Comparative Analysis of Regular and Irregular Multistory Building in Different Seismic zone with IS 1893:2016

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Abstract - *Earthquake never kills people but the defective structures do. The stability and stiffness of any structure is the major issue of concern in any high rise buildings. Shear walls are structural members which resist lateral forces predominant on moment resisting frame. The result is tabulated and graphs are plotted for displacement, base shear, and time period. The comparative study of regular and irregular building using is code 1893-2016.*

***Key Words*:** IS 1893:2016; stad pro, base shear, displacement etc.

1. INTRODUCTION

Earthquake means the sudden vibration of earth which is caused by naturally or manually. We know that different type of vertical irregularities buildings are used in modern infrastructure. During an earthquake, the building tends to collapse. This is mainly due to discontinuity in geometry, mass and stiffness. This discontinuity is termed as Irregular structures. So vertical irregularities are one of the major reasons of failures of structures during earthquakes. In planning stage of vertical irregularity due to some architectural and functional reasons. During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure.

Amongst the natural hazards, earthquakes have the potential for causing the greatest damages. Since earthquake forces are random in nature & unpredictable, the engineering tools needs to be sharpened for analysing structures under the action of these forces. About 60% of the land area of our country is susceptible to damaging levels of seismic hazard. In future, earthquakes can't be avoided, but preparedness and safe building construction practices can certainly reduce the extent of damage and loss. The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. The earthquake forces developed at different floor levels in a building need to be brought down along the height to the ground by the shortest path; any deviation or discontinuity in this load transfer path results in poor performance of the building.

Although there are so many studies about earthquakes but however it has not been possible to predict when and where earthquake will happen. It has been learned how to pinpoint the locations of earthquakes, how to accurately measure their sizes, and how to build flexible structures that can withstand the strong shaking produced by earthquakes and protect our loved ones.

In recent times, damaging earthquakes experienced in our country include (1) Bihar Nepal earthquake (1988), (2) Uttarkashi earthquake (1991), (3) Killari earthquake (1993), (4) Jabalpur earthquake (1997), (5) Chamoli earthquake (1999) and (6) Bhuj earthquake (2001) and recently occurred (7) West Bengal earthquake (2011). In all of these earthquakes there is huge loss of life and very large destruction of existing reinforced concrete (RC) buildings. Most recent constructions in the urban areas consist of poorly designed and constructed buildings. The older buildings, even if constructed in compliance with prevailing standards, may not comply with the more stringent specifications of the latest standards of IS 1893(Part 1):2016, IS 4326:1993 and IS 13920: 1993.

- **Regular and Irregular structures:**

Buildings with simple regular geometry and uniformly distributed mass and stiffness in plan and in elevation, suffer much less damage, than buildings with irregular configurations. All efforts shall be made to eliminate irregularities by modifying architectural planning and structural configurations. A building shall be considered to be irregular for the purposes of this standard, even if any one of the conditions given in Tables 5 and 6 is applicable. Limits on irregularities for Seismic Zones III, IV and V and special requirements are laid out in Tables 5 and6.

There are basically two types of irregularities in building,

1. Plan irregularity
2. Vertical irregularity

There are again various types plan irregularities such as,

a) Torsional Irregularity
b) Re-entrant Corners
c) Floor slabs having excessive cut-off and opening
d) Out-of-plane Offsets in vertical elements
e) Nonparallel lateral force system

- **Objectives:**

The objective of the present study is to analyse R.C.C. buildings of plan irregularities using response spectrum analysis method. The different objectives of the present study are:

1. The present study is an effort to understand response spectrum analysis method.

2. To employ STAAD PRO software.
3. To study parameters such as base shear, displacement, peak story and story drift.
4. To study seismic response of building with plan discontinuities under earthquake excitations.

Theme:

Theme of the present work is to study response spectrum analysis of R.C.C. buildings with plan regularity and irregularity. For this, buildings with various shapes such as regular, L, C and T shaped buildings are taken. These buildings are evaluated using STAAD PRO software (Version) computer program. From this displacement peak story base shear are evaluated these results are compared to know the best suited building plan for irregular building. It is well known that Dynamic analysis is most accurate evaluation method.

2. LITERATURE REVIEW

Paper [1] shows Reinforced Concrete (RC) building frames are most common types of constructions in urban India. These are subjected to several types of forces during their lifetime, such as static forces due to dead and live loads and dynamic forces due to earthquake. This paper presents a review of the previous work done on multistoried buildings vis-à-vis earthquake analysis. It focuses on static and dynamic analysis of buildings

In paper [2] the behaviour of G+11 multi story building of regular and irregular configuration under earth quake is complex and it varies of wind loads are assumed to act simultaneously with earth quake loads. In this paper a residential of G+11 multi story building is studied for earth quake and wind load using ETABS and STAAS PRO V8i Assuming that material property is linear static and dynamic analysis are performed. These analysis are carried out by considering different seismic zones and for each zone the behaviour is assessed by taking three different types of soils namely Hard , Medium and Soft .Different response like story drift, displacements base shear are plotted for different zones and different types of soils[

Paper [3] deals with the comparison between equivalent static technique &response spectrum technique. The earthquake effect lead to the damage the property and many people loss of life. So we have to know the structural performance under seismic load before construction. Method of analysis Adopt the equivalent static and response spectrum techniques to analyze the model for the present study and observe the lateral displacement of the structure in a regular and irregular structure in various zones.

In Paper [4] it's a very big challenge that building or structure must withstand lateral forces such as earthquake and wind load. In the present work, the comparative analysis of various structures is performed using SAP 2000. The main aim of the project is comparative study of the stiffness of the structure by considering the three models that is Regular Structure, Plan irregular structure Vertical irregular structure. All these three models are analyzed with static and dynamic earthquake loading for the Zoned II, III, IV & V. The results are tabulated and graphs are plotted for displacement, drift, base shear and time period.

Based on the results and discussion the structural behavior and Stiffness is concluded for regular and irregular structures, among these structures regular structure shown maximum displacement and drift for all the zones in both static and dynamic analysis

In this paper [5] the national building code of India (NBC) 2015 was released by bureau of Indian standards during December 2016/january2017. The various sections of this NBC have undergone changes as per latest technologies and user requirements. It is necessary to identify the performance of the structures to withstand against disaster for both new and existing one.

The paper [6] discusses the performance evaluation of RC (Reinforced Concrete) Buildings with plan irregularity. Structural irregularities are important factors which decrease the seismic performance of the structures. This study as a whole makes an effort to evaluate the effect of plan irregularity on RC buildings using IS 1893:2002 and IS 1893:2016 in terms of dynamic characteristics.

The paper [7] shows an analytical description of the damages caused by different plan irregularities, during seismic events of different magnitudes. Although these effects of architectonic and/or structural configuration have been identified like not adapted in previous damages, have come maintaining their presence in constructions anywhere in the world. The effects of commented irregularities were studied with qualitative analyses of important and recent investigations, as much in Mexico as abroad. The work describes to the geometric forms that are repeated more in the urban areas in México (squared, rectangular, section U, section L and section T), as well as its variations from plants observed with extracted aerial photography of Google Earth. These architectonic plants were modeled in SAP2000 considering one, two and four levels to determine the effect of the geometric form in the seismic behavior of structures with elastic analyses. Also, effects of the extension in rectangular plants and the inclusion of projections in sections with architectonic plants U, L and T were studied. In all the studied systems, effects of different irregularities are analyzed based on the variation of displacements, with respect to regular systems.

In paper [8], the seismic behavior of three intermediate moment-resisting concrete space frames with unsymmetrical plan in five, seven and ten stories are evaluated by using pushover analysis. In each of these frames, both projections of the structure beyond a reentrant corner are greater than 33 percent of the plan dimension of the structure in the given direction. The performance of these buildings has been investigated using the pushover analysis. Results have been compared with those obtained from non-linear dynamic analysis.

Paper [9], the torsional response of plan asymmetric RC building structures for predicting the seismic responses were investigated. The linear dynamic response of plan asymmetric with different eccentricities were initially compared, in order to evaluate the effects of the torsional response.

The paper [10] shows behaviour of building during earthquake depends critically on its overall shape, size and geometry. Building with simple geometry in plan have performed well during strong past earthquake but building with u, v, H & + shaped in plan have sustained significant damage. So the proposed project attempts to evaluate the effect of plan configurations on the response of structure by

RSM (response spectrum method) The Indian Standard Code (IS-Code) of practice IS-1893 (Part I: 2002) guidelines and methodology are used to analyses the problem. In this proposed work the study is carried on the effect of difference geometrical configurations on the behaviour of structure of the already constructed building located in the same area during earthquake by RSM in paper[12], more emphasis is made on the plan configurations and is analyzed by RSM since the RSM analysis provides a key information for real – world application.

The paper [11] is concerned with the study of seismic analysis and design of high-rise building. The structural analysis of high rise multistory storey reinforced concrete symmetrical and asymmetrical frame building is done with the help of SAP software. In the present study, The Response spectrum analysis (RSA) of regular RC building frames is compare with Response spectrum analysis of regular building and carry out the ductility-based design. as per IS 1893:2002 and IS 1893:2016[13].

The Paper [14] shows a foundation of a building is the substructure through which the loads of the whole structure are transmitted to the soil. There are various types of soil present in India. The types of soil play a major role while designing a structure. Here the analysis and design of building is done by varying the type of soil. The difference in analysis of structure is studied. After that the seismic analysis for various zones are carried out for the same soil conditions and also by changing the model of building, the same are done. And the difference is studied [15].s

3. PROBLEM STATMENT

- **Description of Structure:-**

The structure selected for this project is a simple residential building with different shapes L, T, C with the following description as stated below.

IS Code for Dead Load: - IS 875 Part 1
IS Code for Dead Load:- IS 875 Part 2
IS Code for Seismic Load: - IS 1893-2016 Part (1)
IS Code for Ductile Detailing: 13920-2016

1. Number of bays in X direction and its width= 5 bays of 4 m each
2. Number of bays in Z direction and its width = 5 bays of 4 m each
3. Story height = 3 m each
4. Number of storey = G + 6 (Excluding the plinth and substructure and including the Ground floor)
5. Depth of foundation from ground level = 1.4 m
6. Plinth height = 600 mm
7. Column size = 300 mm x 500 mm
8. Beam size = 300 mm x 450 mm
9. Thickness of Slab =150 mm
10. Density of concrete = 25 kN/m3
11. Live load on roof = 1.5 kN/m2
12. Live load on floors = 3 kN/m2
13. Floor finish = 1.5 kN/m2
14. Brick wall on peripheral beams = 230 mm
15. Density of brick wall 20 kN/m3
16. Grade of concrete M20
17. Grade of steel fe500

- **Seismic design Parameters:-**

For the present study following values for seismic analysis are assumed. The values are assumed on the basis of reference steps given in IS 1893-2016 and IS 13920-1993 and IS 456:2000.

1. Zone factor for zone II – 0.10 (Table 3, P.10 C.N.6.4.2)
2. Zone factor for zone III – 0.16
3. Zone factor for zone IV – 0.24
4. Zone factor for zone V – 0.36
5. Importance factor for office building = 1.2 (Table 8, P.19 C.N.7.2.3)
6. Special Reinforced Concrete Moment resisting Frame (SMRF)
7. SMRF is a moment resisting frame detailed to provide ductile behavior and comply with the requirements of 13920-1993
8. Response reduction factor for ductile shear wall with SMRF = 5
9. Type of soil = Medium (Type II)
10. Damping percent = 5 % (0.05)

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In this section problem is defined for the present study. Sizes of various members of models are stated here. Also the parameters required for seismic analysis are also mentioned in this section.

4. METHODOLOGY

Investigations of past and recent earthquake damage have illustrated that the building structures are vulnerable to severe damage or collapse during moderate to strong ground motion caused by earthquake. An earthquake with a magnitude of six is capable of causing severe damages of engineered buildings, bridges, industrial and port facilities as well as give rise to great economic losses. Several destructive earthquakes in India shows that the RC buildings are mostly damaged and some of them are collapsed. The main reason behind this is non-consideration of earthquake forces while designing, constant upgradation of codes, false supervisions, and faulty construction practices adopted and many more.

Earthquake loads are to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated. In this context response spectrum analysis is carries out which is a dynamic analysis procedure shall be looked upon as an alternative for the orthodox analysis procedures. This study focuses on analysis of regular and irregular building in different seismic zones, the regular building and different plan irregular building are considered in II, III, IV, V seismic zones and are analysis to evaluated different parameters.

Methods of Analysis:

For seismic performance evaluation, a structural analysis of the mathematical model of the structure is required to determine force and displacement demands in various components of the structure. Several analysis methods, both elastic and inelastic, are available to predict the seismic performance of the structures. Following are some of the seismic analysis methods used for seismic evaluation;

1. Elastic methods of analysis
   A. Linear static analysis
   B. Linear dynamic analysis
2. Inelastic methods of analysis
   A. Nonlinear static analysis
   B. Nonlinear dynamic analysis

1. Elastic methods of analysis

The force demand on each component of the structure is obtained and compared with available capacities by performing an elastic analysis. Elastic analysis methods include code static lateral force procedure, code dynamic procedure and elastic procedure using demand-capacity ratios. These methods are also known as force-based procedures which assume that structures respond elastically to earthquakes.

In linear static lateral procedure, a static analysis is performed by subjecting the structure to lateral forces obtained by scaling down the smoothened soil-dependent elastic response spectrum by a structural system dependent force reduction factor, "R". In this approach, it is assumed that the actual strength of structure is higher than the design strength and the structure is able to dissipate energy through yielding. The method does not trace the failure path hence not so popular to use.

In linear dynamic procedure, force demands on various components are determined by an elastic dynamic analysis. The dynamic analysis may be either a response spectrum analysis or an elastic time history analysis. Sufficient number of modes must be considered to have a mass participation of at least 90% for response spectrum analysis. Any effect of higher modes is automatically included in linear time history analysis.

Although force-based procedures are well known by engineering profession and easy to apply, they have certain drawbacks. Structural components are evaluated for serviceability in the elastic range of strength and deformation. Post-elastic behavior of structures could not be identified by an elastic analysis. However, post-elastic behavior should be considered as almost all structures are expected to deform in inelastic range during a strong earthquake. The seismic response reduction factor "R" is utilized to account for inelastic behavior indirectly by reducing elastic forces to inelastic. Response reduction factor, "R", is assigned considering only the type of lateral system in most codes, but it has been shown that this factor is a function of the period and ductility ratio of the structure as well. Elastic methods can predict elastic capacity of structure and indicate where the first yielding will occur, however they don't predict failure mechanisms as the yielding progresses. Thus, the hinge formations at various levels are not identified. Moreover, force-based methods primarily provide life safety but they do not provide damage limitation and easy repair.

2. Inelastic methods of analysis :

Investigating the performance of a structure requires inelastic analytical procedures since structures suffer significant inelastic deformation under a strong earthquake motion. Inelastic analytical procedures help to understand the actual behavior of structures by identifying failure modes and the potential for progressive collapse. Inelastic analysis procedures basically include inelastic time history analysis and inelastic static analysis which is also known as pushover analysis.

Nonlinear Dynamic analysis can be done by direct integration of the equations of motion by step by step procedures. Direct integration provides the most powerful and informative analysis for any given earthquake motion. A time dependent forcing function (earthquake accelerogram) is applied and the corresponding response–history of the structure during the earthquake is computed. That is, the moment and force diagrams at each of a series of prescribed intervals throughout the applied motion can be found. However, the use of inelastic time history analysis is limited because dynamic response is very sensitive to modeling and ground motion characteristics. It requires proper modeling of cyclic load deformation characteristics considering deterioration properties of all-important components. Also, it requires availability of a set of representative ground motion records that accounts for uncertainties and differences in severity, frequency and duration characteristics. Moreover, computation time, time required for input preparation and interpreting voluminous output make the use of inelastic time history analysis impractical for seismic performance evaluation.

Inelastic static analysis, or pushover analysis, has been the preferred method for seismic performance evaluation due to its simplicity. It is a static analysis that directly incorporates nonlinear material characteristics. Inelastic static analysis procedures include Capacity Spectrum Method, Displacement Coefficient Method and the Secant Method.

Calculations for Regular building:

The procedure used for the Standard Pushover analysis using STAAD PRO is validated with manual calculation. A G+6 regular building situated in Zone III, is taken for analysis. The plan area of building is 20 x 20 m with 3m as height of each typical storey. It consists of 5 bays of 4 m each in X-direction and 5 bays of 4m each in Y- direction. Hence, the building is symmetrical about both the axis. The total height of the building is 21m from ground level and 2m foundation. The building is considered as a Special Moment resisting frame. The plan of building is shown in figure. The sectional properties of elements are taken, Size of Column= 300mm x 500mm, Size of Beam= 300mm x 450 mm, Thickness of Slab=120mm thick, Total dead load at roof =4.5kN/m2 and, Live load on all floors= 3.5kN/m2

MASS CALCULATION:

ROOF

1] Dead Load = 0.12 x 25 +1.5 =4.5 KN/M2
= 20 X20 x 4.5 =1800 KN
2] Live Load = (0.25 x2) x 20 x20 =200 KN
3] Column Load = 36 x 1.5 x 25 x0.3 x 0.5 = 202.5 KN
4] Beam Load = (0.3 x 0.45) x25 x (20 x 6 + 20 x 5) = 810 KN
5] Parapet = 4.14 x 80 =331.2 KN

TOTAL = 3343.7 KN

FLOORS

1] Dead Load of Slab = 20 x20 x 4.5 = 1800 KN
2] Column Load = 36 x 25 x 3 x 0.3 x 0.5 = 405 KN

3] Live Load of Slab = (3 x 0.25) x 20 x 20 =300 KN
4] Wall Load = (20 x 6 + 20 x 6) x 13 = 3120 KN
5] Beam Load = 810 KN
TOTAL OF EACH FLOOR = 6435 KN
TOTAL FLOOR LOAD = 6 X 6435 = 38610 KN

WATER LOAD = 10 KN/M2 x 4 x 4 =160 KN

GROUND FLOOR
1] Beam Load = 810 KN
2] Column Load = 36 x 25 x0.3 x 0.5 x (2 + 1.5) = 472.5 KN
3] Wall Load = 3120 KN
TOTAL = 4402.5 KN
TOTAL MASS = 47516.2 KN
Determination of base shear
VB = Ah ×W
Ah = (Z I S_a)/(2 R g)

$$Ta = 0.09h / \sqrt{d} = \frac{0.09 \times 23}{\sqrt{20}} = 0.4628$$

s_(a)/g = 2.5 For medium soil, Page 9 IS 1893 - 2016 Part 1
Design horizontal seismic co-efficient for a structure (Ah)
Ah = (0.16/2) × (1.2/5) × (2.5) = 0.048
Seismic weight of building = weight of all floors of the building
= 47516.2 KN
VB = 47516.2 x 0.048
BASE SHEAR (VB) = 0.048 x 47516.2 = 2280.77 KN

BASE SHEAR (STAAD VALUE) = 2330.57 KN
Calculations for 'C' shaped building:
Seismic weight of building = weight of all floors of the building
= 39152.92 kN
VB = 0.048 ×39152.92 = 1879.37kN
Calculations for 'T' shaped building:
Seismic weight of building = weight of all floors of the building
= 37869.58 KN
VB = 0.048 ×37869.58 = 1817.74 KN

Table 1: Comparison of base shear from manually and STAAD PRO analysis

Type of building	Manually (kN)	STAAD PRO analysis Linear Statics (kN)	STAAD PRO analysis (kN) Linear Dynamic
Regular building	2280.77	2330.57	2330.57
'C' shaped building	1879.37	1900.54	1900.54
'T' shaped building	1817.74	1843.03	1843.03

5. RESULT AND ANALYSIS

General: -

A G+6 regular and irregular T shape and C shape buildings are model in zone II, III, IV, V using STADD PRO software and the results are computed. The configurations of all the models are discussed in previous chapter. Twelve models were prepared in different zones, these models are analysed as per the specifications of Indian Standard codes IS1893 – 2016, IS 875 and IS 456: 2000. The equivalent static method and response spectrum method have been used to find the nodal displacement in the storey for X, Y and Z direction of the regular and irregular building, peak storey shear, base shear and max BM and SF.

Nodal Displacement in the Storey for X, Y and Z Direction of the Regular and Irregular Building: -

Elements or members of building should be designed and constructed to resist the effects of design lateral force. STADDPro gives the lateral force distribution at various levels and at each storey level. Lateral force of earthquake is predominant force which needs to be resisted for any structure to be earthquake resistant. The equivalent static method and response spectrum method have been used to find the nodal displacement in the storey for X, Y and Z direction of the regular and irregular building in STADDPro.

Table 2: Displacement in different zones along X, Y & Z-direction by equivalent static method.

DISPLACEMENT IN MM				
Static	Max displacement	X	Y	Z
Zone 2	Regular	40.547	0	62.751
	T Shape	40.505	0	60.49
	C shape	38.714	0	61.905
	Regular	64.804	0	100.35

Zone 3	T Shape	64.766	0.005	96.983
	C shape	62.05	0	99.098
zone 4	Regular	97.148	0.669	150.482
	T Shape	97.114	0.723	145.641
	C shape	93.164	0.636	148.689
Zone 5	Regular	145.663	2.107	225.681
	T Shape	145.637	2.387	218.627
	C shape	139.836	2.758	223.077

As per the above table zone is ascending lateral displacement increasing and C shape irregular building has lesser displacement than regular shape and T shape in X direction and T shape irregular building has lesser displacement than regular shape and C shape in Z direction.

Table 3: Displacement in different zones along X, Y & Z-direction by equivalent RSM method.

DISPLACEMENT IN MM				
RSM	Max displacement	X	Y	Z
zone 2	Regular	29.617	0.921	36.957
	T Shape	29.493	0.969	36.35
	C shape	29.539	0.0991	36.96
zone3	Regular	40.689	1.265	50.773
	T Shape	40.195	1.303	49.805
	C shape	39.594	1.312	49.806
zone 4	Regular	59.409	1.865	73.726
	T Shape	58.645	1.927	72.279
	C shape	57.992	1.945	72.562
zone5	Regular	89.112	2.797	110.587
	T Shape	87.967	2.89	108.418
	C shape	86.987	2.917	108.843

6. CONCLUSION

Three different models are studied in this present research. Model 1 is a regular building model 2 is a T shape building and model 3 is a C shape building and all these models are made in all 4 zones i.e. zone 2 zone 3 zone 4 zone5. STADDPro software is used for analysis and the results obtained were satisfactory and following are the concluded remarks that can be established from the results.

Response spectrum method allows a clear understanding of the contributions of different modes of vibration. It is also useful for approximate evaluation of seismic reliability of structures.

1. Comparing the maximum base shear for both regular building and irregular building the maximum shear is obtained for regular building and T shape irregular building has lesser base shear than regular shape and C shape
2. Time period is maximum for C shaped plan configuration.
3. Average Frequency was maximum for T- shape Irregular Buildings.
4. Maximum displacement for regular shapes and minimum for irregular shapes. T shape irregular building has lesser displacement than regular shape and C shape in Z direction. C shape irregular building has lesser displacement than regular shape and T shape in X direction for static. But in dynamics T shape irregular building has lesser displacement than regular shape and C shape in both direction Maximum lateral force for regular shapes and minimum for irregular. T shape irregular building has lesser lateral force than regular shape and C shape.
5. In regular building the displacement, peak story shear, base shear, max shear force and bending moment are maximum than irregular models .and T-shape has minimum values than regular and C- shape models.

Future scope:

1. Comparing the maximum base shear, displacement, peak storey for both regular building and irregular building for different shapes by using both IS code IS 1893:2002 & IS 1893:2016.
2. Comparing the maximum base shear, displacement, peak storey for both building with different heights by using both IS code IS 1893:2002 & IS 1893:2016.
3. Comparing Time period & Average Frequency for different shapes plan configuration by IS1893:2002 & IS 1893:2016.
4. Performing push over analysis and comparing displacements, shear, moment and further seismic parameter.

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