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Comparative Study of Equivalent Lateral Force Method and Response Spectrum Method for OMRF Multistory Building – A Review Paper

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Abstract - *The earthquake causes severe damage to properties, life in general and multistoried building in regular. Here, the all type of structures built in the Indian standard and regularly situated in earthquake prone zones as defined by IS 1893: 2002 should be designed for loads, stresses and resulting out of earthquake. Different types of investigation techniques accessible for examination of multi-story structures which are Response spectrum method, Equivalent lateral force method, Time history method and code provision technique. Many authors tried to study analysis of multi-story building one or more method. There is no consensus on the particular method being best one. The most popular among them method are as-seismic coefficient method and response spectrum method. This comparative study is defined as the reviewing some of research reports on analysis of multi-story building using Equivalent Lateral Force Method and Response Spectrum Method. A comparison of both methods for earthquake multistory building presented here.*

The earthquake lateral forces act on whole building is carried out by the use of Equivalent static and Response spectrum method as per IS 1893(Part-1): 2002 for the IV zone. This comparative study is also beneficial for regular and irregular building because both method static and dynamic method well used. The most parameters to be find this comparative study to observe the seismic conduct of zone IV. And the response is read from the design of response spectrum and it gives the natural frequency of the structures which is calculated by the building code. The applied modification factor reduces the design forces (e.g. force reduction factor). The results performance and analysis of the structures are represented by numerically and theoretically.

Key Words: *Equivalent Lateral Force Method, Response Spectrum Method, IS 1893: 2002 (Part-I), modification factor, force reduction factor.*

1. INTRODUCTION

High intensity of earthquake has expanded causing extreme harm to human life and property. Most of us must have the personally experienced earthquakes, and aware of them earthquake is something which causes the shaking of the earth. All building and structures erected on the earth's surface start trembling and when a quake comes. An earthquake is defined as the natural vibration of ground motion produced by forces i.e. seismic forces. Many vibrations are feeble, and may not even ne felt on any appreciate extent, by human beings. Some other vibrations may very severe, and may cause the collapse rupture of buildings and other structures, bringing large scale destruction and disaster in its wake.

Seismic analysis is a subset of structural analysis and calculated by the response of a building structure to earthquakes. It is the part of the process of structural design. The analysis of methods are-

- Equivalent static method
- Response spectrum method
- Linear dynamic method
- Non-linear static analysis
- Non-linear dynamic analysis

1.1.1 Equivalent Static Force Analysis

This approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. For this to be true, the building must be low-rise and must not twist significantly when the ground moves. The response is read from a design response spectrum, given the natural frequency of the building (either calculated or defined by the building code). The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to-yielding of structure, many codes apply modification factors that reduce the design forces (e.g. force reduction factors).Since the static Equivalent Method is accurate and easy for short building especially for single story building so I have decided to analyze the given building in.

1.1.2 Dynamic Analysis (Response Spectrum Method)

This approach permits the multiple modes of response of building to be taken into account (in the frequency domain). This is required in many buildings codes for all except for very simple or very complex structures. The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the Harmonics. Computer analysis can be used to determine these modes for a structure. For each mode, a response is

read from the design spectrum, based on the modal mass, and they are then combined to provide an estimate of the total response of the structure. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building. Combination methods include the following –

Absolute – Peak values are added together

Square Root of the Sum of the Squares (SRSS)

Complete Quadratic Combination (CQC) - a method that is an improvement on SRSS for closely spaced modes.

The result of a response spectrum analysis using the response spectrum from a ground motion is typically different from that would be calculated directly from a linear dynamic analysis using that ground motion directly, since phase information is lost in the process of generating the response spectrum. In cases where structures are either too irregular, too tall or of significance to a community in the disaster response, the response spectrum approach is no longer appropriate, and more complex analysis is often required, such as non-linear static analysis or dynamic analysis.

1.1.3 Linear Dynamic Analysis

Static procedures are appropriate when higher mode effects are not significant. This is generally true for short, regular buildings. Therefore, for all buildings, buildings with torsional irregularities, or non-orthogonal systems, a dynamic procedure is required. In the linear dynamic procedure, the building is modeled as a multi-degree-of-freedom (MDOF) system with linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modeled using either modal spectral analysis or time history analysis but in both cases, the corresponding internal forces and displacement are determined using linear elastic analysis. The advantage of these linear dynamic procedures with respect to linear static procedures is that higher modes can be considered. However, they are based on linear elastic response and hence the applicability decreases with increasing nonlinear behavior, which is approximated by global force reduction factor.

1.1.4 Nonlinear Dynamic Analysis

Nonlinear dynamic analysis utilizes the condition 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 records produces estimates of component deformations for each degree of freedom in the model and the model responses are combined using schemes such as the square root of sum of squares.

In nonlinear dynamic analysis, the nonlinear properties of structures are considered as part of a time domain 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 in 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.

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2. REVIEW OF LITERATURE

To gather various work on seismic analysis of high rise structures and increasing lateral stiffness of the system and also study about the earthquake resistant structures with help of various methods. The work studied had in various papers, thesis and research articles thoroughly and referred. The idea doing literature review was to collect data and have understanding on different methods and approaches that can be comparative study of this project .Literature review was done to have a through guidelines during entire project study work .

Various Indian standard codes have all data of design of earthquake structures. The earthquake data considered in this work study as per IS1893 (part -1):2002, IS 875:1987 and also some data taken from IS 456:2000.

Bagheri, et al, 2012 the analysis of structures for earthquake must take in consideration nature of load is dynamic always. However, static approaches are more suitable in analysis of

earthquake load for regular and simple structure. It is recommended in most codes of practice for simple, low to medium rise buildings by estimating the base shear load and distribute in to each story. Static analysis can be adequate for low to medium rise buildings without substantial coupled lateral torsional modes, which take into consideration the first mode only for each direction, while the other modes can be important especially for the higher buildings and irregular building with torsional effects which are less suitable for the method and required more complex methods.

Wilson, 2002 the dynamic system is presented by mass, damping and stiffness. Stiffness is the resistance it provides to deformations, mass id the matter it contains and damping represents its ability to decrease its own motion with time. Mass is a fundamental property of matter and is present in all physical systems. This is simply the weight of the structure divided by the acceleration due to gravity. Mass contributes an inertia force (equal to mas times acceleration)in the dynamic equation of motion.

Arvindreddy (2015) carried out seismic analysis of RC regular and irregular frame structures. The study showed that the results obtained from static analysis method are lessor in term of story displacement values as compared to response spectrum analysis.

Gottala and Shaikyajdhani (2015) compared the static and dynamic seismic analysis of a multistoried building. The study shows bending moments are 35to 45 % higher for dynamic analysis than the values obtained for static analysis. The values for displacements of columns are 40 to 45 % higher for dynamic analysis than the values obtained for dynamic analysis; the values of nodal displacements in Z direction are 50% higher for dynamic analysis than the values obtained for static analysis.

Adhikari and Rajasekhar (2015) compared the static and dynamic seismic analysis of column sections in a building, the comparison showed that top displacement values from analysis is 16% less than the displacement from static analysis. Also the static approach gives higher values of forces and moments.

Kumar et al, (2014) exposed a case study of earthquake analysis of multistoried residential building. The study shows that bending moment at dynamic analysis are high and the values for displacement in static analysis are comparable to dynamic analysis.

Sharma and Maru (2014) studied the dynamic analysis of multi-storied regular building. Where they showed minor differences in axial forces obtained from static and dynamic analysis. Moreover the bending moment value in beams 10 to 15 % higher for dynamic analysis. Displacement values are 17 to 28 % higher in beams when dynamic analysis is used.

Merter and Ucar (2013) compared the nonlinear static with dynamic analysis of RC frame structures. The comparison showed that the drift ratios obtained from dynamic analyses are generally larger in upper stories and drift ratio obtained from nonlinear static are generally larger in upper stories lower.

Yusuf and shimpale (2013) studied Dynamic analysis of Reinforced concrete building with the help of plan irregularities, they showed that for higher and unsymmetrical building response spectrum method should be used and more realistic lateral load distribution can be achieved because irregularity in plan can result in irregular response so to resist the lateral loads, also for symmetrical building can using lateral load equivalent method.

Causevic and Mitrovic (2011) compared between non-linear dynamic and static seismi9c analysis of structures according to European and US provisions. The study show that the nonlinear dynamic method represents more specific output such as different displacement forms (uniform, triangular and modal).

Mohan and Prabha (2011) studied the dynamic analysis of RC buildings with shear wall, it showed that equivalent static method can be used effectively for symmetric buildings up to 25 m height. For higher and unsymmetrical buildings response spectrum method should be used. For important structures time history analysis should be used due to high accuracy compared to the other two methods.

Aslam (2014) [13] did (G+5) story Hospital building in Agartala one the projects undertaken by L&T. The seismic analysis of the proposed building was done in the software ETABS version-9.7, which is one of the most advanced software in the structural design field. The loads applied on the structure was based on IS: 875 (part I) 1987[dead load] IS: 875 (part II)-1987 [live load], IS: 875 (part III)-1987[wind load], IS: 1893-2002 [Earthquake load].Scale factor is calculated from the design base shear. (V_B) to the base shear calculated using fundamental time period (Ta).Once the analysis was completed all the structural components were designed according to Indian standard code IS:456-2000. This included footings, columns, beams, slabs, staircases and shear walls.

Ankur Agrawal (2012) did seismic evaluation of institute building. There are many buildings which do not meet the current seismic requirement and suffer extensive damage during the earthquake. In 1960 when the institute building of NIT Rourkela was constructed, the seismic loading was not considered. The building is only deigned to take the dead and live loads. Evaluating the building for seismic conditions gives an idea whether the building is able to resist the earthquake load or not. Ankur Agrawal carried out the Demand Capacity Ratio (DCR) for beams and columns in order to evaluate the member for seismic loads. Since he did not find reinforcement details of the building as it was more than 50 years old He have prepared Design-1 applying only

DEAD and LIVE loads according to IS 456:2000 to 9 estimate the reinforcement present in the building and assuming that this much reinforcement is present. In Design-2 seismic loads are applied and for this demand obtained from design-2 and capacity from design -1 the DCR is calculated. If demand is more than capacity member fails and vice versa.

Chopra,(2003) , Clough et al,(1993**)** The response spectrum technique is a simplified technique in which time period of the modes of vibration are determined and the maximum response magnitudes corresponding to each mode are evaluated with reference to a response spectrum. Modal combination rules are then used for superposition of the responses in the various modes. The resultant moments and forces in the structure correspond to the envelopes of maximum values, rather than a set of simultaneously existing values**.**

S.S,Patil et al.(2013) presented seismic analysis of high rise building using different lateral load resisting system. This analysis is done with response spectrum method,and using STAAD pro software. Test result is based on parameters like base shear, story drift and story deflection. They concluded that shear wall model gives less story deflection and story drift than bare frame and braced frame.

Hassaballa A.E. Et. Al (2013) studied the seismic analysis of a RC building, and investigate the performance of existing building if exposed to seismic loads. This building frame was analyzed by Response Spectrum Method and frame is computed through STAAD Pro software. For seismic analysis of multistory building they used static load and seismic load and get result that design based on response spectrum method required large dimension of to resist large displacement. And concluded that drift resulting from nodal displacement due to combination of static load and seismic loads were about 2to 3 times the allowable drifts.

Mindaye et al (2016), studied the seismic response of residential G+10 RC frame building is analyzed by the linear analysis approaches of equivalent static lateral forces and response spectrum method using ETAB ultimate 2015 software as per IS 1893:2002 (part-1).Different response like lateral force, overturning moment, story drift, displacement ,base shear are plotted ib order to compare the result of static and dynamic analysis. They concluded that dynamic story shear is less than story shear for all cases. Equivalent static lateral force method gives higher value of force and moments which make building uneconomical hence consideration of response spectrum met5hgod is also needed.

Bhagwat et al.(2014) studied dynamic analysis of G+12 multistoried practiced RCC building considering for Koyna and Bhuj earthquake is carried out. The time history analysis and response spectrum analysis and seismic responses of the building are comparatively studied. The modeled helped of ETABS 9.7.2 software. Two time histories (i.e. Koyna and Bhuj)have been used to develop different criteria (base shear ,story displacement, story shear)and concluded that the value of base shear for Bhuj earthquake is 49.11% more than the Koyna earthquake, and response spectrum method gives 50%more result.

Jun Chen (2016) clarified the impact and reaction of floor acceleration because of seismic forces. He explained that due to seismic forces there is a jumping occurs on the floor. An experiment was conducted on individuals by taking jumping forces and taking 506 records. Every individual was considered as single degree freedom system with varying frequency and damping ratio calculated using response spectrum method and after a curve was plotted as per the results obtained and design spectrum curves was obtain by statistical. The design spectra considered 0.5 hz-15 hz. The experiment and analysis conducted under various floor models and concluded that response spectrum varies as per existing floor design to any individual or crowd.

Khaldoon A.et al (2017), compared time history method and response spectrum method and explained that for non-linear dynamic analysis response spectrum method is adopted. He considered all past earthquake records, spectrum records. Study main focused structure design of two multistory building built to resist earthquake in two different areas in Kabul. Analysis and comparison is done by creating an artificial field of seismic forces. All method are compared by models those building and analysis under various loading conditions by creating artificial accelerograph.

Lukas Moschen (2016), paper represented method of response spectrum method for peak flow response of any structure. The analysis is done by model which is prepared under complete quadratic combination. He also explained the concept of stochastic bas excitation for various high rise building. Method has been tested multistoried structures at various planes but with particular ground motion technique embraced both flexible and inelastic structures all the while. Paper compass modern quadratic rule with model displacement for calculation in this paper all p[resent day technique and mix of strategy are considered.

Mahmoud M. Hachem, considered utilization of ground movement records in the seismic plan of structures is ending up noticeably more broad because of the expanding accessibility of ground movement record databases and enhancing figuring power. Contingent upon the construction law and structure included, the specialist may be required to perform one or a mix of many sorts of seismic examinations including reaction range investigation, nonlinear sucker investigation, and straight or nonlinear reaction history investigation. The genuine procedure took after is frequently an element of the individual understanding of the seismologist or design and affected by nearly normal practice and the elucidations of building offices and companion survey advisory groups. Seismic outline criteria and ground movement determination techniques from five diverse world locales were introduced and locked at. Reaction history investigation is infrequently utilized

practice, so the code arrangements for this sort examination are in some cases dubious and a few choices are incidentally left to the creator. All codes appear to permit ground movement alternation utilizing unearthly coordinating, and mimicked ground movements give off an impression of being for the most part acknowledged.

Kumar, et al, Researched different level of ductility in a building can be considered by using different response reduction factor in linear analysis However, the actual non-linear behavior of the building cannot be predicated on same basis. The seismic performance of low-rise and midrise RC buildings designed as per Indian codes with consideration of seismic forces with two sets design levels SMRF and OMRF and only gravity forces designed for only gravity loadings have been evaluated by fragility relationships. The inner powers are figured from flexible examination. It can likewise be expressed as the harm potential to a class of comparable structure in a specific building shock subjected to a given seismic hazard. With a specific end goal to recreate these three gathering of structures, three outline levels have been considered for this review i.e. the building is designed as Special Moment Resisting Frame (SMRF),Ordinary Moment Resisting Frame(OMRF)and for gravity loads only. The response reduction factor (R) is based on ductility, over-strength and redundancy effects and thus requires the proper detailing of structure. Even though the base shear observed for OMRF building was higher than the SMRF was observed 30% more than that of building designed as OMRF.

Panchal & Marathe (2011) presented a comparative study of g+30 story commercial building which is situated in earthquake zone 4. For this work steel concrete composite, steel and RCC options are used. For the comparative study here seismic static method of analysis is used. For the modeling composite, steel and RCC structure, ETABS software is used and the results are compared and it is found that composite structure is found to be more economical.

Esmaili et al. (2008) studied the structural aspect of a 56 stories high tower located in a high seismic zone in Tehran. Seismic evaluation of the building was done by no-linear dynamic analysis. The existing building had main walls and its side walls as shear walls, connected to the main wall by coupling of beams. The conclusion was to consider the time dependency of concrete. Steel bracing system should be provided for energy absorption for ductility, but axial can have adverse effect on their performance. It is both conceptually and economically unacceptable to use shear wall as both gravity and bracing system. Confinement of concrete in shear walls is good option for providing ductility and stability.

Chandurkar & pajgade (2013) in the seismic design of buildings, reinforced concrete structural wall, or shear walls, 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 is important to evaluate the seismic response of the walls appropriately. Effectiveness of shear wall has been studied with the help of four different models. Model one is bare frame structural system and other three models are dual type structural system. An earthquake load is applied to a building of ten stories located in zone II, zone III, zone IV, zone V. Parameters like lateral displacement story drift and total cost required for ground floor are calculated in both the cases replacing column with shear wall.

Hasan et.al (2010) reported that exterior shear walls can be successfully applied to existing vulnerable building to improve seismic capacity provided that the dowels are well designed.

Can Balkaya et al (1993) studied about the shear wall dominant structures. Shear-wall dominant buildings are the prevailing multi-story RC buildings type particularly in the regions prone to high seismic risk. To identify their most essential design parameters, dynamic and inelastic static pushover analyses were conducted on the backbone of performance based design methodology.

Antonio F. Barbosa et al (2000) presented a paper considering the practical application of nonlinear models in the analysis of reinforced concrete structures. The results of some analyses performed using the reinforced concrete model of the general-purpose finite element code ANSYS are presented and discussed. The differences observed in the response of the same reinforced concrete beam as some variations are made in a material model that is always basically the same are emphasized.

Anthony J. Wolanski, B.S (2004) did research on the flexural behavior of reinforced and pre-stressed concrete beams using finite element analysis. The two beams that were selected for modeling were simply supported and loaded with two symmetrically placed concentrated transverse loads.

Joel. M. Barron and Mary Beth D. Hueste (2004) studied the diaphragm Effect in Rectangular Reinforced Concrete Building. Under Seismic Loading, floor and roof systems in RC building acts as diaphragms to transfer lateral earthquake loads to the vertical lateral force resisting system. The impact of in- plane diaphragm deformation on the structural response of RC building is evaluated using a performance-based approach.

Mohan H.S et al (2015) conducted the work of analysis of a both commercial multistoried building with flat slab and conventional slab for G+5. They compared the results for parameters like base shear, story drift, axial force, and displacement in all seismic zones of India. They got the result as story shear 5% more when compared to conventional slab type, the axial forces was found to be 6% more in flat slab. They also found out that story displacement was differing approximately 4mm in each floor and both flat slab and conventional slab structure.

Sumit Pahwa et al (2014) carried out the study of flat slab with two way slab for comparative behavior values of various parameters using Staad pro. 2006. They created models for two way slabs and flat slab without shear wall for each plan size of 16*24 m and 15*25 m. they considered the models ins seismic zones III, IV,V with the varying height of the above models such as 21m, 27m, 33m, and 39m. After the modeling and analysis on the basis of results they conducted that the model of flat slab increases drift value in shorter plans and decreases drift in larger plans which is in range of 0.5mm - 3mm.

Kalyan Chowdhry Kodali, et al (2014) carried out analysis of conventional beam slab and flat slab models. G+30storey building model with shear wall are considered, which are subjected for different load condition. The seismic zone considered zone V. They concluded that the time periods of conventional beam slab is more when compared to flat slab. They found that story drift of flat slab model is high when compared to beam slab model. Due to the higher drift ratios in flat slabs additional moments will develop. In such case the columns should be designed considering additional moments in beam slab model base shear is more when compared to flat slab building.

Manu K V et al (2015) carried out the study of characteristic seismic behavior of conventional RC frame building and flat slab buildings. They carried out the analysis using ETABS V9.7.4. They found out that lateral displacement is minimum at plinth level and maximum at terrace level, as number of stories increases lateral displacement also increases. Story drift is minimum at plinth and minimum at terrace level, as the total number of stories increases base shear increases.

Payam Tehrani (2006) studied about the equated the nonlinear static pushover and nonlinear dynamic responses in the purposes of maximum displacement of present steel structure retrofitted with different methods.

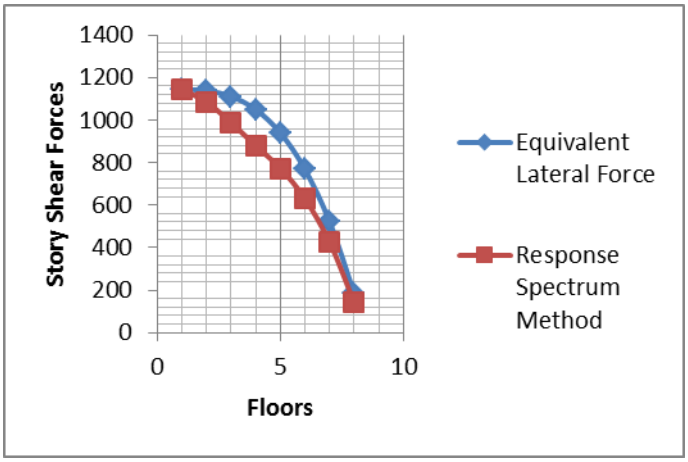
A.R. Touqan (2008) studied of assessment of response spectrum and equivalent static lateral load with the more elegant response spectrum method of analysis as they apply to arrange of different structural models.

Dr. Qaiseruz Zaman Khan (2010) a paper of response spectrum method of 20 story building has been conferred in detail and comparison of static and dynamic analysis and design results of buildings up to 400 feet height (40 story) in relations of percentage decrease in bending moments and Shear force of beams, bending moments of columns, top story deflection and support reaction are conferred.

Romy Mohan (2011) paper highlights the exactness time history analysis in comparison with the utmost commonly adopted response spectrum analysis different shape of shear walls

3. DISCUSSION

We are also talked about before seismic investigation has a prime significance also; it ought to be done all the more exactly. The two approaches (Response spectrum method and Equivalent lateral force method), Equivalent method is pretended technique as it take seismic load i.e. lateral force as static and RSM is most correctly as it consider dynamic nature of seismic load . Where Equivalent static method is simple to apply as: opposition with RSM. Similar review has demonstrate that ESM indicate direct dissemination of base shear through RSM demonstrate indirect in reality in RSM base shear at lower story is higher than ESM. The difference between these techniques also shown in the graph i.e. very beneficial carried out the seismic forces. The forces i.e. lateral forces and story shear forces in up-down at floors leve



Graph 1- Comparison between Equivalent lateral force and Response spectrum technique

4. CONCLUSION

However, fundamentally the two techniques are taken from same principle but in comparison equivalent lateral force method is not more precise in description of structure under dynamic load and it cannot give more specific approximation of the inner stresses and also time consuming. And Where, Response spectrum method saves lot of resources and time. Response spectrum gives valuable information during the periods of earthquake.

- The earthquake lateral force analysis i.e. Equivalent lateral method gives most conservative result relative to the Response spectrum method.
- To compute the seismic forces- story shears, base shear and lateral forces easily by the use of equivalent lateral force method and Response spectrum method.
- To compare both methods i.e. equivalent lateral force process varies on the computations of natural periods and basic formulae for carried out the forces. On the other response method or modal

method varies on the mode shapes, frequencies and fundamental periods of the different mode of ground motion.

- By comparison of both methods equivalent lateral force varies on the computations of natural periods and basic formulae for carried out the forces. On the other hand response method or modal method varies on the mode shapes, frequencies and fundamental periods of the different mode of ground motion.
- Response spectrum method is more suitable for the building with regular distribution of mass and stiffness with extra height.
- It is used for structures having closely spaced frequencies.
- The responses may be estimated less than that of SRSS.

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