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Seismic Response Analysis of Symmetrical and Asymmetrical High Rise Structures in Seismic ZoneII

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ABSTRACT
Multi-level storey buildings are very much common in the urban areas nowadays due to scarcity of land and increase in the cost of land. Many of these structures are not regular either in shape, stiffness or mass distribution. A structure with irregular configuration may be constructed so as to meet all the codal requirements, but the performance of such a structure will not be as good as a structure with regular configuration. It is even suggested to avoid such configuration but irregularity in structural components has been unavoidable due to various reasons. This dissertation aims to determine the differences in seismic performance of Symmetric and Asymmetric structures in vertical geometric irregularities. Models of square-shaped, G+25 storied buildings are considered for analysis in STAAD Pro software. From the static and dynamic analyses of these models, various parameters like storey shear, base shear, storey drift and natural period have been calculated and compared. It is concluded that symmetrical structures are superior to asymmetric structures in view of resistance against seismic forces.

Keywords: Storey Drift, Base shear, Seismic wave, seismic response, aspect ratio

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I. INTRODUCTION

An Earthquake is a phenomenon that results from and is powered by the sudden release of stored energy in the crust that propagates Seismic waves. At the Earth's surface, earthquakes may manifest themselves by a shaking or displacement of the ground and sometimes tsunamis, which may lead to loss of life and destruction of property. The word Earthquake is used to describe any seismic event whether a natural phenomenon or an event caused by humans that generates seismic waves. Most naturally occurring earthquakes are related to the tectonic nature of the earth. Such earthquakes are called tectonic earthquakes. The Earth's lithosphere is a patchwork of plates in slow but constant motion caused by the heat in the Earth's mantle and core. Plate boundaries grind past each other, creating frictional stress. When the frictional stress exceeds a critical value, called local strength, a sudden failure occurs. The boundary of tectonic plates along which failure occurs is called the fault plane. When the failure at the fault plane results in a violent displacement of the Earth's crust, the elastic strain energy is released and seismic waves are radiated, thus causing an earthquake.

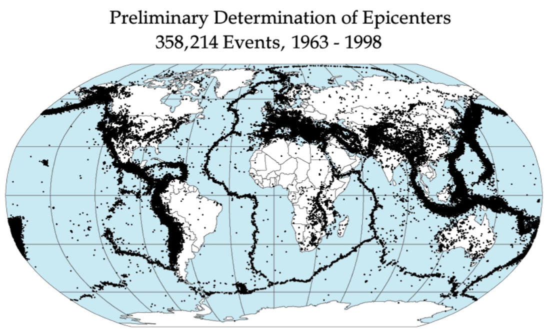


Fig. 1. 0World map showing epicenters

Earthquakes occurring at boundaries of tectonic plates are called interpolate earthquakes, while the less frequent events that occur in the interior of the lithospheric plates are called interpolate earthquakes. The severity of an earthquake can be measured in terms of magnitude and intensity. For that seismologists use two fundamentally different but equally important types of scales. The original force or energy of an earthquake is measured on a magnitude scale. The Richter scale is a well-known example of a magnitude scale. The second type of scale measures the intensity of shaking occurring at any given point on the Earth's surface. These scales are referred to as intensity scales. The Mercalliintensity scale, which measures the effects of the seismic waves, is an example of a commonly used intensity scale. The non-specialized media will often refer to the magnitudes of the earthquakes as being reported on the Richter scale. However, the magnitudes reported nowadays are actually on the moment magnitude scale**.** This is because the older Richter scale is not well-suited to accurately measure earthquakes with magnitudes over 6.8

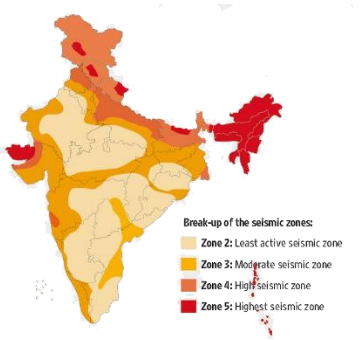


Fig. 1 Seismic Zone Map of India, IS 1893 (Part 1): 2002

The loads are broadly classified as vertical loads, horizontal loads and longitudinal loads. The vertical loads consist of dead load, live load and impact load. The horizontal loads comprises of wind load and earthquake load. The longitudinal loads i.e. tractive and braking forces are considered in special case of design of bridges, gantry girders etc.

Earthquake load

Earthquake loads are horizontal loads caused by the earthquake and shall be computed in accordance with IS 1893. For monolithic reinforced concrete structures located in the seismic zone II, and III without more than 5 storey high and importance factor is 1, then the seismic forces are not critical. Unlike all other loading effects, e.g., wind loads, wave loads (excluding tsunami loads), blast loads, snow loads, imposed (live) loads and dead loads, earthquake shaking is the most severe. The objective of the present work is to model a symmetric structure and its equivalent asymmetric structures in Staad Pro software and perform seismic analysis by dynamic methods of analysis. To compare the seismic response of symmetric and asymmetric structures. To study the effect of storey drift for symmetric and asymmetric multi-storied G+25 high rise R.C building in seismic zone II.To study the response spectrum method for analysis of symmetric and asymmetric building structures.To compare the response parameters such as storey drift, base shear, storey shear, and natural period of Symmetrical and Asymmetrical building.

II. LITERATURE REVIEW

It has been observed repeatedly in earthquakes that the presence of asymmetry in the plan of a structure makes it more vulnerable to seismic damages. There are reports of extensive damages to buildings that are attributed to excessive torsion responses caused by asymmetry in earthquakes such as the 1972 Managua earthquake (Pomares Calero5 1995), the 1985 Michanocan earthquake (Esteva6 1987) and the 1989 Loma Prieta earthquake (Mitchell et al7 (1990)).

Asymmetry in plan causes torsion in a building because the centre of mass and the centreof rigidity do not coincide. The distance between the two centers is termed structural eccentricity and the magnitude of this eccentricity can be estimated. Torsion can also arise in a building due to other sources for which estimating their magnitude is difficult. Some examples of these sources for the so-called accidental torsion are the rotational components in the ground motion, an unfavorable distribution of live load, and the difference between computed and actual stiffness/mass/yield strength of the elements. All these factors cause coupling between the lateral and torsion motions in a building that leads to non-uniform distribution of in-plan floor displacement. This results in uneven demands on the lateral resisting elements at different locations of the system.

1.Dr. S. N. Tande, S. J. Patil Presented "Seismic Response of Asymmetric Buildings" In this paper Structural asymmetry can be a major reason for buildings poor performance under severe seismic loading, asymmetry contributes significantly to the potential for translational-torsional coupling in the structures dynamic behavior which can lead to increased lateral deflections, increased member forces and ultimately the buildings collapse. In this paper the inelastic seismic behavior and design of asymmetric multistoried buildings are studied. The effects of torsion on buildings are investigated. The buildings with setbacks are analyzed for torsion. Study also shows that there is increase in shear, in columns and the columns at outer frame need some special attention

2.Undareson A , Ganesh Baravkar , VijayaSarathy R Presented "Parametric study of response of an asymmetric building for various earthquake resistance factors" In this paper

Earthquake is a major concern in high seismic prone areas. The structure which lies in seismic zones are to be specially designed. The goal of earthquake-resistant design is to construct structures that fare better during seismic activity than their conventional counterparts. In this paper a study is conducted on the performance of a asymmetric structure, with plan irregularity, strength and stiffness irregularities.. A time history analysis is performed using relevant software, a comparative discussion is made on the response of structure between normal building and building which is designed for earthquake resistant. The results showed that it was important to select a suitable parameter, for the type of resistance that the building must offer. This parametric study clears the importance of each earthquake resistance factors.

3.Khante.S.N, LavkeshR.Wankhade Presented “Study of seismic response of symmetric and symmetric base isolated building with mass asymmetry in plan” In this paper, the effect of mass asymmetry in symmetric and asymmetric building is studied. To study the effect of torsion in seismic behavior of base isolated structures, a symmetric and asymmetric multi storey concrete building is reference model. These models with mass eccentricity of 5%, 10%, 15% and 20% of greatest dimension of building in indirection and bidirectional are considered. The response spectrum and non linear time historey analysis of this eccentric model of fixed base and base isolated building using SAP2000 software is done.

4.Sachin G. Maske, Dr. P. S. Pajgade presented behavior of asymmetrical buildings” in this paper, Torsional behavior of asymmetric building is one of the most frequent source of structural damage and failure during strong ground motions. In this work a study on the influence of the torsion effects on the behavior of structure is done. In building two cases are considered, case one is without considering torsion and case two is considering torsion. The Indian standard code of practice IS-1893 (Part I: 2002) guidelines and methodology are used to analyzed and designed building. Results are compared in terms of % Ast in columns

III. METHODOLOGY

Modeling and analysis of G+25 storey high-rise building are carried out using STAAD Pro software. The model is a regular-shaped symmetrical plan with dimensions 48m x 44m. The slab spans are 4m, arranged in 12 bays in X-direction and 11 bays in Y-direction, as shown in Fig 3.1. Conventional RCC slabs were used for the two structures. The storey height is assumed to be 3m. The plan arrangement for asymmetric structure varies due to its vertical geometric irregularities for every 5 stories the vertical geometrical plan change is considered. STAAD Pro software is used to model and perform the analysis for the two models. The result is compared among the models for the better understanding of irregularities under gravity and seismic loading.

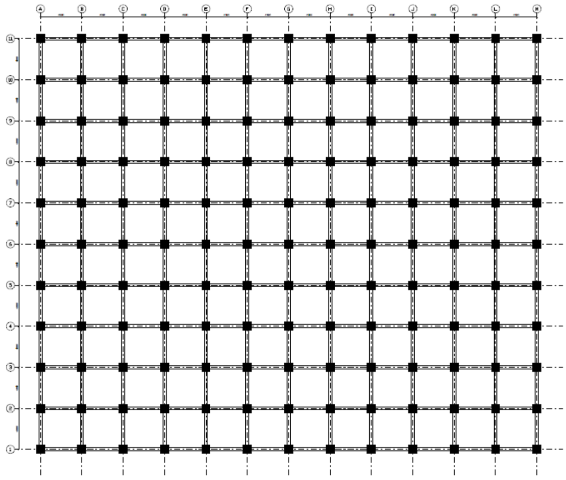
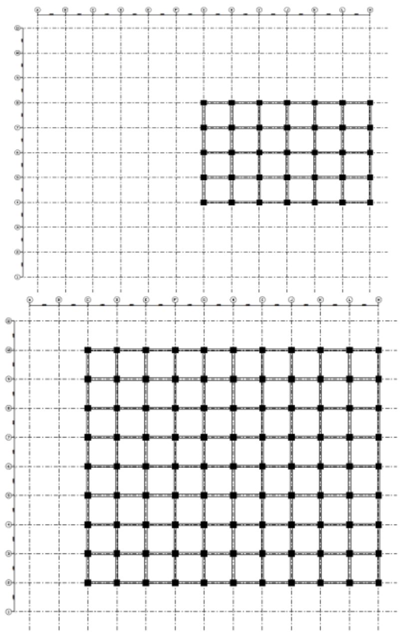
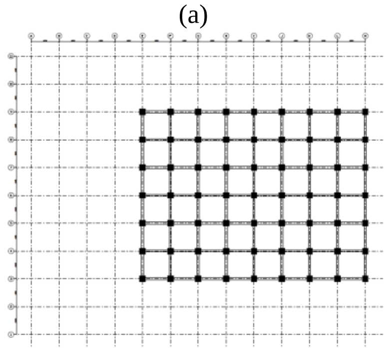


Fig. 3 plan layout of symmetric structure.



(a)



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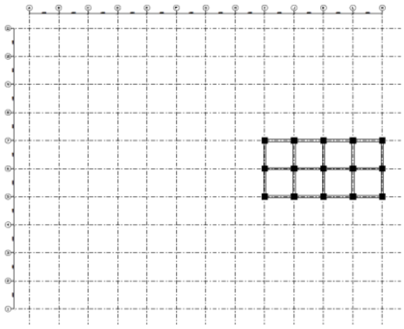

(c)

Fig. 4 Asymmetric plan layouts: (a) at 18m, (b) at 33m, (c) at 48m, (d) at 63m

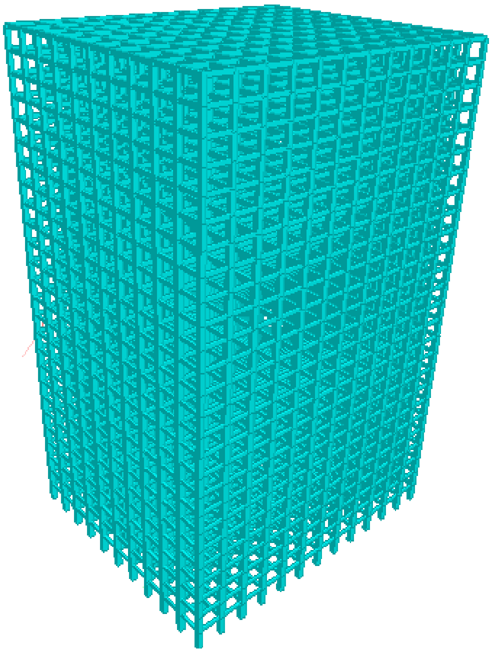

Fig. 5 Isometric view of symmetric structure

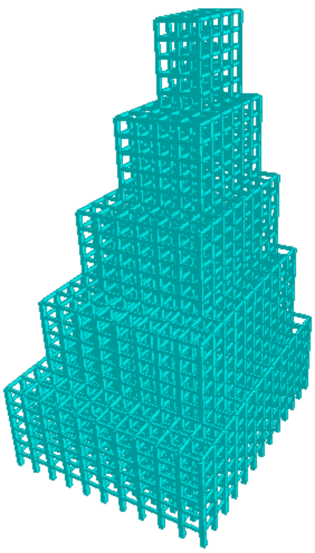

Fig. 6 Isometric view of asymmetric structure

MODELING OF STRUCTURE IN STAAD PRO SOFTWAREFor modelling of G+25 storey symmetric and asymmetric high-rise buildings with storey height 3m, Simple Square Geometry, Plan aspect ratio (L/B)1.09(L48m and B 44m), Slenderness Ratio (H/B)1.77(H 78m,B 44m) Column size 0.8m x 0.8m (1-10stories), 0.7m x 0.7m (10-20stories), 0.6m x 0.6m (20-25stories), Beams size 0.3m x 0.6m, Floor finish 2kN/m^2 Masonry 6kN/m and Imposed load 3kN/m^2 Seismic zone II, Zone factor 0.10 Response reduction factor5, Soil type II, Importance factor 1.0 were considered.

SEISMIC DESIGN

While structural design for seismic loading is mainly worried about structural safety during significant earthquakes, there is concern about serviceability and the possibilities for financial failure. As such, seismic design requires knowledge of the structural behaviour under large inelastic, cyclic deformations. Behaviour under this loading is essentially distinct from wind or gravitational loading. It needs a more comprehensive analysis and the implementation of a set of strict detailing criteria to ensure appropriate seismic output beyond the elastic limit. When the building encounters design ground movements, some structural harm can be anticipated because almost all building codes enable inelastic energy dissipation in structural systems. Traditionally, seismic analysis and building design have concentrated on decreasing the danger of lives lost in the largest earthquake anticipated.

Building codes focus their measures on the historical performance of buildings and their deficiencies and have established clauses on life-safety issues by concentrating their focus on preventing failure during a structure's lifetime under the most severe earthquake anticipated at a location. These clauses are based on the principle that the successful performance of buildings in areas of high seismicity depends on a combination of strength; ductility embodied in the details of construction; and the presence of a fully interconnected, balanced, and complete lateral force-resisting system. The need for ductility decreases significantly in areas with poor seismicity. And actually, strength can even replace an absence of ductility. Outstanding performance can be very brittle lateral force-resistant structures as soon as they are never pressed beyond their elastic resistance.

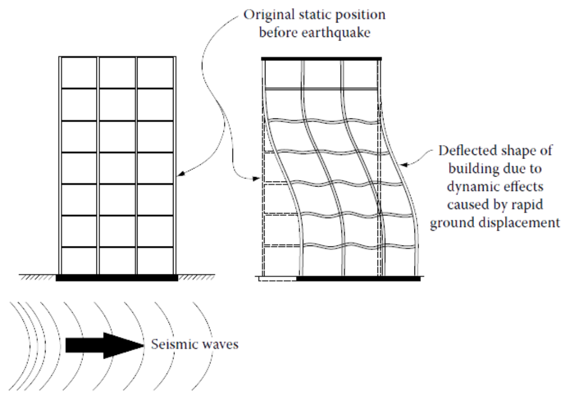

Fig. 6 Building behavior during earthquakes

Considering the simpler response shape, an idea of a building's behaviour during an earthquake can be understood .as the ground on which the building sits is displaced, the base of the building shifts with it. The building above the base, however, is unwilling to move with it as the building mass's inertia resists movement and distorts the structure. This distortion flow moves the height of the structure and triggers the building to suffer a complicated sequence of oscillations with continuous shaking of the base. While both wind and seismic forces are fundamentally dynamic, the way they are produced in a building is significantly different. Wind loads, introduced as external loads, are characteristically relative to the exposed surface of a structure, while the earthquake forces are mainly internal forces resulting from the distortion produced by the inertial resistance of the structure to earthquake motions. The magnitude of earthquake forces is a function of the mass of the structure rather than its exposed surface. Whereas in wind design, one would feel greater assurance about the safety of a structure made up of heavy sections, in seismic design, this does not necessarily produce a safer design.

Building Behavior

A building's behaviour during an earthquake is a issue of vibration. The seismic movements of the ground or externally implemented pressure such as wind, do not destroy a building by impact, but by inertial forces produced internally triggered by the vibration of the building mass. A rise in mass has two unwanted impacts on the design of the earthquake. First, it leads to an increase in the force, and second, it can cause buckling or crushing of columns and walls when the mass pushes down on a member bent or moved out of plumb by the lateral forces. This effect is recognized as the PΔ effect and the higher the vertical forces, the higher the movement due to PΔ. It is almost always the vertical load that causes buildings to collapse; in earthquakes, buildings very rarely fall over they fall down. The delivery of dynamic deformities triggered by the ground motions and the duration of motion is of consideration in seismic design. Although the duration of strong motion is an important design issue, it is not presently expressly accounted for in design. In particular, tall buildings respond to seismic movement different manner than low-rise buildings.

The magnitude of inertia forces caused in an earthquake relies on the building mass, ground acceleration, the type of the foundation, and the structure's dynamic features If a building and its foundation were vastly rigid, it will have the same acceleration as the ground, likely to result in an inertia force F= ma for a given acceleration on the ground, a. However, because buildings have some flexibility, the force appears to be less than the mass and acceleration of structures. Tall buildings are typically more flexible than low-rise buildings, and in particular, they experience much lower accelerations than low-rise buildings. But a versatile building that has been subjected to ground movements for a long duration may encounter much greater forces if its natural period is close to that of the ground waves. Thus, the magnitude of lateral force is not a function of the acceleration of the ground alone but is influenced to a great extent by the type of response of the structure itself and its foundation as well. This interrelationship of building behaviour and seismic ground motion also relies on the building period as defined in the so-called Response Spectrum,

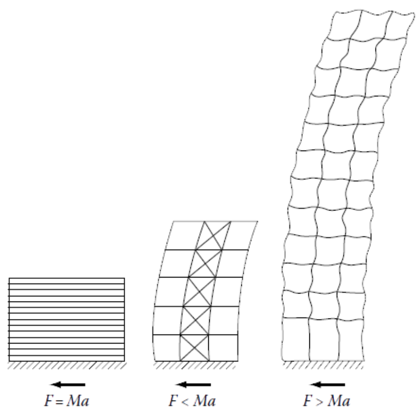

Fig. 7. Schematic representations of seismic forces

Dynamic Analysis

Symmetrical buildings with uniform mass and stiffness distribution behave in a pretty predictable way, whereas buildings that are asymmetrical or with areas of discontinuity or irregularity will not. For these buildings, dynamic analysis is used to evaluate significant response characteristics such as (1) the effects of the structure's dynamic characteristics on the vertical distribution of lateral forces; (2) the rise in dynamic loads due to torsional motions; and (3) the influence of higher modes, resulting in an increase in storey shears and deformations Static methods indicated in building codes are focused on single-mode response with easy adjustments to include greater mode impacts. While appropriate for simple regular structures, the simpler procedures will not take into account with the full range of seismic behaviour of complex structures. Hence, dynamic analysis is the preferred approach for the design of buildings with unusual or irregular geometry. Two methods of dynamic analysis are enabled: (1) elastic response-spectrum analysis and (2) elastic or inelastic time-historey analysis. The response-spectrum analysis is the preferred way because it is easier to use.

The time-historey method is used if it is essential to portray inelastic response characteristics or to implement time-dependent impacts when computing the structure's dynamic response. Structures that are built into the ground and extended vertically some distance above-ground respond as vertical oscillators when subject to ground motions. A single lumped mass at the top of a vertically cantilevered pole can idealize a simple oscillator

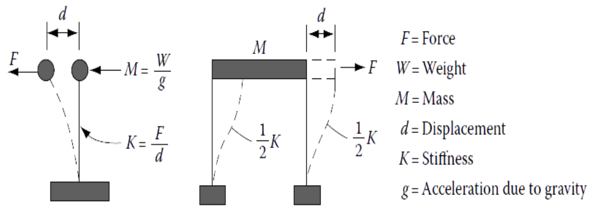

Fig. 8 Idealized SODF system

The idealized system represents two types of structures: (1) a single-column structure with a relatively large mass at the top and (2) a single-storey frame with flexible columns and a rigid beam The mass M is the weight W of the system divided by the acceleration of gravity g, that is, M = W / g.

The stiffness K of the system is the force F divided by the corresponding displacement Δ. If the mass is deflected and then suddenly released, it will vibrate at a certain frequency, called its natural or fundamental frequency of vibration. The reciprocal of frequency is the period of vibration. It symbolizes the time for the mass to move through one complete cycle. The period T is given by the relation

$$T = 2\pi\sqrt{M/K}$$

A perfect damping-free system would vibrate forever (Fig. 3.8). However, in a real system, with some damping, the amplitude of motion will gradually decrease for each cycle until the structure comes to a complete stop (Fig. 3.9). The system responds similarly if a sudden impulse is applied to the base instead of displacing the mass at the top. Buildings are evaluated as multi-degree-of-freedom (MDOF) structures by lumping storey-masses along a vertically cantilevered base at periods. During vibration, each mass will deflect in one direction or another. For higher modes of vibration, some masses may move in opposite directions. Or all masses may simultaneously deflect in the same direction as in the fundamental mode.

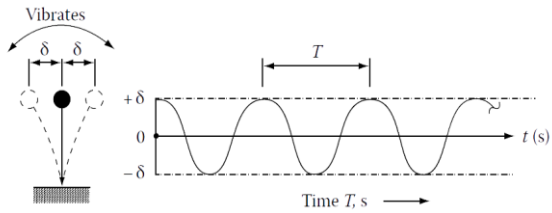

Fig. 9 Undamped free vibrations of SDOF system

An idealized MDOF system has a number of modes equal to the number of masses. Each mode has its own natural period of vibration with a unique mode shaped by a line connecting the deflected masses

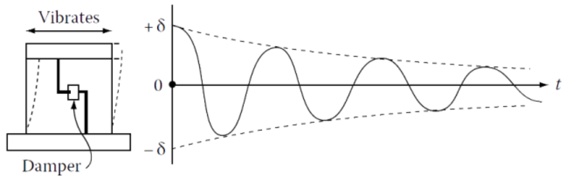

Fig. 10 Damped free vibrations of SDOF system

When ground motion is introduced to the base of a multi-mass system, the deflected shape of the system is a mixture of all mode shapes, but modes having periods near predominant periods of the base motion will be excited more than the other modes. Each mode of a multi-mass system can be portrayed by an equivalent single-mass system having generalized values M and K for mass and stiffness, respectively. The generalized values portray the equivalent combined effects of storey masses m1, m2 …and k1, K2… This idea, offers a computational basis for using response spectra based on single-mass systems for analysing multi-storeyed buildings. Given the period, mode shape, and mass distribution of a multi-storeyed building, we can use the response spectra of a single-degree-of-freedom (SDOF) system for computing the deflected shape, storey accelerations, forces, and overturning moments. Each predominant mode is analysed separately and the results are combined statistically to compute the multimode response.

Buildings with symmetrical form, stiffness and mass distribution and vertical continuity and uniformity act in a relatively linear way, whereas when buildings are eccentric or have areas of discontinuity or irregularity; the behavioural attributes are very complicated. The building's predominant response may be skewed from the building's obvious principal axes. The generated torsional response, as well as the coupling or interaction of the two translational response paths, must be regarded using a 3D model for analysis.

A 2D model is usually adequate for a building that is regular and fundamentally symmetrical. Note that when the building's floor-plan aspect ratio (length-to-width) is big, torsion response may predominate, needing a 3D analysis in an otherwise symmetrical and regular structure. For most buildings, the inelastic response can be expected to take place during a major earthquake, suggesting that an inelastic analysis is more appropriate for design. However, in spite of the availability of nonlinear inelastic programs, they are not used in typical design practice because (1) their proper use involves the knowledge of their inner workings and concepts, (2) the results produced are hard to interpret and apply to common design criteria, and (3) the required calculations are expensive. Therefore, analyses in practice typically use linear elastic procedures based on the response-spectrum method

EQUIVALENT STATIC METHOD

As per this method, first, the design base shear V_B shall be computed for the building as a whole. Then, this V_B shall be distributed to the various floor levels at the corresponding centres of mass. And, finally, this design seismic force at each floor level shall be distributed to individual lateral load resisting elements through structural analysis considering the floor diaphragm action. This method shall be applicable for regular buildings with height less than 15m in Seismic Zone II.

The design base shear V_B along any principal direction of a building shall be determined by:

$$\boldsymbol{V_B = A_h\,W}$$

Where,
A_h = design horizontal acceleration coefficient
W = seismic weight of the building

SEISMIC DESIGN FORCE

Earthquake shaking is random and time variant. But, most design codes represent the earthquake-induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force. This force is called as the Seismic Design Base Shear (VB) and remains the primary quantity involved in force-based earthquake-resistant design of buildings. This force depends on the seismic hazard at the site of the building represented by the Seismic Zone Factor Z. Also, in keeping with the philosophy of increasing design forces to increase the elastic range of the building and thereby reduce the damage in it, codes tend to adopt the Importance Factor I for effecting such decisions. Further, the net shaking of a building is a combined effect of the energy carried by the earthquake at different frequencies and the natural periods of the building. Codes reflect this by the introduction of a Structural Flexibility Factor S_a/g, to make normal buildings economical, design codes allow some damage for reducing cost of construction. This philosophy is introduced with the help of Response Reduction Factor R, which is larger for ductile buildings and smaller for brittle ones. Each of these factors is discussed in this and subsequent chapters. In view of the uncertainties involved in parameters, like Z and Sa/g, the upper limit of the imposed deformation demand on the building is not known as a deterministic upper bound value. Thus, design of earthquake effects is not termed as earthquake-proof design. Instead, the earthquake demand is estimated only based on concepts of probability of exceedence, and the design of earthquake effects is termed as earthquake-resistant design against the probable value of the demand.

As per the Indian Seismic Code IS: 1893 (Part 1) - 2007, Design Base Shear VB is given by

$$\boldsymbol{V_B = A_h W = \frac{Z}{2}\frac{I}{R}\left(\frac{S_a}{g}\right)W}$$

where Z is the Seismic Zone Factor (Table 3.1), I the Importance Factor (Table 3.2), R the Response Reduction Factor (Table 3.3), and Sa g the Design Acceleration Spectrum Value (Figure 3.14) given by

$$\frac{S_a}{g} = \begin{cases} \begin{cases} 2.5 & 0.00 < T < 0.40 \\ \frac{1.00}{T} & 0.40 < T < 4.00 \end{cases} & \text{for Soil Type I : rocky or hard soil sites} \\ \begin{cases} 2.5 & 0.00 < T < 0.55 \\ \frac{1.36}{T} & 0.55 < T < 4.00 \end{cases} & \text{for Soil Type II : medium soil sites} \\ \begin{cases} 2.5 & 0.00 < T < 0.67 \\ \frac{1.67}{T} & 0.67 < T < 4.00 \end{cases} & \text{for Soil Type III : soft soil sites} \end{cases},$$

in which T is the fundamental translational natural period of the building in the considered direction of shaking

Table 1 Seismic Zone Factor Z as per IS: 1893 (Part 1) - 2007 of the site where the building to be designed is located

Seismic Zone	V	IV	III	II
Z	0.36	0.24	0.16	0.1

Table 1 Importance Factor Z of buildings as per IS: 1893 (Part 1) - 2007

Building	Importance factor (I)
Normal Buildings	1
Important Buildings	1.5

Table 2 Response Reduction Factor R of buildings as per IS: 1893 (Part 1) – 2007

Lateral Load Resisting System	*R*
Building Frame Systems	
Ordinary RC moment resisting frame (OMRF)	3.0
Special RC moment-resisting frame (SMRF)	5.0
Steel frame with	
(a) Concentric braces	4.0
(b) Eccentric braces	5.0
Steel moment resisting frame designed as per SP 6 (6)	5.0
Buildings with Shear Walls	
Ordinary reinforced concrete shear walls	3.0
Ductile shear walls	4.0
Buildings with Dual Systems	
Ordinary shear wall with OMRF	3.0
Ordinary shear wall with SMRF	4.0
Ductile shear wall with OMRF	4.5
Ductile shear wall with SMRF	5.0

Table 3 Proportion of Live Load to be considered in the estimate of Seismic Weight of buildings as per IS: 1893-2004

Imposed Uniformity Distributed Floor Loads (kN/m^2)	Percentage of Imposed Load
Up to and including 3.0	25
Above 3.0	50

IV. RESULTS AND DISCUSSIONS

Static Earthquake and Response Spectrum Analysis are performed for the symmetric and asymmetric structure. The result are based on the response of the two models. The results include changes in base shear, storey drift and time period for ground motion along both the horizontal directions calculated individually in STAAD Pro software. The results of the base shear, storey drift, and the storey displacement were then compared with each other.

STOREY DRIFT

It is the relative displacement between the floors above and /or below the storey under consideration

Comparison of Storey Drift

In the present study, the storey drifts were compared for the two structures under Static Earthquake load in both directions. It is observed that the asymmetric structure's drift is more in comparison with the symmetric structure. Hence the drifts results are tabulated for 26 stories, According to the Clause 7.11.1 of IS 1893 (Part I): 2002 the maximum allowable drift is 0.004h (h/250) where h is the storey height, under specified design lateral force, with partial load factor of 1.0. Hence, the maximum allowable storey drifts is .004x3000 = 12 mm

Allowable storey drift is **12 mm,** the symmetric structure is safe under drift criteria since, all the levels of the building are in permissible limits in both (X and Z) directions of ground shaking. While the Asymmetric structure fails to satisfy the permissible storey drift limit at bottom stories in both (X and Z) directions of ground shaking.

Table 5 storey drifts under static earthquake loads for two models in +X direction

EQ(+X)		
Storey Drift (mm)		
Storey	Symmetric	Asymmetric
26	0.17	1.02
25	0.24	1.41
24	0.32	1.80
23	0.39	2.13
22	0.46	3.39
21	0.47	1.44
20	0.52	1.68
19	0.56	1.92
18	0.60	2.10
17	0.64	3.49
16	0.67	1.57
15	0.70	1.69
14	0.72	1.81
13	0.74	1.90
12	0.76	3.26
11	0.72	1.41
10	0.73	1.55

9	0.74	1.87
8	0.74	2.68
7	0.70	7.13
6	0.74	9.62
5	0.73	14.13
4	0.72	17.36
3	0.68	18.63
2	0.58	16.87
1	0.29	8.73

Table 6 storey drifts under static earthquake loads for two models in -X direction

EQ(-X)		
Storey Drift (mm)		
Storey	Symmetric	Asymmetric
26	-0.17	-1.02
25	-0.24	-1.41
24	-0.32	-1.80
23	-0.39	-2.13
22	-0.46	-3.39
21	-0.47	-1.44
20	-0.52	-1.68
19	-0.56	-1.92
18	-0.60	-2.10
17	-0.64	-3.49
16	-0.67	-1.57
15	-0.70	-1.69
14	-0.72	-1.81
13	-0.74	-1.90
12	-0.76	-3.26
11	-0.72	-1.41
10	-0.73	-1.55
9	-0.74	-1.87

8	-0.74	-2.68
7	-0.70	-7.13
6	-0.74	-9.62
5	-0.73	-14.13
4	-0.72	-17.36
3	-0.68	-18.63
2	-0.58	-16.87
1	-0.29	-8.73

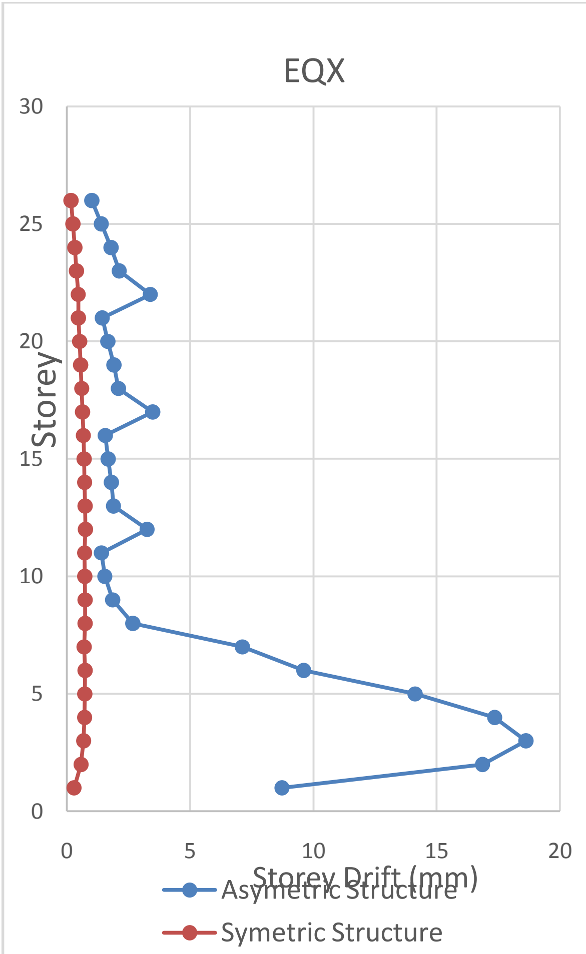

Fig. 15 comparison of storey drifts under static earthquake loads for two models in X direction

Table 7 storey drifts under static earthquake loads for two models in +Z direction

EQ (+Z)		
Storey Drift (mm)		
Storey	Symmetric	Asymmetric
26	0.20	1.05
25	0.27	1.44

24	0.35	1.83
23	0.42	2.16
22	0.49	3.42
21	0.50	1.47
20	0.55	1.71
19	0.59	1.95
18	0.63	2.13
17	0.67	3.52
16	0.70	1.60
15	0.73	1.72
14	0.75	1.84
13	0.77	1.93
12	0.79	3.29
11	0.75	1.44
10	0.76	1.58
9	0.77	1.90
8	0.77	2.71
7	0.73	7.16
6	0.77	9.65
5	0.76	14.16
4	0.75	17.39
3	0.71	18.66
2	0.61	16.90
1	0.32	8.76

Table 8 storey drifts under static earthquake loads for two models in -Z direction

EQ(-Z)		
Storey Drift (mm)		
Storey	Symmetric	Asymmetric
26	-0.20	-1.05
25	-0.27	-1.44
24	-0.35	-1.83
23	-0.42	-2.16
22	-0.49	-3.42
21	-0.50	-1.47
20	-0.55	-1.71
19	-0.59	-1.95
18	-0.63	-2.13
17	-0.67	-3.52
16	-0.70	-1.60
15	-0.73	-1.72
14	-0.75	-1.84
13	-0.77	-1.93
12	-0.79	-3.29
11	-0.75	-1.44
10	-0.76	-1.58
9	-0.77	-1.90
8	-0.77	-2.71
7	-0.73	-7.16
6	-0.77	-9.65
5	-0.76	-14.16
4	-0.75	-17.39
3	-0.71	-18.66
2	-0.61	-16.90
1	-0.32	-8.76

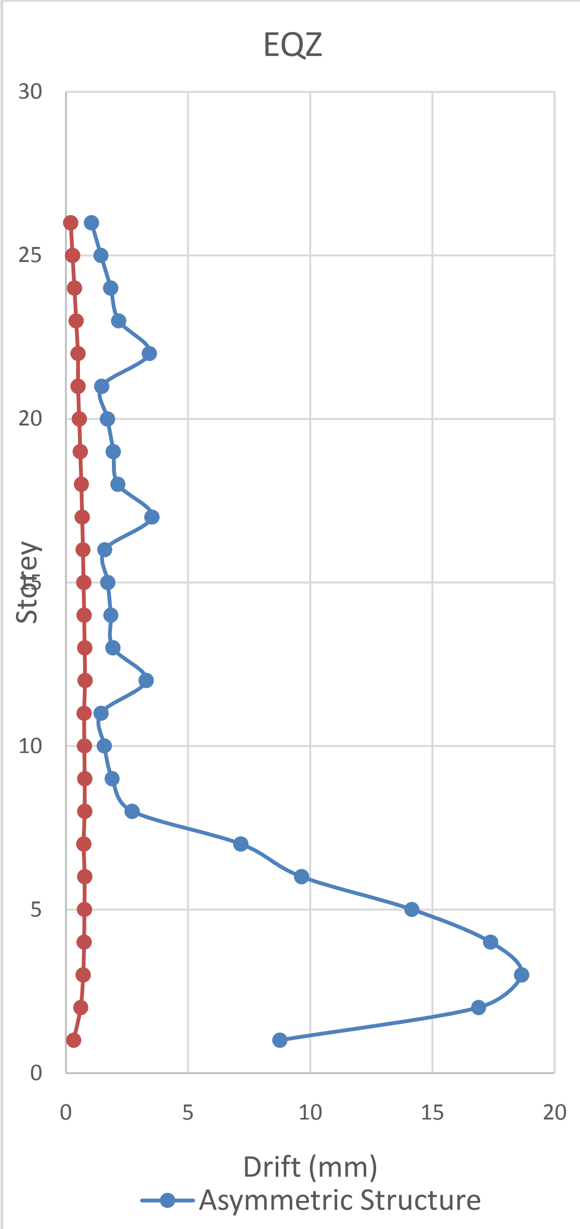

Fig. 16 comparison of storey drifts under static earthquake loads for two models in Z direction

BASE SHEAR

Earthquake shaking is random and time variant. Indian Standard Code represent the earthquake-induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force. This force is called as the Seismic Design Base Shear (V_B)

Comparison of Base Shear

The base shear was found decreasing from symmetric structure to asymmetric structure. The percentage reduction from symmetric structure to asymmetric structure is 23%, it is well known that if mass, increases the base shear increases. The base shear is same for the both x and Z ground motions, since the plan is almost symmetric.

Design Base Shear obtained by Performing Static Analysis

The base shear is evaluated by using fundamental translation natural period (T_a)

Design Base Shear (V_B):4199.16 kN

Design Base Shear obtained by Performing Response Spectrum Analysis

Design Base Shear (V_b):2874.10 kN

Scaled Design Base Shear:4199.16 kN

The value of base shear obtained from response spectrum analysis is observed to be lesser when compared to value of base shear obtained from static analysis, according to this situation IS 1893 (part 1): 2002 under clause 7.8.2 Dynamic analysis may be performed either by the Time Historey Method or by the Response Spectrum Method. However, in either method, the design base shear (V_b) shall be compared with a base shear (V_B) calculated using a fundamental period T, where the dynamic base shear is less than the static base shear at all the response quantities (for example member forces, displacements, storey forces, storey shears and base reactions) must be multiplied by V_B/V_b.

4199.16/2874.10 = **1.461** (scale factor)

2874.10 x 1.461 = 4199.16 kN

Similarly the same procedure has been carried out for the Asymmetric structure and the results obtained are presented in Table 4.3

Table 9 Static, dynamic and scaled dynamic base shear values

Base Shear (kN)		
Values	Symmetric	Asymmetric
Static	4199.16	3321.43
Dynamic	2874.1	1845.96
Scaled Dynamic	4199.16	3321.43

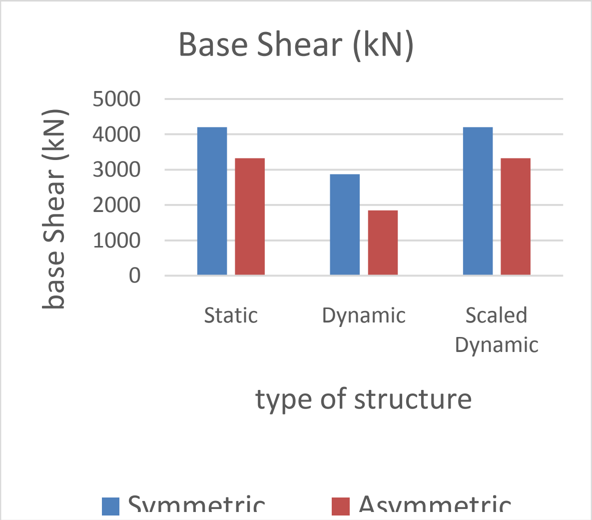

Fig. 17 comparison of base shear for two structures

STOREY SHEAR

It is the sum of design lateral forces at all levels above the storey under consideration.

Comparison of Storey Shears

The storey shears obtained by performing static earthquake analysis (EQ_x/EQ_z) and linear dynamic analysis i.e., response spectrum method (RS) for both X and Z directions are presented in tables 4.4 and 4.5. Since, the plan is almost symmetric the results were drawn for one direction. It is observed from the comparison of storey shears under Static ground motion and dynamic loads the storey shears accompanying Asymmetric structure are less than Symmetric structure.

Table 10 storey shears for two structures with respect to static ground motion

Storey shear (kN) EQ		
Storey	Symmetric	Asymmetric
26	386.00	117.27
25	782.01	239.56
24	1140.44	347.53
23	1450.61	347.53
22	1708.06	437.62
21	1921.48	508.55
20	2103.65	642.01
19	2259.82	778.14
18	2401.37	903.33
17	2537.26	1013.85
16	2671.98	1107.47
15	2805.38	1230.46
14	2934.18	1352.95
13	3054.45	1470.98
12	3164.10	1583.17

11	3267.73	1688.06
10	3371.48	1834.02
9	3477.60	1998.56
8	3590.32	2167.36
7	3710.55	2334.44
6	3834.73	2495.30
5	3955.03	2699.80
4	4060.95	2903.90
3	4142.07	3085.47
2	4191.11	3224.54
1	4198.40	3308.85
base	4198.40	3321.43

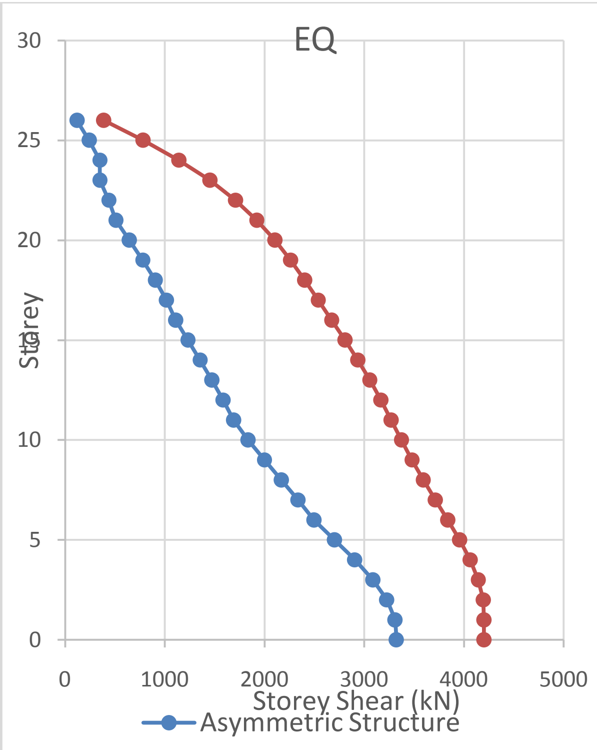

Fig. 18 storey shears for all structural systems with respect to static ground motion

Table 11 comparisonstorey shears for two structures with respect to dynamic ground motion

Storey shear (kN) RS		
Storey	Symmetric	Asymmetric
26	264.2	65.15
25	535.26	133.09
24	780.59	193.07
23	992.89	193.07
22	1169.1	243.12
21	1315.18	282.53
20	1439.87	356.67
19	1546.76	432.3
18	1643.65	501.85
17	1736.66	563.25
16	1828.87	615.26
15	1920.18	683.59
14	2008.34	751.64
13	2090.66	817.21
12	2165.71	879.54
11	2236.64	937.81
10	2307.65	1018.9
9	2380.29	1110.31
8	2457.44	1204.09
7	2539.73	1296.91
6	2624.73	1386.28
5	2707.07	1499.89
4	2779.57	1613.28
3	2835.09	1714.15
2	2868.66	1791.41
1	2873.65	1838.25
base	2873.65	1845.24

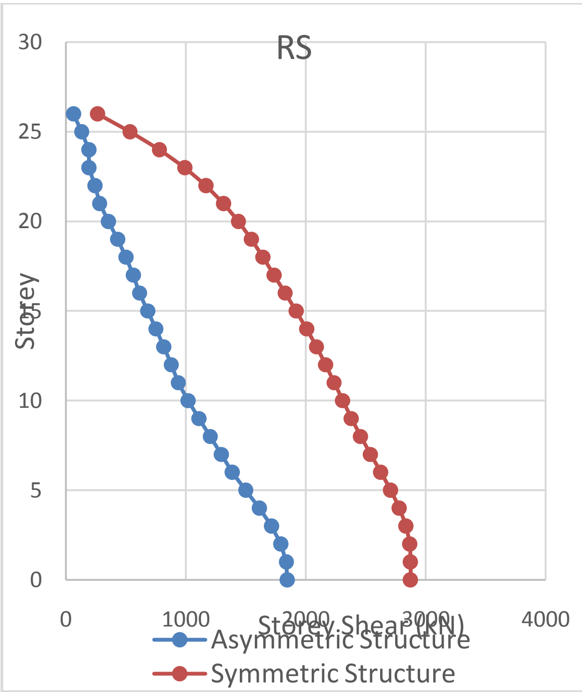

Fig. 19 storey shears for two structures with respect to dynamic ground motion

NATURAL PERIOD

Natural Period T_n of a building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by its mass m and stiffness k. These three quantities are related by

$$T_n = 2\pi\sqrt{\frac{m}{k}}$$

Its units are seconds (s). Thus, buildings that are heavy (with larger mass m) and flexible (with smaller stiffness k) have larger natural period than light and stiff buildings. Buildings oscillate by translating along X, Y or Z directions, or by rotating about X, Y or Z axes, or by a combination of the above. When a building oscillates, there is an associated shape of oscillation

Comparison of Natural Periods
There are three basic modes of oscillation, namely, pure translational along X-direction, pure translational along Y-direction and pure rotation about Z-axis. Regular buildings have these pure mode shapes. In the comparison of natural periods it is observed that the fundamental torsional mode of oscillation is not more than the first two translational modes of oscillation for both structures. Hence, both Symmetric and Asymmetric structures are safe against Torsion.

Table 12 comparison of natural period for Symmetric and Asymmetric structure.

Natural period		
Mode	Symmetric	Asymmetric
1	2.54207	1.7
2	2.50746	1.619
3	2.33481	1.21
4	1.23893	0.827
5	0.93612	0.808
6	0.86617	0.768
7	0.85587	0.733
8	0.80651	0.607
9	0.79705	0.548
10	0.73231	0.548
11	0.65118	0.535
12	0.64371	0.499
13	0.58799	0.49
14	0.53775	0.475
15	0.52286	0.434
16	0.50745	0.414
17	0.50368	0.402
18	0.48488	0.394
19	0.48321	0.384
20	0.4681	0.375
21	0.45745	0.365
22	0.43867	0.357
23	0.42373	0.352
24	0.41653	0.329
25	0.40649	0.323

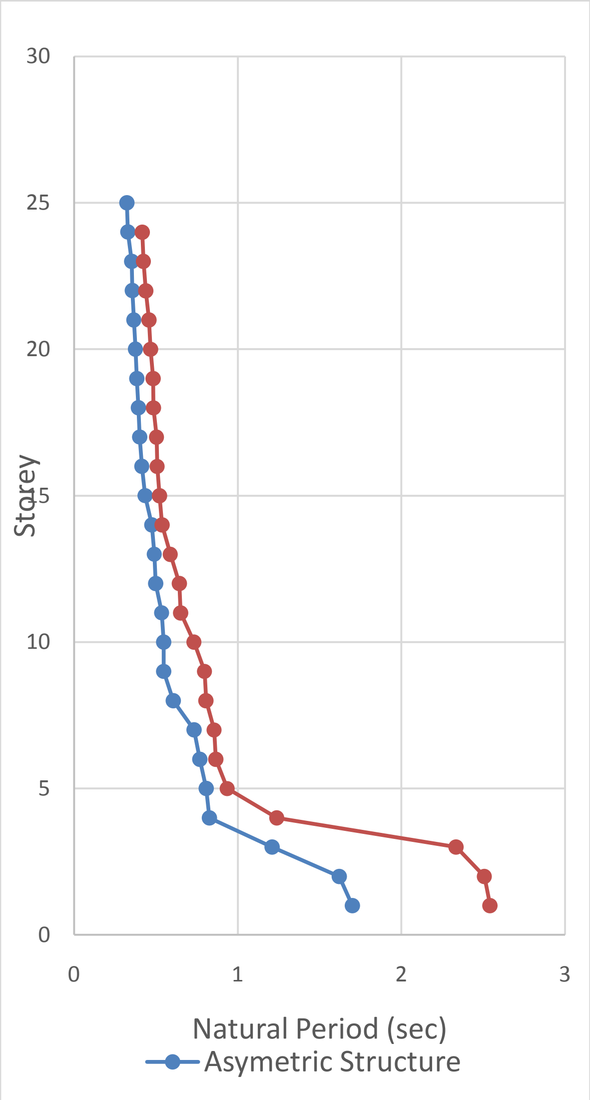

Fig. 20 Comparison of natural period for Symmetric and Asymmetric structure

V. CONCLUSION

From the analysis results and comparative study made among the Symmetric and Asymmetric structures using equivalent static and dynamic earthquake analysis the following set of conclusions are drawn.

- ✓ An attempt is made in this study to understand and perceive the behaviour of building frame system. The core idea in comparison between Symmetric and Asymmetric tall building is to restrict the storey drift of the building into something more rigid and stable to limit deformation and enhance stability.
- ✓ Performance of Symmetrical building is better than Asymmetrical building.
- ✓ The storey drift is observed to be more in Asymmetric structure when compared to the Symmetric structure.

- ✓ Storey Drifts of Symmetric structure are within the limit according to clause number 7.11.1 of IS 1893 (Part I): 2002. The maximum allowable drift is 0.004times the height of the storey i.e. (h/250).
- ✓ Natural period of building reduces with increase in stiffness and increases with increase in mass.
- ✓ Buildings tend to oscillate in the directions in which they are most flexible and have larger translational natural periods.
- ✓ Base shear of Symmetrical structure is more as compare to Asymmetrical structure.

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