International Conference on Recent Trends in Engineering Science and Technology (ICRTEST 2017) ISSN: 2321-8169
Volume: 5 Issue: 1(*Special Issue 21-22 January 2017*) 361 - 364

Comparative Analysis of Building by Response Spectrum Method and Seismic Coefficient Method

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Abstract- Right from the evolution of the earth, Earthquakes have been cause great disasters in the form of destruction of property, injury and loss of life to the population. The effective design and construction of earthquake resistant structures has much greater importance in this country due to rapid industrial development and concentration of population in cities. In this project, the earthquake response of symmetric multi-storied building by two methods will be studied. The methods include seismic coefficient method and response spectrum method as recommended by IS Code 1893-2002 part I, where natural frequencies, period, base shear, lateral forces are calculated by STAAD-PRO software as well as manually by seismic coefficient method. The methods include seismic coefficient method (by empirical formula) and modal analysis using response spectrum method of IS Code in which the stiffness matrix of the building corresponding to the dynamic degrees of freedom is generated by considering the building as shear building. The responses obtained by above methods in zones IV as mentioned in IS code will be studied. Test results on Base Shears, Lateral Forces and Storey Moments will be compared.

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I. Introduction

A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to take into account the seismic load for the design of high-rise structure. In tall building the lateral loads due to earthquake are a matter of concern. These lateral forces can produce critical stresses in the structure, induce undesirable stresses in the structure, induce undesirable vibrations or cause excessive lateral sway of the structure. Seismic design approaches are stated, as the structure should be able to ensure the minor and frequent shaking intensity without sustaining any damage, thus leaving the structure serviceable after the event. The structures withstand moderate level of earthquake ground motion without structural damage, but possibly with some structural as well as non-structural damage. In present study, the earthquake analysis of G+10 storied building will be done by both methods i.e. Seismic Coefficient Method and Response Spectrum Method. In Response Spectrum Method, the Time Periods, Natural Frequencies and Mode Shape Coefficients are calculated by STAAD-Pro program then remaining process will be done by manually. The modal combination rule for Response Spectrum Analysis is SRSS. The main parameters considered in this study to compare the seismic performance of the zone IV are Base Shear, Storey Moment and Lateral Forces.

Terminology

Centre of Mass - The point through which the resultant of the masses of a system acts. This corresponds to centre of gravity of the system.

Centre of Rigidity **-**The point through which the resultant of their storing forces of a system acts.

Critical Damping **-**The damping beyond which the motion will not be oscillatory.

Damping - The effect of internal friction, imperfect elasticity of Material, slipping, sliding,etc, in reducing the amplitude of vibration and is expressed as a percentage of critical damping.

Epicenter **-**The geographical point on the surface of earth vertically above the focus of the earthquake.

Focus **-**The originating source of the elastic waves which cause shaking of ground.

Intensity of Earthquake **-**The intensity of an earthquake at a place is a measure of the effects of the earthquake, and is indicated by a number according to the Modified Metrically Scale of Seismic Intensities.

Liquefaction **-**Liquefaction is a state in saturated cohesion less soil where in the effective shear strength is reduced to negligible value for all engineering purposes due to pore pressures caused by vibrations during an earthquake when they approach the total confining pressure. In this condition the soil tends to behave like a fluid mass.

Litho logical Features **-**The nature of the geological formation of the earth's crust above bed rock on the basis of such characteristics as colour, structure, mineralogical composition and grain size.

Magnitude of Earthquake (Richter's Magnitude) **–**The magnitude of earthquake is a number, which is a measure of energy released in an earthquake. The magnitude of an earthquake is the logarithm to the base 10 of the maximum trace amplitude, expressed in microns, with which the standard short period torsion seismometer (with a period of 0.8 second, magnification 2800 and damping nearly critical) would register the earthquake at an epicentral distance of 100 km.

Mode Shape Coefficient **-**When a system is vibrating in a normal mode, the amplitude of the masses at any particular instant of time expressed as a ratio of the amplitude of one of the masses is known as mode shape coefficient.

Normal Mode -A system is said to be vibrating in a normal mode or principal mode when all its masses attain maximum values of displacement simultaneously and also they pass through equilibrium positions simultaneously.

Response Spectrum-The representation of the maximum response of idealized single degree freedom systems having certain period and damping, during earthquake ground motion. The maximum response is plotted against the undamped natural period and for various damping values, and can be expressed in terms of maximum absolute acceleration, maximum relative velocity or maximum relative displacement,

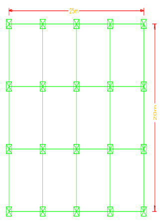
Seismic zone Factor (Z) - A factor to be used for different seismic zone along with the average acceleration spectra.

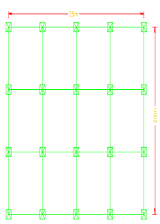
Importance Factor (I) - A factor to modify the basic seismic coefficient and seismic zone factor, depending on the importance of a structure.

Tectonic Feature **-**The nature of geological formation of the bedrock in the earth's crust revealing regions characterized by structural features, such as dislocation, distortion, faults, folding, thrusts, volcanoes with their age of formation which are directly involved in the earth movement or quakes resulting in the above consequences.

II. METHODOGY

The G+10 storied building is shown in Fig 1. The seismic analysis of building is done by Seismic Coefficient and response spectrum methods with given above procedures for Zone II and V. The obtained results of both methods are compared with each other.





IV.RESPONSE SPECTRUM METHOD

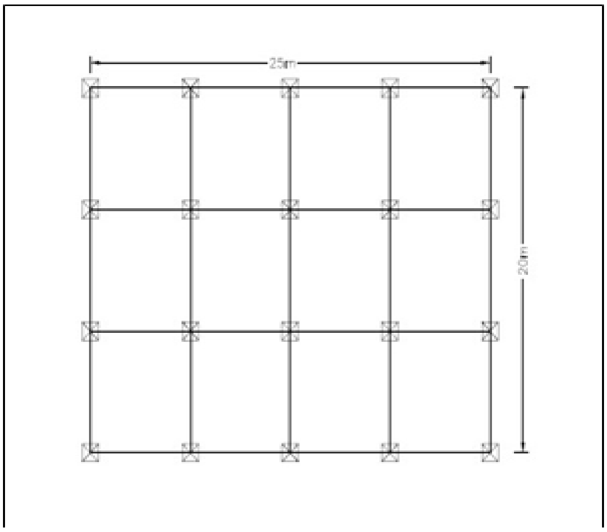


Fig. 1 Shows the plan of G+10 storied building.

In order to perform the seismic analysis and design of a structure to be built at a particular location, the actual time history record is required. However, it is not possible to have such records at each and every location. Further, the seismic analysis of structures cannot be carried out simply based on the peak value of the ground acceleration as the response of the structure depend upon the frequency content of ground motion and its own dynamic properties. To overcome the above difficulties, earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions. The codal provisions as per IS: 1893 (Part 1)-2002 code for response spectrum analysis of multi-story building is also summarized. In this method, first the response acceleration coefficient for the natural vibration period and damping of the structure are required. Based on these values, the horizontal seismic coefficient, αh, can be computed as:

$$\alpha h = Z.I.Sa / 2.R.g$$

Where, R = Performance factor depending upon the structural framing system and / or ductility of construction. *I = a factor depending upon the Importance of the structure.*

Z = Seismic Zone Factor for average acceleration spectra.

Sa/g = average acceleration coefficient based on appropriate natural periods and damping of the structure. As per IS 1893 (part1)-2002, Response Spectrum Method is summarized in following steps:-

a) Modal mass (M_k) – Modal mass of the structure subjected to horizontal or vertical as the case may be, ground motion is a part of the total seismic mass of the Structure that is effective *in mode k of vibration. The modal mass for a given mode has a unique value, irrespective of scaling of the mode shape.*

$$M_k = \frac{[\sum w_i \phi_{ik}]^2}{g \sum w_i \phi_{ik}^2}$$

Where, g = acceleration due to gravity.

ϕ_{ik} = mode shape coefficient at floor i in mode k.

b) Modal Participation factor (Pk) – Modal participation factor of mode k of vibration is the amount by which mode k contributes to the overall vibration of the structure under horizontal or vertical earthquake ground motions. Since the amplitudes of 95 percent mode shape can be scaled arbitrarily, the value of this factor depends on the scaling used for the mode shape.

$$P_k = \frac{\sum w_i \phi_{ik}}{\sum w_i \phi_{ik}^2}$$

c) Design lateral force at each floor in each mode – The peak lateral force (Q_{ik}) at floor i in Mode k is given by:- $Q_{ik} = A_{hk} \phi_{ik} P_k W_i$

Where,

A_{hk} = Design horizontal spectrum value using natural period of vibration (Tk) of mode k.

A_{hk}= Z.I.S_a / 2.R.g

Z= zone factor for the maximum considered earthquake,

I= Importance factor depending upon the functional use of the structures,

R= Response Reduction factor

Sa/g= Average response acceleration coefficient for rock or soil sites as given by response spectra and based on appropriate natural periods and damping of the structure.

d) Storey shear forces in each mode – The peak shear force (Vik) acting in storey i in mode k is given

$$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$$

e) Storey shear force due to all modes considered : The peak storey shear force (Vi) in storey i due to all modes considered is obtained by combining those due to each mode as per SRSS. If the building does not have closely spaced modes, than the peak response quantity due to all modes considered shall be obtained as per Square Root of Sum of Square method Dynamic analysis may be performed either by time history method or by the response spectrum method. However in either method, the design base shear VB shall be compared with a base shear (V_b) calculated using a fundamental period Ta. When VB is less than all the response quantities shall be multiplied by V_b/VB.

Seismic Coefficient Method

A Seismic coefficient is a subset of structural analysis and is the calculation of the response of a building (or nonbuilding) structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit (see structural engineering) in regions where earthquakes are prevalent.This method is simple and may be used for simple structures where Response Spectrum Method is not warrant. In this method, the seismic forces can be computed on the basis of importance of the structures and its soil- foundation systems. The horizontal seismic coefficient αh, can be computed as:

$$\alpha h = \beta \, I \, \alpha 0$$

where: β = a coefficient depending upon the foundation system .

I = a factor depending upon the Importance of the structure.

α0 = basic horizontal seismic coefficient.

As per IS 1893 (part1)-2002, Seismic Coefficient analysis Procedure is summarized in following steps :-a) Design Seismic Base Shear- The total design lateral force or design seismic base shear (Vb) along any principal direction of the building shall be determined by the following expression:- (VB= Ah x W)

Where,

Ah = Design horizontal seismic coefficient

W = Seismic weight of the whole building.

b) Seismic Weight of Building- The seismic weight of each floor is its full dead load plus appropriate amount of imposed load as specified. While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey. The seismic weight of the whole building is the sum of the seismic weights of all the floors. Any weight supported in between the storey shall be distributed to the floors above and below in inverse proportion to its distance from the floors.

c) Fundamental Natural Time Period- The fundamental natural time period (Ta) calculates from the expression:-

Ta = 0.075 h0.75 for RC frame building

Ta = 0.085 h0.75 for steel frame building

If there is brick filling, then the fundamental natural period of vibration, may be taken as:-

$$Ta = 0.09\, H / \sqrt{d}$$

d) Distribution of Design Force- The design base shear, VB computed above shall be distributed along the height of the building as per the following expression.

Qi = VB

Table 1. Time Periods, Natural Frequencies and Mode Shape Coefficients.

MODE	1	2	3
Time period(Sec)	1.339	0.449	0.271
Natural frequency (rad/sec)	4.692	13.993	23.185

Mode Shape Coefficients at Various Floor Levels			
11	9.7077	2.3777	-2.3833
10	9.0245	3.1496	-1.772
9	8.2864	3.7517	-0.898
8	7.4979	4.1512	0.1093
7	6.6637	4.3268	1.1003
6	5.789	4.269	1.9282
5	4.879	3.9807	2.47
4	3.9393	3.4777	2.6456
3	2.9757	2.7871	2.4287
2	1.9939	1.946	1.8517
1	1	1	1

Table 2. Comparison of Lateral Forces, Storey Shears and Storey Moments of G+10 storied building for Zone IV

Storey No	Lateral Force (KN)		Storey Shear (KN)		Storey Moment (KN-M)	
	Seismic Coefficient Method	Response Spectrum Method	Seismic Coefficient Method	Response Spectrum Method	Seismic Coefficient Method	Response Spectrum Method
11	52.739	49.948	1041.115	839.619	19964.091	15860.391
10	43.546	47.061	1084.661	886.68	23218.074	18520.431
9	35.199	44.722	1119.86	931.402	26577.654	21314.637
8	27.821	42.492	1147.681	973.894	30020.697	24236.319
7	21.289	42.091	1168.97	1015.985	33527.607	27284.274
6	15.604	41.728	1184.574	1057.713	37081.329	30457.413
5	10.886	41.053	1195.46	1098.766	40115.955	33753.711
4	6.894	38.757	1202.354	1137.523	44274.771	37166.28
3	3.87	33.615	1206.224	1171.138	47893.443	40679.694
2	1.693	25.045	1207.917	1196.183	51517.194	44268.243
1	0.362	13.421	1208.279	1209.904	55142.031	47897.055

III. COMPARISON OF RESULTS

1. There is a gradual increase in the value of lateral forces from bottom floor to top floor in both the Seismic Coefficient Method and Response Spectrum Method in Zone IV. The lateral forces are obtained by Seismic Coefficient Method are more for upper floors and are less for lower floors when compared to Response Spectrum Method.
2. The percentage of over estimation of Storey Shear in both Seismic Coefficient and Response Spectrum Methods decrease with increase in height of the building in Zones IV.
3. The percentage of over estimation of Base Moment in both Seismic Coefficient and Response Spectrum Methods decrease with the increase in height of the building in Zones IV. When compared to Response Spectrum Method, the Storey Moments obtained by Seismic Coefficient Method are higher for all floors.

IV. CONCLUSIONS

1. The Seismic Coefficient Method is conservative at top floors compared to response Spectrum method and vice-versa.
2. According to IS 1893 (Part 1):2002, clause 7.8.2 response values have been modified and considered for comparative study.
3. As storey moments are high in Seismic Coefficient Method when compared to response spectrum method, it is suggested to relay on Response Spectrum Method even in symmetric multi-storied buildings for seismic analysis and design.

References

[1] Chetan Raj, Vivek Verma, Bhupinder Singh, Abhishek, "Seismic Analysis of Building with Mass and Vertical Geometric Irregularity by Response Spectrum and Seismic Coefficient Method in Zone V and II", International Journal of Recent Research Aspects ISSN: 2349-7688, Vol. 2,Issue 2, June 2015, pp. 204-211

[2] Clough, R.W., & Penzien, J. 1993. Dynamics of Structures, McGraw-Hill, New York.

[3] Duggal, S.K., Earthquake Resistant Design of Structures (Oxford University Press, 2007).

[4] IS 1893(Part1):2002, Criteria for earthquake resistant design of structures, Part 1 General provisions and buildings, Bureau of Indian Standard, 2002

[5] Pankaj Agarwal, Manish Shrikhande, Earthquake Resistant design of Structures (Prentice Hall India Publication).

[6] Pravin B. Waghmare, P.S.Pajgade and N. M. Kanhe, Response spectrum analysis of a shear frame structure by using MATLAB, Int. Journal of Applied Sciences and Engineering Research, Vol. 1, No. 2, 2012.

[7] S.S. Patil, S.A. Ghadge, C.G. Konapure, and C.A. Ghadge, Seismic Analysis of High-Rise Building by Response Spectrum Method, international Journal Of Computational Engineering Research Vol.3 Issue.3.

[8] B. Srikanth, V.Ramesh, "Comparative study of seismic response for seismic coefficient and response spectrum methods" al Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 3, Issue 5, Sep-Oct 2013, pp.1919-1924.