Seismic Investigation of Vertical Irregular Rcc And Steel Building By Dynamic Analysis

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Abstract- *The important objective of earthquake engineers is to design and build a structure in such a way that damage to the structure and its structural component during the earthquake is minimized. This report aims towards the dynamic analysis of a multi-storey RCC building with symmetrical configuration. For the analysis purpose model of ten storey's RCC with symmetrical floor plan is considered. The analysis is carried by using finite element based software SAP 2000. Various response parameters such as lateral force, base shear, story drift, story shear can be determined. For dynamic analysis time history method or response spectra method can be used. Time-history analysis is a step-by-step analysis of the dynamical response of a structure to a specified loading that may vary with time. The analysis may be linear or non-linear. Dynamic analysis can be performed for symmetrical as well as unsymmetrical building. Dynamic analysis can be in the form of nonlinear dynamic time history analysis. In this paper, a nonlinear time history analysis is performed on a ten storey RCC building frame considering time history of El Centro earthquake 1940 using SAP 2000. The main parameters of the seismic analysis of structures are load carrying capacity, ductility, stiffness, damping and mass. The various response parameters like base shear, storey drift, storey displacements etc are calculated. The storey drift calculated is compared with the minimum requirement of storey drift as per IS 1 893:2002..*

I. INTRODUCTION

Irregular buildings constitute a large portion of the modern urban infrastructure. The group of people involved in constructing the building facilities, including owner, architect, structural engineer, contractor and local authorities, contribute to the overall planning, selection of structural system, and to its configuration. This may lead to building structures with irregular distributions in their mass, stiffness and strength along the height of building. When such buildings are located in a high seismic zone, the structural engineer's role becomes more challenging. Therefore, the structural engineer needs to have a thorough understanding of the seismic response of irregular structures. In recent past, several studies have been carried out to evaluate the response of irregular buildings work that has been already done pertaining to the seismic response of vertically irregular building frames. Buildings with plan irregularities (e.g., those with re-entrant corners such as L-shape plans on corner plots) and those with elevation irregularities (e.g., large vertical setbacks in elevation such as a plaza-type configuration in commercial structures) are common in the affected area.

Torsion responses in structures arise from two sources: Eccentricity in the mass and stiffness distributions, causing a torsion response coupled with translation response; and torsion arising from accidental causes, including uncertainties in the masses and stiffness, the differences in coupling of the structural foundation with the supporting earth or rock beneath and wave propagation effects in the earthquake motions that give a torsion input to the ground, as well as torsion motions in the earth itself during the earthquake.

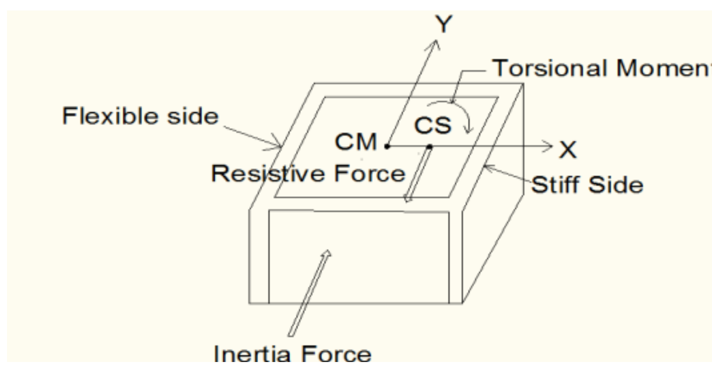


Fig 1 Generation of torsional moment in asymmetric structures

There are different types of irregularity is given in the code which are listed in below. Major failures occurred due to irregularities like soft storey Failure, Mass Irregularity Failure, Plan Irregularity Failure, Shear Failure.

- Seismic Analysis of T-shaped building is done for torsional analysis manually. Center of mass and center of rigidity are calculated, and then static eccentricity and design eccentricity is calculated. Torsional moments are calculated for seismic force at each floor. Additional shear along each column line is calculated.

- Same building is analyzed as regular building, building with soft storey and Modified building (with soft storey) as per IS 1893 (Part-I): 2002. And comparison of different parameters like bending moments, storey drift, and storey displacement is done by using software.

1.1 Types of irregularities:

1.1.1 Plan Irregularities:

i. Torsion irregularity
ii. Re-entrant Corners
iii. Diaphragm Discontinuity
iv. Out of plane offsets
v. Non parallel Systems

1.1.2 Vertical irregularities:

i. Stiffness Irregularity
ii. Mass Irregularity
iii. Vertical Geometric Irregularity
iv. In Plane discontinuity in vertical elements resisting lateral force
v. Discontinuity in capacity-weak storey

1.2 Objectives

- To study the concept of eccentricity with reference to building subjected to lateral force i.e. earthquake in vertical irregular structure
- To study the effect of stiffness of infill wall on the behavior of structure when subjected to seismic loading in vertical irregular structure
- To compare the variation of the performance level of the building with and without consideration stiffness of infill wall over the variation of eccentricity.
- To determine the collapse strength building in vertical irregular structure
- To observe the level change of internal forces coupled with increased eccentricity in vertical irregular structure

II. METHODOLOGY

The structure is modeled in SAP for the purpose of analysis the building design. The structures are two models one of 6 stories of 21.5m in height with infilled walls on each storey at periphery except parking storey, a cross-section size of about 230x450 mm and the columns are made of the cross section 300 x 750 mm with the longer side along the longer span and other is of 6 stories of 21.5m in height with infilled walls on each storey at periphery except parking storey, a cross-section size of about 230x450 mm and the internal columns are made of the cross section 300 x 750 mm and corner columns of size 300 x 900 mm with the longer side along the longer span. The structure has 4 spans in the Y direction with the being 4m each. The material assumed is Concrete of grade M25 and the Steel used is Fe 415. The Structure is loaded with a live load of about 3KN/m2 as per the live load requirements form IS 845 Part II assuming the structure to be a residential building. The design of the structure was designed in SAP as per IS 456. Two Load Cases were constructed to conduct the analysis in both directions the force is applied as acceleration.

2.1 Codal Provisions

Torsion provisions are incorporated in most building codes to redistribute the strength among elements to minimize the torsion effects. Codes usually divide the buildings into regular and irregular buildings and consider that static torsion provisions will be suitable for regular buildings. For irregular buildings, design based on dynamic analysis, such as the response spectrum method, is suggested.

The basic approach of design codes is application of linear static or dynamic load methods for design based on Earthquake Loading. Some of the codal provisions are studied in the following.

As per [IS 1893 (Part 1), 2002] the Static Eccentricity (e) is designed in the design codes as the distance between the Center of Mass (CM) and Center of Rigidity (CR) of the structure. The Center of Rigidity is designed as The point through which the resultant of the restoring forces of a system acts. The Center of Mass is designed as The point through which the resultant of the masses of a system acts. This point corresponds to the center of gravity of masses of system." The Design Eccentricities (edi,esi) are obtained based on the values of the static eccentricity after accounting for the dynamic implication of torsion and allowance for accidental torsion induced by rotational component of ground motion. Most design eccentricities are based on the formula

$$e_{di} = \alpha e + \beta b$$
$$e_{si} = \gamma e - \beta b$$

Table 1 Values In Different Codes

	IS 456	IBC 2003	NZ 4203: 1992	NBCC 1995
α	1.5	1	1	1.5
β	0.05	0.05Ax	0.1	0.01Az
γ	1	1	1	0.05

2.2 Indian Standard 1893: 2002

The IS 1893: 2002 assumes the inertial force caused by the Earthquake to act at the Center of Mass (CM) of the structure. The Static Eccentricity (e) is the distance between the Center of Mass (CM) and Center of Rigidity (CR) of the structure. The Design Eccentricity is obtained by using the formula for ed = 1.5es + 0.5b. The code has been modified to correctly include the stiffness of the infill walls in calculation of the Time Period (T) of the structure. Neglecting the stiffness of the infill wall causes the calculated period to be higher leading a reduced calculated Earthquake Load .The code has been revised to calculate the Time Period (T) of the building as $T = 0.9h/(d)^{1/2}$ instead of the old code.

All codes examined use the concept of minimum eccentricity to be assumed during design calculation for safety. The value of the dynamic eccentricity is also generally calculated based on the same formula involving the static eccentricity the width of the structure based on the direction of the eccentricity in question. The basis of difference among the codes is primarily on the values of the coefficients used in the formula while some codes prescribe a direct formula for calculation others codes prescribe a particular constant value.

2.3 Old Code Provisions:

In 1984 version of Indian Seismic Code makes provision for the increase in shear resulting from horizontal torsion due to the eccentricity (e) between the centre of mass and the centre of rigidity. The torsion moment (T) at each storey = the shear (V) in that storey multiplied by eccentricity (e). Since there could be quite a bit of variation in the computed value of e, the code recommends that the design eccentricity (ed) be taken as 1.5e. Negative torsion shears shall be neglected. The net effect of this torsion is to increase the shear in certain structural elements and reduction in certain others. The code recommends that reduction in shear on account of torsion should not be applied and only increased shear in the elements be considered. The torsion forces shall be distributed to the various vertical components of the seismic resisting system with due consideration given to the relative stiff nesses of the vertical components and the diaphragm. It is then corrected for torsion taking into account the increases produced, but not the decreases as specified in the code. The following steps are involved to determine the additional shears due to torsion in a building.

Let OX and OY be a set of rectangular coordinate axes, the origin O being taken at the left corner of the building. If x and y are the coordinates of various elements and Kx and Ky their stiff nesses in the two directions, the coordinates (Xr,Yr) of the centre of rigidity or the point of rotation are computed as

$$Xr = \Sigma Kyx / \Sigma Ky \quad \ldots\ldots\ldots 1$$
$$Yr = \Sigma Kxy / \Sigma Kx \quad \ldots\ldots\ldots 2$$

The rotational stiffness Ip of the structure about the centre of rotation Cr is given by

$$Ip = \Sigma(KxY2 + KyX2) \quad \ldots\ldots 3$$

If the torsional moment,

$$T= Ved \quad \ldots\ldots\ldots 4$$

Where ed = 1.5e, the torsion shears Vx and Vy on any column line be computed as:

$$Vx = T.\ Y.\ Kxx/ Ip \quad \ldots\ldots\ldots 5$$
$$Vy = T.\ X.\ Kyy/ Ip \quad \ldots\ldots\ldots 6$$

Where Kxx, Kyy are the total stiff nesses of the column line under consideration and X and Y are coordinates w.r.t the centre of rigidity Cr.

III. STRUCTURAL MODELS, LOADINGS & RESPONSE PARAMETERS OF INTEREST

The study in this work is based on the analysis of a family of structural models representing multi-story asymmetrical buildings. These models are subjected to both critical and lateral loadings expected on buildings during an earthquake. A set of response parameters is used to illustrate the effect of torsion in these buildings. The purpose of this chapter is to present the basic assumptions and the tools utilized in this work. The different building configurations are introduced first. Then the methods and the loadings used in the analysis are discussed. Finally the chosen response parameters are outlined. The material presented in this chapter prepares the background information for the results to be presented in the subsequent chapters.

3.1 Building Configurations:

The basic structural model used throughout this a study is uniform G+6 story building; symmetric with respect to both X and Y axis to demonstrate many of the features expected from multi-story buildings subjected to seismic loading. The assumed plan of building is shown in Fig. It has square shape floor plan of dimensions 16.0 m by 16.0 m, and a uniform floor height of 3 m and lower storey of height 3.5 Fig. The plan considered is symmetric. For convenience, the X-direction is referred to as the main direction and the Y-direction is referred to as the transverse direction. To resist the lateral loads, there are 25 RC columns supporting to slab. The slab is of thickness 0.15 m with beams of size 0.23x0.45 m are provided throughout the building in all floors. All the columns are placed at strategic locations with spacing of 4.0 x 4.0 m, having 4 bays in X direction & 4 bays in Y direction. The grids are marked as 1 to 5 in X direction and A to E in Y direction as shown in Fig. The Seismic analysis is carried out as per the latest IS-1893-2002 code by the Response Spectrum technique. The buildings are assumed to be located in zone-II, zone-V and located on three types of soils (Hard, Medium; Soft soils). The Response quantities considered includes axial forces, moments in X & Y directions, twisting moments, % steel, steel area etc. for the columns; further both ordinary moment resisting frame (OMRF) is considered.

3.2 Computer Software SAP 2000:

The static and dynamic behavior of the multi-story asymmetric buildings in the elastic range is the main focus of the study reported in this work. Therefore computer program with the ability of performing 3-D elastic static and dynamic analysis was necessary. The program SAP 2000 has been chosen as the base computer software in performing the analyses. To have a clear understanding of the analysis a study has been carried out to evaluate this program by comparing its results with the responses derived from the manual calculations.

3.3 Basic Assumptions In Modeling:

The following are the main modeling assumptions used in this study.

3.4 Modeling Of The Building

- **Rigid slab:**

It is assumed that all the columns in the buildings are connected by floor diaphragms that are rigid in their own plane. Therefore every floor has only two translational and One rotational degrees of freedom. The in-plane displacements of all the nodes on the floor are constrained by these degrees of freedom. However, the nodes can have independent vertical displacements.

- **Fixed base:**

The columns of buildings are assumed to be fixed at their base on rigid foundation. No soil-structure interaction effect is considered in this study.

- **One directional earthquake input:**

Only one direction of response values are applied at the junction of columns and floor diaphragms. Due to the fixed base assumption, all supports are assumed to move in phase. No vertical translation is applied to the buildings.

- **Lumped mass at floor level:**

The mass and the mass rotational moments of inertia of the buildings are assumed to be lumped at the floor levels.

PROBLEM STATEMENT

Present research involves the study effect of vertical irregularity in multistoried building under seismic loading. For this study, a G+15, G+20, G+25 story building with 3.1 meters height for each story, regular in plan is considered. This building is considered to be situated in seismic zone III and designed in compliance to the Indian Code of Practice for Earthquake Resistant Design of Structures IS 1893(part–I):2002.The building is considered to be fixed at the base. The building is modeled using relevant software. Model is studied for comparing base shear, storey shear and max. Storey displacement, shear in column. Also different model are study with reduction of column sizes up to top floor and floating column at various floor height. We also study effect of mass irregularity and stiffness in various height structures.

Table 3.1: Description for All Frames

Type of structure	Special Moment Resisting frame (SMRF)
Number of stories	G+15, G+20, G+25
Seismic zone	III
Floor height	3.1m
Type of soil	Medium
Size of Column	300*600, 300*450
Size of Beam	300*600
Depth of Slab	150mm
Live Load	3 kN/m^2
Material	M30 & Fe 500 reinforcement,
Unit weight	Concrete -25 kN/m^3 Masonry – 20 kN/m^3
Damping in structure	5%
Importance factor	1.5

Type of load	Load value
Dead load	
On floor slabs	
Self weight	3.75 kN/m2
partition wall (assumed)	2.00 kN/m2
floor finish (assumed)	1.00 kN/m2
Total dead load on floors	6.75 kN/m2
On roof slab	
Self weight	3.75 kN/m2
weathering course (assumed)	2.00 kN/m2
Total dead load on roof	5.75 kN/m2
Live load	
On floor slabs	
Live load on floors	2.50 kN/m2
On roof slab	
Live load on floors	1.50 kN/m2

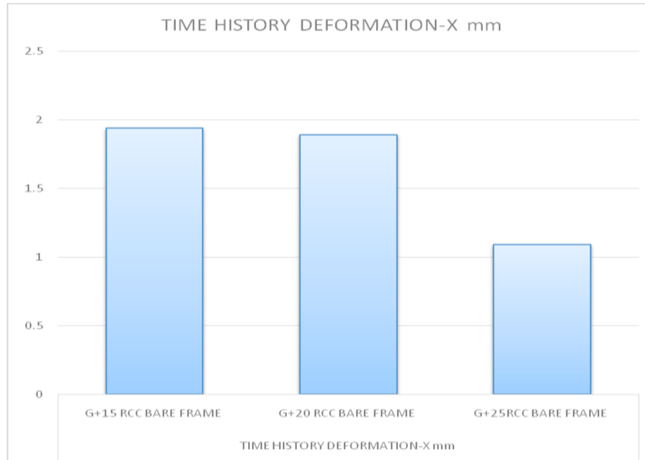
IV. RESULTS AND DISCUSSION

GRAPHS AND BAR CHARTS:

4.1 TIME HISTORY DEFORMATION FOR ELCENTRO GRAPH:

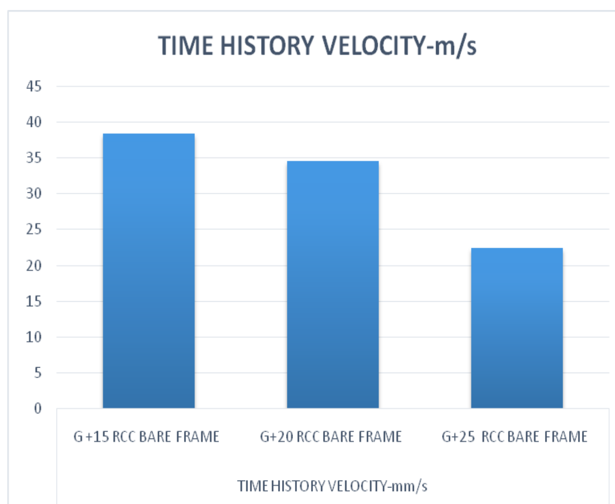
Table.4.1: Member, Nodes and Supports for All Frames

G+15 RCC BARE FRAME	G+20RCC BARE FRAME	G+25RCC BARE FRAME
1.89	1.74	1.09



4.2 TIME HISTORY VELOCITY GRAPH FOR ELCENTRO:

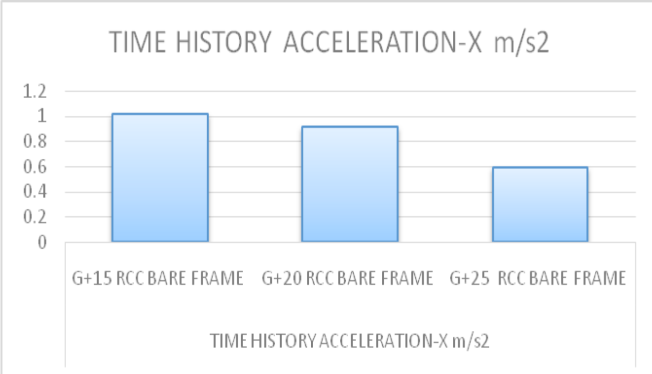
TIME HISTORY VELOCITY-mm/s			
	G+15 RCC BARE FRAME	G+20 RCC BARE FRAME	G+25RCC BARE FRAME
	34.56	22.464	26.9568



From above chart it is observed that time history velocity for G+15 is greater than G+20 RCC bare frame.

TIME HISTORY ACCELERATION GRAPH FOR ELCENTRO:

TIME HISTORY ACCELERATION-X m/s2			
RCC BARE FRAME	G+15 RCC BARE FRAME	G+20 RCC BARE FRAME	G+25RCC BARE FRAME
1.02	0.918	0.5967	0.71604



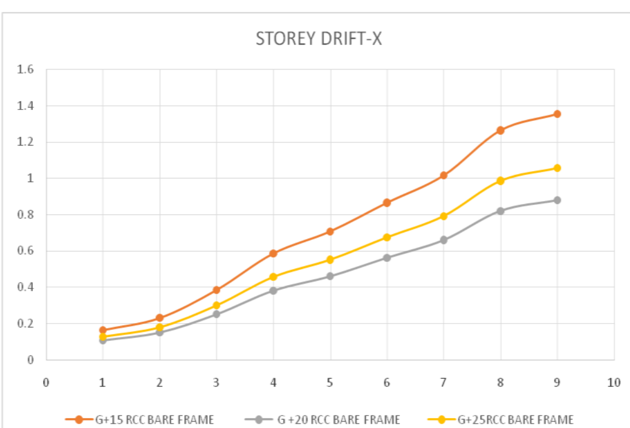
From above chart it is observed that time history acceleration for G+15 is greater than G+20 RCC bare frame.

A. Comparative dynamic analysis

1) 4.1 STOREY DRIFT FOR EL CENTRO :

Table 6.5.1: Member, Nodes and Supports for All Frames

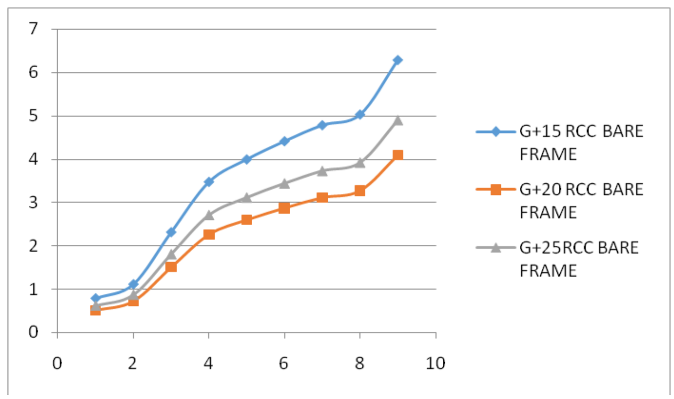
STOREY NO.	G+15 RCC BARE FRAME	G +20 RCC BARE FRAME	G+25RCC BARE FRAME
1	0.1638	0.10647	0.127764
2	0.2304	0.14976	0.179712
3	0.3843	0.249795	0.299754
4	0.585	0.38025	0.4563
5	0.7065	0.459225	0.55107
6	0.864	0.5616	0.67392
7	1.0143	0.659295	0.791154
8	1.2618	0.82017	0.984204
9	1.3518	0.87867	1.054404



STOREY DRIFT FOR ELCENTRO IN Y DIRECTION :

STOREY NO.	G+15 RCC BARE FRAME	G+20 RCC BARE FRAME	G+25RCC BARE FRAME
1	0.7884	0.51246	0.614952
2	1.1133	0.723645	0.868374
3	2.313	1.50345	1.80414
4	3.4722	2.25693	2.708316
5	3.99069	2.5939485	3.1127382
6	4.41	2.8665	3.4398
7	4.779	3.10635	3.72762
8	5.0256	3.26664	3.919968
9	6.282	4.0833	4.89996

4.2Storey drift graph for RCC bare frames in Y direction for EL CENTRO.



V. CONCLUSION

1. From above results it is observed that,
2. The storey shear force is maximum for the first storey and it decreases to minimum in the top storey.
3. It is observed that time history deformation for G+15 is greater than G+25 RCC bare frame.
4. It is observed that time history velocity for G+15 is greater than G+20 RCC bare frame.
5. It is observed that time history acceleration for G+15 is greater than G+20 RCC bare frame.
6. It is observed that storey drift RCC bare frame is more than G+15,G+20 than G+25 RCC bare frame.
7. It is observed that storey drift RCC bare frame is more than G+15,G+20 than G+25 RCC bare frame.
8. It is observed that base shear for RCC bare frame is more than G+15,G+20 than G+25 RCC bare frame
9. It is observed that Natural frequency for model no 1 is more than model no 2 and model no 3.

10. The stiffness irregular structure experiences lesser base shear than similar regular structures.
11. The mass irregular structures experiences larger base shear than similar regular structures.

VI. FUTURE SCOPE

- A further research for development of new technologies in composite construction such as slim-floor slabs with semi continuous connections to the columns, new steel sheets or systems to minimize the time of erection and assembly is desirable.
- The idealizing assumption of beam-to-column connections as hinged or fully rigid due to lack of more realistic guidance in view of modeling advocates for further research on non-linear response of joints considering rotational stiffness, moment of resistance and rotational capacity. Preparation of guidelines for modeling different type of connections may also prove very helpful.
- Preparation of miniature specimens for testing may be thought of to avoid costly experimentation generally carried out on full size models to known the exact behavior of steel-concrete composite structural elements. A numerical analysis of the same will also be highly desirable to correlate the data and result.
- Recent development in composite construction technology, which have successfully transformed the market place in other countries, providing added value to the customers and rapid return on the invested capital. These, if adopted in India for residential and commercial building, could be very beneficial to the Indian community. In this regard, development of suitable design aids may be very fruitful.
- The use of precast concrete and even the prestressed concrete component in certain composite structure applications may prove fruitful as it has potential due to the economy that can be achieved by these components in terms of time, labour and money.

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