Journal of **N**onlinear **A**nalysis and **O**ptimization
Vol. 13, Issue. 2 : 2022
ISSN : **1906-9685**

DESIGN AND ANALYSIS OF A G+15 BUILDING IN SEISMIC ZONES IN INDIA USING STAAD PRO

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ABSTRACT
One of the most frightening and destructive phenomena of nature is a severe earthquake and its terrible aftereffects. Earthquakes strike suddenly, violently and without warning at any time of the day or night. If an earthquake occurs in a populated area, it may cause many deaths and injuries and extensive property damage. Although there are no guarantees of safety during an earthquake, identifying potential hazards ahead of time and advance planning to save lives and significantly reduce injuries and property damage. Hence it is mandatory to do seismic analysis and design to structural against collapse. It is highly impossible to prevent an earthquake from occurring, but the damage to the buildings can be controlled through proper design and detailing. Designing a structure in such a way that reducing damage during an earthquake makes the structure quite uneconomical, as the earthquake might or might not occur in its life time and is a rare phenomenon. In order to compete in the ever-growing competent market, it is very important for a structural engineer to save time. There are several methods for analysis of different frames like Kani's method, cantilever method, portal method, and Matrix method. The present project deals with the seismic analysis and design of a multi storied residential building of G+15 RCC Residential Building. The design is made using software on structural analysis design (STAAD-pro). The building was subjected to both vertical loads as well as horizontal loads. The vertical load consists of dead load of structural components such as beams, columns, slabs etc. and live loads. The horizontal load consists of the wind forces thus building is designed for dead load, live load and wind load and seismic loads as per IS 875. The help is taken by software available in institute and the computations of loads, moments and shear forces and obtained from this software.

Keywords: Earthquake, Seismic Analysis, STAAD Pro, Collapse.

I. INTRODUCTION

1.1 GENERAL

Seismic Analysis is a subset of structural analysis and is the calculation of the response of a building structure to earthquakes. It is part of the process of structural design or structural assessment and retrofit in regions where earthquakes are prevalent. Nonlinear dynamic analysis utilizes the combination of ground motion records with a detailed structural model, therefore is capable of producing results with relatively low uncertainty. In nonlinear dynamic analysis, the detailed structural model subjected to a ground motion record produces estimated of component deformations for each degree of freedom in the model and the modal responses are combined using schemes such as the square root sum of squares. In nonlinear dynamic analysis, the nonlinear properties of the structure are considered as part of a time domain analysis. This approach is the most rigorous, and is required by some building codes for buildings of unusual configuration or of special importance. However, the calculated response can be very sensitive to the characteristics of the individual ground motion used as seismic input.

Therefore, several analyses are required using different ground motion records to achieve a reliable estimation of the probabilistic distribution of structural response. Since the properties of the seismic response depend on the intensity, or severity, of the seismic shaking, a comprehensive assessment calls for numerous nonlinear dynamic analyses at various levels of intensity to represent different possible earthquake scenarios. This has led to the emergence of methods like the incremental dynamic analysis.

1.2 EARTHQUAKES:

Vibrations of the earth's surface caused by waves coming from a source of disturbances inside the earth are described as earthquake. By far the most important earthquake from an engineering standpoint is of tectonic origin, that is, those associated with large scale strains in the crust of the earth. One of the theories describing this phenomenon is termed elastic rebound theory. It explains that the strain energy that accumulates due to deformation in earth mass, gets released through rupture when it exceeds the resilience of the storing materials.

The energy thus released is propagated in the form of wave which impact energy to the media through which they pass and vibrate the structure standing on the earth's surface.

A major tectonic earthquake is generally preceded by small 'foreshocks' caused either by small rupture or plastic deformation and followed by 'aftershocks 'due to the fresh rupture or the readjustments of the fractured mass. A major shock may result from a rapture of the rock over a length of 100 to 400 km and several kilo meters wide and thick.

Small earthquakes may also be caused by volcanic eruptions, subsidence in mines, blasts, impounding of reservoirs, pumping of oil, etc. They may cause considerable damage in the small areas, but vast areas are shaken only by tectonic movements across active faults. Recently, geologists have proposed a theory termed plate tectonics. It offers an elegant comprehensive explanation for continent drift and mountain buildings. It holds that the surface earth consists of about a dozen giant plates of rock, 100km thick, which float on the earth's semi molten mantel and propelled by an undetermined force. The plates are in constant motion, and where the meet, friction temporarily locks them in place cause stress to build up near their edges. Eventually the rock fractures allowing the plates to resume their motion. The energy released causes earthquakes.

Figure 1: Concrete Building Damaged due to earthquake

An earthquake is what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the earth's surface where the earthquake starts is called the hypocentre, and the location directly above it on the surface of the earth is called the epicentre.

Sometimes an earthquake has foreshocks. These are smaller earthquakes that happen in the same place as the larger earthquake that follows. Scientists can't tell that an earthquake is a foreshock until the larger earthquake happens. The largest, main earthquake is called the mainshock. Mainshocks always have aftershocks that follow. These are smaller earthquakes that occur afterwards in the same place as the mainshock. Depending on the size of the mainshock, aftershocks can continue for weeks, months, and even years after the mainshock.

The earth has four major layers: the inner core, outer core, mantle and crust. The crust and the top of the mantle make up a thin skin on the surface of our planet.

But this skin is not all in one piece – it is made up of many pieces like a puzzle covering the surface of the earth. Not only that, but these puzzle pieces keep slowly moving around, sliding past one another and bumping into each other. We call these puzzle pieces tectonic plates, and the edges

JNAO Vol. 13, Issue. 2: 2022

of the plates are called the plate boundaries. The plate boundaries are made up of many faults, and most of the earthquakes around the world occur on these faults. Since the edges of the plates are rough, they get stuck while the rest of the plate keeps moving. Finally, when the plate has moved far enough, the edges unstick on one of the faults and there is an earthquake.

1.3 EARTHQUAKE TERMINOLOGY

Aftershock: **III.**

An earthquake of similar or lesser intensity that **IV.** follows the main earthquake.

Earthquake:

A sudden slipping or movement of a portion of the earth‘s crust, accompanied and followed by a series of vibrations.

Epicentre:

The place on the earth’s surface directly above the point on the fault where the earthquake ruptures began. Once fault slippage begins, it expands along the fault during the earthquake and can extend hundreds of miles before stopping.

Faults:

The fracture across which displacement has occurred during an earthquake. The slippage may range from less than an inch to more than 10 years in a severe earthquake.

Magnitude:

The amount of energy released during an earthquake, which is computed from the amplitude of the seismic waves. A Magnitude of 7.0 on the Richter scale indicates an extremely strong earthquake. Each whole number on the scale represents an increase of about 30 times more energy released than the previous whole number represents. Therefore, an earthquake measuring 6.0 is about 30 times more powerful than one measuring 5.0.

Figure 2: Earthquake Magnitude Effects

1.14 OBJECTIVE OF THE PROJECT

Following specific objectives has been made for the present study

1) To develop, planning and analysis model of the High-rise structure in STAAD Pro

2) Study of seismic load applied to the structure as per IS 1893-2002.

5) To study the performance in zones II, III, IV and V.

LITERATURE REVIEW

2.1 GENERAL

Current literature survey includes earthquake response of multi storey building frames. Some of the literatures emphasized on strengthening of the existing buildings in seismic prone regions.

Chandrasekaran and Rao, investigated the design of multi- storied RCC building for seismicity. Reinforced concrete multi-storied buildings are very complex to model as structural systems for analysis. Usually, they are modelled as 2-D or 3-D frame system using finite beam element. However, no guidelines are available for the rational computation of sectional properties incorporating the effect of reinforcement in concrete members and the analysis is full of approximations.

A case history of a RC structure, where the first author was involved in the study, is briefly cited in the paper. The current version of the IS: 1893-2002 requires that practically all multi-storied building be analyzed as three-dimensional system. This is due to the fact that the building has generally irregularities in plan or elevation or in both Further, seismic intensities have been upgraded in weaker zones as compared to the last version IS: 1893-1984.

It has now indirectly become mandatory to analyze all multistoried buildings in the country for seismic forces. This paper appraises briefly the significant changes in the current version of the code compared to the previous version. Some of the poor planning and construction practices of multistoried buildings in Peninsular India in particular, which lead to irregularities in plan and elevation of the buildings are also discussed in this paper. At present, there is too wide a variation in the modelling of buildings. This paper emphasizes the need for guidelines in order to limit the range of assumptions to a narrow range. This is necessary to certify the analysis and design, or in case legal disputes arise later regarding the procedure adopted.

Shunsuke Otani, studied earthquake resistant design of RCC Buildings (Past and Future) This paper briefly reviews the development of earthquake resistant design of buildings measurement of ground acceleration started in 1930's, and the response calculation was made possible in 1940's. Design response spectra were formulated in the late 1950's to 1960's.

Non- linear response was introduced in seismic design in 1960's and the capacity design concept were introduced in 1970's for collapse safety. The damage statistics of RCC buildings in 1995 Kobe disaster demonstrated the improvement of building performance with the development of design methodology. Buildings outdated methodology should be upgraded. Performance basis engineering should be emphasized, especially for the protection of building functions following frequent earthquakes.

Janakkumar M. Mehta, observed that the building height is more and more slender, and more susceptible to sway and hence dangerous in the earthquake. Such type of the building can be strengthening by providing an appropriate lateral load resisting system. In the seismic design of the buildings, reinforced concrete structural walls or shear- wall, act as major earthquake resisting members. Structural walls provide an efficient bracing system and offer great potential for lateral load resistance.

The properties of these seismic shear-walls dominate the response of the buildings and therefore, it was important to evaluate the seismic response of the walls appropriately. In this study the (G+17) storey building was analyzed with different shear-wall configuration. The modelling is done to examine the effect of different cases on seismic parameters like base shear, lateral displacements, lateral drifts and model time period for the zone-V in medium soil as specified in IS: 1893-2002.

Maikesh Chouhan: The design of multi storey building is to have a good lateral load resisting system along with gravity load system for safety of occupant and for better performance of structure even in most adverse condition. Shear wall are more efficient in resisting lateral load in multi storied buildings. Steel and reinforced concrete shear walls are kept in major positions of multi storied buildings which are made in consideration of seismic forces and wind forces.

To solve this purpose shear walls are a very powerful structural elements, if used judiciously can reduce deflections and stresses to a very great extent. Quantity of Concrete and steel required in shear wall building is more as compared to without shear wall building, which makes, it uneconomical.

R.Ellingwood, studied the prospect and future improvement in earthquake resistant and design procedure based on the more rational probability-based treatment of uncertainty are examined.

IS 1893(part1):2002 [21] these standard deals with assessment of seismic loads on various structures and earthquake resistant design of buildings, its basic provision is applicable for building; elevated structures; industrial and stack like structures; bridges; concrete masonry and earth dams; embankments and retaining walls and other structures.

S.K. Ahirwar, S.K.Jain and M.M.Pande, Estimated earthquake loads on multi-story

R.C. Framed buildings as per IS:1893-1984 and IS:1893-2002 recommendations. They considered three, five, seven and nine storey buildings and each was analysed individually. For each building, a set of five individual sequences was decided in the process. The methods of analysis adopted were the Seismic Coefficient method, Response Spectrum method, and Modal Analysis method. Seismic responses viz. storey shear, base shear.

L.G.Kalurkar, The design and analysis of multi-storeyed G+5 building using composite structure at earthquake zone3. A three-dimensional modelling and analysis of the structure are carried out with the help of SAP 2000 software. Equivalent Static Method of Analysis and Response spectrum analysis method are used for the analysis of both Composite and RCC structures. The results are compared and found that composite structure more economical.

Akshay R. Kohli, Analysis and Design of An Earthquake Resistant Structure Using STADD-Pro. With the advent of advanced technology, civil structures such as high- rise buildings and long span bridges are designed with increased flexibility, increasing their susceptibility to external excitation. Therefore, these structures are vulnerable to excessive modes of vibration under the effect of a strong wind and earthquake. To protect such civil structures from significant structural damage, the seismic response of these structures is analysed along with wind force calculation and forces such as support reactions and joint displacement are calculated and included in the structural design for a vibration resistant structure.

METHODOLOGY

3.1 GENERAL

The building structure is designed, analyzed using Staad pro software mainly focusing on seismic and wind analysis parameters. As per IS 456:2000 and the Linear Static Method all the structural members of the diagrid model are designed and IS 1893 (PART 1): 2002 is considered for load combination of seismic analysis. the structures are carried out on the basis of lateral force assumed to act along with the gravity loads. The base shear which is the total horizontal force on the structure is calculated on the basis of structure mass and fundamental period of vibration and corresponding mode of shape. The base shear is distributed along the height of the structure in terms of lateral forces according to codal provisions (Kazuhiro, 1987). In this study, a multi storied RC building has been analyzed using the equivalent static method in staadpro.

3.2 TYPES OF LOADS ACTING ON THE STRUCTURE

In an advancement of building two essential issue considered are security and economy. If the piles are adjusted and taken higher then economy is affected. In case economy is considered and stacks are taken lesser then the security is bartered. So the estimation of various weights acting is to figured unequivocally. Indian Standard code IS: 875-1987 and American Standard Code ASCE 7: Minimum Design Loads for Buildings and Other Structures decides distinctive layout loads for structures.

Sorts of weights falling up on the structure are:

- Dead loads
- Imposed loads
- Wind loads
- Snow loads
- Earthquake

Dead load: A constant load in a structure (such as a bridge, building, or machine) that is due to the weight of the members, the supported structure, and permanent attachments or accessories.

Live load: The second vertical load that is considered in plan of a structure is forced loads or live loads. Live loads are either portable or moving burdens with no quickening or effect. These heaps are thought to be delivered by the planned utilize or inheritance of the building including weights of versatile parcels or furniture and so forth. Live load continues changing now and again. These heaps are to be reasonably expected by the planner. It is one of the significant loads in the plan. The base estimations of live loads to be expected are given in IS 875 (section 2) – 1987. It relies on the expected utilization of the building.

Floor load: The load that a floor (as of a building) may be expected to carry safely if uniformly distributed, usually calculated in KN per square meter of area.

Seismic load: Seismic loading is one of the basic concepts of earthquake engineering which means application of an earthquake generated agitation to a structure. It happens at contact surfaces of a structure either with the ground or with adjacent structures or with gravity waves from tsunami.

Wind load: Wind is a mass of air that moves in a mostly horizontal direction from an area of high pressure to an area with low pressure. The wind load is defined as the load on a structure due to the action of wind. High winds can be very destructive because they generate pressure against the surface of a structure. The effect of the wind is dependent upon the size and shape of the structure. Calculating wind load is necessary for the design and construction of safer, more wind-resistant buildings and placement of objects such as antennas on top of buildings.

3.3 PLAN

The general plotting represents the plan of multi stored building. The Structure which is surrounded by many apartments. In each block the entire floor consists of a two-bed room flats which occupies entire floor of a block. The plan shows the details of dimensions of each and every room and the type of room and orientation of the different rooms like bed room, bathroom, kitchen, hall etc. All the stories have similar room arrangement.

The entire plan area is about 256 sq.m There is some space left around the building for parking of cars. The plan gives detail of arrangement of various furniture like sofa etc. So, these represent the plan of our building and detailed explanation of remaining parts like elevations and designing is carried in the next sections.

3.4 ELEVATION

Figures represent the proposed elevation of building. It shows the elevation of a multi stored building representing the front view which gives the overview of a building block.

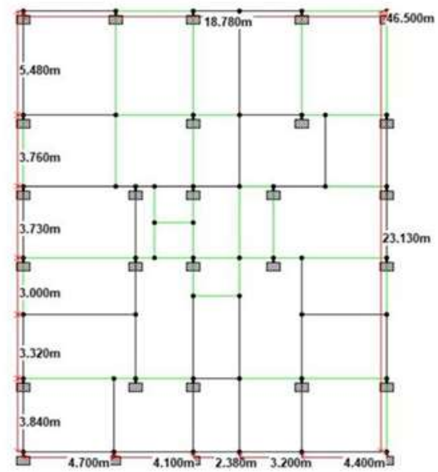
Each floor consists of height 3 m which is taken as per municipal corporation rules for single column buildings. The building is not designed for increasing the number of floors in future. So, the number of floors is fixed for future also for this building due to unavailability of the permissions of respective authorities.

Inputting the job Information:

Firstly, the information of the project is written after opening the Staad-Pro. As the name of the project/job, Client's name and the date when project started and the name of the Engineer as well and much more information is inputted.

Generating the 3d model geometry:

There are two methods of creating a structure data in Staad-Pro. a. Using the command file also called "The Staad-Pro editor method". b. Using the graphical user interface (GUI). We have done our whole of the programming with the help of GUI method because it is easier and much advance tool of Staad-Pro. The model of the framed structure is generated in Staad-Pro by Snap.



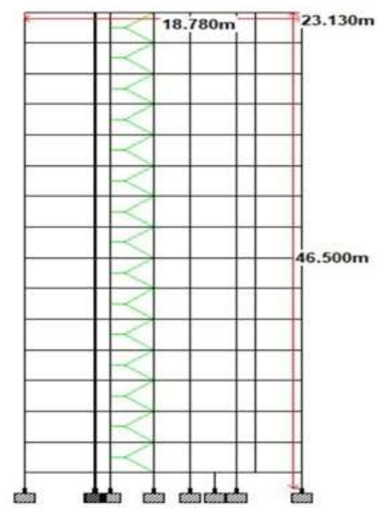
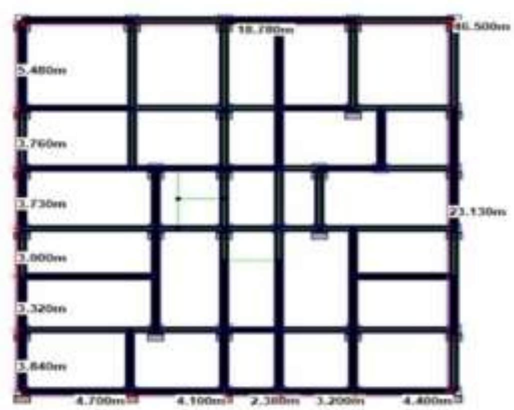


Figure 5: Plan view of G+15 building



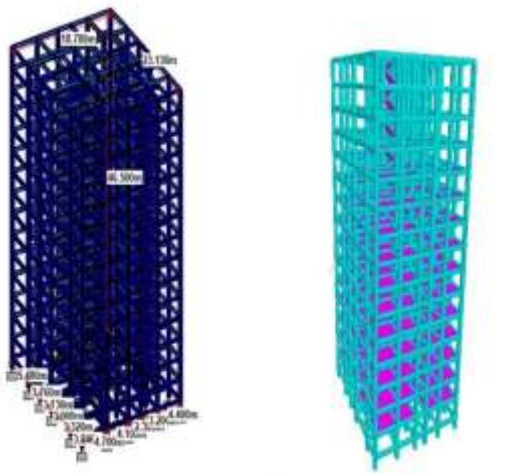


Figure 6: Rendering view:

3.5 PARTICULARS OF THE BUILDING

Table1: Particulars of the building

S. No.	Particular	Details of Multi storey building structure
1	Type of construction	R.C.C framed structure
2	Dead Load	Self-weight: 1 Outer wall load:11.73 KN/m Inner wall load: 5.36/m Parapet wall load: 4.75 KN/m Floor load: 4.75KN/mm 2
3	Live load	3 KN/m2 at typical floor, 1.5KN/m2 on terrace
4	Wind load	As per IS 875 – Not designed for wind load, since earthquake loads exceed the wind loads
5	Earthquake Load	Select Zone II,III,IV,V (as per IS-1893 (Part 1) – 2002)
6	Number of stories	G+15(16 storeys)
7	Depth of foundation below ground	1.5m
8	Slab Thickness	150mm
9	Type of soil	Type II, Medium as per IS:1893
10	Storey height	Floor to Floor – 3m Floor to Ground Floor – 1.5m
11	Plan size	18.78m X 23.13m
12	No. of bays in X direction	5
13	No. of bays in Y direction	6
14	Grade of concrete	M-30
15	Grade of steel	Fe 415 Structural Steel
17	Column size	0.6m x 0.6m
19	Beam size	0.5m x 0.4m
21	Building importance factor	1
22	Response reduction factor for concentric and eccentric respectively	5
23	Height of building	19.5m

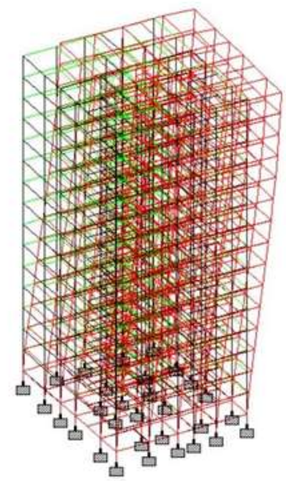


Figure 7: Displacement of the building due to the load calculations

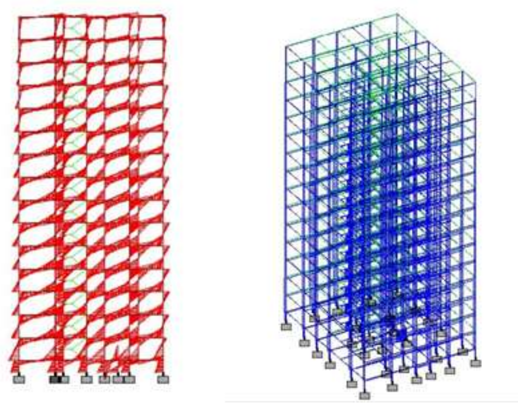


Figure 8: Bending moment and shear force of the building due to the load conditions

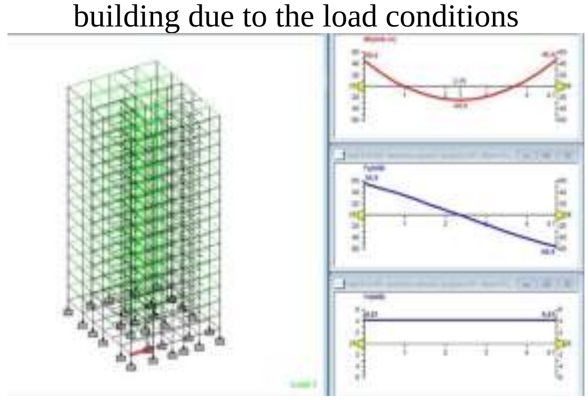


Figure 9: Shear force and bending moment diagrams of beam

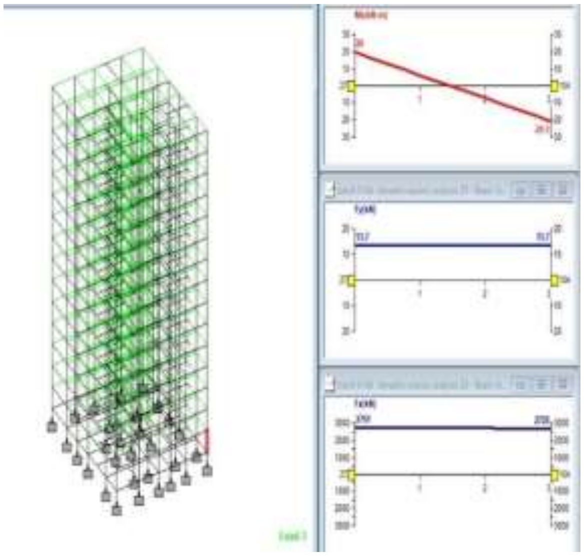
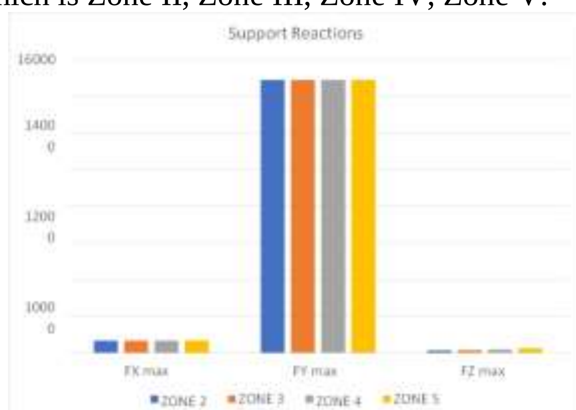


Figure 10: Shear force and bending moment diagrams of column

RESULTS & DISCUSSIONS

4.1 SUPPORT REACTIONS:

Maximum and Minimum support reactions of the building for the different seismic zone conditions which is Zone II, Zone III, Zone IV, Zone V.

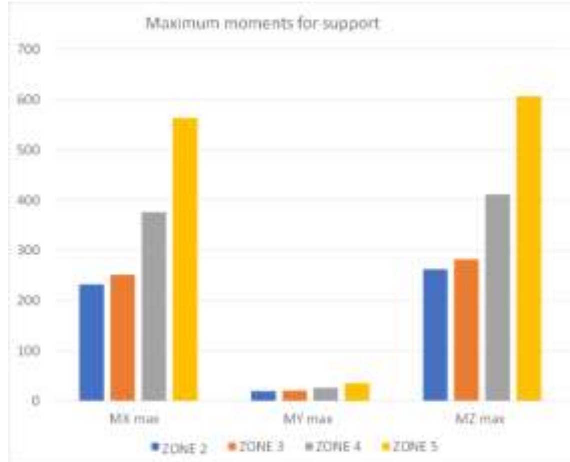


Graph 1: Maximum forces for support reactions

The table shows the maximum force value of support reactions developed for the critical load combination which may possible to act on the building for the different seismic zone factors. They are as listed in below table:

Table 2: Maximum forces for support reactions

	ZONE 2	ZONE 3	ZONE 4	ZONE 5
FX max	665.18	665.18	665.18	677.835
FY max	14900	14900	14900	14900
FZ max	138.119	149.11	185.465	255.534



Graph 2: Maximum moments for support reactions

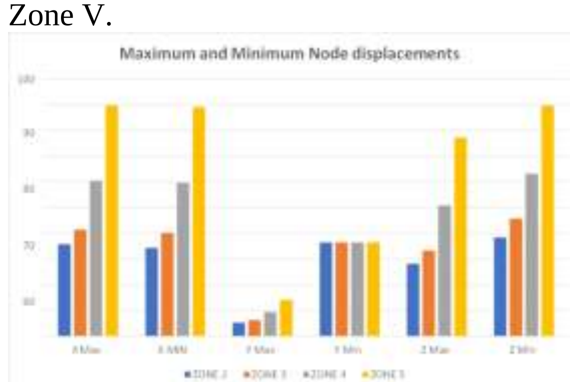
The table shows the maximum moment value of support reactions developed for the critical load combination which may possible to act on the building for the different seismic zone factors. They are as listed in below table:

Table 3: Maximum moments for support reactions

	ZONE 2	ZONE 3	ZONE 4	ZONE 5
MX max	231.735	251.209	376.12	563.487
MY max	19.158	20.656	25.647	34.886
MZ max	261.969	281.365	411.508	606.723

4.2 MAXIMUM AND MINIMUM NODE DISPLACEMENTS

The maximum and minimum node displacement of the building for the different seismic zone conditions which is Zone II, Zone III, Zone IV, Zone V.



Graph 3: Maximum and minimum displacements

The above graph shows the maximum and minimum value of node Displacements for the critical load combination which may possible to occur in the building for the different seismic zone factors.

CONCLUSIONS

The following conclusions have been drawn from the comparative assessment of provisions of different Code: -

There is no uniformity in type of building described in various results.

- The base shears, base moments and hydrodynamic pressures increase with increasing zone factors.
- Maximum nodal displacement and minimum nodal displacement found at the beams and columns of building
- Shear force and bending moment of building increased with seismic Zone II to Zone V Because of Zone factor, response reduction factor etc. While considering seismic analysis
- Displacement of the building is increase with seismic Zone II to Zone V Because of Zone factor, response reduction factor etc. While considering seismic analysis
- Base shear of the building increase with seismic Zone II to Zone V Because of Zone factor, response reduction factor etc. While considering seismic analysis
- Most of the results don't provide lower bound limit on spectral values for building.
- Ratio of Base Shear of building is 6 to 7 for low ductility building and 3 to 4 for high ductility building.
- Suitable provisions for lower bound limit on spectral values for building are necessary. Only ACI 371, dealing with elevated building and IBC 2000 have such provisions.
- Convective Mode Base Shear values obtained from API 650 and Euro Code 8 are similar but those obtained from ACI 350.3 is 2.5 times greater than that of ACI370.
- Indian Code needs to include provisions on lower bound limit on spectral values of buildings and building and also Convective Mode of vibration in the seismic analysis of building.
- Based on the review of various International Codes, it is recommended that IS1893 should have values of R in range of 1.1to2.25 for different types of building.
- R Value taken in IS 1893:1984 is nowhere in the range corresponding to that value in different international codes.
- Base Shear and Base Moment increases from Zone 3 to Zone 4 to Zone5.
- With the increase in R value Base Shear and Base Moment decreases.
- The seismic forces remain constant in a particular Zone provided the soil properties remain same.
- In coastal region Wind force is predominant, but in interior earthquake forces are more predominant lying in the same Zone.

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