SEISMIC EVALUATION AND RETROFITTING OF BUILDING WITH ROOFTOP TELECOMMUNICATION TOWER

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Abstract
As the technology is advancing, the need for the telecommunication towers is increasing to a large extent such a way that rooftop towers are taken into practice everywhere, even in the rural areas of India. The construction of buildings is not always done with proper structural designs to withstand additional loads. Recent earthquakes during the last decade indicated that major damages were not only due to the earthquake effects but also due to the poor performance of the structures during earthquake. Existing old structures which have been planned and constructed without considering the structural aspects and seismic resistance pose enormous risk in particular to human life and property. In this present study, a G+6 building (ZONE V) is considered. The seismic behaviour of the building with the rooftop telecommunication tower is analyzed and compared with that of the building without the tower. Then the building is retrofitted properly and the seismic behaviour of it is analyzed. A three legged telecommunication tower of height 15m is considered and the analysis is done using ETABS Software.

Keywords: Seismic evaluation, Retrofitting, ETABS, Earthquake, Telecommunication tower

I. INTRODUCTION

India being one of the most disaster prone countries, is vulnerable to all natural and manmade disasters. About 85% of the land area is vulnerable to one or multiple disasters and about 57% area falls under seismic zones of higher risk. the disasters from the last few decades i.e., the Earthquakes at Latur (1993), Jabalpur(1997), Chamoli(1999) and Bhuj (2001) had shown the vulnerability of buildings in India. Prevention of disasters caused by earthquakes has become increasingly important. This includes the reduction of seismic risk through retrofitting the existing buildings. The planning for the existing buildings differs from planning of new building. The new structure can be built earthquake resistant by adopting proper design methodology, but Existing old structures which have been planned and constructed without considering the structural aspects and seismic resistance, pose enormous risk, in particular to human life and property. Under these situations, the Disaster prevention involves engineering intervention in buildings and structures to make them strong enough to withstand the impact of natural hazard so that the society is least affected by the hazardous situations.

With advances in technology, the need for the telecommunication towers is increasing to a large extent such a way that rooftop towers are taken into practice everywhere, even in the rural areas of India. At present there are about 4,00,000 telecommunication towers in India, which are estimated to increase at a rate of 3% over next 4 – 5 years. The construction of buildings is not always done with proper structural designs to withstand additional loads. Most of the existing buildings do not meet the strength requirements due to any of the following reasons:

- structure not designed to code
- update of code and design practice
- upgrading of seismic zone
- Reduction of strength of the structure with age
- Modification of the existing structure
- change in the use of building

In this study, a case of modification of existing structure with the installation of rooftop telecommunication tower is adopted to evaluate.

There has been a lot of research done on seismic analysis of various structures and retrofitting them to reduce the affect of the earthquakes. A brief summary of some studies referred are mentioned below.

Ghyslaine Mcclure, Laura Georgi And Rola Assi did Time history analysis to explore the correlation between the building accelerations and the maximum seismic base shear and the base overturning moment of towers mounted on building rooftops. Two medium-rise buildings combined with two self-supporting lattice steel towers were considered. The correlation between various peak response indicators such as rooftop acceleration vs. ground acceleration; Tower top acceleration vs. rooftop acceleration; Horizontal relative displacement between the tower top and base vs. rooftop acceleration; Tower base shear vs. rooftop acceleration; Tower base overturning moment vs. rooftop acceleration. A linear correlation between the rooftop acceleration and the tower base reaction, shear force and overturning moment was obtained.

Siddharth Pastariya considered two buildings (G+6 and G+10) for various positions of the triangular tower on them and analysed. Different parameters like displacement, moments, stresses, shear and axial forces were examined for medium soil condition under seismic forces for earthquake zone IV. Most suitable and efficient position was determined. According to the study, the best suitable location of tower by considering different result parameters seems to be tower at center of short size of the building.

Syed Ehtesham Ali, Izeelden Hassan and Randy A Garcia conducted a seismic study of a building with rooftop telecommunication tower using staad.pro software. They carried out seismic analysis of the building in two ways. By lumping the tower mass at roof level and By considering the full tower. They concluded that installation of tower at roof top makes a building vulnerable to earthquake, as it requires additional steel in both columns and beams. For tall towers, lumping of the tower mass at roof level of the building, underestimates the force and moment.

II. OBJECTIVES

- Analyze the seismic behavior of building without telecommunication tower.
- Analyze the seismic behavior of building with rooftop telecommunication tower.
- Comparative analysis of building with and without telecommunication tower.
- Analyze the seismic behavior of retrofitted building with rooftop telecommunication tower.
- Comparative analysis of building with telecommunication tower before and after retrofitting.

III. METHODOLOGY

A G+6 building which falls in Zone V region, assumed to be located in Bhuj, kutch district, Gujarat with a three legged telecommunication tower of height 15m is considered and the seismic analysis is done using ETABS Software. Initially, wind load analysis was done in staad.pro software to determine the best suitable position for installing the telecommunication tower. Then further seismic analysis was done using ETABS software. The seismic behaviour of the building with the rooftop telecommunication tower was analyzed and compared with that of the building without the tower. Then the building was retrofitted properly and the seismic behaviour of it was analyzed.

IV. MODELING AND ANALYSIS

Structural Geometry

Plan area = 28x20 m; Height of each storey= 3m ;
Beam cross section = 230x300 mm;
Column cross section = 300x400 mm; Thickness of slab = 150 mm;
Type of tower = Three legged tower; Number of bays along height = 10
Height of each bay = 1.5m; Angle of tower = 60^0;
Section adopted = ISA 100x75x10 mm thick
Section adopted for Lateral bracing = ISMB400

Load considerations

The self-wt. of the members is calculated by the software itself. Considering the thickness of exterior walls as 230mm and the interior walls as 150mm and the parapet wall as 115mm. Thickness of plaster is taken as 12mm.

Dead load (IS 875:2016 PART I)

Exterior walls = [(0.23x19)+(2x0.012x20)]
= 4.85 KN/m^2
interior walls = [(0.15x19)+(2x0.012x20)]

= 3.33 KN/m^2

Parapet walls = [(0.115x19)+(2x0.012x20)]

= 2.67 KN/m^2

Live load (IS 875:2016 PART II)

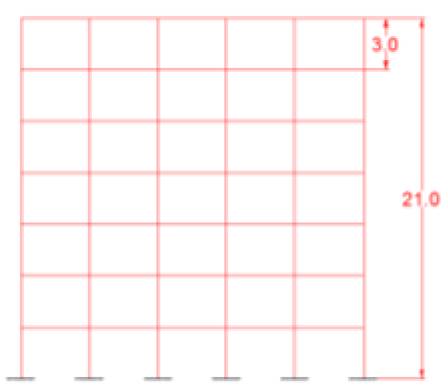
Imposed load on residential building = 2 KN/m^2
Imposed load on roof = 1.5 KN/m^2

Wind load (IS 875:2016 PART III**)**

Basic wind speed V_b = 50 m/s
Design wind speed at height Z m is V_z= $k_1.k_2.k_3.k_4.V_b$
Where k_1 is risk coefficient = 1.0
k_2 is terrain roughness and height factor= 1.009
k_3 is topography factor = 1.0
k_4 is importance factor= 1.0
V_z= $k_1.k_2.k_3.k_4.V_b$= (1.0x1.009x1.0x1.0x50)
=50.45 m/s
Design wind pressure P_z= $0.6x(V_z)^2$= 0.6x $(50.45)^2$ = 1.527 KN/m^2

4.2.4. Seismic Load

The parameters considered for seismic analysis according to IS 1893- part I
Seismic Zone is taken as Zone V
Zone factor = 0.36
Importance factor =1.0
Soil type = medium (type II)
Response Reduction factor = 3
% of live load to be considered in seismic weight = 50%
Percentage of damping = 5%



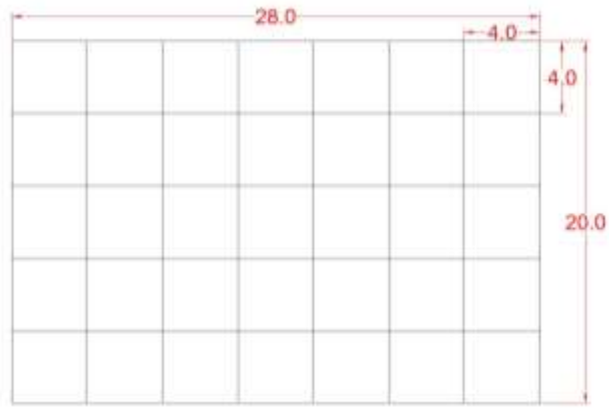


Fig. 1 Plan and elevation of the structure without tower

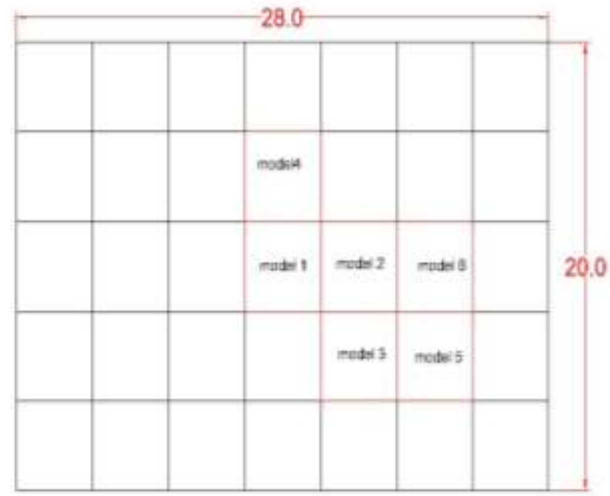


Fig. 2 Position of tower in various models

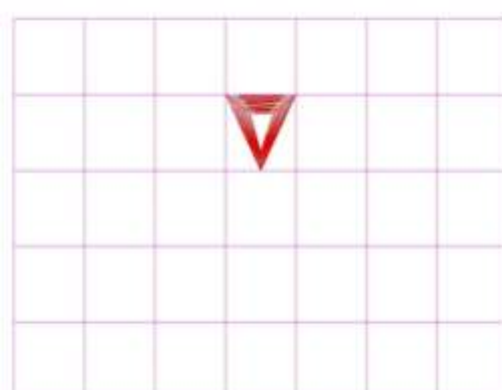


Fig. 3 Position of tower in various model 4

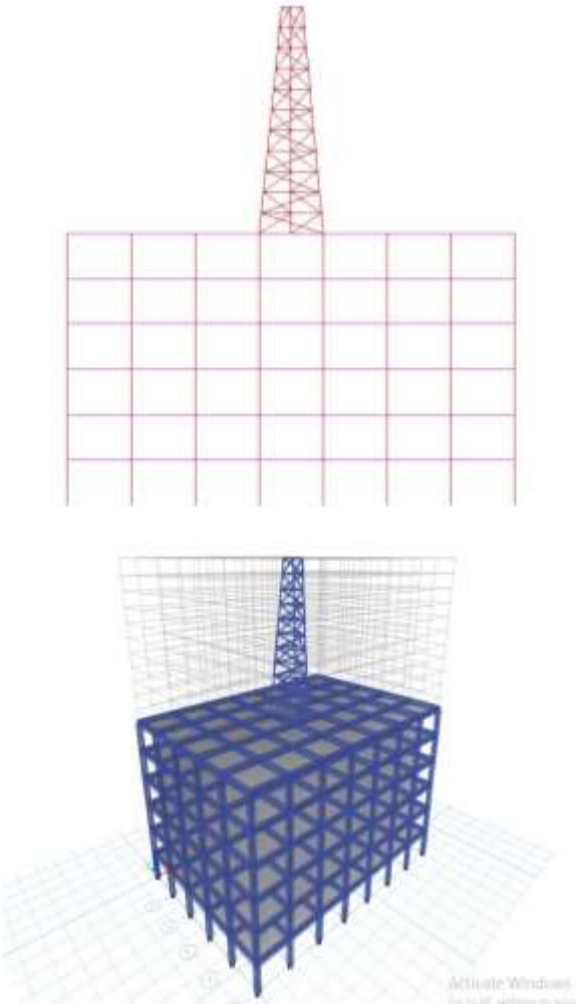


Fig. 4 Elevation and 3-D view of the building with telecommunication tower

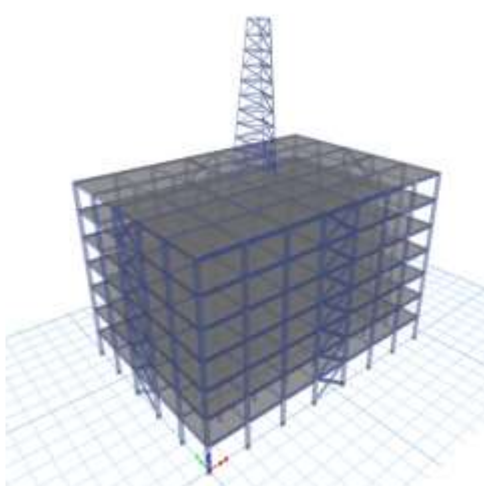


Fig. 5 3-D view of retrofitted building with telecommunication tower

V. RESULTS AND DISCUSSION

Initially the analysis was done in Staad.Pro software to determine the best suitable position for the installation of telecommunication tower. The maximum displacements were noted.

Table 1 Maximum Displacements of all models

MODEL	DISPLACEMENT (mm)			MAX. RESULTANT DISPLACEMENT (mm)
	MAX X	MAX Y	MAX Z	
MODEL 1	26.76	30.646	22.436	34.613
MODEL 2	34.467	31.544	74.556	78.874
MODEL 3	33.724	27.841	72.474	76.867
MODEL 4	32.897	28.175	74.878	74.362
MODEL 5	33.008	27.766	73.038	77.396
MODEL 6	34.132	28.213	73.758	78.216

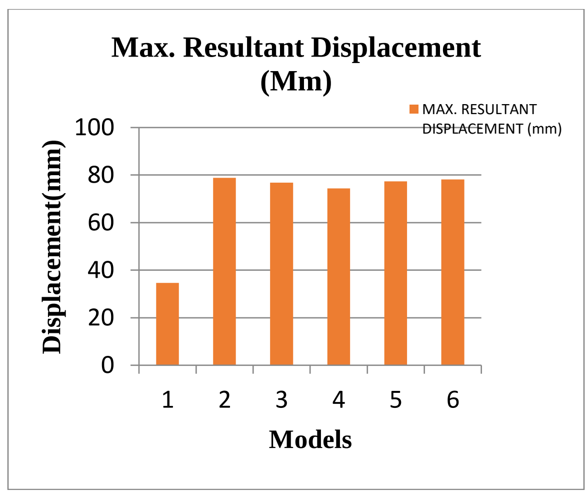


Fig. 6 Maximum Displacements of all models

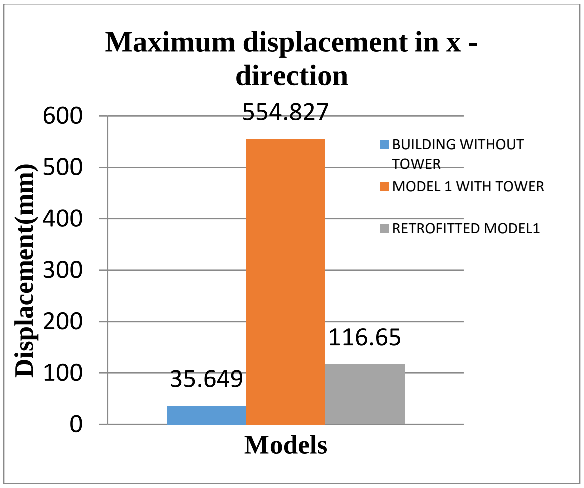
Note: Models are considered as per Fig. 2 Position of tower in various models

Considering the maximum displacements in x and z directions and also the maximum resultant displacements in each model, it is evident that the model 1 shows least values of displacement and model 2 shows maximum values. Therefore, in this study further analysis was carried out using model 1 in ETABS.

Seismic analysis was done in ETABS 2018 Software using Response Spectrum method. Parameters like maximum displacement, storey shear, storey drift ratio of every model were tabulated and studied.

Table 2 Maximum Storey Displacement (mm)

	BUILDING WITHOUT TOWER	MODEL 1	RETROFITTED MODEL1
RSX	35.649	554.827	116.65
RSY	41.46	611.045	90.19



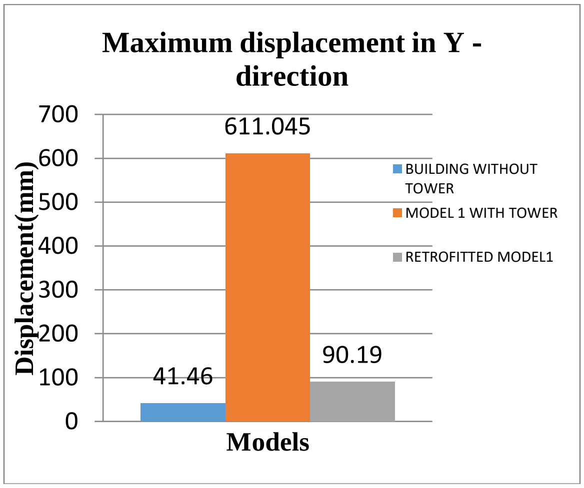
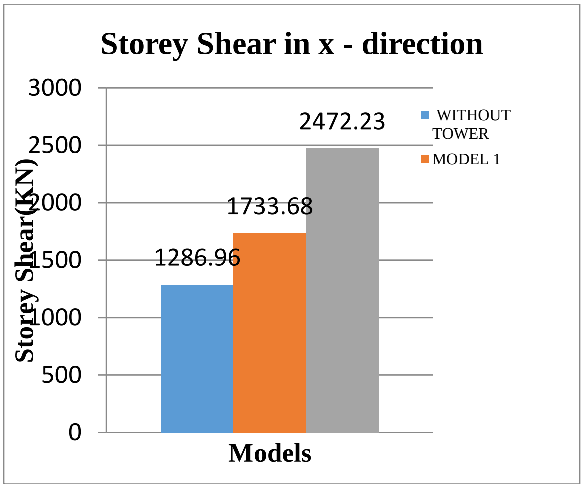


Fig. 7 Maximum Storey Displacement (mm)

The above graph, Maximum storey displacements in X and Y directions shows that the displacement of the building without telecommunication is negligible compared with the displacement of the building with tower. The displacement has increased by almost 1400%. When the building with telecommunication tower was retrofitted with lateral bracings, the displacement of the structure was decreased by 78.97%.

Table 3 Maximum Storey Shear(KN)

	BUILDING WITHOUT TOWER	MODEL 1	RETROFITTED MODEL1
RSX	1286.9631	1733.687	2472.231
RSY	1173.7887	1579.922	2393.742



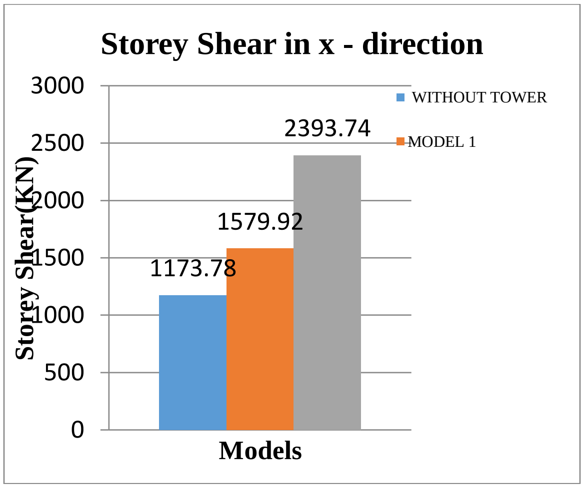


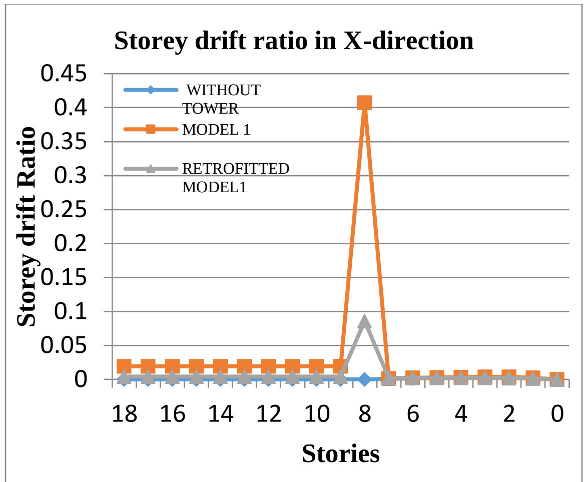
Fig. 8 Maximum Storey Shear (KN)

The above graph shows the maximum storey shear (KN) of the building without telecommunication tower, building with tower in Model 1 and retrofitted model 1. The storey shear of the retrofitted model is higher than that of model without retrofitting. It means that the retrofitted model is much stiffer comparatively.

Table 4 storey drift ratio in X direction (RS X)

	BUILDING WITHOUT TOWER	MODEL 1	RETROFITTED MODEL1
Storey 18	-	0.019414	0.004101
Storey 17	-	0.019412	0.004101
Storey 16	-	0.019412	0.004101
Storey 15	-	0.019412	0.004101
Storey 14	-	0.01941	0.004101
Storey 13	-	0.019421	0.004103
Storey 12	-	0.019409	0.004101
Storey 11	-	0.019409	0.004101
Storey 10	-	0.019408	0.004101
Storey9	-	0.019405	0.0041
Storey8	-	0.407191	0.085965
Storey7	0.00085	0.001198	0.001729
Storey6	0.001353	0.0021	0.002052
Storey5	0.001791	0.00281	0.00222
Storey4	0.002143	0.003335	0.002259
Storey3	0.002393	0.003741	0.002143
Storey2	0.00238	0.003816	0.001838
Storey1	0.001406	0.002304	0.001099
Base	0	0	0

Note: Base to storey7 indicates G+6 Building and storey8 to storey18 indicates telecommunication tower at a constant height of 1.5m each



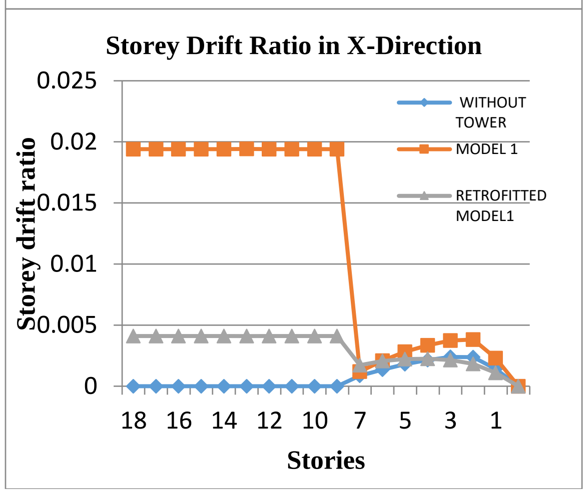


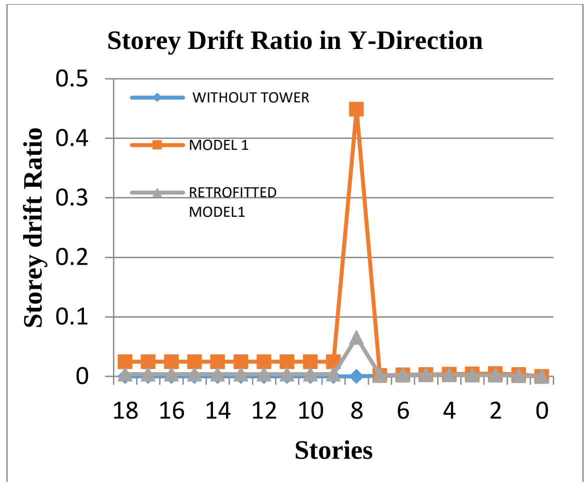
Fig. 9 storey drift ratio in X direction (RS X)

The above graph shows storey drift ratios of the building without telecommunication tower, building with tower in Model 1 and retrofitted model 1in X -Direction. The storey drift ratio of the building without tower is less than 0.004, conforming to IS considerations. The building with tower i.e., Model 1 has storey drift ratios much greater than 0.004. The retrofitted model 1 shows storey drift ratios comparatively less except at storey 8(bottom of the tower), indicating strengthening of the tower at the bottom.

Table 5 storey drift ratio in Y direction (RS Y)

	BUILDING WITHOUT TOWER	MODEL 1	RETROFITTED MODEL1
Storey 18	-	0.024815	0.00363
Storey 17	-	0.024813	0.00363
Storey 16	-	0.024801	0.003628
Storey 15	-	0.024813	0.003629
Storey 14	-	0.024811	0.003629
Storey 13	-	0.024812	0.003629
Storey 12	-	0.024809	0.003628
Storey 11	-	0.02481	0.003628
Storey 10	-	0.024797	0.003626
Storey9	-	0.024807	0.003627
Storey8	-	0.449192	0.065398
Storey7	0.000955	0.001255	0.001947
Storey6	0.001565	0.002338	0.002267
Storey5	0.002057	0.003176	0.002418
Storey4	0.002444	0.003789	0.002431
Storey3	0.002753	0.004298	0.002285
Storey2	0.002843	0.004527	0.001942
Storey1	0.001834	0.00299	0.001206
Base	0	0	0

Note: Base to storey7 indicates G+6 Building and storey8 to storey18 indicates telecommunication tower at a constant height of 1.5m each



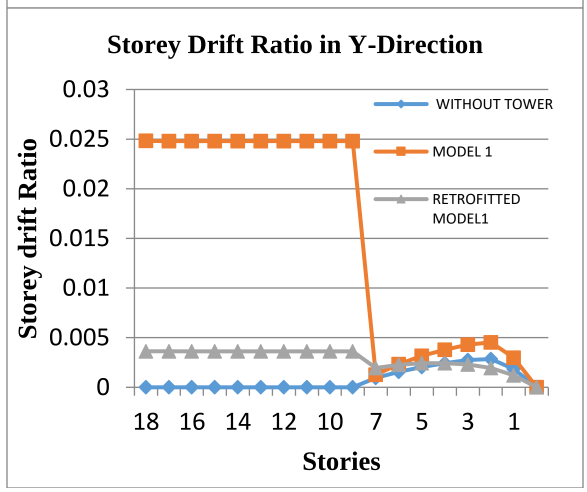


Fig. 10 storey drift ratio in Y direction(RS Y)

The graph above indicates the storey drift ratios in Y –direction, similar to that of the X – direction the retrofitted model is much stiffer than the structure without retrofitting and strengthening of the tower at the bottom is necessary.

VI. CONCLUSION

Based on the analysis done, the following conclusions were made:

1. The best suitable position for installation of telecommunication tower is at model 1 position whereas the most vulnerable position for installation of tower is model 2 position.
2. The maximum storey displacements after seismic analysis of the building with telecommunication tower at model 1 position are about 1400% more than that of the building without tower.

3. After retrofitting model 1 the maximum storey displacement decreased by almost 78.97%.
4. The retrofitted model is much stiffer than the model without retrofitting.
5. The retrofitted model 1 shows storey drift ratios comparatively less except at storey 8(bottom of the tower), therefore strengthening of the bottom of the tower is necessary.

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