3.939	131.350
1168	8	0.000	533.322	88.701	-0.230	-0.050	0.531	129.734
1625	10	0.333	1209.927	73.755	12.851	-0.000	-21.208	125.383
1625	1	0.167	318.519	58.286	-6.041	-0.000	12.733	124.048
1130	8	0.083	822.226	95.099	-2.433	-0.505	3.281	123.378
1149	8	0.000	728.058	83.812	-1.033	-0.264	2.318	122.020
1625	8	0.500	1396.414	90.341	11.696	-0.000	-14.410	115.257
1625	1	0.250	318.519	58.286	-6.041	-0.000	11.457	111.661
1168	10	0.000	502.396	75.610	-0.182	0.063	0.400	110.477
1625	10	0.417	1212.048	73.755	12.851	-0.000	-18.550	109.722
1130	10	0.083	812.495	84.521	-2.434	-0.405	3.269	109.701
1149	10	0.000	682.537	73.124	-1.055	-0.148	2.238	108.493
1187	8	0.000	328.835	76.751	-0.378	-0.183	0.690	108.130
1168	8	0.083	532.262	88.701	-0.230	-0.050	0.459	107.644
1105	3	1.000	1057.452	-42.427	1.844	-0.000	4.559	107.278
1109	3	1.000	1295.212	-43.017	-4.647	-0.000	-11.731	106.383
1104	3	1.000	1443.379	-40.693	-1.398	0.000	-3.589	102.670

Fig.3.10 Sorted bending moment value before retrofitting

Fig.3.9& 3.10 shows the bendingmoment value before retrofitting. The fig.3.10 shows Bending moment value of all the beams parallel to Y axis, i.e., columns. Load case 8 shows maximum bending. The column 1625 is the one with maximum bending moment in the ground floor.

3.5 DESIGN OF RC JACKETING FOR FAILED COLUMN

Jacketing is one of the most frequently used techniques used to strengthen RC columns .With this method, axial strength, bending strength and stiffness of the original column are increased. The column no. 1625 was chosen as the failed column in the bottom storey. It showed a maximum bending moment value of 230.302kN-m. The following are the given details;

Height of column= 2500mm

Width of column, B= 300mm

Depth of column, D=400mm

Area of steel provided =804.25 mm^2

f_y =415 N/mm^2 f_{ck} =35N/mm^2

Axial Force, P = 965.156 kN

Factored axial force, P_u =1447.734 kN

$P_u = 0.4* f_{ck}*A_c+0.67* f_y*A_{sc}$ (3.4)

According to cl.8.5.12 of IS 15988:2013,

A_{sc} = 0.8 % of A_c

ie, $1447.734*10^3 = 0.4*35*A_c+0.67*415*0.8\ \%\ A_c$

Therefore, A_c =89234.10 mm^2

As per cl.8.5.1 of IS 15988: 2013,

$Á'_C$ =1.5 A_c = 133851.15 mm^2

Taking B = 400mm,

$D = \frac{133851.15}{400} = 334.63 \approx 400$ mm

As per IS 15988: 2013, minimum jacketing thickness to be provided is 100mm.

ie, Width of the column, B =600mm

Depth of the column, D =600mm

Hence provide a column of size 600mm*600mm

4. RESULTS AND DISCUSSIONS

From the studies it was evident that the structure is vulnerable to seismic activity. In order to resist the seismic activity, RC jacketing was chosen as the retrofitting technique. As per IS 15988:2013, RC jacketing was designed. It was applied and the following figures show the results;

Beam	L/C	Section	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kN-m	Moment-Y kN-m	Moment-Z kN-m
1625	8	0.000	1234.134	43.890	5.942	-0.000	-14.867	113.763
1104	3	1.000	1445.407	-44.761	-1.771	-0.000	-4.566	112.750
1105	3	1.000	1059.989	-43.582	1.461	0.000	3.564	110.134
1130	10	0.000	833.497	73.182	-2.730	-0.812	4.390	110.045
1149	10	0.000	697.400	71.223	-1.132	-0.254	2.296	106.924
1168	10	0.000	511.430	72.387	-0.287	0.048	0.547	105.585
1109	3	1.000	1290.919	-42.248	-5.673	-0.000	-14.420	104.492
1625	8	0.083	1235.018	43.890	5.942	-0.000	-13.545	104.409
1187	8	0.000	334.490	74.010	-0.518	-0.180	0.896	104.312
1104	3	0.917	1446.113	-44.761	-1.771	-0.000	-4.169	103.464
1168	8	0.083	542.665	84.833	-0.361	-0.061	0.612	102.739
1105	3	0.917	1060.696	-43.582	1.461	0.000	3.266	101.054
1130	8	0.083	845.505	81.299	-2.751	-0.978	3.704	100.977
1169	8	0.000	581.323	67.471	1.087	0.166	-1.346	99.822
1110	3	1.000	826.935	-40.461	-2.071	0.000	-5.331	99.759
1103	3	1.000	706.097	-39.444	6.903	0.000	17.218	99.525
1149	8	0.083	744.172	81.568	-1.133	-0.376	2.084	99.280
1108	3	1.000	1035.748	-39.170	14.783	-0.000	36.800	97.116
1109	3	0.917	1291.625	-42.248	-5.673	-0.000	-13.197	95.734
1128	8	0.000	933.389	66.615	-9.827	-0.479	15.876	95.700
1142	3	1.000	1092.873	-57.485	-6.316	0.796	-11.070	95.564
1625	8	0.167	1235.901	43.890	5.942	-0.000	-12.243	95.020
1104	3	0.833	1446.820	-44.761	-1.771	-0.000	-3.751	94.114
1161	3	1.000	772.618	-60.315	-8.108	0.613	-11.773	93.400
1625	10	0.000	1077.224	35.793	6.137	-0.000	-15.360	92.709
1105	3	0.833	1061.403	-43.582	1.461	0.000	2.969	91.916
1099	3	1.000	1087.585	-37.384	3.808	0.000	9.463	91.743
1110	3	0.917	827.642	-40.461	-2.071	0.000	-4.882	91.396
1130	10	0.083	832.621	73.182	-2.730	-0.812	3.642	91.304
1103	3	0.917	706.804	-39.444	6.903	0.000	15.769	91.296

Fig.4.1 Sorted bending moment value after retrofitting

Fig.4.1 shows sorted bending moment value after retrofitting. The beam parallel to Y axis, i.e, column no. 1625 was chosen as the failed column. Since it was the column in ground floor with maximum bending moment. The retrofitting technique employed was RC jacketing. Design of RC jacketing was based on IS 15988:2013 'Seismic Evaluation and Strengthening of existing RC Buildings'and the size of the column were assigned to 600mm*600mm. The property of the column was changed as per design and it was seen that the value of bending moment decreased from that before retrofitting.

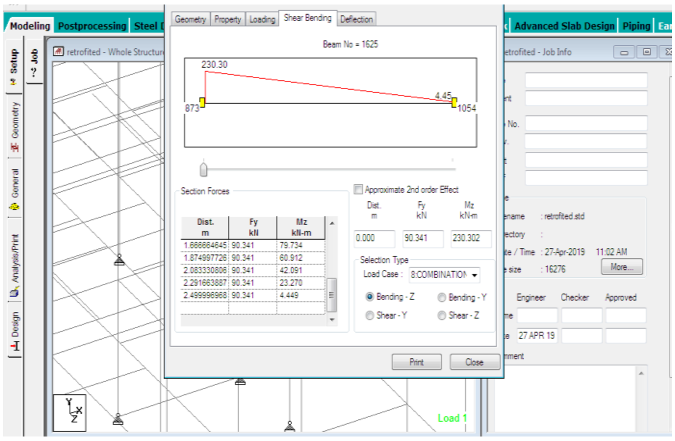

Fig.4.4 Shear & Bending value of the Column 1625 before Retrofitting.

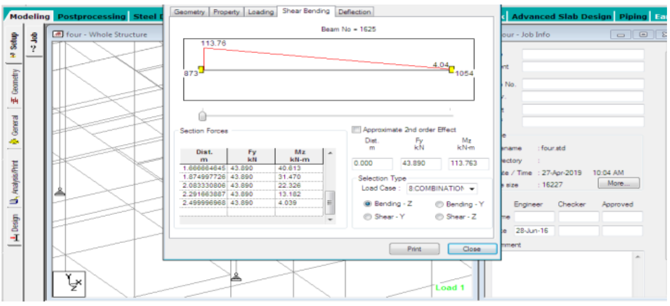

Fig.4.5 Shear & Bending value of the Column 1625 after Retrofitting.

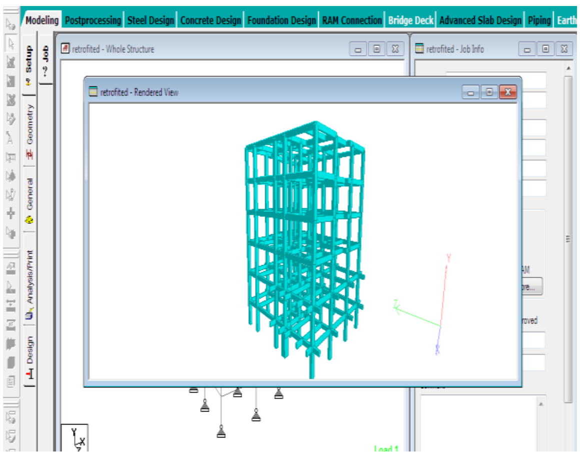

Fig.4.6 Rendered view of the model after Retrofitting

Bending Moment plays a major role in the amount of reinforcement to be placed in any reinforced concrete structures. Moment by its nature has a capacity to cause tension and compression at the same time in a section. In reinforced concrete structures concrete is good in compression and steel is good both in tension and compression, but due to the slenderness of rebar material it easily buckles. So we place the reinforcement steel on tension side.

In Columns bending moment causes the section to have decreased axial load capacity. Always if the moment on the section increase, the axial load capacity decrease hence the amount of reinforcement should increase. After applying retrofitting it was evident that the Bending moment value has decreased from 230.302kN-m to 113.763kN-m. It showed that retrofitting is an efficient technique in strengthening the structure vulnerable to seismic activity.

5. CONCLUSIONS

The study was to investigate the seismic response of an existing building. It showed that the building was vulnerable to seismic activity and after that RC jacketing was provided. It was analysed in STAAD Pro v8i.The important conclusions formulated from the project are as follows:

- We investigated the vulnerability of the building to seismic activity and it was found that the building responded to seismic activity.
- According to IS 1893 (Part 1)2002, Seismic load was calculated as 341.63kN. Considering seismic load, dead load and live load, the structure was modelled and analysed in STAAD Pro v8i.
- Retrofitting techniques were evaluated from different journals. RC jacketing was chosen as the most appropriate technique to be employed in this project. According to IS 15988:2013 'Seismic Evaluation and Strengthening of existing RC Buildings' RC jacketing was designed.
- In Columns bending moment causes the section to have decreased axial load capacity. Always if the moment on the section increases, the axial load capacity decrease hence the amount of reinforcement should increase.
- Column no.1625 was employed with RC jacketing. The Bending moment was the criteria in choosing the column. The column was having an initial bending moment value of 230.302kN-m. The structure after analysis with retrofitting showed a value of 113.763kN-m.
- A decrease of 49.39% of bending moment value occurred by the provision of providing retrofitting.
- The analysis of the structure before and after retrofitting evidently showed that the retrofitting

technique complimented in strengthening of the structure. It showed that retrofitting aims in strengthening a structure to satisfy the requirements of the current codes for seismic design.

- From completing the project it was concluded that seismic retrofitting provides existing structures with more resistance to seismic activity due to earthquakes.

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