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"SEISMIC RETROFITTING OF HIGH-RISE BUILDING"

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ABSTRACT: *Nowadays The repair of a structure or its element has always been very difficult, and adequate solutions have often entailed extensive works. Specialized techniques of strengthening, stiffing and repair are needed to deal with damaged structural elements due to fire, earthquake, foundation movement, impact and overload. Many existing bridges, industrial structures, urban transport structures, marine structures and earth retaining structures are in need of repair or upgrade. During the service life due to many reasons the reinforced concrete structures have to face some modifications and improvements. In such case there are two possible solutions: replacing or retrofitting. Replacing of whole structures causes disadvantages like high costs for labor and material. So, without replacing the complete structure, if is desirable to repair it or upgrade it by using retrofitting techniques if possible and feasible.*

In this study a G+20 storey building model of Existing building structure without retrofitting, Deteriorated building structure and Retrofitted building structure by considering percentage variation in deterioration and retrofication of overall building structure is taken into account and the analysis is carried out by using response spectrum analysis.

The analysis and comparison of Existing building without retrofitting with Deteriorated building structure and Retrofitted building structure by considering percentage variation in deterioration and retrofication at different locations of overall building structure by applying various methods of retrofitting are studied to investigate the seismic behavior of high-rise building.

Codes referred:
IS 456:2000, IS 1893:2016

Keywords: Retrofitting, Displacement, Response Spectrum Analysis, Shear Wall, Jacketing,

- **OBJECTIVES**

This proposed work is focused on:

- Study of Retrofitting of Building.
- Analysis of multistoried building without Retrofitting.
- Analysis of multistoried building with various methods of Retrofitting.
- Study of structural behavior of building by applying various methods of Retrofitting at different location of building.
- Comparison of results for various methods of Retrofitting.

1. INTRODUCTION:

Deterioration of concrete structure is a worldwide problem. The reasons behind this are many, like - occurrence of natural hazards like earthquakes, lack of awareness of several important codal provisions in construction, poor quality of supervision etc... These factors lead to strength deficient structures. Sometimes, overloading of structures leads to excessive deformations and corrosion which need considerable attention today.

To overcome all these effects on reinforced concrete structures: repair, retrofitting or strengthening are regularly required activities in construction field today. The damages caused by all of these possible ways will require variety of possible repair techniques, from which most effective one will be chosen in each particular case. In some cases, even newly built structures require, repair and strengthening so as to eliminate defects due to mistakes in design or construction.

The repair of concrete structure or its element has always been very difficult, and adequate solutions have often entailed extensive works. Specialized techniques of strengthening, stiffing and repair are needed to deal with damaged structural elements due to unusual event such as fire, earthquake, foundation movement, impact and overload. Many existing bridges, industrial structures, urban transport structures, marine structures and earth retaining structures are in need of repair or upgrade. During the service life due to many reasons the reinforced concrete structures have to face some modifications and improvements. In such case there are two possible solutions: replacing or retrofitting. Replacing of whole structures causes disadvantages like high costs for labor and material. So, without replacing the whole structure, if is desirable to repair it or upgrade it by retrofitting if possible and feasible.

2. RETROFITTING:

"Retrofit" means the use of new innovations to a more seasoned system. Retrofitting is the process of adding some new elements to a structure that were not there previously. It is the method of changing or repairing something after it has been made. There are different retrofitting techniques for RCC buildings. The

retrofitting techniques for RCC buildings are generally classified into two categories, such as, Global retrofitting techniques and Local retrofitting techniques.

It is the method of changing or repairing and modifying something after it has been made. Retrofitting of buildings is needed for the houses that are influenced by disappointments and harmed by seismic forces. Retrofitting of structures implies making changes to an existing structure so as to protect it from flooding or different hazards like earthquakes, high winds, etc.

Retrofitting a building includes changing its structures or systems after its initial construction. This work can further develop conveniences for the building's occupants and work on the performance of the building. As technology develops, the retrofitting of buildings can essentially decrease energy and water utilization.

- **Methods of Retrofitting**
  - Adding Steel Bracing
  - **Jacketing Method**
  - External Plate Bonding
  - Base Isolation Technique
  - Mass Reduction Technique
  - Wall Thickening Technique
  - Fiber Reinforced Polymer (FRP)
  - **Adding Shear Wall**
  - Epoxy Injection Method
  - Section Enlarging Reinforcing Method

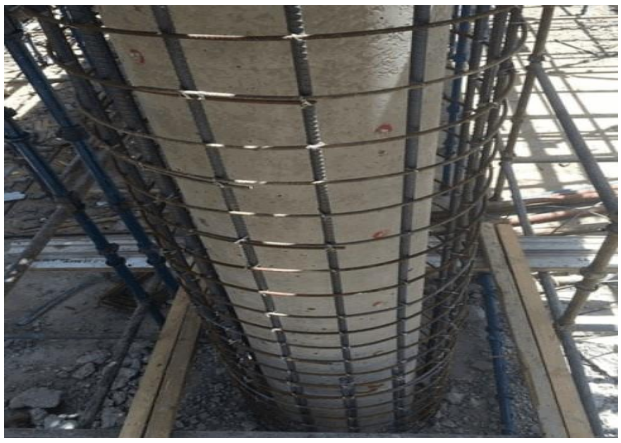


Fig.1.2.1 Column jacketing

Fig.1.2.2 Shear wall

2.1 NECESSITY OF RETROFITTING

Some of the need for retrofitting are as mentioned below:

1) It is necessary for maintenance of structural cracks and structural members damages.
2) It is used to correct the error in construction or design.
3) It assures the safety and security of a building, structure functionality, employees, inventory and machinery.
4) To reconstruct the structure by using various retrofitting techniques for the advantages of excessive loading.
5) To reconstruct and provide stability to the structure against the damages caused by the seismic hazard.

2.2 NEED OF STUDY

The retrofitting of concrete structures has become increasingly important in view aging and more deterioration of infrastructure. The problem is more severe due to optimized technologies for construction. Many expansive methods are available for retrofit ting structures and choice of suitable method/material is a challenge to a structural engineer. Retrofitting is the Science and Technology of strengthening the existing structures or structural elements to enhance their performance with new technology, features and components. Retrofitting of an existing reinforced concrete structure includes either repair, rehabilitation (or) strengthening terms. The term retrofit is used if the damaged structure performance was satisfying than before with some additional resistance then the term retrofit will be representative.

➢ **Goals of Seismic Retrofit**

The goals of seismic retrofit refer to the actions to be taken with reference to the attributes for seismic design, in qualitative terms. They can be summarized as follows:

1) To increase the lateral strength and stiffness of the structure.
2) To increase the ductility in the behavior of the structure, this aims to avoid the brittle modes of failure.
3) To increase the integral action and continuity of themembers in a structure.
4) To eliminate or reduce the effects of irregularities in the structure.
5) To enhance redundancy in the lateral load resisting system, this aims to eliminate the possibility of progressive collapse of the structure.
6) To ensure adequate stability against overturning and sliding caused due to seismic forces.

3. METHODOLOGY

Taking into the consideration the need and objectives of dissertation,

1) A G+20 storey building model of Existing building structure without retrofitting, Deteriorated building structure and Retrofitted building structure by considering percentage variation in deterioration and retrofication of overall building structure is taken into account and the analysis is carried out by using response spectrum analysis.

2) Considering earthquake loads as loading for the structure according to Indian standards, IS 1893:2016 by using structural analysis software.

3) The analysis of displacement evaluated for G+20 storey building model of Existing building structure without retrofitting, Deteriorated building structure and Retrofitted building structure by considering percentage variation in deterioration and retrofication of overall building structure is investigated.

4) The analysis and comparison of Existing building without retrofitting with Deteriorated building structure and Retrofitted building structure by considering percentage variation in deterioration and retrofication at different locations of overall building structure by applying various methods of retrofitting are studied to investigate the seismic behavior of high-rise building.

5) For the analysis and comparison of Existing building without retrofitting with Deteriorated building structure and Retrofitted building structure by considering percentage variation in deterioration and retrofication at different locations of overall building structure by applying various methods of retrofitting the seismic response displacement, drift, and Storey shear are evaluated.

This study based on response spectrum analysis of a G+20 storey building model of Existing building structure without retrofitting. The work presented in this report is seismic analysis of Existing building without retrofitting with Deteriorated building structure and Retrofitted building structure by considering percentage variation in deterioration and retrofication at different locations of overall building structure by applying various methods of retrofitting using seismic analysis software by considering earthquake loads according to Indian standard, IS 1893:2016 and response spectrum analysis. Computational model for validation case taken from reference and building is modeled as per IS 456:2000 and IS 1893:2016 in structural analysis software.

Mainly, eleven case studies have been chosen for the seismic retrofitting of high-rise building using structural analysis software are given below,

Case 1: Model of Existing building

To analyze the high-rise building without retrofitting a G+20 storey building model is selected and analyzed in structural analysis software using response spectrum analysis. The seismic response such as Displacement, Drift and Storey shear are discussed.

Case 2: Model of 18.36 % Deteriorated building

In this model 18.36 % deterioration is considered of overall existing building model. and analyzed in structural analysis software using response spectrum analysis. The results of analysis of Displacement are discussed.

Case 3: Model of 51.02 % Deteriorated building

In this model 51.02 % deterioration is considered of overall existing building model. and analyzed in structural analysis software using response spectrum analysis. The results of analysis of Displacement are discussed.

Case 4: Model of 100% Deteriorated building

In this model 100 % deterioration is considered of overall existing building model. and analyzed in structural analysis software using response spectrum

analysis. The results of analysis of Displacement are discussed.

Case 5: Model of 18.36 % Retrofitted building using jacketing

In this model 18.36 % Retrofitting using jacketing is of overall existing building model. and analyzed in structural analysis software using response spectrum analysis. The results of analysis of Displacement are discussed.

Case 6: Model of 51.02 % Retrofitted building using jacketing

In this model 51.02 % Retrofitting using jacketing is of overall existing building model. and analyzed in structural analysis software using response spectrum analysis. The results of analysis of Displacement are discussed.

Case 7: Model of 100 % Retrofitted building using jacketing

In this model 100 % Retrofitting using jacketing is of overall existing building model. and analyzed in structural analysis software using response spectrum analysis. The results of analysis of Displacement are discussed.

Case 8: Model of 18.36 % Retrofitted building using Shear wall

In this model 18.36 % Retrofitting using Shear wall is of overall existing building model. and analyzed in structural analysis software using response spectrum analysis. The results of analysis of Displacement are discussed.

Case 9: Model of 51.02 % Retrofitted building using Shear wall

In this model 51.02 % Retrofitting using Shear wall is of overall existing building model. and analyzed in structural analysis software using response spectrum analysis. The results of analysis of Displacement are discussed.

Case 10: Model of 100 % Retrofitted building using Shear wall

In this model 100 % Retrofitting using Shear wall is of overall existing building model. and analyzed in structural analysis software using response spectrum analysis. The results of analysis of Displacement are discussed.

Case 11: Comparative Study

A comparative study between Existing building without retrofitting with Deteriorated building structure and Retrofitted building structure by considering percentage variation in deterioration and retrofication at different locations of overall building structure by applying various methods of retrofitting using seismic analysis software. The results of analysis of Displacement are evaluated.

Case 1) MODEL OF EXISTING BUILDING WITHOUT RETROFITTING

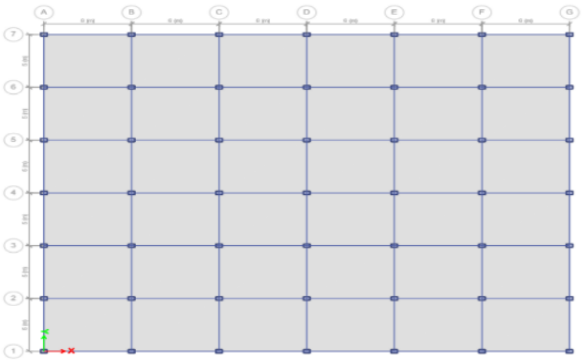


Fig 3.1 PLAN

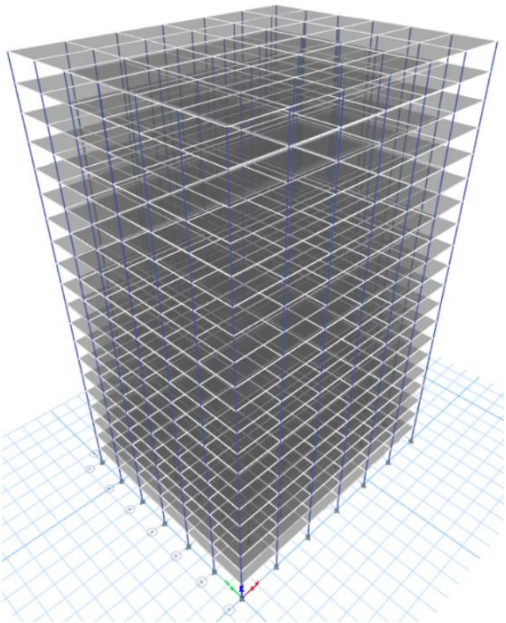


Fig 3.2 3D View

Case2) MODEL OF 18.36 % DETERIORATED BUILDING

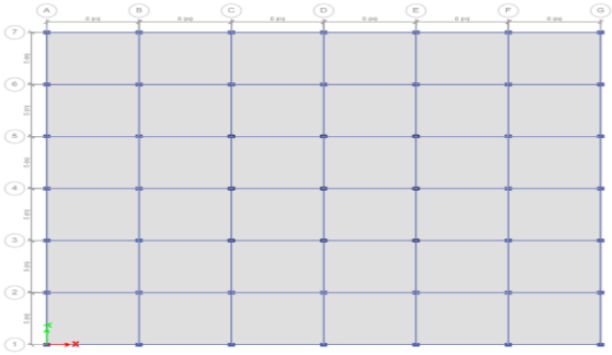


Fig 3.3 PLAN

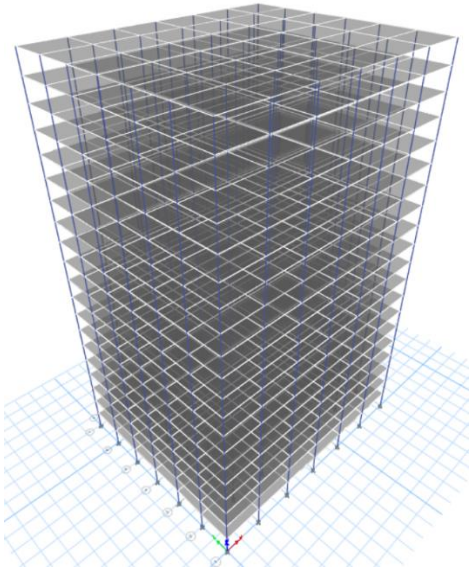


Fig 3.4 3D View

Case 3) MODEL OF 51.02% DETERIORATED BUILDING

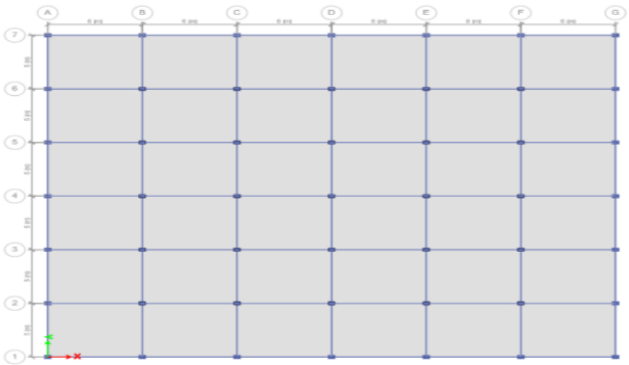


Fig 3.5 PLAN

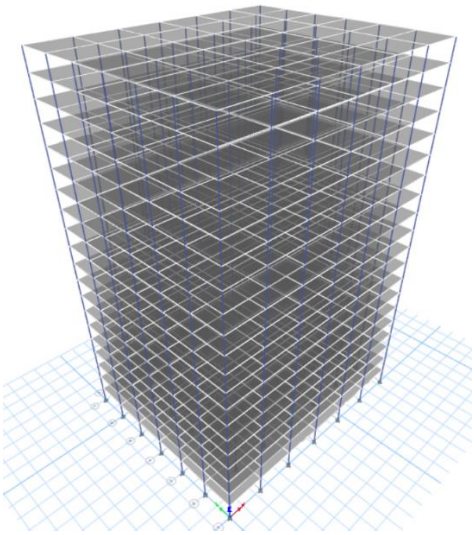


Fig 3.6 3D View

Case 4) MODEL OF 100% DETERIORATED BUILDING

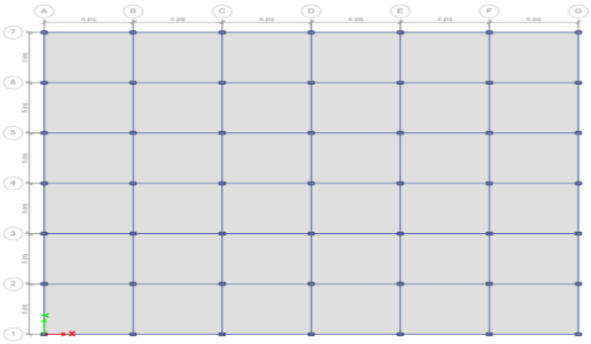


Fig 3.7 PLAN

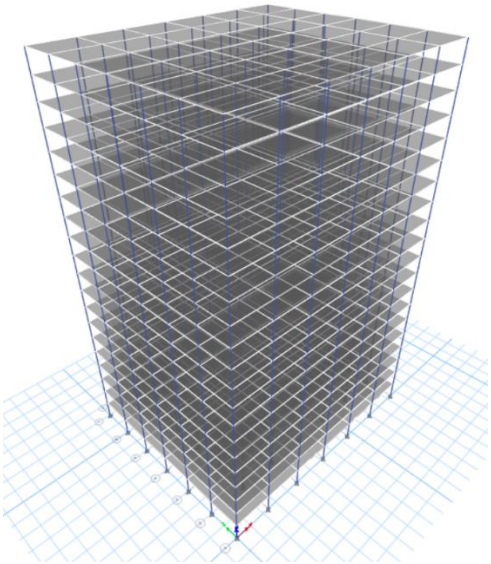


Fig 3.8 3D View

Case 5) MODEL OF 18.36% RETROFITTED BUILDING USING JACKETING

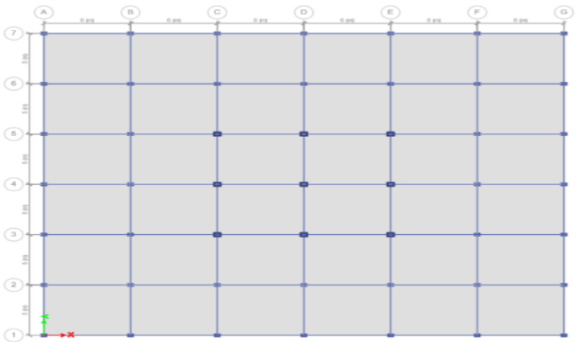


Fig 3.9 PLAN

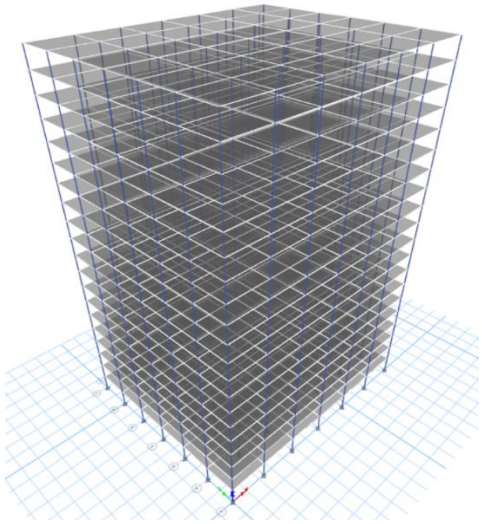


Fig 3.10 3D View

Case 6) MODEL OF 51.02% RETROFITTED BUILDING USING JACKETING

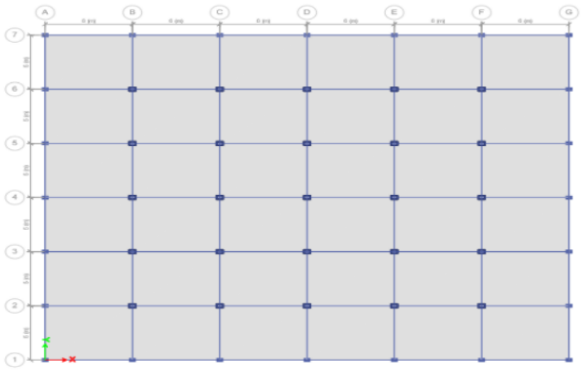


Fig 3.11 PLAN

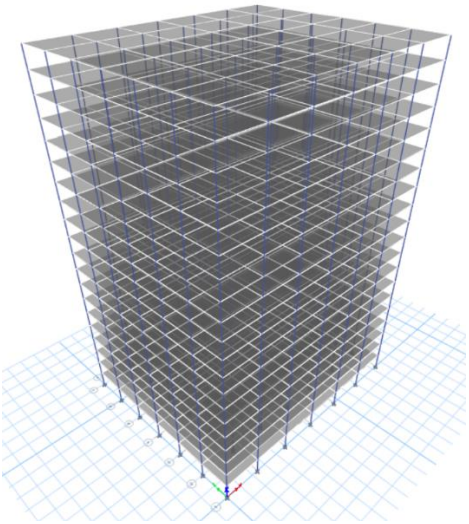


Fig 3.12 3D View

Case 7) MODEL OF 100 % RETROFITTED BUILDING USING JACKETING

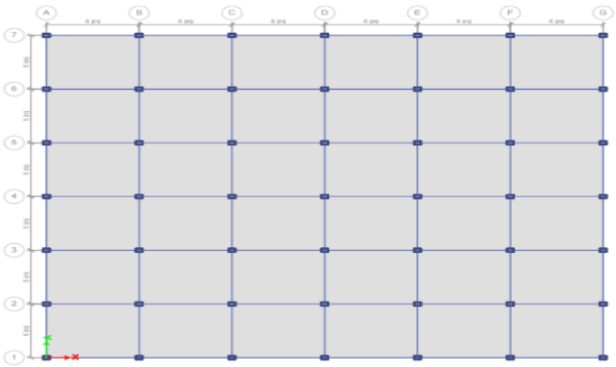


Fig 3.13 PLAN

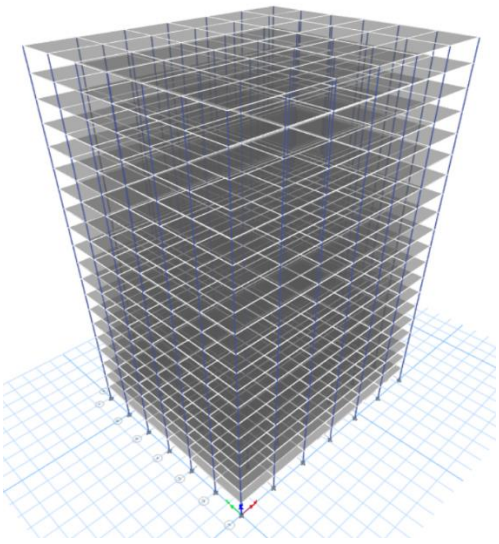


Fig 3.14 3D View

Case 8) MODEL OF 18.36 % RETROFITTED BUILDING USING SHEAR WALL

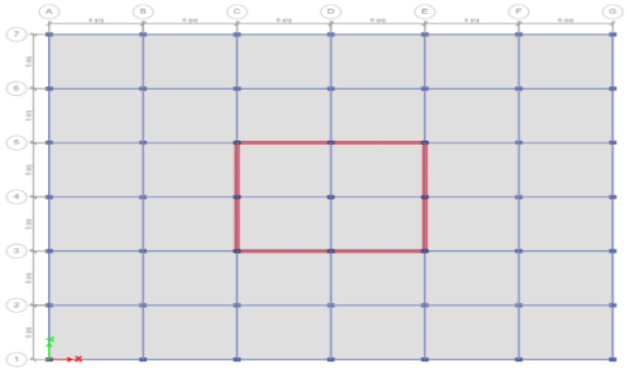


Fig 3.15 PLAN

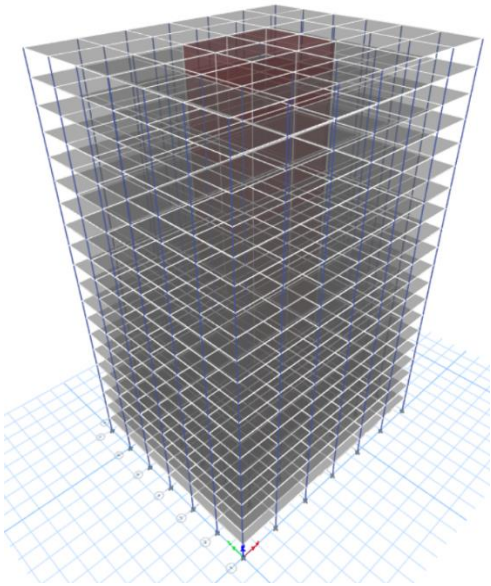


Fig 3.16 3D View

Case 9) MODEL OF 51.02 % RETROFITTED BUILDING USING SHEAR WALL

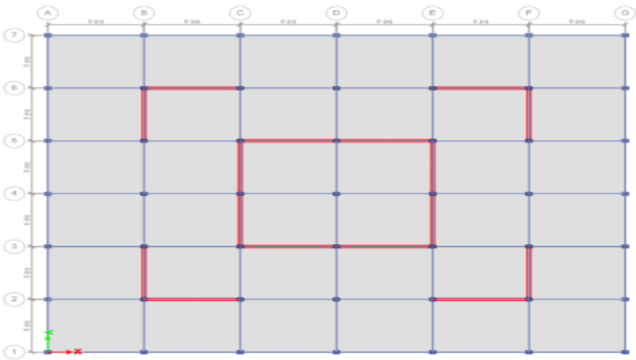


Fig 3.17 PLAN

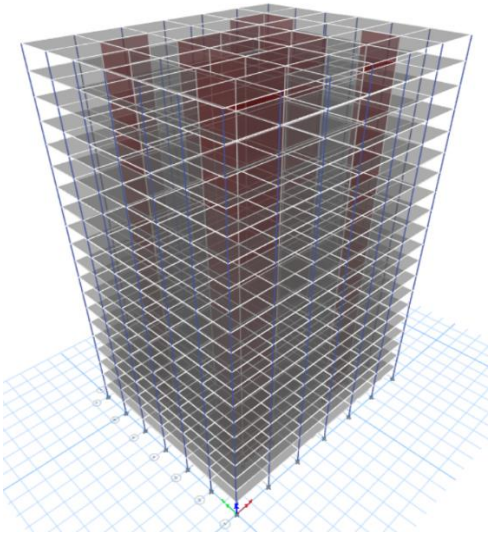


Fig 3.18 3D View

Case 10) MODEL OF 100% RETROFITTED BUILDING USING SHEAR WALL

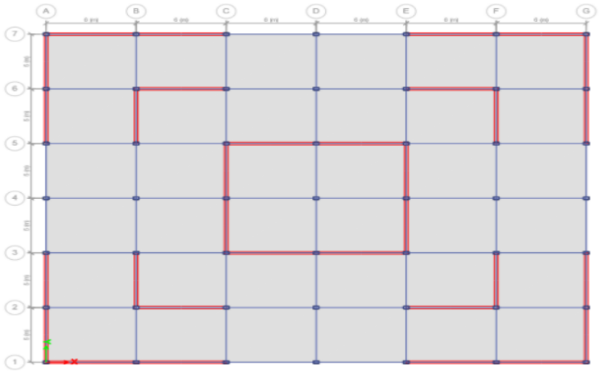


Fig 3.19 PLAN

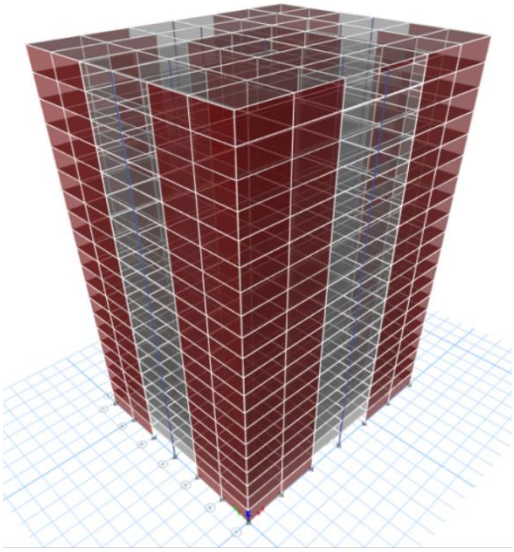


Fig 3.20 3D View

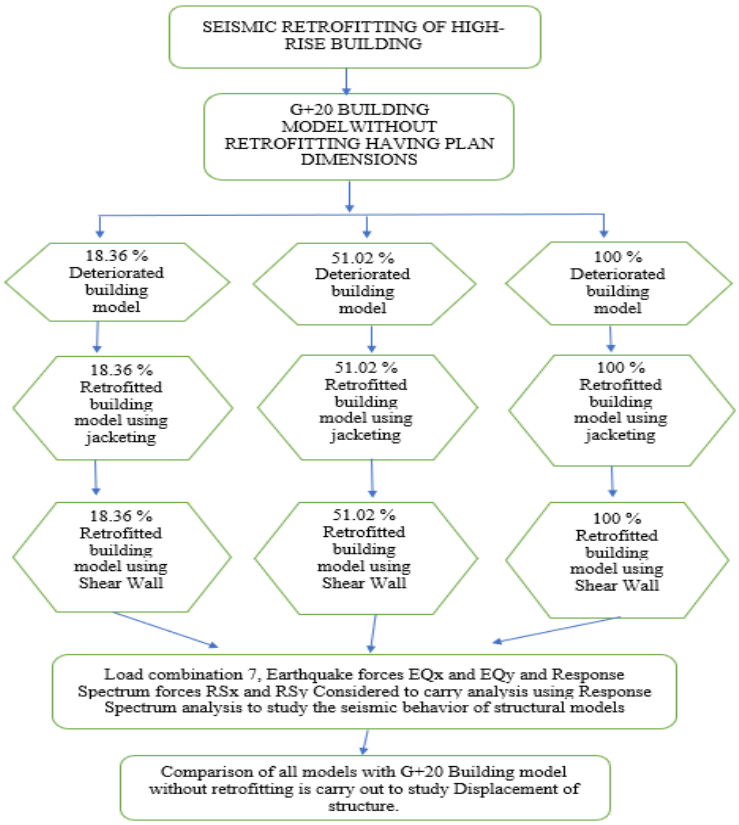
Specifications: The following specifications are adopted for study.

Table 1. Specifications of Modeling

Specifications	Plan Dimensions = 36m X 30m
A. For Existing building without Retrofitting	
1. Grade of concrete	M 30
2. Grade of steel	HYSD 500
3.Column size	350 mm X 450 mm
4. Beam size	250 mm X 350 mm
5. Slab Thickness	120 mm
B. For Deteriorated building	
1. Grade of concrete	M 30
2. Grade of steel	HYSD 500
3.Column size	270 mm X 370 mm
4. Beam size	150 mm X 250 mm
5. Slab Thickness	120 mm
C. For Retrofitted building using jacketing	
1. Grade of concrete	M 35
2. Grade of steel	HYSD 550
3.Column size	400 mm X 500 mm
4. Beam size	300 mm X 400 mm
5. Slab Thickness	120 mm
D.For Retrofitted building using Shear wall	
1. Grade of concrete	M 35
2. Grade of steel	HYSD 550
3. Shear wall size	230 mm
Basic Data considered	
a) Storey height for all models	3 m
b) Location of Building	Pune
c) Earthquake zone	III
d) Zone Factor	0.16
e) Damping Ratio	5%
f) Importance Factor	1
g) Response reduction factor	5
h) Soil Type	II (Medium soil)
i) Type of structure	Special moment resisting frame
j) Type of diaphragm	Rigid
k) Direction of lateral forces	X direction and Y direction
l) Load pattern considered	DL, LL, EQx, Eqy
1.DL	Programme calculated
2. LL	3 kN/m
m) Response Spectrum Forces	RSx and Rsy
No of Models	10 models
Existing Building without retrofitting	1 model
Deteriorated building with percentage variation in deterioration	3 models with percentage variation as (18.36%, 51.02% and 100%)
Retrofitted building using jacketing with percentage variation in retrofication	3 models with percentage variation as (18.36%, 51.02% and 100%)
Retrofitted building using Shear wall with percentage variation in retrofication	3 models with percentage variation as (18.36%, 51.02% and 100%)
Load Combinations	All load combinations as per IS 1893:2016
Type of support at base	Fixed

Flow of work

The Flow chart shows Overview the Methodology of project work.



3. Analysis Results of all cases

➢ **Table 2. Evaluation of maximum Displacement for Existing Building**

Sr no	Load combination	Maximum Displacement (mm)
1	1.2(DL+LL+EQX)	91.992
2	1.2 (DL+LLEQX)	91.992
3	1.2(DL+LL+EQY)	94.811
4	1. (DL+LL-EQY)	94.811
5	1.5(DL+LL+EQX)	114.99
6	1.5 (DL+LLEQX)	114.99
7	**1.5(DL+LL+EQY)**	**118.513**
8	1.5 (DL+LL-EQY)	118.513
9	0.9 (DL+LL+EQX)	68.994
10	0.9 (DL+LL-EQX)	68.994
11	0.9 (DL+LL+EQY)	71.108
12	1.2 (DL+LL-EQY)	71.108

Observations:

In this Existing Building model for all load combinations the dynamic analysis is carried out to observe the maximum Displacement.

The analysis results for each are shown in above table from that the maximum values of Displacement are obtained for Load combination 7.

So, the combination 7 is considered for further analysis of all cases.

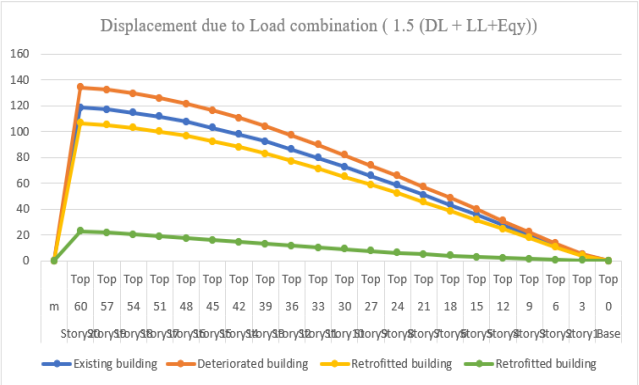
The analysis is carried out to study the seismic behavior of the structure under the influence of

1) Load Combination 1.5(DL+LL+EQY)
2) Response Spectrum Forces RSx and RSy
3) Earthquake Forces EQx and EQy

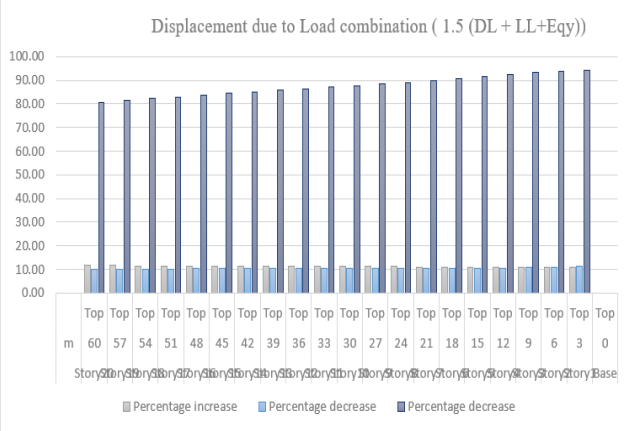
The above Forces are considered to study the seismic behavior of building structure such as Displacement under 10 cases as mentioned.

Table 3. Displacement Comparison due to load combination (1.5 (DL + LL + EQy)) for Case 1, Case 2, Case 5 and Case 8

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	Y direction (mm)	18.36 % deterioration Y direction (mm)	Percentage increase	18.36 % Retrofitted building using jacketing Y direction (mm)	Percentage decrease	18.36 % Retrofitted building using shear wall Y direction (mm)	Percentage decrease
S20	**118.513**	**134.102**	**11.62**	**106.421**	**10.20**	**23.067**	**80.54**
S19	117.015	132.293	11.55	105.075	10.20	21.717	81.44
S18	114.683	129.565	11.49	102.976	10.21	20.333	82.27
S17	111.533	125.929	11.43	100.141	10.21	18.925	83.03
S16	107.641	121.469	11.38	96.636	10.22	17.497	83.75
S15	103.084	116.271	11.34	92.532	10.24	16.056	84.42
S14	97.939	110.42	11.30	87.899	10.25	14.608	85.08
S13	92.277	103.994	11.27	82.801	10.27	13.163	85.74
S12	86.165	97.069	11.23	77.3	10.29	11.731	86.39
S11	79.666	89.714	11.20	71.453	10.31	10.322	87.04
S10	72.839	81.996	11.17	65.312	10.33	8.947	87.72
S9	65.738	73.974	11.13	58.926	10.36	7.619	88.41
S8	58.412	65.705	11.10	52.342	10.39	6.351	89.13
S7	50.906	57.239	11.06	45.598	10.43	5.154	89.88
S6	43.261	48.623	11.03	38.733	10.47	4.043	90.65
S5	35.514	39.898	10.99	31.778	10.52	3.031	91.47
S4	27.696	31.102	10.95	24.765	10.58	2.133	92.30
S3	19.845	22.276	10.91	17.725	10.68	1.363	93.13
S2	12.037	13.509	10.90	10.732	10.84	0.737	93.88
S1	4.644	5.211	10.88	4.125	11.18	0.272	94.14
Base	0	0	0	0	0	0	0



Graph 4.1 Displacement due to load combination (1.5 (DL + LL + Eqy))



Graph 4.2 Percentage variation due to Displacement

Observations:

The table 3 and graphs 4.1 and 4.2 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 18.36 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 10.88 % to 11.62 %

b) The maximum displacement at storey 20 is increased by 11.62 % (i.e. increase from 118.513 mm to 134.102 mm)

2) By comparing existing building model to 18.36 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 11.18 % to 10.20 %

b) The maximum displacement at storey 20 is decreased by 10.20 % (i.e. decrease from 118.513 mm to 106.421 mm)

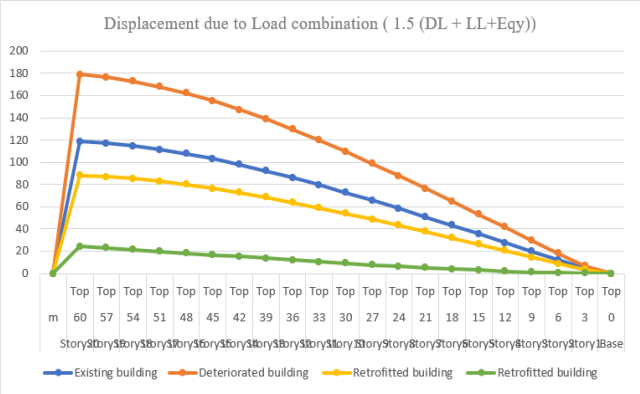
3) By comparing existing building model to 18.36 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 94.14 % to 80.54 %.

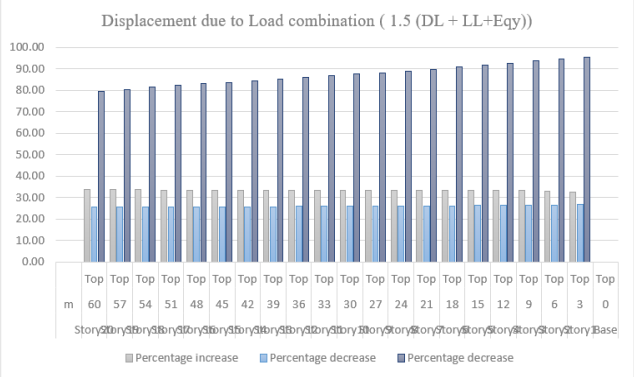
b) The maximum displacement at storey 20 is decreased by 80.54 % (i.e. decrease from 118.513 mm to 23.067 mm)

Table 4. Displacement Comparison due to load combination (1.5 (DL + LL + Eqy)) for Case 1, Case 3, Case 6 and Case 9

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	Y direction (mm)	51.02 % deterioration Y direction (mm)	Percentage increase	51.02 % Retrofitted Building using jacketing Y direction (mm)	Percentage decrease	51.02 % Retrofitted Building using shear wall Y direction (mm)	Percentage decrease
S20	**118.513**	**178.918**	**33.76**	**88.101**	**25.66**	**24.407**	**79.41**
S19	117.015	176.454	33.69	86.977	25.67	22.901	80.43
S18	114.683	172.797	33.63	85.226	25.69	21.373	81.36
S17	111.533	167.952	33.59	82.862	25.71	19.83	82.22
S16	107.641	162.023	33.56	79.943	25.73	18.273	83.02
S15	103.084	155.121	33.55	76.528	25.76	16.71	83.79
S14	97.939	147.353	33.53	72.674	25.80	15.148	84.53
S13	92.277	138.819	33.53	68.438	25.83	13.596	85.27
S12	86.165	129.617	33.52	63.869	25.88	12.064	86.00
S11	79.666	119.837	33.52	59.017	25.92	10.565	86.74
S10	72.839	109.563	33.52	53.925	25.97	9.108	87.50
S9	65.738	98.874	33.51	48.635	26.02	7.708	88.27
S8	58.412	87.845	33.51	43.184	26.07	6.377	89.08
S7	50.906	76.541	33.49	37.606	26.13	5.128	89.93
S6	43.261	65.024	33.47	31.932	26.19	3.976	90.81
S5	35.514	53.35	33.43	26.189	26.26	2.935	91.74
S4	27.696	41.571	33.38	20.403	26.33	2.021	92.70
S3	19.845	29.745	33.28	14.599	26.43	1.25	93.70
S2	12.037	17.999	33.12	8.838	26.58	0.64	94.68
S1	4.644	6.903	32.72	3.399	26.81	0.212	95.43
Base	0	0	0	0	0	0	0



Graph 4.3 Displacement due to load combination (1.5 (DL + LL + Eqy))



Graph 4.4 Percentage variation due to Displacement

Observations:

The table 4 and graphs 4.3 and 4.4 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 51.02 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 32.72 % to 33.76 %

b) The maximum displacement at storey 20 is increased by 33.76 % (i.e. increase from 118.513 mm to 178.918 mm)

2) By comparing existing building model to 51.02 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 26.81 % to 25.66 %

b) The maximum displacement at storey 20 is decreased by 25.66 % (i.e. decrease from 118.513 mm to 88.101 mm)

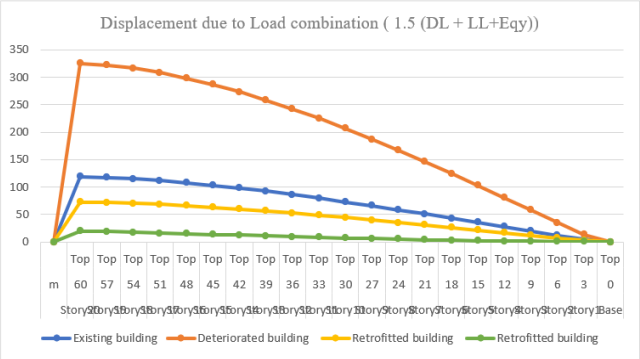
3) By comparing existing building model to 51.02 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 95.43 % to 79.41 %.

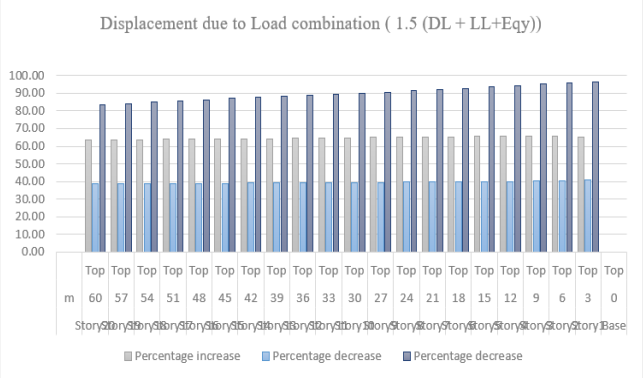
b) The maximum displacement at storey 20 is decreased by 79.41 % (i.e. decrease from 118.513 mm to 24.407 mm)

Table 5. Displacement Comparison due to load combination (1.5 (DL + LL + Eqy)) for Case 1, Case 4, Case 7 and Case 10

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	Y direction (mm)	100 % deterioration Y direction (mm)	Percentage increase	100 % Retrofitted building using jacketing Y direction (mm)	Percentage decrease	100 % Retrofitted building using shear wall Y direction (mm)	Percentage decrease
S20	**118.513**	**325.544**	**63.60**	**72.633**	**38.71**	**19.857**	**83.24**
S19	117.015	322.03	63.66	71.652	38.77	18.595	84.11
S18	114.683	316.318	63.74	70.162	38.82	17.32	84.90
S17	111.533	308.422	63.84	68.171	38.88	16.036	85.62
S16	107.641	298.514	63.94	65.725	38.94	14.746	86.30
S15	103.084	286.776	64.05	62.874	39.01	13.454	86.95
S14	97.939	273.388	64.18	59.667	39.08	12.169	87.57
S13	92.277	258.516	64.31	56.148	39.15	10.896	88.19
S12	86.165	242.318	64.44	52.361	39.23	9.644	88.81
S11	79.666	224.943	64.58	48.345	39.32	8.423	89.43
S10	72.839	206.526	64.73	44.138	39.40	7.241	90.06
S9	65.738	187.194	64.88	39.773	39.50	6.109	90.71
S8	58.412	167.063	65.04	35.283	39.60	5.037	91.38
S7	50.906	146.238	65.19	30.696	39.70	4.035	92.07
S6	43.261	124.816	65.34	26.038	39.81	3.115	92.80
S5	35.514	102.881	65.48	21.333	39.93	2.289	93.55
S4	27.696	80.517	65.60	16.6	40.06	1.567	94.34
S3	19.845	57.823	65.68	11.864	40.22	0.962	95.15
S2	12.037	35.053	65.66	7.173	40.41	0.489	95.94
S1	4.644	13.411	65.37	2.754	40.70	0.16	96.55
Base	0	0	0	0	0	0	0



Graph 4.5 Displacement due to load combination (1.5 (DL + LL + Eqy))



Graph 4.6 Percentage variation due to Displacement

Observations:

The table 5 and graphs 4.5 and 4.6 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 100 % deteriorated building model,

a) It is observed that the displacement from storey 1 to storey 20, is increased by 65.37 % to 63.60 %

b) The maximum displacement at storey 20 is increased by 63.60 % (i.e. increase from 118.513 mm to 325.544 mm)

2) By comparing existing building model to 100 % Retrofitted building model using jacketing

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 40.70 % to 38.71%,

b) The maximum displacement at storey 20 is decreased by 38.71 % (i.e. decrease from 118.513 mm to 72.633 mm)

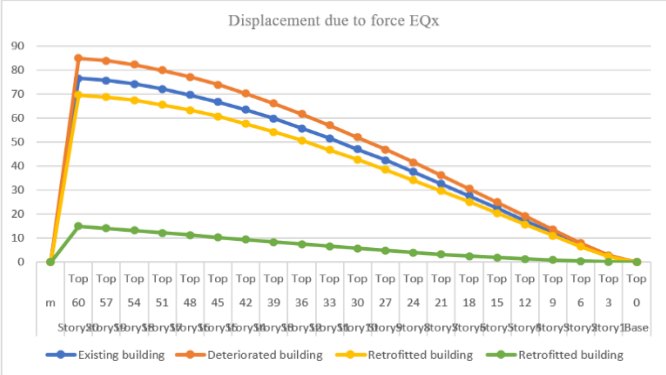
3) By comparing existing building model to 100 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 96.55 % to 83.24 %.

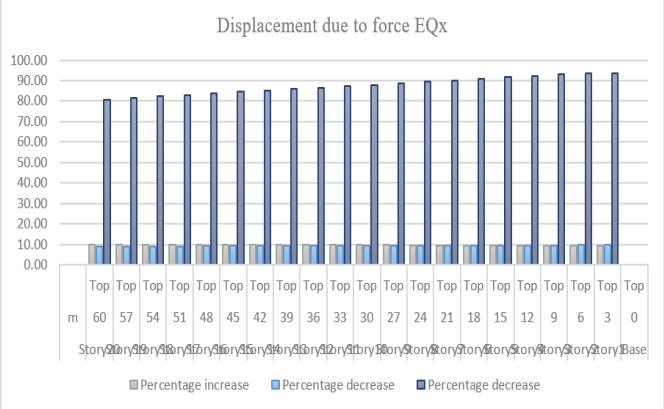
b) The maximum displacement at storey 20 is decreased by 83.24 % (i.e. decrease from 118.513 mm to 19.857 mm)

Table 6. Displacement Comparison due to force EQx for Case 1, Case 2, Case 5 and Case 8

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	X direction (mm)	18.36 % deterioration X direction (mm)	Percentage increase	18.36 % Retrofitted building using jacketing X direction (mm)	Percentage decrease	18.36 % Retrofitted building using shear wall X direction (mm)	Percentage decrease
S20	**76.66**	**85.081**	**9.90**	**69.684**	**9.10**	**14.993**	**80.44**
S19	75.709	83.977	9.85	68.818	9.10	14.081	81.40
S18	74.239	82.306	9.80	67.478	9.11	13.151	82.29
S17	72.237	80.052	9.76	65.653	9.11	12.209	83.10
S16	69.741	77.259	9.73	63.379	9.12	11.258	83.86
S15	66.802	73.98	9.70	60.7	9.13	10.302	84.58
S14	63.469	70.269	9.68	57.663	9.15	9.347	85.27
S13	59.788	66.178	9.66	54.31	9.16	8.398	85.95
S12	55.805	61.755	9.63	50.682	9.18	7.462	86.63
S11	51.561	57.046	9.62	46.817	9.20	6.546	87.30
S10	47.095	52.094	9.60	42.751	9.22	5.657	87.99
S9	42.441	46.936	9.58	38.516	9.25	4.802	88.69
S8	37.633	41.61	9.56	34.142	9.28	3.989	89.40
S7	32.699	36.148	9.54	29.656	9.31	3.226	90.13
S6	27.667	30.579	9.52	25.082	9.34	2.521	90.89
S5	22.561	24.93	9.50	20.442	9.39	1.883	91.65
S4	17.406	19.231	9.49	15.761	9.45	1.32	92.42
S3	12.241	13.523	9.48	11.074	9.53	0.84	93.14
S2	7.169	7.921	9.49	6.477	9.65	0.453	93.68
S1	2.57	2.84	9.51	2.316	9.88	0.166	93.54
Base	0	0	0	0	0	0	0



Graph 4.7 Displacement due to force EQx



Graph 4.8 Percentage variation due to Displacement

Observations:

The table 6 and graphs 4.7 and 4.8 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 18.36 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 9.51 % to 9.90 %

b) The maximum displacement at storey 20 is increased by 9.90 % (i.e. increase from

76.66 mm to 85.081 mm)

2) By comparing existing building model to 18.36 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 9.88 % to 9.10 %

b) The maximum displacement at storey 20 is decreased by 9.10 % (i.e. decrease from 76.66 mm to 69.684 mm)

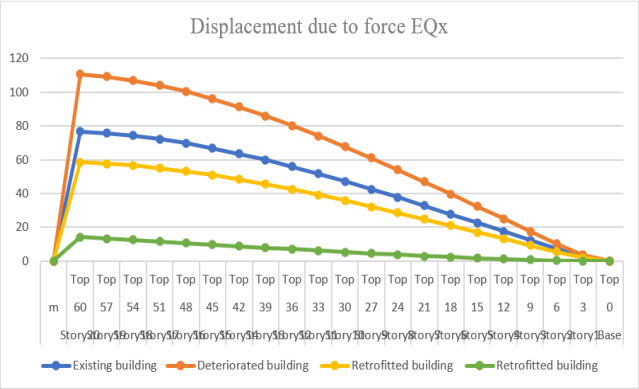
3) By comparing existing building model to 18.36 % Retrofitted building model using Shear wall

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 93.54% to 80.44%.

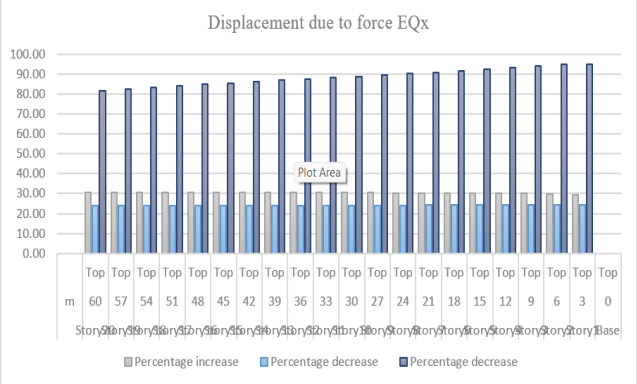
b) The maximum displacement at storey 20 is decreased by 80.44 % (i.e. decrease from 76.66 mm to14.993 mm)

Table 7. Displacement Comparison due to force EQx for Case 1, Case 3, Case 6 and Case 9

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	X direction (mm)	51.02 % deterioration X direction (mm)	Percentage increase	51.02 % Retrofitted building using jacketing X direction (mm)	Percentage decrease	51.02 % Retrofitted building using shear wall X direction (mm)	Percentage decrease
S20	**76.66**	**110.593**	**30.68**	**58.376**	**23.85**	**14.209**	**81.46**
S19	75.709	109.102	30.61	57.651	23.85	13.33	82.39
S18	74.239	106.896	30.55	56.527	23.86	12.438	83.25
S17	72.237	103.948	30.51	54.994	23.87	11.537	84.03
S16	69.741	100.311	30.48	53.082	23.89	10.628	84.76
S15	66.802	96.051	30.45	50.83	23.91	9.717	85.45
S14	63.469	91.235	30.43	48.278	23.93	8.806	86.13
S13	59.788	85.928	30.42	45.462	23.96	7.902	86.78
S12	55.805	80.192	30.41	42.416	23.99	7.011	87.44
S11	51.561	74.084	30.40	39.172	24.03	6.138	88.10
S10	47.095	67.658	30.39	35.762	24.06	5.291	88.77
S9	42.441	60.962	30.38	32.212	24.10	4.477	89.45
S8	37.633	54.043	30.36	28.548	24.14	3.704	90.16
S7	32.699	46.943	30.34	24.792	24.18	2.979	90.89
S6	27.667	39.701	30.31	20.964	24.23	2.31	91.65
S5	22.561	32.351	30.26	17.085	24.27	1.707	92.43
S4	17.406	24.933	30.19	13.173	24.32	1.177	93.24
S3	12.241	17.505	30.07	9.258	24.37	0.73	94.04
S2	7.169	10.223	29.87	5.418	24.42	0.376	94.76
S1	2.57	3.644	29.47	1.941	24.47	0.127	95.06
Base	0	0	0	0	0	0	0



Graph 4.9 Displacement due to force EQx



Graph 4.10 Percentage variation due to Displacement

Observations:

The table 7 and graphs 4.10 and 4.11 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 51.02 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 29.47 % to 30.68 %

b) The maximum displacement at storey 20 is increased by 30.68 % (i.e. increase from 76.66 mm to 110.593 mm)

2) By comparing existing building model to 51.02 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 24.47% to 23.85 %

b) The maximum displacement at storey 20 is decreased by 23.85 % (i.e. decrease from 76.66 mm to 58.376 mm)

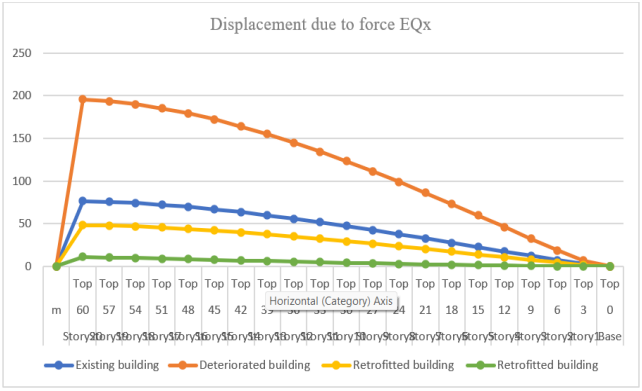
3) By comparing existing building model to 51.02 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 95.06% to 81.46 %.

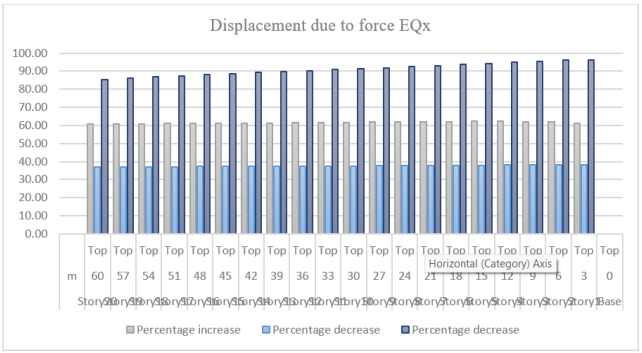
b) The maximum displacement at storey 20 is decreased by 79.41 % (i.e. decrease from 76.66 mm to 14.209 mm)

Table 8. Displacement Comparison due to force EQx for Case 1, Case 4, Case 7 and Case 10

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	X direction (mm)	100 % deterioration X direction (mm)	Percentage increase	100 % Retrofitted building using jacketing X direction (mm)	Percentage decrease	100 % Retrofitted building using shear wall X direction (mm)	Percentage decrease
S20	**76.66**	**195.607**	**60.81**	**48.24**	**37.07**	**11.155**	**85.45**
S19	75.709	193.405	60.85	47.615	37.11	10.449	86.20
S18	74.239	189.95	60.92	46.661	37.15	9.735	86.89
S17	72.237	185.179	60.99	45.371	37.19	9.014	87.52
S16	69.741	179.172	61.08	43.77	37.24	8.291	88.11
S15	66.802	172.033	61.17	41.89	37.29	7.566	88.67
S14	63.469	163.872	61.27	39.765	37.35	6.845	89.22
S13	59.788	154.793	61.38	37.423	37.41	6.131	89.75
S12	55.805	144.897	61.49	34.895	37.47	5.429	90.27
S11	51.561	134.275	61.60	32.208	37.53	4.743	90.80
S10	47.095	123.014	61.72	29.385	37.60	4.08	91.34
S9	42.441	111.192	61.83	26.451	37.68	3.445	91.88
S8	37.633	98.883	61.94	23.427	37.75	2.843	92.45
S7	32.699	86.153	62.05	20.331	37.82	2.281	93.02
S6	27.667	73.063	62.13	17.181	37.90	1.765	93.62
S5	22.561	59.673	62.19	13.993	37.98	1.3	94.24
S4	17.406	46.05	62.20	10.784	38.04	0.894	94.86
S3	12.241	32.315	62.12	7.576	38.11	0.553	95.48
S2	7.169	18.795	61.86	4.434	38.15	0.284	96.04
S1	2.57	6.621	61.18	1.59	38.13	0.096	96.26
Base	0	0	0	0	0	0	0



Graph 4.11 Displacement due to force EQx



Graph 4.12 Percentage variation due to Displacement

Observations:

The table 8 and graphs 4.11 and 4.12 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 100 % deteriorated building model,

a) It is observed that the displacement from storey 1 to storey 20, is increased by 61.18 % to 60.81 %

b) The maximum displacement at storey 20 is increased by 60.81 % (i.e. increase from 76.66 mm to 195.607 mm)

2) By comparing existing building model to 100 % Retrofitted building model using jacketing

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 38.13% to 37.07 %,

b) The maximum displacement at storey 20 is decreased by 38.71 % (i.e. decrease from 76.66 mm to 48.24 mm)

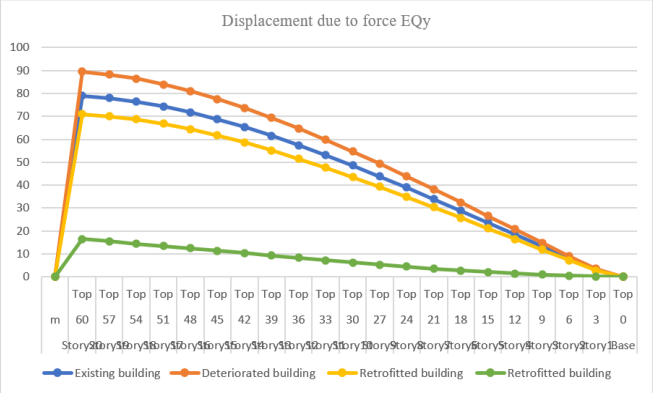
3) By comparing existing building model to 100 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 96.26% to 85.45 %.

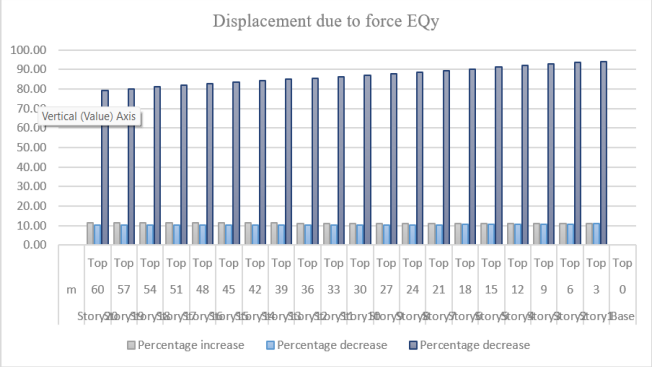
b) The maximum displacement at storey 20 is decreased by 83.24 % (i.e. decrease from 76.66 mm to 11.155 mm)

Table 9. Displacement Comparison due to force EQy for Case 1, Case 2, Case 5 and Case 8

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	Y direction (mm)	18.36 % deterioration Y direction (mm)	Percentage increase	18.36 % Retrofitted building using jacketing Y direction (mm)	Percentage decrease	18.36 % Retrofitted building using shear wall Y direction (mm)	Percentage decrease
S20	**79.009**	**89.401**	**11.62**	**70.947**	**10.20**	**16.483**	**79.14**
S19	78.01	88.195	11.55	70.05	10.20	15.496	80.14
S18	76.455	86.376	11.49	68.651	10.21	14.488	81.05
S17	74.356	83.953	11.43	66.76	10.22	13.464	81.89
S16	71.761	80.979	11.38	64.424	10.22	12.43	82.68
S15	68.723	77.514	11.34	61.688	10.24	11.388	83.43
S14	65.293	73.613	11.30	58.599	10.25	10.344	84.16
S13	61.518	69.329	11.27	55.201	10.27	9.306	84.87
S12	57.443	64.713	11.23	51.533	10.29	8.279	85.59
S11	53.111	59.81	11.20	47.635	10.31	7.272	86.31
S10	48.559	54.664	11.17	43.541	10.33	6.291	87.04
S9	43.825	49.316	11.13	39.284	10.36	5.347	87.80
S8	38.941	43.803	11.10	34.894	10.39	4.447	88.58
S7	33.937	38.159	11.06	30.399	10.43	3.601	89.39
S6	28.841	32.415	11.03	25.822	10.47	2.817	90.23
S5	23.676	26.599	10.99	21.186	10.52	2.106	91.10
S4	18.464	20.735	10.95	16.51	10.58	1.477	92.00
S3	13.23	14.851	10.92	11.817	10.68	0.939	92.90
S2	8.025	9.006	10.89	7.155	10.84	0.505	93.71
S1	3.096	3.474	10.88	2.75	11.18	0.184	94.06
Base	0	0	0	0	0	0	0



Graph 4.13 Displacement due to force EQy



Graph 4.14 Percentage variation due to Displacement

Observations:

The table 9 and graphs 4.13 and 4.14 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 18.36 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 10.88 % to 11.62 %

b) The maximum displacement at storey 20 is increased by 11.62 % (i.e. increase from 79.009 mm to 89.401 mm)

2) By comparing existing building model to 18.36 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 11.18 % to 10.20 %

b) The maximum displacement at storey 20 is decreased by 10.20 % (i.e. decrease from 79.009 mm to 70.947 mm)

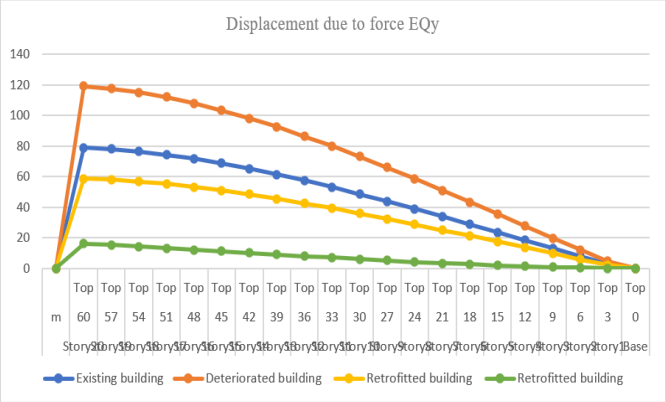
3) By comparing existing building model to 18.36 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 94.06 % to 79.14%.

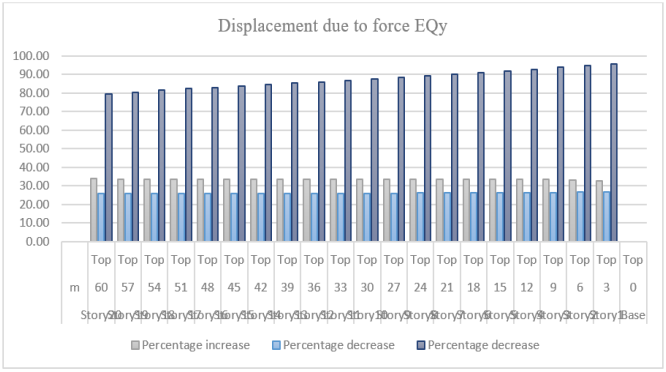
b) The maximum displacement at storey 20 is decreased by 80.44 % (i.e. decrease from 79.009 mm to16.483 mm)

Table 10. Displacement Comparison due to force EQy for Case 1, Case 3, Case 6 and Case 9

Story	Existing building	Deteriorated building	Percentage increase	Retrofitted building	Percentage decrease	Retrofitted building	Percentage decrease
	Y direction (mm)	51.02 % deterioration Y direction (mm)		51.02 % Retrofitted building using jacketing Y direction (mm)		51.02 % Retrofitted building using shear wall Y direction (mm)	
S20	**79.009**	**119.28**	**33.76**	**58.734**	**25.66**	**16.271**	**79.41**
S19	78.01	117.64	33.69	57.985	25.67	15.267	80.43
S18	76.455	115.2	33.63	56.817	25.69	14.249	81.36
S17	74.356	111.97	33.59	55.242	25.71	13.22	82.22
S16	71.761	108.02	33.56	53.295	25.73	12.182	83.02
S15	68.723	103.41	33.55	51.018	25.76	11.14	83.79
S14	65.293	98.235	33.53	48.45	25.80	10.098	84.53
S13	61.518	92.546	33.53	45.625	25.83	9.064	85.27
S12	57.443	86.411	33.52	42.58	25.87	8.043	86.00
S11	53.111	79.891	33.52	39.345	25.92	7.043	86.74
S10	48.559	73.042	33.52	35.95	25.97	6.072	87.50
S9	43.825	65.916	33.51	32.423	26.02	5.139	88.27
S8	38.941	58.563	33.51	28.789	26.07	4.251	89.08
S7	33.937	51.027	33.49	25.071	26.12	3.419	89.93
S6	28.841	43.349	33.47	21.288	26.19	2.651	90.81
S5	23.676	35.567	33.43	17.46	26.25	1.957	91.73
S4	18.464	27.714	33.38	13.602	26.33	1.348	92.70
S3	13.23	19.83	33.28	9.733	26.43	0.833	93.70
S2	8.025	11.999	33.12	5.892	26.58	0.427	94.68
S1	3.096	4.602	32.72	2.266	26.81	0.141	95.45
Base	0	0	0	0	0	0	0



Graph 4.15 Displacement due to force EQy



Graph 4.16 Percentage variation due to Displacement

Observations:

The table 10 and graphs 4.15 and 4.16 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 51.02 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 32.72 % to 33.76 %

b) The maximum displacement at storey 20 is increased by 33.76 % (i.e. increase from 79.009 mm to 119.28 mm)

2) By comparing existing building model to 51.02 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 26.81 % to 25.66 %

b) The maximum displacement at storey 20 is decreased by 25.66 % (i.e. decrease from 79.009 mm to 58.734 mm)

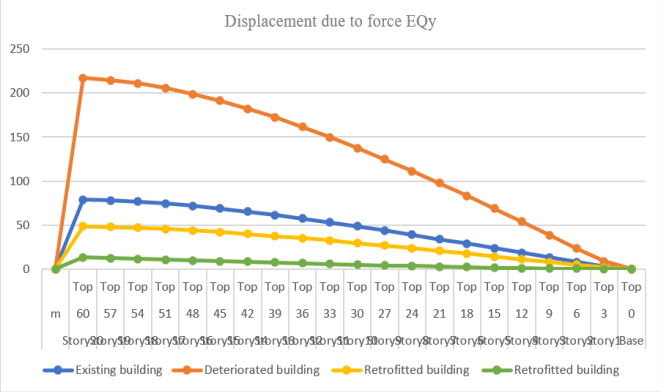
3) By comparing existing building model to 51.02 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 95.45 % to 79.41 %.

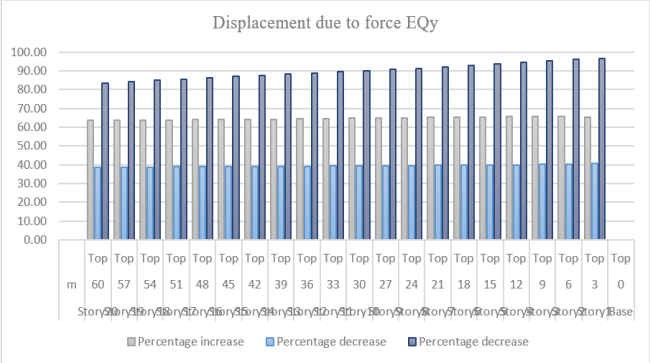
b) The maximum displacement at storey 20 is decreased by 79.41 % (i.e. decrease from 76.66 mm to 16.271 mm)

Table 11. Displacement Comparison due to force EQy for Case 1, Case 4, Case 7 and Case 10

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	Y direction (mm)	100 % deterioration Y direction (mm)	Percentage increase	100 % Retrofitted building using jacketing Y direction (mm)	Percentage decrease	100 % Retrofitted building using shear wall Y direction (mm)	Percentage decrease
S20	**79.009**	**217.03**	**63.60**	**48.422**	**38.71**	**13.238**	**83.24**
S19	78.01	214.69	63.66	47.768	38.77	12.397	84.11
S18	76.455	210.88	63.74	46.775	38.82	11.547	84.90
S17	74.356	205.62	63.84	45.447	38.88	10.691	85.62
S16	71.761	199.01	63.94	43.816	38.94	9.83	86.30
S15	68.723	191.18	64.05	41.916	39.01	8.97	86.95
S14	65.293	182.26	64.18	39.778	39.08	8.112	87.58
S13	61.518	172.34	64.31	37.432	39.15	7.264	88.19
S12	57.443	161.55	64.44	34.907	39.23	6.43	88.81
S11	53.111	149.96	64.58	32.23	39.32	5.615	89.43
S10	48.559	137.68	64.73	29.425	39.40	4.827	90.06
S9	43.825	124.8	64.88	26.515	39.50	4.073	90.71
S8	38.941	111.38	65.04	23.522	39.60	3.358	91.38
S7	33.937	97.492	65.19	20.464	39.70	2.69	92.07
S6	28.841	83.21	65.34	17.359	39.81	2.077	92.80
S5	23.676	68.588	65.48	14.222	39.93	1.526	93.55
S4	18.464	53.678	65.60	11.067	40.06	1.044	94.35
S3	13.23	38.549	65.68	7.909	40.22	0.642	95.15
S2	8.025	23.369	65.66	4.782	40.41	0.326	95.94
S1	3.096	8.94	65.37	1.836	40.70	0.107	96.54
Base	0	0	0	0	0	0	0



Graph 4.17 Displacement due to force EQy



Graph 4.18 Percentage variation due to Displacement

Observations:

The table 11 and graphs 4.17 and 4.18 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 100 % deteriorated building model,

a) It is observed that the displacement from storey 1 to storey 20, is increased by 65.37 % to 63.60 %

b) The maximum displacement at storey 20 is increased by 63.60 % (i.e. increase from 79.009 mm to 217.03 mm)

2) By comparing existing building model to 100 % Retrofitted building model using jacketing

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 40.70 % to 38.71 %,

b) The maximum displacement at storey 20 is decreased by 38.71 % (i.e. decrease from 79.009 mm to 48.422 mm)

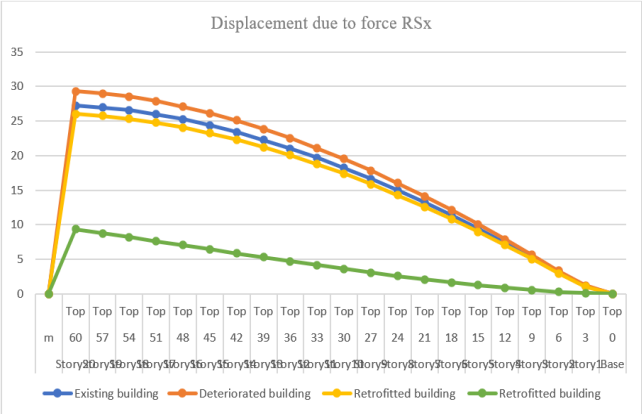
3) By comparing existing building model to 100 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 96.54 % to 83.24 %.

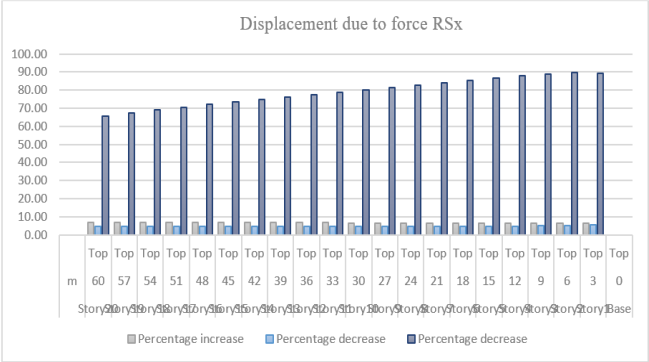
b) The maximum displacement at storey 20 is decreased by 83.24 % (i.e. decrease from 79.009 mm to 13.238 mm)

Table 12. Displacement Comparison due to force RSx for Case 1, Case 2, Case 5 and Case 8

Story	Existing building	Deteriorated building	Percentage increase	Retrofitted building	Percentage decrease	Retrofitted building	Percentage decrease
	X direction (mm)	18.36 % deterioration X direction (mm)		18.36 % Retrofitted building using jacketing X direction (mm)		18.36 % Retrofitted building using shear wall X direction (mm)	
S20	**27.253**	**29.305**	**7.00**	**26.011**	**4.56**	**9.343**	**65.72**
S19	26.973	28.988	6.95	25.744	4.56	8.781	67.45
S18	26.546	28.515	6.91	25.336	4.56	8.209	69.08
S17	25.965	27.878	6.86	24.78	4.56	7.63	70.61
S16	25.239	27.087	6.82	24.085	4.57	7.046	72.08
S15	24.376	26.15	6.78	23.259	4.58	6.461	73.49
S14	23.382	25.073	6.74	22.309	4.59	5.876	74.87
S13	22.263	23.863	6.70	21.239	4.60	5.295	76.22
S12	21.025	22.527	6.67	20.056	4.61	4.722	77.54
S11	19.675	21.072	6.63	18.765	4.63	4.16	78.86
S10	18.216	19.501	6.59	17.371	4.64	3.613	80.17
S9	16.653	17.82	6.55	15.877	4.66	3.085	81.47
S8	14.989	16.032	6.51	14.288	4.68	2.58	82.79
S7	13.23	14.143	6.46	12.609	4.69	2.104	84.10
S6	11.38	12.158	6.40	10.842	4.73	1.661	85.40
S5	9.438	10.078	6.35	8.989	4.76	1.255	86.70
S4	7.405	7.903	6.30	7.048	4.82	0.892	87.95
S3	5.288	5.642	6.27	5.029	4.90	0.579	89.05
S2	3.136	3.346	6.28	2.977	5.07	0.32	89.80
S1	1.134	1.21	6.28	1.074	5.29	0.123	89.15
Base	0	0	0	0	0	0	0



Graph 4.19 Displacement due to force RSx



Graph 4.20 Percentage variation due to Displacement

Observations:

The table 12 and graphs 4.19 and 4.20 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 18.36 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 6.28 % to 7 %

b) The maximum displacement at storey 20 is increased by 7 % (i.e. increase from 27.253 mm to 29.305 mm)

2) By comparing existing building model to 18.36 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 5.29 % to 4.56 %

b) The maximum displacement at storey 20 is decreased by 4.56 % (i.e. decrease from 27.253 mm to 26.011 mm)

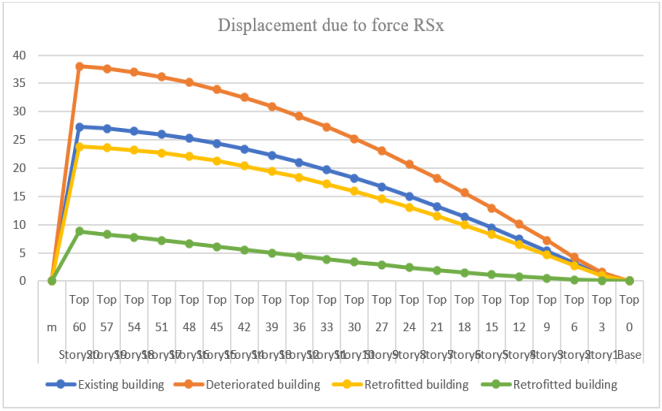
3) By comparing existing building model to 18.36 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 89.15 % to 65.72 %.

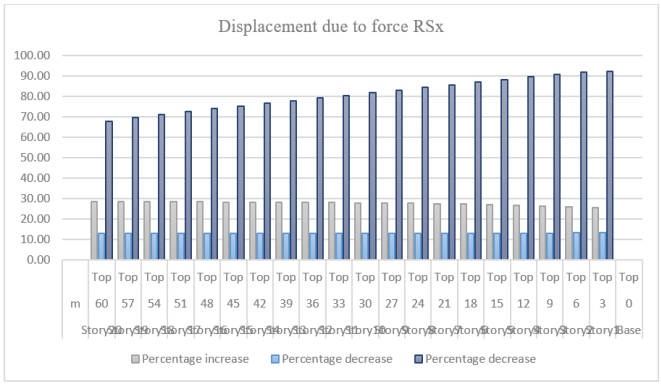
b) The maximum displacement at storey 20 is decreased by 65.72 % (i.e. decrease from 27.253 mm to 9.343 mm)

Table 13. Displacement Comparison due to force RSx for Case 1, Case 3, Case 6 and Case 9

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	X direction (mm)	51.02 % deterioration X direction (mm)	Percentage increase	51.02 % Retrofitted building using jacketing X direction (mm)	Percentage decrease	51.02 % Retrofitted building using shear wall X direction (mm)	Percentage decrease
S20	**27.253**	**38.043**	**28.36**	**23.798**	**12.68**	**8.81**	**67.67**
S19	26.973	37.619	28.30	23.555	12.67	8.27	69.34
S18	26.546	36.999	28.25	23.181	12.68	7.723	70.91
S17	25.965	36.172	28.22	22.671	12.69	7.172	72.38
S16	25.239	35.144	28.18	22.034	12.70	6.616	73.79
S15	24.376	33.924	28.15	21.276	12.72	6.059	75.14
S14	23.382	32.519	28.10	20.405	12.73	5.503	76.46
S13	22.263	30.937	28.04	19.425	12.75	4.951	77.76
S12	21.025	29.188	27.97	18.342	12.76	4.405	79.05
S11	19.675	27.28	27.88	17.161	12.78	3.871	80.33
S10	18.216	25.221	27.77	15.885	12.80	3.35	81.61
S9	16.653	23.017	27.65	14.519	12.81	2.848	82.90
S8	14.989	20.673	27.49	13.067	12.82	2.369	84.20
S7	13.23	18.199	27.30	11.532	12.83	1.918	85.50
S6	11.38	15.605	27.07	9.918	12.85	1.499	86.83
S5	9.438	12.897	26.82	8.223	12.87	1.117	88.16
S4	7.405	10.079	26.53	6.449	12.91	0.778	89.49
S3	5.288	7.167	26.22	4.602	12.97	0.49	90.73
S2	3.136	4.23	25.86	2.726	13.07	0.257	91.80
S1	1.134	1.519	25.35	0.985	13.14	0.09	92.06
Base	0	0	0	0	0	0	0



Graph 4.21 Displacement due to force RSx



Graph 4.22 Percentage variation due to Displacement

Observations:

The table 13 and graphs 4.21 and 4.22 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 51.02 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 25.35 % to 28.36 %

b) The maximum displacement at storey 20 is increased by 28.36 % (i.e. increase from 27.253 mm to 119.28 mm)

2) By comparing existing building model to 51.02 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 13.14 % to 12.68 %

b) The maximum displacement at storey 20 is decreased by 12.68 % (i.e. decrease from 27.253 mm to 23.798 mm)

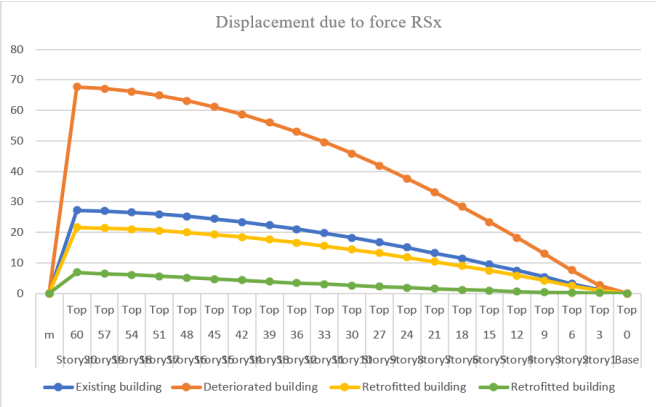
3) By comparing existing building model to 51.02 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 92.06 % to 67.67 %.

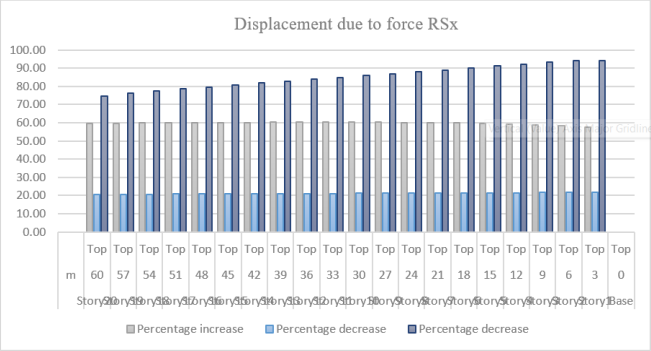
b) The maximum displacement at storey 20 is decreased by 79.41 % (i.e. decrease from 27.253 mm to 8.81 mm)

Table 14. Displacement Comparison due to force RSx for Case 1, Case 4, Case 7 and Case 10

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	X direction (mm)	100 % deterioration X direction (mm)	Percentage increase	100 % Retrofitted building using jacketing X direction (mm)	Percentage decrease	100 % Retrofitted building using shear wall X direction (mm)	Percentage decrease
S20	**27.253**	**67.66**	**59.72**	**21.622**	**20.66**	**6.878**	**74.76**
S19	26.973	67.068	59.78	21.389	20.70	6.446	76.10
S18	26.546	66.137	59.86	21.039	20.75	6.011	77.36
S17	25.965	64.835	59.95	20.565	20.80	5.572	78.54
S16	25.239	63.161	60.04	19.976	20.85	5.131	79.67
S15	24.376	61.124	60.12	19.279	20.91	4.69	80.76
S14	23.382	58.733	60.19	18.48	20.96	4.251	81.82
S13	22.263	55.998	60.24	17.584	21.02	3.815	82.86
S12	21.025	52.932	60.28	16.595	21.07	3.386	83.90
S11	19.675	49.55	60.29	15.518	21.13	2.967	84.92
S10	18.216	45.864	60.28	14.357	21.18	2.56	85.95
S9	16.653	41.886	60.24	13.116	21.24	2.169	86.98
S8	14.989	37.632	60.17	11.799	21.28	1.797	88.01
S7	13.23	33.118	60.05	10.409	21.32	1.449	89.05
S6	11.38	28.365	59.88	8.948	21.37	1.127	90.10
S5	9.438	23.39	59.65	7.415	21.43	0.835	91.15
S4	7.405	18.214	59.34	5.812	21.51	0.579	92.18
S3	5.288	12.884	58.96	4.146	21.60	0.361	93.17
S2	3.136	7.541	58.41	2.456	21.68	0.189	93.97
S1	1.134	2.668	57.50	0.888	21.69	0.065	94.27
Base	0	0	0	0	0	0	0



Graph 4.23 Displacement due to force RSx



Graph 4.24 Percentage variation due to Displacement

Observations:

The table 14 and graphs 4.23 and 4.24 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 100 % deteriorated building model,

a) It is observed that the displacement from storey 1 to storey 20, is increased by 57.50 % to 59.72 %

b) The maximum displacement at storey 20 is increased by 59.72 % (i.e. increase from 27.253 mm to 67.66 mm)

2) By comparing existing building model to 100 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 21.69 % to 20.66 %,

b) The maximum displacement at storey 20 is decreased by 20.66 % (i.e. decrease from 27.253 mm to 21.622 mm)

3) By comparing existing building model to 100 % Retrofitted building model using Shear wall.

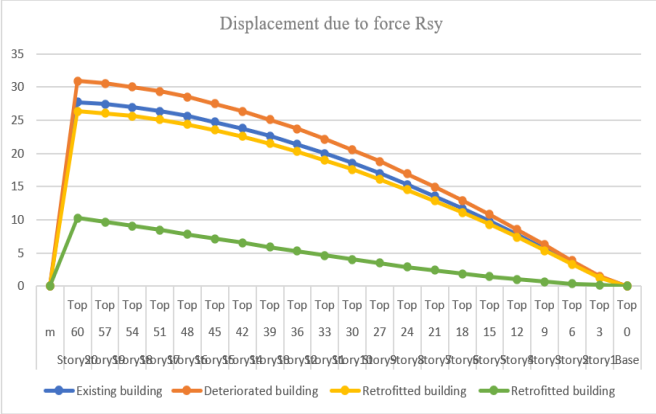
a) It is observed that the displacement from storey 1 to storey 20 is decreased by 94.27 % to

74.76 %.

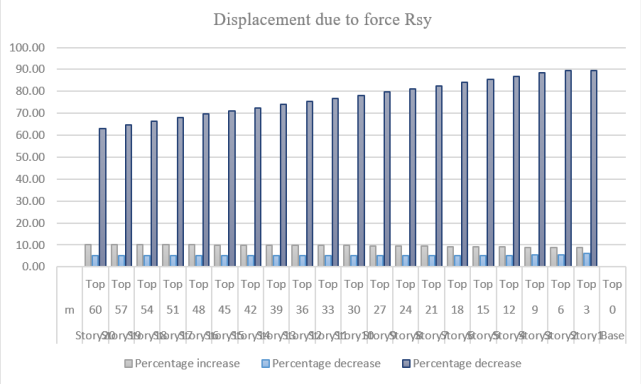
b) The maximum displacement at storey 20 is decreased by 74.76 % (i.e. decrease from 27.253 mm to 6.878 mm)

Table 15. Displacement Comparison due to force RSy for Case 1, Case 2, Case 5 and Case 8

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	Y direction (mm)	18.36 % deterioration Y direction (mm)	Percentage increase	18.36 % Retrofitted building using jacketing Y direction (mm)	Percentage decrease	18.36 % Retrofitted building using shear wall Y direction (mm)	Percentage decrease
S20	**27.709**	**30.882**	**10.27**	**26.325**	**4.99**	**10.282**	**62.89**
S19	27.417	30.531	10.20	26.048	4.99	9.673	64.72
S18	26.969	30.012	10.14	25.622	4.99	9.052	66.44
S17	26.366	29.324	10.09	25.049	5.00	8.424	68.05
S16	25.62	28.477	10.03	24.338	5.00	7.789	69.60
S15	24.738	27.481	9.98	23.499	5.01	7.151	71.09
S14	23.729	26.344	9.93	22.538	5.02	6.513	72.55
S13	22.597	25.071	9.87	21.461	5.03	5.879	73.98
S12	21.35	23.672	9.81	20.274	5.04	5.251	75.41
S11	19.994	22.152	9.74	18.982	5.06	4.635	76.82
S10	18.533	20.517	9.67	17.591	5.08	4.034	78.23
S9	16.969	18.77	9.60	16.103	5.10	3.453	79.65
S8	15.308	16.917	9.51	14.523	5.13	2.896	81.08
S7	13.555	14.962	9.40	12.856	5.16	2.368	82.53
S6	11.712	12.913	9.30	11.104	5.19	1.874	84.00
S5	9.783	10.771	9.17	9.27	5.24	1.421	85.47
S4	7.762	8.536	9.07	7.35	5.31	1.014	86.94
S3	5.651	6.208	8.97	5.345	5.41	0.659	88.34
S2	3.473	3.812	8.89	3.278	5.61	0.365	89.49
S1	1.352	1.484	8.89	1.271	5.99	0.14	89.64
Base	0	0	0	0	0	0	0



Graph 4.25 Displacement due to force Rsy



Graph 4.26 Percentage variation due to Displacement

Observations:

The table 15 and graphs 4.25 and 4.26 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 18.36 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 8.89 % to 10.27 %

b) The maximum displacement at storey 20 is increased by 10.27 % (i.e. increase from 27.709 mm to 30.882 mm)

2) By comparing existing building model to 18.36 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 5.99 % to 4.99 %

b) The maximum displacement at storey 20 is decreased by 4.99 % (i.e. decrease from 27.709 mm to 26.325 mm)

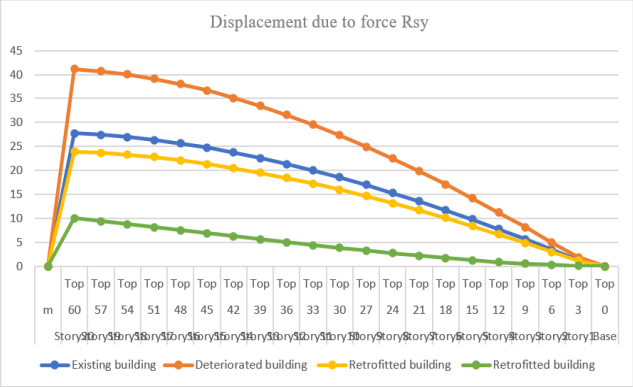
3) By comparing existing building model to 18.36 % Retrofitted building model using Shear wall.

4) It is observed that the displacement from storey 1 to storey 20 is decreased by 89.64 % to 62.89 %.

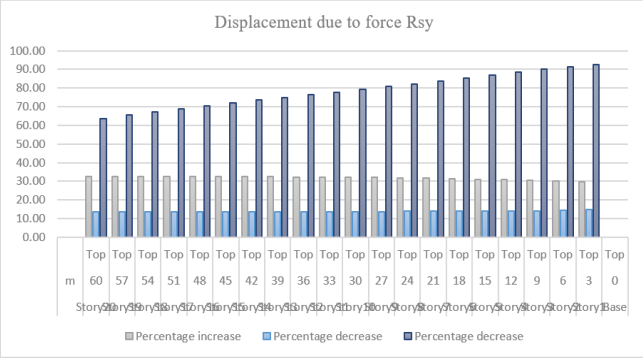
5) The maximum displacement at storey 20 is decreased by 62.89 % (i.e. decrease from 27.709 mm to 10.282 mm)

Table 16. Displacement Comparison due to force RSy for Case 1, Case 3, Case 6 and Case 9

Story	Existing building	Deteriorated building	Percentage increase	Retrofitted building	Percentage decrease	Retrofitted building	Percentage decrease
	Y direction (mm)	51.02 % deterioration Y direction (mm)		51.02 % Retrofitted building using jacketing Y direction (mm)		51.02 % Retrofitted building using shear wall Y direction (mm)	
S20	**27.709**	**41.174**	**32.70**	**23.935**	**13.62**	**10.046**	**63.74**
S19	27.417	40.701	32.64	23.681	13.63	9.431	65.60
S18	26.969	40.013	32.60	23.291	13.64	8.809	67.34
S17	26.366	39.103	32.57	22.765	13.66	8.182	68.97
S16	25.62	37.981	32.55	22.114	13.68	7.55	70.53
S15	24.738	36.657	32.51	21.347	13.71	6.916	72.04
S14	23.729	35.139	32.47	20.47	13.73	6.283	73.52
S13	22.597	33.436	32.42	19.489	13.75	5.655	74.97
S12	21.35	31.558	32.35	18.408	13.78	5.035	76.42
S11	19.994	29.513	32.25	17.232	13.81	4.426	77.86
S10	18.533	27.311	32.14	15.967	13.85	3.834	79.31
S9	16.969	24.957	32.01	14.615	13.87	3.263	80.77
S8	15.308	22.459	31.84	13.18	13.90	2.717	82.25
S7	13.555	19.828	31.64	11.667	13.93	2.201	83.76
S6	11.712	17.073	31.40	10.078	13.95	1.722	85.30
S5	9.783	14.202	31.12	8.413	14.00	1.284	86.88
S4	7.762	11.219	30.81	6.67	14.07	0.895	88.47
S3	5.651	8.129	30.48	4.849	14.19	0.563	90.04
S2	3.473	4.97	30.12	2.973	14.40	0.295	91.51
S1	1.352	1.92	29.58	1.153	14.72	0.101	92.53
Base	0	0	0	0	0	0	0



Graph 4.27 Displacement due to force Rsy



Graph 4.28 Percentage variation due to Displacement

Observations:

The table 16 and graphs 4.27 and 4.28 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 51.02 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 29.58 % to 32.70 %

b) The maximum displacement at storey 20 is increased by 32.70 % (i.e. increase from 27.709 mm to 41.174 mm)

2) By comparing existing building model to 51.02 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 14.72 % to 13.62 %

b) The maximum displacement at storey 20 is decreased by 13.62 % (i.e. decrease from 27.709 mm to 23.935 mm)

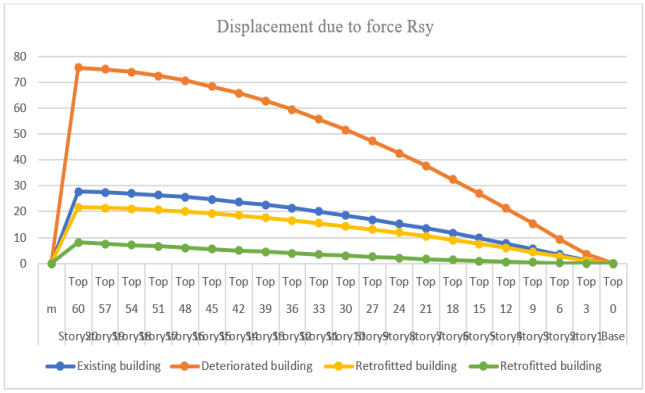
3) By comparing existing building model to 51.02 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 92.53 % to 63.74 %.

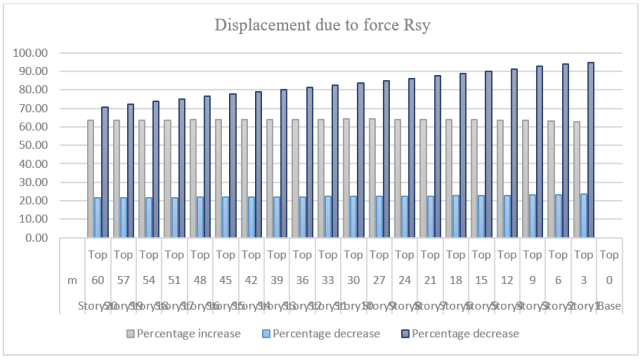
b) The maximum displacement at storey 20 is decreased by 63.74 % (i.e. decrease from 27.709 mm to 10.046 mm)

Table 17. Displacement Comparison due to force RSy for Case 1, Case 4, Case 7 and Case 10

Story	Existing building	Deteriorated building		Retrofitted building		Retrofitted building	
	Y direction (mm)	100 % deterioration Y direction (mm)	Percentage increase	100 % Retrofitted building using jacketing Y direction (mm)	Percentage decrease	100 % Retrofitted building using shear wall Y direction (mm)	Percentage decrease
S20	**27.709**	**75.555**	**63.33**	**21.732**	**21.57**	**8.127**	**70.67**
S19	27.417	74.921	63.41	21.485	21.64	7.615	72.23
S18	26.969	73.893	63.50	21.117	21.70	7.099	73.68
S17	26.366	72.453	63.61	20.626	21.77	6.579	75.05
S16	25.62	70.607	63.71	20.023	21.85	6.057	76.36
S15	24.738	68.366	63.82	19.315	21.92	5.535	77.63
S14	23.729	65.74	63.90	18.509	22.00	5.015	78.87
S13	22.597	62.74	63.98	17.61	22.07	4.5	80.09
S12	21.35	59.38	64.05	16.622	22.15	3.993	81.30
S11	19.994	55.673	64.09	15.549	22.23	3.498	82.50
S10	18.533	51.634	64.11	14.397	22.32	3.017	83.72
S9	16.969	47.276	64.11	13.169	22.39	2.555	84.94
S8	15.308	42.615	64.08	11.868	22.47	2.116	86.18
S7	13.555	37.67	64.02	10.498	22.55	1.704	87.43
S6	11.712	32.46	63.92	9.061	22.63	1.324	88.70
S5	9.783	27.003	63.77	7.557	22.75	0.979	89.99
S4	7.762	21.317	63.59	5.985	22.89	0.676	91.29
S3	5.651	15.425	63.36	4.346	23.09	0.42	92.57
S2	3.473	9.407	63.08	2.662	23.35	0.217	93.75
S1	1.352	3.613	62.58	1.031	23.74	0.073	94.60
Base	0	0	0	0	0	0	0



Graph 4.29 Displacement due to force Rsy



Graph 4.30 Percentage variation due to Displacement

Observations:

The table 17 and graphs 4.29 and 4.30 shows the displacement and percentage variation due to displacement along storey height of building.

1) By comparing existing building model to 100 % deteriorated building model.

a) It is observed that the displacement from storey 1 to storey 20 is increased by 62.58 % to 63.33 %

b) The maximum displacement at storey 20 is increased by 63.33 % (i.e. increase from 27.709 mm to 75.555 mm)

2) By comparing existing building model to 100 % Retrofitted building model using jacketing.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 23.74 % to 21.57 %

b) The maximum displacement at storey 20 is decreased by 21.57 % (i.e. decrease from 27.709 mm to 21.732 mm)

3) By comparing existing building model to 100 % Retrofitted building model using Shear wall.

a) It is observed that the displacement from storey 1 to storey 20 is decreased by 94.60 % to 70.67 %.

b) The maximum displacement at storey 20 is decreased by 70.67 % (i.e. decrease from 27.709 mm to 8.127 mm)

3. CONCLUSIONS:

1) Displacement shows grater results in deteriorated building model considering various percentage deterioration as compared to existing building model without retrofitting and retrofitted building models considering various percentage retrofication.

2) Displacements are decreased in retrofitted building models considering various percentage retrofication compared to deteriorated building structure and existing building structure without retrofitting.

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