[Farrukhanwar, 3(10): October 2016]
DOI- 10.5281/zenodo.163598

ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

SEISMIC ANALYSIS OF HIGH RISE BUILDING RESTING ON A SLOPING GROUND

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ABSTRACT

In some parts of world, hilly area is more prone to seismic activity; e.g. northeast region of India. A scarcity of plain ground in hilly area compels the construction activity on sloping ground. Hill buildings constructed in masonry with mud mortar/cement mortar without conforming to seismic codal provisions have proved unsafe and, resulted in loss of life and property when subjected to earthquake ground motions. The economic growth and rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Therefore, there is popular and pressing demand for the construction of multistory buildings on hill slope in and around the country. The buildings on a sloping terrain undergo severe torsion under earthquake excitations due to considerable variation in the height of ground floor columns. Buildings constructed on hill slopes are highly unsymmetrical in nature.The building considered for analysis is an eight storey RC framed building. It is in zone IV and is on sloping grounds ranging from 0° and 10°. Hence there will be geometrical and vertical irregularity in a building.

Keywords- *Seismic Analysis, Building, Sloping ground etc.*

I. INTRODUCTION

On the earth surface, everyone is aware that many natural disasters such as earthquakes, floods, tornadoes, hurricanes, droughts, and volcanic eruptions occur of all natural disasters the least understood and most destructive are earthquakes. The annual losses due to earthquakes are very large in many parts of the world. They not only cause great destruction in terms of human casualties, but also have a tremendous economic impact on the affected area. Although the incidents of earthquakes of destructive intensity have been confined to a relatively few areas of the world, the catastrophic consequences of the few that have struck near centers of population have stressed on the need to provide adequate safety against this most terrible nature's quirks.

Regularity

Regular building configurations are almost symmetrical (in plan and elevation) about the axis and have uniform distribution of the lateral force-resisting structure such that it provides a continuous path for both gravity and lateral loads.

Planning the building and structures in simple rectangular plan perform well in an earthquake than shapes with unduly long dimensions (Figure 10) Buildings which are too long in plan may be subjected to different earthquake movements simultaneously at the two ends, leading to disastrous results

Irregularities

Decisions made at the planning stage on building configuration are more important or are known to have made greater difference, than accurate determination of code specified design forces. The shape and proportions of the building have a major effect on the distribution of earthquake forces as they work their way through the building. Earthquake resistant design of reinforced concrete buildings is a continuing area of research. Geometric configurations, type of structural members, details of connections, and materials of construction all have a profound effect on the structural-dynamic response of a building. In spite of all the weaknesses in the structure, either code imperfections or error in analysis and design, the structural configuration system has played a vital role in catastrophe.

The IS-1893 (Part-l):2002 has recommended building configuration system in Section 7 for the better performance of RC buildings during earthquakes. The building configuration has been described as regular or irregular in terms of size and shape of the building, arrangement of structural elements and mass. These irregularities may cause interruption of force flow and stress concentrations. Asymmetrical arrangements of mass and stiffness of elements may cause a large torsional force (where the Centre of mass does not coincide with the Centre of rigidity).The Section-7 of **IS-1893 (Part I): 2002** categorized these irregularities in two types.

(i) Vertical irregularities referring to sudden change of strength, stiffness.
(ii) Geometry and mass results in irregular distribution of forces and/or deformation over the height of building.
(iii) Horizontal irregularities which refer to asymmetrical plan shapes (e.g. L,T,U,F) or discontinuities in horizontal resisting elements (diaphragm) such as cut outs, large openings, re-entrant corners and other abrupt changes resulting in torsion, diaphragm deformations and stress concentration.

Vertical irregularities

(a) Vertical discontinuities in load path:-

One of the major contributors to structural damage during strong earthquake is the discontinuities irregularities in the load path or load transfer. The structure should contain a continuous load path for transfer of the seismic force which develops due to accelerations of individual elements, to the ground failure is to provide adequate strength and toughness of individual elements in the system, failure to tie individual elements together can result in distress or complete collapse of the system. Therefore, all the structural and non-structural elements must be adequately tied to the structural system. The load path must be complete and sufficiently strong.

The examples of load path irregularities are discontinuous columns, shear walls, bracing, frames, that arise a floating box type situation. For example, the absence of some vertical structural elements in one storey of a building can lead to a dangerous concentration of ductility demand (that is, a column side sway mechanism) in the' remaining elements of that storey. Vertical irregularities in the bottom storey make the beams and columns more susceptible to damage or failure.

Irregularities in Strength and Stiffness:

A "weak" storey is defined as one in which the storey's lateral strength is less than 80 percent of that in the storey above. The storey's lateral strength is the total strength of all seismic resisting elements sharing the storey shear for the direction under consideration. The deficiency that usually makes a storey weak is inadequate strength of frame columns. A "soft storey is one in which the lateral stiffness is less than 70% of that in the storey immediately above, or less than 80% of the combined stiffness of the three stories above". The essential characteristic of a "weak" or "soft" storey consists of a discontinuity of strength or stiffness, which occurs at the second storey connections. This discontinuity is caused by lesser strength, or increased flexibility, the structure results in extreme deflections in the first storey of the structure, which in turn results on concentration of forces at the second storey connections.

(b) Mass Irregularities:

Mass irregularities are considered to exist where the effective mass of any storey is more than 200% of the effective mass of an adjacent storey. The effective mass is the real mass consisting of the dead weight of the floor plus the actual weight of partition and equipment. Excess mass can lead to increase in lateral inertial forces, reduced ductility of vertical load resisting elements, and increased tendency towards collapse due to P-Δ effect.

(c) Vertical Geometric Irregularity:

A vertical setback is a geometric irregularity in a vertical plane. It is considered, when the horizontal dimension of the lateral force resisting system in any storey is more than 150% of that in its adjacent storey.

(d) Proximity of Adjacent Building:

When two buildings are too close to each other, they may pound on each other resulting in strong shaking, Pounding may result in irregular response of adjacent buildings of different heights due to different dynamic characteristics. When the two adjacent units hit each other due to lateral displacement, it is known as pounding this problem arises when buildings are built without separations, right up to property lines order to make maximum use of the space. When floors of these buildings are constructed at the same height, damage due to pounding usually is not serious. With increase in building height, this collision can be a great problem. When building heights do not match, the roof of the shorter building may pound at the mid-height column of the taller one, this can be very dangerous.

(e) Torsion irregularities:

Torsional irregularity has to be considered when diaphragms are not flexible. Torsional irregularity shall be considered to exist when the maximum storey drift computed with design eccentricity, at one end of the structure transverse to an axis is more than 1.2 times the average of the storey drifts at the second end of the structure. The lateral force resisting elements should be a well-balanced system that is not subjected to significant torsion. Significant torsion will be taken as the condition where the distance between the storey's Centre of rigidity and storey's Centre of mass is greater than 20% of the width of the structure in either major plan dimension. Torsion or excessive lateral deflection is generated in asymmetrical buildings, or eccentric and asymmetrical layout of the bracing system that may result in permanent set or even partial collapse. Torsion is most effectively resisted at point farthest away from the Centre of twist, such as the corners and perimeter of the buildings.

(f) Non-Parallel Systems:

The vertical lateral-load resisting elements are not parallel to or symmetrical about the major orthogonal axes or the lateral force resisting elements. Architects often face these situations. This condition results in a high probability of torsional forces under a ground motion, because the centre of mass and resistance does not coincide. The narrower portion of the building will tend to be more flexible than the wider ones, which will increase the tendency of torsion

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(g) Diaphragm Discontinuity:

The diaphragm is a horizontal resistance element that transfers forces between vertical resistance elements. The diaphragm discontinuity may occur with 'abruptions in stiffness, including those having cut-out or open areas greater than 50% of gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50% from one storey to the next storey. The diaphragm act as a horizontal beam, and its edge acts as flanges. The opening cut in tension flange of a beam will seriously weaken its load carrying capacity.

II. RESPONSE SPECTRUM ANALYSIS

This method is also known as modal method or mode superposition method. It is based on the idea that the response of a building is the superposition of the responses of individual modes of vibration, each mode responding with its own particular deformed shape, its own frequency, and with its own modal damping.

According to **IS-1893(Part-l):2002,** high rise and irregular buildings must be analyzed by response spectrum method using design spectra. There are significant computational advantages using response spectra method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves only the calculation of the maximum values of the displacements and member forces in each mode using smooth spectra that are the average of several earthquake motions. Sufficient modes to capture such that at least 90% of the participating mass of the building (in each of two orthogonal principle horizontal directions) have to be considered for the analysis. The analysis is performed to determine the base shear for each mode using given building characteristics and ground motion spectra. And then the storey forces, accelerations, and displacements are calculated for each mode, and are combined statistically using the SRSS combination. However, in this method, the design base shear (V_B) shall be compared with a base shear (V_b) calculated using a fundamental period T. If V_B is less than V_b, all response quantities are (for example member forces, displacements, storey forces, storey shears and base reactions) multiplied by $\mathbf{V_B / V_b}$

III. BUILDING CONFIGURATION

In the present study, three groups of building (i.e. configurations) are considered, out of which first one is on the plain ground and the two are resting on ground of (7^{O}of slope).

- **Setback buildings.**
- **Step back buildings.**
- **Setback -Step back buildings.**

The slope of ground is **10^{o}** degree with horizontal, which is neither too steep or nor too flat. The height and length of building in a particular pattern are in multiple of blocks (in vertical and horizontal direction) the size of block is being maintained at 5 m x 5 m x 4 m. The depth of footing below ground level is taken as 1.5m, where the hard stratum is available.

Description of Building

The structure chosen for study is an Eight storey building. The building is located in seismic zone II on a Rock and Hard soil site. Three dimensional mathematical models for the same are generated in ETABS software. For all structural elements, M25 grade of concrete was used. However M35 grade of concrete is used for central columns up to plinth, in ground floor and first floor. The floor diaphragms are assumed to be rigid. Seismic loads were considered acting in the horizontal direction along either of the two principal directions and not along the vertical direction, since it is not considered to be significant.

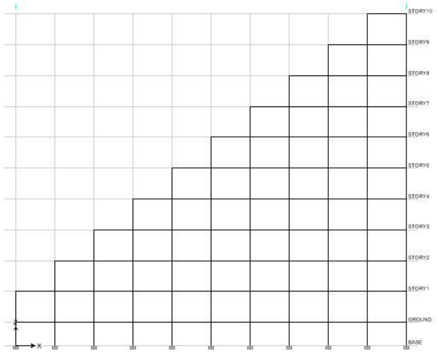
Basic Data

Structure : Symmetric Regular Building
Plan Dimension : 40 x 40 m
Height of Typical Floor : 4 m
Ground Floor Height : 4m
Floors : 8 to 10 floor
Dimension of Column : 300 x 600 mm
Dimension of Beam : 230 x 500 mm
Slab Thickness : 150 mm
Walls : 230 mm thick brick masonry wall on
Support : fixed
Type of Soil : Type II, Medium Soil As Per IS: 1893
Zone : IV

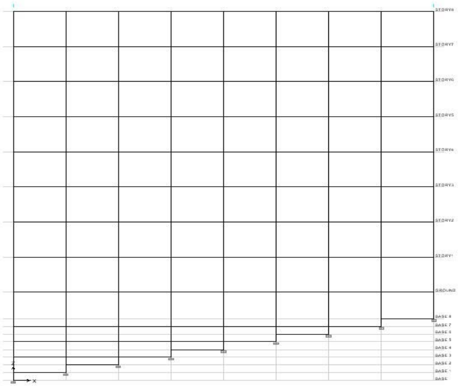
Loads

Live Load on Typical Floor : 4.0 KN/M^{2}
Live Load on Terrace : 1.5 KN/M^{2}
Floor Finishes : 1.0 KN/M^{2}

SET BACK BUILDINGS WITH 0^0 - 10^0SLOPE



STEP BACK BUILDINGS WITH 0^0 - 10^0SLOPE



Set & Step Back Buildings With 0^0 - 10^0slope

4.3.2 Calculation Of Seismic Base Shear, V_b (Static) For Setback Building

S.NO	DESCRIPTION		VAULE	UNIT	REFER CODE
1	Seismic Zone of the building	=	IV		IS:1893(Part I)-2002 - Annexe – E
2	Building system	=	OMRF (Ordinary Moment Resisting Frame)		
3	Soil type	=	Medium soil site		
4	Height of the Building, h	=	36.000	M	
5	Weight of Structure, W	=	48322.00	KN	
6	Zonal Factor, Z	=	0.24		IS:1893(Part I)-2002 Table-2 Pg-16
					Seismic Intensity – Low
7	Importance Factor, I	=	1.00		IS:1893(Part I)-2002 Table-6 Pg-18
					Cl.6.4.2 (All other Buildings)
8	Response Reduction Factor, R	=	5.00		IS:1893(Part I)-2002 Table-7 Pg-23
				Ordinary RC-Moment Resisting Frame (OMRF)	
9	Fundamental Natural Period, Ta	=	1.17	0.075h0.75	IS:1893(Part I)-2002 Cl.7.6.1
10	Average Response Acceleration Co-efficient, Sa/g	=	1.12	Sec	
11	Design Horiz.Seis.Co-eff, Ah	=	0.040		IS:1893(Part I)-2002 Cl.6.4.2
12	Design Seismic Base Shear, Vb	=	1948.34	KN	IS:1893(Part I)-2002

4.4.2 calculation of sesmic base shear, vb (static) for step back building

S.NO	DESCRIPTION		VAULE	UNIT	REFER CODE
1	Seismic Zone of the building	=	IV		IS:1893(Part I)-2002 - Annex – E
2	Building system	=	OMRF (Ordinary Moment Resisting Frame)		
3	Soil type	=	Medium soil site		

ISSN 2348 – 8034
Impact Factor- 4.022

4	Height of the Building, h	=	39.000	M	
5	Weight of Structure, W	=	48322.00	KN	
6	Zone Factor, Z	=	0.24		S:1893(Part I)-2002 Table-2 Pg-16
					Seismic Intensity – Low
7	Importance Factor, I	=	1.00		S:1893(Part I)-2002 Table-6 Pg-18
					Cl.6.4.2 (All other Buildings)
8	Response Reduction Factor, R	=	5.00		S:1893(Part I)-2002 Table-7 Pg-23
				Ordinary RC-Moment Resisting Frame (OMRF)	
9	Fundamental Natural Period, Ta	=	1.17	).075h0.75	IS:1893(Part I)-2002 Cl.7.6.1
10	Average Response Acceleration Co-efficient, Sa/g	=	1.12	Sec	
11	Design Horiz.Seis.Co-eff, Ah	=	0.040		IS:1893(Part I)-2002 Cl.6.4.2
12	Design Seismic Base Shear, Vb	=	1911.57	KN	IS:1893(Part I)-2002

Table 5.1Comparison of lateral load distribution with storey height by linear static method & response spectrum method (empirical method)
SET BACK (STOREY 8)

STOREY LEVEL	STOREY NO	LATERAL FORCES BY LINEAR STATIC METHOD(KN)	LATERAL FORCES BY RESPONSE SPECTRUM METHOD(KN)
Eighth	8	93.4	33.87
Seventh	7	120.4	89.63
Sixth	6	291.2	159.21
Fifth	5	527.4	232.58
Fourth	4	817.8	302.93
Third	3	1141.4	363.62
Second	2	1467.0	410.07
First	1	1753.0	440.25
Ground	Ground	1948.3	443.61

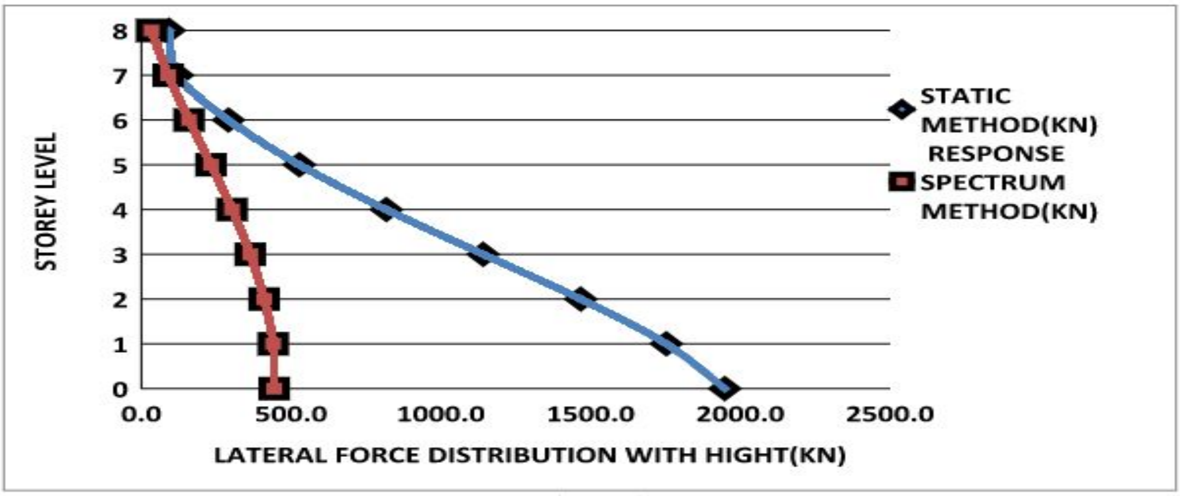


Figure 5.1

From the table 5.1 and figure 5.1 it is noticed that there is considerable difference in the lateral loaded distribution with the building height using linear static method and response spectrum method and therein lies the advantage of dynamic analysis compared to linear static method.

Table 5.2Comparison of lateral load distribution with storey height by linear static method & response spectrum method (empirical method)

STOREY LEVEL	STOREY NO	LATERAL LOADS BY LINEAR STATIC METHOD(KN)	LATERAL LOAD BY RESPONSE SPECTRUM METHOD(KN)
Eighth	8	85.3	33.87
Seventh	7	120.4	89.63
Sixth	6	291.2	159.21
Fifth	5	527.4	232.58
Fourth	4	817.8	302.93
Third	3	1141.4	363.62
Second	2	1467.0	410.07
First	1	1753.0	440.25
Ground	Ground	1948.3	443.61

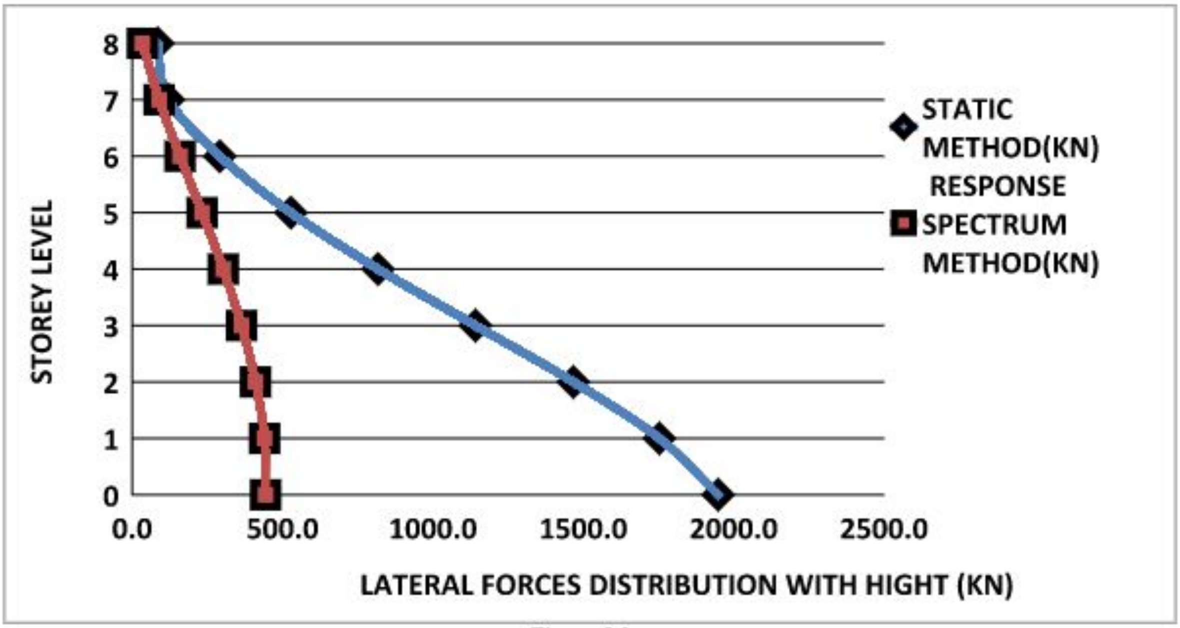


Figure 5.2

From the table 5.1 and figure 5.2 it is noticed that there is considerable difference in the lateral loaded distribution with the building height using linear static method and response spectrum method and therein lies the advantage of dynamic analysis compared to linear static method.

Comparison of lateral load distribution with storey height by linear static method & response spectrum method (empirical method)
SET & STEP BACK (STOREY 8)

STOREY LEVEL	STOREY NO	ATERAL LOADS BY LINEAR STATIC METHOD(KN)	LATERAL LOAD BY RESPONSE SPECTRUM METHOD(KN)

Eighth	8	365.8	169.54
Seventh	7	562.7	445.68
Sixth	6	871.8	790.92
Fifth	5	1356.2	1157.10
Fourth	4	1904.4	1523.14
Third	3	2498.5	1850.48
Second	2	2707.9	2128.73
First	1	2989.0	2322.34
Ground	Ground	2996.0	2348.47

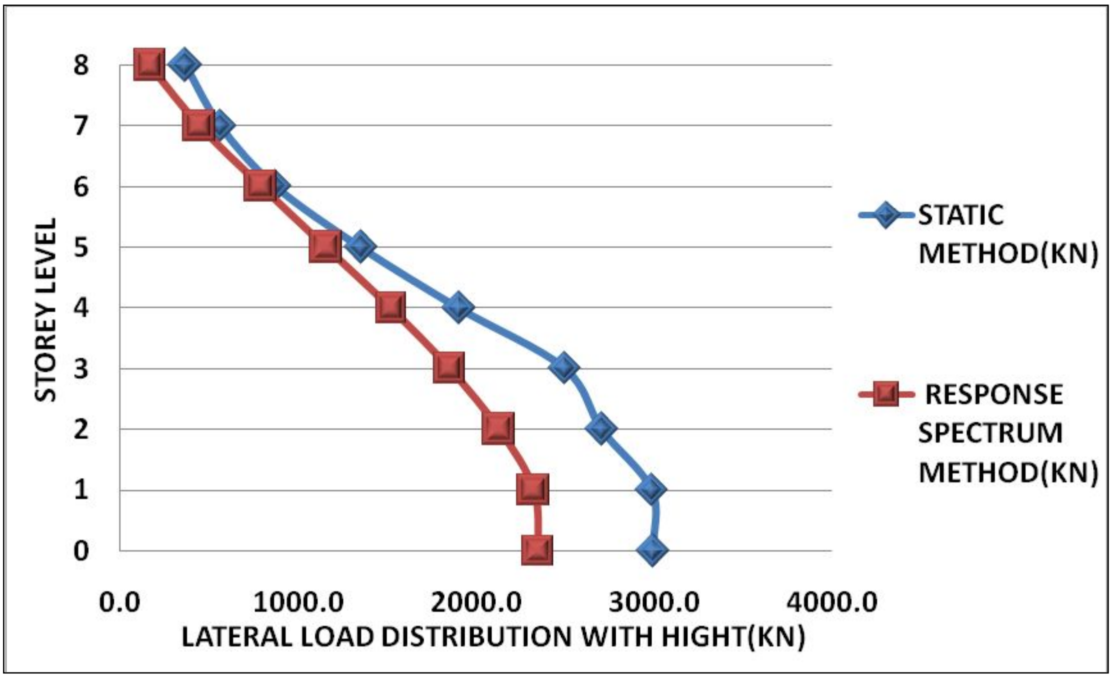


Figure 5.3

From the table 5 3 and figure 5.3 it is noticed that there is not more difference in the lateral loaded distribution with the building height using linear static method and response spectrum method and therein lies the advantage of dynamic analysis compared to linear static method

IV. STOREY DISPLACEMENT

Displacement for individual frames along the direction considered is tabulated at each storey level figure presents a typical floor plan showing the frame identification

Table 5.4: Displacement Values For Storey 8

S.NO	STOREY LEVEL	UX		
		SET BACK	STEP BACK	SET AND STEP BACK
1	STOREY8	0.0618	0.5588	0.2315
2	STOREY7	0.0624	0.54	0.189
3	STOREY6	0.0621	0.5099	0.1577

4	STOREY5	0.0563	0.4681	0.1309
5	STOREY4	0.0473	0.4144	0.1062
6	STOREY3	0.0367	0.3483	0.0827
7	STOREY2	0.0258	0.2685	0.0598
8	STOREY1	0.0151	0.1735	0.0368
9	GROUND	0.0046	0.0614	0.0126

REFERENCES

1. *IS 456,(2000),"Indian standard Code of practice for Plain and Reinforced Concrete (Fourth revision)", Bureau of Indian Standards, New Delhi.*
2. *IS 1893,(Part 1),(2002)"Criteria for earthquake resistant design of structures",Part1General Provisions and building, Bureau of Indian Standards.*
3. *IS 875(Part3)(1987), "Indian standard code of practice for design loads (Other than earthquake) for buildings and structures", Part 3 Wind loads (Second Revision), Bureau of Indian Standards.*
4. *IS 13920, (1993), Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces, Bureau of Indian Standards, New Delhi.*
5. *Murty, C.V.R., IIT, Kanpur, BMTPC, New Delhi 'Earthquake tips' Feb 2004.*
6. *A.S.Warudkar, R.P.Sudarsan and G.Visalakshi-"Effect of torsional stiffness on the dynamic response of RC framed structures" Proceedings of the Tenth Symposium on Earthquake Engineering, Nov. 16-18, 1994, Roorkee.*
7. *AshokK.Jain and Satish Annigeri - "Torsional Provisions for Asymmetrical Multi-storey buildings" Proceedings of the Tenth Symposium on Earthquake Engineering, Nov. 16-18 1994, Roorkee.*
8. *Satish Kumar and D.K.Paul "Dynamic Analysis of Step back and Setback Buildings", Proceedings of the Tenth Symposium on Earthquake Engineering, Nov. 16-18, 1994, Roorkee.*
9. *Paulay, T., and Priestley, M.J.N, "Seismic design of reinforced concrete and masonry buildings", John-Wiley Publishers, 1992.*
10. *Pankaj Agarwal and Manish Shrikhande, "Earthquake Resistant Design of Structures", Prentice Hall of India, 2006.*