Study of Impact between Two Equal & Unequal Height of Building during of Earthquake

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Abstract- *Increasing population and growing social and commercial activities but limited land resources available in a modern city lead to more and more buildings being built closely to each other. These buildings, in most cases, are separated without any structural connections. The ground motion during earthquakes causes' damage to the structure by generating inertial forces caused by the vibration of the buildings masses. From previous studies it was observed that majority researchers did the work on the separation gap between two adjacent structures. Thus, after reviewing the existing literature it was observed that most of literature compares existing & low-rise structure. The project objective is to decrease the effect of earthquake responses on structures. The main objective and scope are to evaluate the effects of structural pounding on the global response of building structures and to determine the minimum seismic gap between equal and unequal but adjacent buildings. In this project using response spectrum analysis we have checked whether two models have displacement within the permissible limit for adjacent buildings as well as to determine & compare the seismic gap provided as per IS 1893-2002 and other codal provisions.*

Keywords- Structural pounding, Adjacent buildings, Seismic separation distance, Response Spectrum, Separation Gap, IS code, Deflection.

I. INTRODUCTION

Increasing population and growing social and commercial activities but limited land resources available in a modern city lead to more and more buildings being built closely to each other. These buildings, in most cases, are separated without any structural connections. Hence, wind-resistant or earthquake resistant capacity of each building mainly depends on itself. The ground motion during earthquakes causes‟ damage to the structure by generating inertial forces caused by the vibration of the buildings masses. Tall structures are extremely vulnerable to the structural damage because the masses at the levels are relatively large, supported by slender columns. The displacement of the upper stories is very large as compared to the lower ones. This includes large shear forces on the base columns. If the separation distances between adjacent buildings are not sufficient, mutual pounding may also occur during an earthquake. During strong earthquakes, adjacent structures that do not have appropriate distance and hit each other, that is called impact. The difference between dynamic properties (mass, hardness and height) of adjacent structures results different-phase oscillations which is the main cause to impact and the more different in shape of vibration causes stronger impact and vice versa. Impact phenomenon has been reported in the strong earthquakes**.**

1.2 SEPARATION GAP

A separation gap is the distance between two different building structures often two wings of the same facility that allows the structures to move independently of one another. Investigations of past and recent earthquake damage have illustrated that the building structures are vulnerable to severe damage and/or collapse during moderate to strong ground motion.

1.3 OBJECTIVES OF STUDY

From literature survey, it was observed that majority researchers did the work on the separation gap between two adjacent structures. Thus, after reviewing the existing literature it was observed that most of literature compares existing & low-rise structure. In this thesis separation gap is determined & compared as per Indian codal provision & other relevant codes. The objective of the thesis is to ensure that the overall building behaviour meets stated performance objectives at serviceability and code design levels. The resulting design provides a level of safety and overall building occupant comfort equivalent to that provided by building code requirements (Indian and in some instances American) as well as good practices for tall buildings.

II. LITERATURE REVIEW

1. Jankowski 2006a.

This paper proposes the idea of impact force response spectrum for two structures; peak pounding force vs. natural periods. Pounding has been simulated by nonlinear viscoelastic model. The structural parameters, such as gap, natural periods, damping, mass and ductility as well as the time lag of input ground motion records, might have a substantial influence

2. Maison, Kasai 1992.

A formulation and solution of the multiple-degree-of-freedom equations of motion for floor-to-floor pounding between two 15-storey and 8-storey buildings are presented. The influence of building separation, relative mass, and contact location properties are assessed

3. Warnotte Viviance (2007)

Adjacent buildings subjected to seismic excitations collide against each other when the separation distance is not large enough accommodate the displacement response of the structures relative to one another

4. Jeng et al (1998) Taipei City, with its high seismicity, soft soil condition, and many tall buildings without proper seismic separation, is vulnerable to seismic pounding destruction similar to that occurred in Mexico City during the 1985 earthquake. Amar M Rahman et al (2000) Collisions between adjacent structures due to insufficient separation gaps have been witnessed in almost every major earthquake since the 1960's.

III. STRUCTURAL MODELING AND ANALYSIS

In order to evaluate the Seismic separation gap between buildings with rigid floor diaphragms using dynamic and P-Delta analysis procedures five case studies are adopted. Various methods of differing complexity have been developed for the seismic analysis of structures. The three main techniques currently used for this analysis are:

1. Dynamic analysis.

- Linear Dynamic Analysis.
- Non-Linear Dynamic Analysis.

2. P-Δ (Delta) Analysis.

3.1 Brief Description of the Structure

No. Of Case	Configuration	Base dimension		Height (From Base)	Aspect Ratio (Ht./ Width)
		LX	Ly		
Model-Case-1	S + 30 floors	32.4 m.	29.0 m.	91.20m	3.144
Model-Case- 2	S + 25 floors	32.4 m.	29.0 m.	76.7m	2.64

The floor heights for various floors are as follows:

- Stilt floor: 4.2 m
- Typical floor: 2.9 m

The dimension of columns & beams for various floors are as follows:

- Typical Columns: 600 X 600
- Typical Beams: 230 X 600

The shear wall thicknesses for various floors are as follows:

- Typical floor: 230 mm
- Podium: 300 mm
- Stilt: 350 mm

3.2Seismic Design Parameters- *(As per IS 1893-(part 1)2002)*

Sr. no.	Parameter	Description	Reference
1.	Analysis	Dynamic Analysis (Response Spectrum Method)	
2.	Seismic Zone	Mumbai - III	**Fig-1: I.S1893 (Part 1) : 2002)**
3.	Zone factor: Z	0.16	**Table-2 : I.S1893 (Part 1) : 2002)**
4.	Importance factor : I	1	**Table-6: I.S 1893 (Part 1) : 2002**
5.	Soil Type	I	
6.	Response Reduction Factor : R	4 **Ductile shear walls** are those	**Table-7 : I.S1893 -2002 Clause -6.4.2 ,**

		designed and detailed as per IS 13920	**sr.no- 7 (Part 1) : 2002)**
7.	Seismic resisting structural system	Ductile shear walls	

3.3 Wind Design Parameters-*(As per IS875-part 3)*

Sr.	Parameter	Description	Reference
1.	Basic Wind Speed	44m/sec (	**Appendix A, I.S 875 (Part 3): 1987)**
2.	Probability factor K1	1.0	**Table-1, I.S**
3.	Terrain Factor : k2	0.24 to 0.67 (Category - 3)-Class-C	**Table-33, I. S**
4.	Topography Factor k3	1.0	**Clause 5.3.3, I.S 875 (Part 3): 1987**

IV. RESULT AND DISCUSSION

4.1 Seismic Weight of the Building

The Seismic Weight of the whole building is the sum of the seismic weights of all the floors. The seismic weight of each floor is its full dead load plus appropriate amount of imposed load. While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey.

Seismic weight of Case-1*: W = (DL +0.25 LL)*

W = 277074.36 kN

Seismic weight of Case-2: *W = (DL +0.25 LL)*

W = 236122.08Kn

4.2 Fundamental Natural Period for *Case*-1 model

As per clause 7.6.1 of IS 1893 (part 1) 2002 the fundamental time period of vibration (Ta) is,

Along x-direction :

$$Tx = \frac{0.09 \text{ x } H}{\sqrt{dx}}$$

$$Tx = \frac{0.09 \text{ x } 91.2}{\sqrt{32.4}}$$

$$Tx = 1.44 \text{ sec}$$

Along y-direction :

$$Ty = \frac{0.09 \text{ x } H}{\sqrt{dy}}$$

$$Ty = \frac{0.09 \text{ x } 91.2}{\sqrt{29}}$$

$$Ty = 1.52 \text{ sec}$$

From the response spectrum graph Average response acceleration coefficient

(Sa/g) is found to be 1.4183.

Along x-direction :

$$Ahx = \frac{Z \text{ x } I \text{ x } Sa}{2 \text{ x } R \text{ x } g}$$

$$Ahx = \frac{0.16 \text{ x } 1 \text{ x } Sa}{2 \text{ x } 4 \text{ x } g}$$

Ahx =0.0139

Along y-direction :

$$Ahx = \frac{Z \text{ x } I \text{ x } Sa}{2 \text{ x } R \text{ x } g}$$

$$Ahx = \frac{0.16 \text{ x } 1 \text{ x } Sa}{2 \text{ x } 4 \text{ x } g}$$

Ahx =0.0132

Design Base Shear (Vb)

Along x-direction :

$$V_{bx} = \text{Ahx X W}$$

V_{bx} =0.0139 x 277074.36

Vbx =3848.25 kN

Along y -direction :

$$V_{by} = \text{Ahy X W}$$

V_{by} =0.0132 x 277074.36

Vby =3645.72 kN

Vby =3645.72 kN

4.3 Fundamental Natural Period for *Case*-2 model

As per clause 7.6.1 of IS 1893 (part 1) 2002 the fundamental time period of vibration (Ta) is, *Along x-direction :*

$$Tx = \frac{0.09 \times H}{\sqrt{dx}}$$

$$Tx = \frac{0.09 \times 76.7}{\sqrt{32.4}}$$

$$Tx = 1.21 \text{ sec}$$

Along y-direction :

$$Ty = \frac{0.09 \times H}{\sqrt{dy}}$$

$$Ty = \frac{0.09 \times 76.7}{\sqrt{29}}$$

$$Ty = 1.28 \text{ sec}$$

$$Ahx = \frac{Z \times I \times Sa}{2 \times R \times g}$$

$$Ahx = \frac{0.16 \times 1 \times Sa}{2 \times 4 \times g}$$

Ahx =0.0165

Along y-direction :

$$Ahx = \frac{Z \times I \times Sa}{2 \times R \times g}$$

$$Ahx = \frac{0.16 \times 1 \times Sa}{2 \times 4 \times g}$$

Ahx =0.0169

Design Base Shear (Vb)

Along x-direction :

$$Vbx = Ahx \text{ X } W$$

Vbx =0.0165 x 236122.08

Vbx =3902.84 kN

Along y -direction :

$$Vby = Ahy \text{ X } W$$

Vby =0.0169 x 236122.08

Vby =3808.42 kN

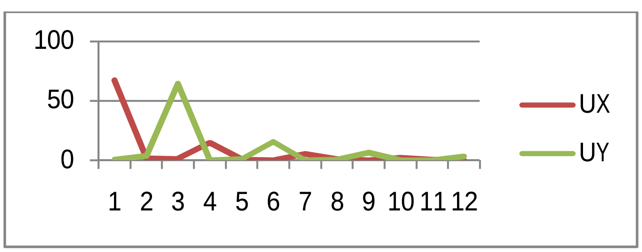

Fig 4.1: Mass Participation Ratio vs. Mode for model Case-1

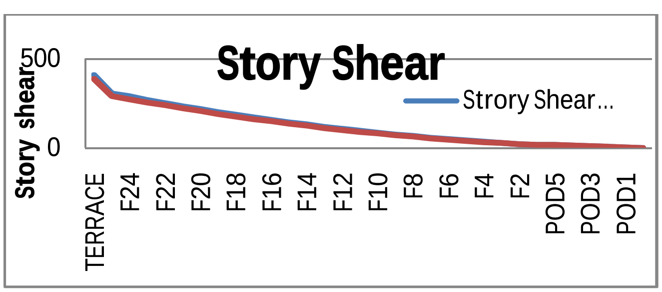

Fig 4.2.: Seismic Story shear –Story shear vs. story for model Case-1

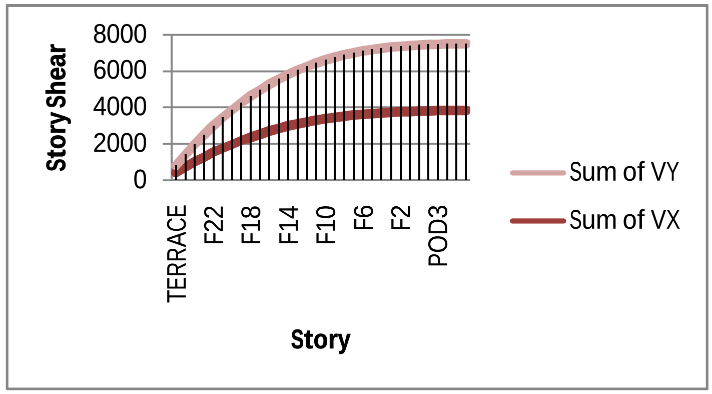

Fig 4.3: Seismic Base shear –Story shear vs story for model Case-1

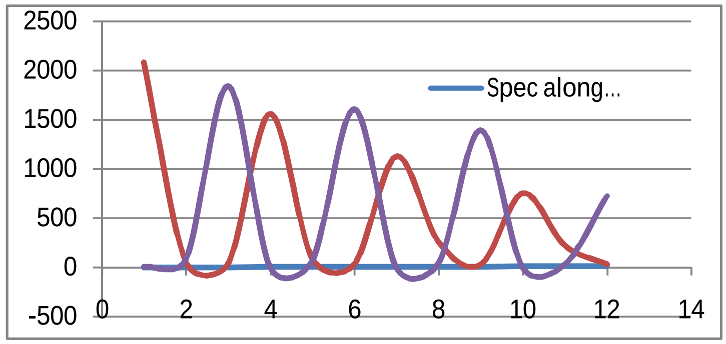

Fig4..4: Response Spectrum Reaction vs mode shape (x & y-Direction)

4.4 Seismic Displacement

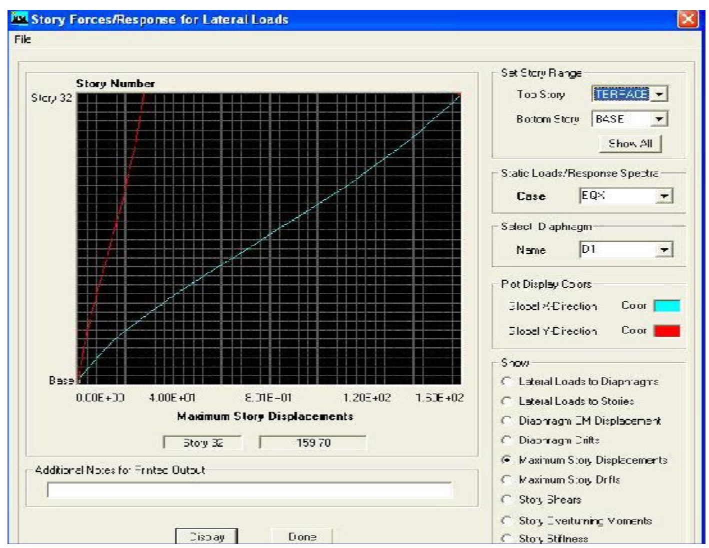

Fig.4.5 Seismic Displacement-Maximum Story Displacements along EX-Direction.

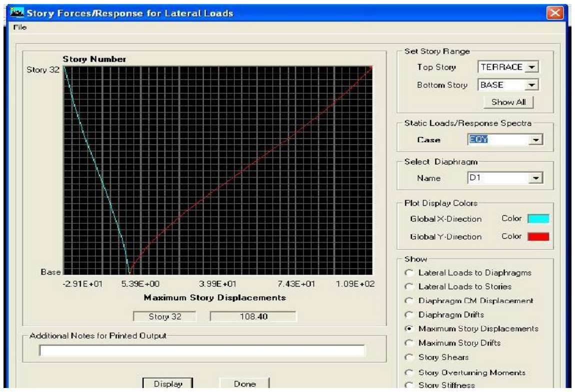

Fig.4.6 Seismic Displacement- Maximum Story Displacements along EQ Y- Direction.

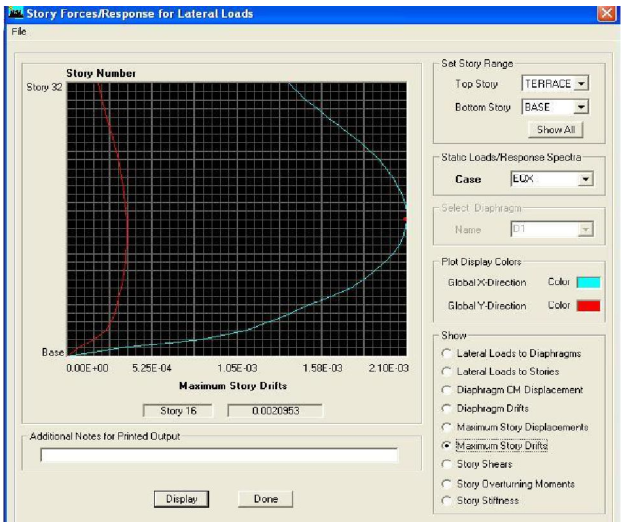

Fig 4.7 Seismic Displacements - Maximum Story Drift along EQ X- Direction.

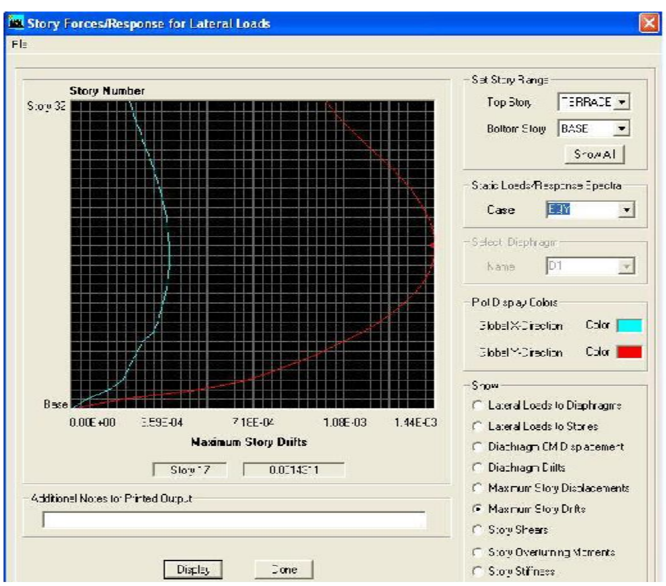

Fig 4.8 Seismic Displacement - Maximum Story Drift along EQ Y-Direction.

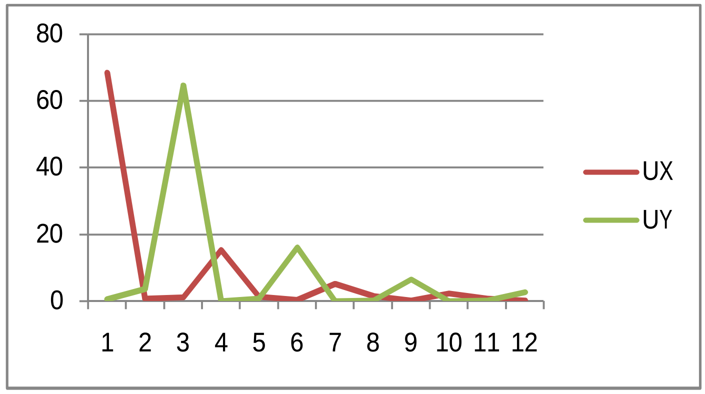

Fig4.9 Mass Participation Ratio vs Mode for model Case-2

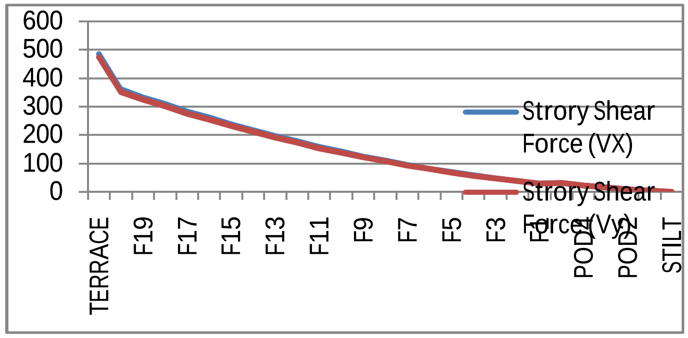

Fig 4.10 Seismic Story shear –Story shear vs story for model Case-2

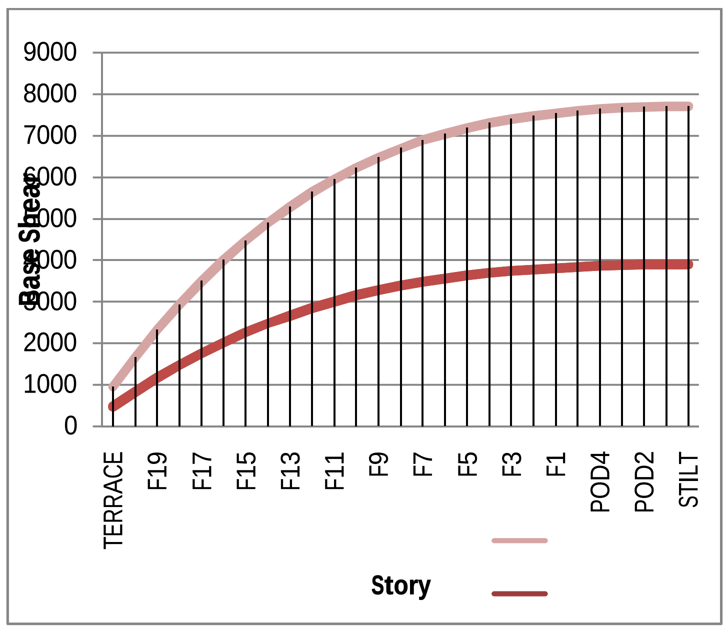

Fig 4.11: Seismic Base shear –Story shear vs story for model Case2-2

4.5 ANALYSIS RESULT OF MODEL (*Case-2*)

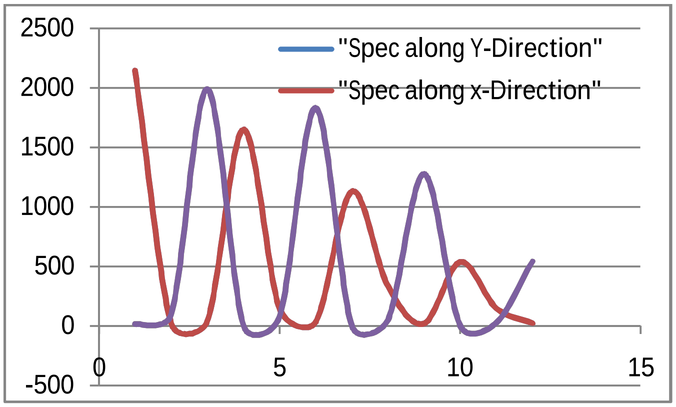

Fig 4.12 Response Spectrum Reaction vs mode shape (x & y-Direction)

4.6 Displacement-case 2

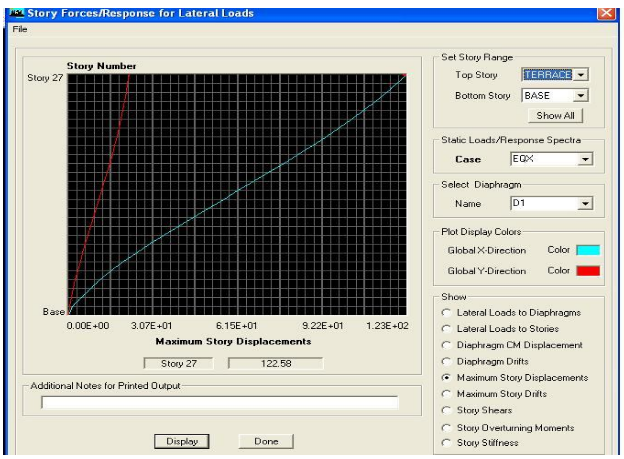

Fig 4.13–Maximum Story Displacements along EQ X-Direction (Case-2 Unequal Equal Height)

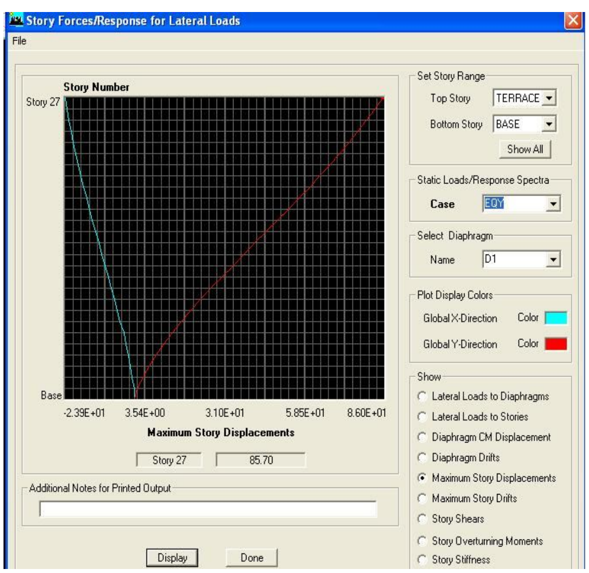

Fig 4.14–Maximum Story Displacements along EQ Y-Direction (Case-2 Unequal Equal Height)

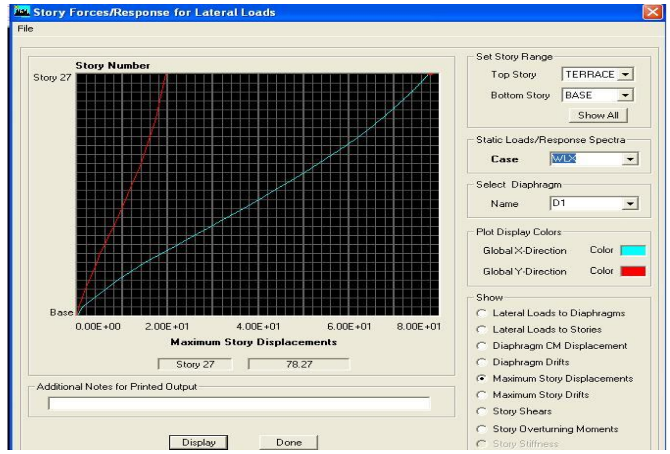

Fig 4.15 –Maximum Story Displacements along WL X-Direction (Case-2 Unequal Equal Height)

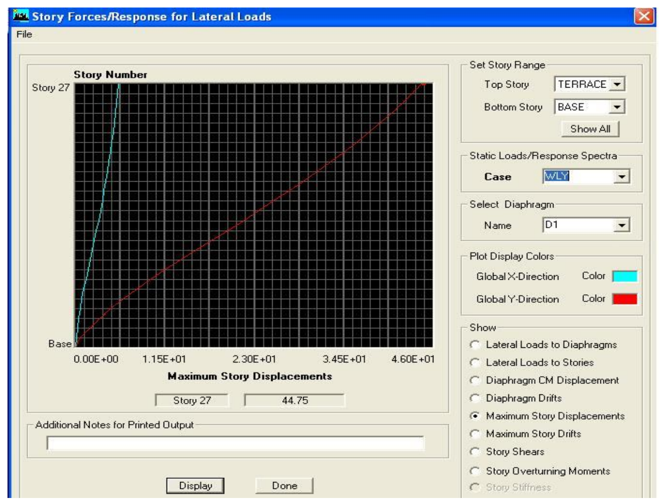

Fig 4.16–Maximum Story Displacements along WL Y-Direction (Case-2 Unequal Equal Height)

4.7 DEFLECTION

Model –M1 Equal Height

S+30			S+30		
	Max. Deflection(mm)	Permissible Limit		Max. Deflection(mm)	Permissible Limit
EQX	156.7939	364.8	EQX	156.7939	364.8
EQY	105.7987	364.8	EQY	105.7987	364.8
WLX	155.2225	182.4	WLX	155.2225	182.4
WLY	68.691	182.4	WLY	68.691	182.4

Model -M2 Unequal Height

Model -M2 Unequal Height

S+25			S+30		
	Max. Deflection(mm)	Permissible Limit		Max. Deflection(mm)	Permissible Limit
EQX	120.1265	306.8	EQX	156.7939	364.8
EQY	82.9824	306.8	EQY	105.7987	364.8
WLX	77.6978	153.4	WLX	155.2225	182.4
WLY	44.559	153.4	WLY	68.691	182.4

4.8 SEPARATION GAP

	Model –M1 Equal Height G+30			
	IS1893-2000	IS4326-1993	FEMA-273(1997)	IBC-ASCE1997
EQX	627.17	547.2	221.74	313.5878
EQY	423.19	547.2	149.62	211.5878
	Model -M2 Unequal Height G+25&G+30			
	IS1893-2000	IS4326-1993	FEMA-273(1997)	IBC-ASCE1997
EQX	1107.6816	503.7	197.5214	313.5878
EQY	755.1252	503.7	134.4598	211.5878

Table 4.1: Separation distances from codes G+30 Equal Building

Code	Deflection EQX 156.7939	Deflection EQY 105.7987
Canada	313.5878	211.5974
Egypt	627.1756 OR 364.8	423.1948 OR 3364.8
Ethiopia	627.1756	423.1948
India	627.1756	423.1948
Peru	209.058 OR 365.8	141.049 OR 365.8

Code	Deflection EQX 25 - 120.1265 EQX 30 - 156.7939	Deflection EQY25 - 82.9824 EQY30 - 105.7939
Canada	276.9204	188.7763
Egypt	553.839	377.5526
Ethiopia	553.839	377.5526
India	1107.6816	755.1052
Peru	184.6136	125.8508

Table 7.2: Separation distances from codes G+25 & G+30 Unequal Building

V. CONCLUSION

1. In general when the separation distance between the two structures decreases, the amount of impact is increases, which is not in all cases.
2. Among all the codal provisions, the calculated separation distance is less for FEMA: 273-1997 and PeruE030-2003. Because the clauses for these codes depends on height of the structure.
3. Equal height required less separation gap, Unequal height required more separation gap
4. Existing adjacent buildings which are not properly separated from each other can be protected from effects of pounding by placing elastic materials between them.
5. The pounding effect can be decreased with increasing separation distance.
6. The pounding forces are also decreasing gradually between two adjacent buildings by introducing shear walls at suitable locations

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