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Seismic Analysis and Design of Vertically Irregular Mutistoried RC Concrete Building using Staad Pro V8i

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ABSTRACT

This paper is concerned with the effects of a variety of vertical irregularities on the seismic response of a structure. The objective of the project is to carry out Response spectrum analysis (RSA) and Time history Analysis (THA) of vertically irregular RC building frames and to carry out the ductility based design using IS 13920 corresponding to Equivalent static study and Time history analysis. Comparison of the results of analysis and design of irregular structures with regular structure was done. The scope of the project also includes the evaluation of response of structures subjected to high, low and intermediate frequency content earthquakes using Time history analysis. Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were measured. According to our examination the storey shear force was found to be maximum for the first storey and it decreases to minimum in the peak storey in all cases. The mass irregular structures were observed to occurrence larger base shear than similar regular structures. The stiffness irregular structure experienced lesser base shear and has larger inter-storey drifts. The total displacements obtained from time history analysis of geometry irregular structure at respective nodes were found to be larger than that in case of regular structure for high stories but steadily as we moved to lower stories displacements in both structures tended to congregate. Lower stiffness results in higher displacements of upper stories. In case of a mass irregular structure, time history analysis gives a little higher displacement for upper stories than that in regular structures whereas as we move down lower stories show higher displacements as compared to that in regular structures. When time history analysis was done for regular as well as stiffness irregular structure, it was found that displacements of upper stories did not vary much from each other but as we moved down to lower stories the total displacement in case of soft storey were higher compared to respective stories in regular structure. High structures were found to have low natural frequency hence their response was found to be maximum in a low frequency earthquake. It is because low natural frequency of tall structures subjected to low frequency earthquake leads to resonance resulting in larger displacements. If a high rise structure (low natural frequency) is subjected to high frequency ground motion then it results in small displacements. Similarly, if a low rise structure (high natural frequency) is subjected to high frequency ground motion it results in larger displacements whereas small displacements arise when the high rise structure is subjected to low frequency ground motion.

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INRODUCTION

The structure is the main focus at the duration of an earthquake and when it goes fail it shows a weakness of this structure. Due to the incoherence of stiffness, mass and geometry of structure this weakness appears. This is called as 'Irregular Structure' and it also adds a huge division of urban area. During earthquakes, vertical irregularities are the main cause of failure. Soft story structure hits more and collapsed with each other when an earthquake occurs. Hence vertically irregularities have more effects on the seismic performance of structures. There is some characteristic like change in height, mass and stiffness which are different from regular buildings.IS 1893 definition of Vertically Irregular structures:

Due to lack of strength, mass, stiffness as well as height causes irregularity in the structure of the building. Design and analysis become more complex when these buildings are built in seismic areas.

A. Plan Irregularities
B. Vertical Irregularities.

Vertical Irregularities are mainly of five types-

Mass Irregularity-Mass irregularity shall be looked to occur at the place that the seismic mass of every storey is actually a lot more compared to 200 % of this of the adjacent storeys. If roofs irregularity doesn't have to be regarded as.

Stiffness Irregularity —Soft Storey-A soft storey is but one whereby the lateral stiffness is actually under 70 % of this storey previously mentioned or even under 80 % of typical lateral stiffness of 3 storeys previously mentioned.

Vertical Geometric Irregularity- A framework is actually regarded as Vertical geometric irregular if the horizontal dimension of lateral pressure resisting method in almost any storey is actually a lot more compared to 150 % of that storey within the adjacent storey of this structure.

In-Plane Discontinuity in Vertical Elements Resisting Lateral Force-An in a plane set off of lateral pressure resisting components better compared to the measurements of these components.

Discontinuity in Capacity —Weak Storey-A weak storey is but one whereby the storey lateral toughness is actually under 80 % of this within the storey previously mentioned. IS 1893, Part one Linear fixed evaluation of buildings could be utilized for normal buildings of small level as within this procedure lateral forces are actually estimated as a code based the mostly essential period of time of this framework. Linear powerful evaluation is actually an enhancement of "Linear Static Analysis" because this evaluation creates the outcome of greater vibration modes and also the real division forces within flexible assortment within a far better method. Structures are actually intended as a Design grounded earthquake, though the particular forces acting on the system is much more compared to this of DBE (Ductility Based Earthquake). So, within increased seismic zones Ductility based style strategy is actually desired as ductility of this framework narrows the gap. The main goal within developing an earthquake proof components is actually to make sure that the structure has sufficient ductility to resist the earthquake forces that it'll be put through in the course of an earthquake.

LITERATURE REVIEW

Tesfamariam and Rajeeva (2014) Fragility grounded seismic vulnerability of buildings with an account of "Soft Storey" (SS) and also "Quality of Construction" (CQ) was evidenced on 3, 5, as well as 9 storey RC setting up frames created just before the 1970s. "Probabilistic Seismic demand Model" (PSDM) for anyone gravity load created constructions were created, utilizing nonlinear limited component evaluation since the interactions involving CQ and SS The resulting area technique is utilized to produce a predictive situation for PSDM details as a characteristic of SS as well as CQ. Result of this evaluation displays the awareness of this product parameter to the interaction of CQ and SS.

Sarkar et al. (2016) recommended an interesting approach to quantifying irregularity within vertically unusual construction frames, accounting for powerful qualities (stiffness and mass). The salient conclusions had been as follows:

1. An empirical formulation is actually suggested to compute the essential period of time of stepped developing, as a characteristic of regularity index.
2. A way of measuring vertical irregularity, ideal for stepped structures, referred to as ‗regularity index', is actually suggested, accounting for your adjustments within stiffness as well as a mass on the level of this construction.

Karavasilis et al. (2013) studied the inelastic seismic effect of plane metal moment resisting frames with vertical mass irregularity. The evaluation on the produced result databank demonstrated that the number of storeys, the ratio of the power of column and beam and also the place of the thicker mass impact the height wise division as well as the amplitude of inelastic deformation requires, even though the result doesn't appear to be impacted by the mass ratio.

Athanassiadou (2015) concluded that this impact of this ductility category on the price of structures is actually negligible, while the functionality of the abnormal frames put through earthquake seems to be just as good enough, not substandard to this of normal types, quite possibly for two times the layout earthquake forces. DCM frames had been discovered to always be better also much less ductile compared to corresponding DCH styles. The about sturdiness of abnormal frames was discovered to become much like this of normal types, while DCH frames have been found to dispose better about power compared to DCM shoes. Pushover evaluation appeared to undervalue the result numbers within the top flooring surfaces of abnormal frames. 1:12 scope 17 story RC wall structure creating clothes airers owning various kinds of irregularity on the bottom part 2 accounts to exactly the same number of simulated earthquake excitations to look at the seismic response characteristics of theirs was subjected by lee plus Ko (2017). The very first item had a symmetrical moment resisting frame (Model one), the next had an infilled shear wall structure within the main frame (Model two), and also the 3rd had an infilled shear wall in just among the outside frames (Model three) on the bottom part 2 accounts. The entire quantities of power absorption by harm are actually very similar no matter the presence and also spot of the infilled shear wall structure. The most well-known power absorption was as a result of overturning, and then the shear deformation.

Devesh et al. (2016) agreed on the increased drift need within the tower component of setback buildings as well as on the increased seismic need for structures with discontinuous distributions in deep mass, stiffness and power. The most significant seismic need was discovered for that consolidated stiffness as well as power irregularity.

Moehle and Shahrooz (2014) assumed analytical and experimental research to recognize the earthquake reply of setback constructions. The experimental analysis required layout, building, as well as earthquake simulation tests associated with a quarter scope type of a multistory, reinforced concrete, setback frame. Style, as well as inelastic evaluation of a number of multistory frames owning different amounts of setbacks, were involved by the analytical scientific studies. Along with were: was dealt with by the problems

1. The adequacy of present fixed and also powerful style demands for setback buildings;
2. Design solutions to boost the result of setback structures;
3. The impact of setbacks on powerful response;

Valmundsson, as well as Nau (2014), evaluated the earthquake effect of 5-, 10, as well as 20story framed buildings with non-uniform stiffness, mass, as well as toughness distributions. The result estimated out of TH evaluation was in contrast to the first coat expected through the ELF process embodied around UBC. Based on this comparability, the goal was evaluating the present needs beneath what a framework could be seen as frequent and also the ELF provisions applied

OBJECTIVES

1. To compare the result about regular as well as irregular structures and with the use of RSA to calculate structure forces on irregular or regular structure.
2. Vertical geometry irregularities, mass and stiffness are the main irregularities that should be checked.
3. In order to compute the result of structures subjected in order to different kinds of terrain movements specifically small, high and intermediate frequency land surface movements through the Time historical analysis and also to evaluate the outcomes.
4. In order to perform ductility based earthquake resistant look as a IS 13920 corresponding to equivalent fixed evaluation as well as THA and then to evaluate the distinction of style and design.

SCOPE OF THE STUDY

1. We have studied that column has been molded to base not fixed.
2. We have studied that the result of soil structure and taken to be rockey soil.
3. We have studied vertical irregularity only.
4. We have studied that the contribution of the infill wall structure to the stiffness wasn't thought as Loading of infill wall structure was grabbed into consideration.
5. We have studied that on structure only linear elastic analysis has been done.
6. We have considered RC building only.

ANALYSIS METHODS

SEISMIC ANALYSIS

'Seismic analysis' is actually a significant instrument of earthquake engineering that is utilized to recognize the result of structures because of seismic excitations. In past times the structures had been developed simply for seismic examination as well as gravity lots is a recently available growth. It's part of structural analysis and integral part of structural style in which earthquake is actually common. Some earthquakes analysis methods are given below:

A. 'Time History Analysis'(THA)
B. 'Equivalent Static Analysis'(ESA)
C. 'Response Spectrum Analysis'(RSA)

EQUIVALENT STATIC ANALYSIS

The equal/equivalent fixed evaluation treatment is basically a flexible style method. It's, nonetheless, easy to utilize as opposed to the multi-model effect technique, while using the absolute simplifying assumptions getting arguably a lot more constant along with other assumptions complete somewhere else within the layout process.

This has some below mention steps:

1. Use the particular style reply spectra to figure out that this lateral base shear of total development is actually constant with all the amount of post elastic (ductility) reply assumed.
2. Distribute the base shear involving the different lumped mass amounts generally based upon an inverted triangular shear division of 90 % of this base shear generally, with 10% of the base shear getting imposed within the very best fitness level to permit increased method consequences.
3. Estimate the original method reply phase of this and put together in the layout effect spectra.

RESPONSE SPECTRUM ANALYSIS

This method enables the many modes of reaction of construction to be taken into consideration. This' s needed in building codes that are many for those apart from quite simple or perhaps quite complicated buildings. The structural reply is usually identified for a blend of countless modes. Personal computer evaluation could be utilized to figure out the modes for a frame work .For every function, a result is actually received using the layout spectrum, resultant to modal frequency as well as the modal mass, after which they're put together to calculate the entire result of this framework. Through this, the magnitude of forces in most instructions is actually estimated and next influences on the structure are actually noticed.

There are some methods for combination:

- 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 product of an RSM evaluation in the resulting spectrum of a ground movement is usually totally different from that and will be estimated from a "Linear Dynamic Analysis" making use of that ground motion straight, as info of this stage is actually forfeited within the procedure of producing the reply spectrum.

TIME HISTORY ANALYSIS

Precious time historical analysis methods include the stepwise option within the time domain name of multi degree-of-freedom equations of movements which in turn stand for the particular result of construction. It's probably the most advanced evaluation technique accessible to a structural engineer.

DESIGN METHOD

DUCTILITY BASED DESIGN

Hence the chief undertaking would be to make certain this creating has sufficient ductility to resist the consequences of planet quakes, that is actually apt being encountered with the framework throughout the lifetime of its. Ductility of this framework functions as a shock absorber and also lowers the transmitted forces to the framework. The ductility of a framework is able to evaluated by ductility based method.

Ductility in the parts results originating from inelastic articles conduct and also reinforcement detailing to ensure that breakable fracture is really stayed away from along with ductility is really launched by allowing metallic to provide within a controlled manner. Hence the chief commencing is making particular the producing has adequate ductility to

withstand the implications of world quakes, that's really apt-getting came across together with the framework through the lifetime of its.

ORGANISATION OF DISSERTATION

The very first chapter of the launch is spread cover by Dissertation, goals of this task, range of review, strategy, evaluation strategies used and lastly develop method required. The benefits of seismic evaluation of buildings and also the necessity of an effective style method are shown by the very first chapter. It offers an introduction to the evaluation techniques implemented together with the benefits of ductility grounded style and design.

WORKING WITH STAAD. Pro

INPUT GENERATION:

The GUI (Graphical User Interface) communicates with the STAAD analysis engine through the STD input file. That input file is a text file consisting of a series of commands which are executed sequentially. The commands contain either instructions or data pertaining to analysis and/or design. The STAAD input file can be created through a text editor or the GUI Modeling facility. In general, any text editor may be utilized to edit/create the STD input file. The GUI Modeling facility creates the input file through an interactive menu-driven graphics oriented procedure.

TYPES OF STRUCTURES

A STRUCTURE can be defined as an assemblage of elements. STAAD is capable of analyzing and designing structures consisting of frame, plate/shell and solid elements. Almost any type of structure can be analyzed by STAAD.

A SPACE structure, which is a three dimensional framed structure with loads applied in any plane, is the most general.

A PLANE structure is bound by a global X-Y coordinate system with loads in the same plane.

A TRUSS structure consists of truss members which can have only axial member forces and no bending in the members.

A FLOOR structure is a two or three dimensional structure having no horizontal (global X or Z) movement of the structure [FX, FZ & MY are restrained at every joint]. The floor framing (in global X-Z plane) of a building is an ideal example of a FLOOR structure. Columns can also be modeled with the floor in a FLOOR structure as long as the structure has no horizontal loading. If there is any horizontal load, it must be analyzed as a SPACE structure.

BEAM DESIGN

Beams are actually created for flexure, torsion as well as shear. In case demanded the outcome of axial pressure might be looked at. For everything, the forces, just about all energetic beam loadings are actually rescanned to recognize the crucial ton instances from various areas on the beams. For style being done as an IS 13920 the breadth of this part shan't be a bit less compared to 200mm. additionally, the part shall ideally enjoy a width to the level ratio of over 0.3.

Design for Flexure

Design procedure is the same as that for IS 456. However, while designing the following criteria are satisfied as per IS-13920:

3.1 The least quality of concrete shall ideally be M20.

3.2 Steel reinforcements of quality Fe415 or even much less simply shall be worn.

3.3 The least stress metal ratio is actually provided by: min = 0.24fck/fy

3.2.3 The highest metal ratio is actually provided by max = 0.025

3.2.4 The good metal ratio with a joint facial skin should be for minimum comparable to fifty percent the bad metal within this value.

3.2.5 The metal offered within every one of the bottoms and top facial skin, shall, at any rate, be comparable to one-fourth of this optimum unfavorable second metal provided with the facial skin of both joint.

Design for Shear

The shear pressure being resisted by vertical hoops is actually instructed through the IS 13920:1993 modification. Flexible drooping, as well as hogging occasions of the opposition of this beam aisle at giving ends, are believed to be while calculating shear pressure. Clear plastic drooping as well as hogging occasions of opposition could additionally be looked at for shear look in case PLASTIC parameter is actually pointed out within the type in the file. Shear reinforcement is actually estimated to fight each torsional occasions as well as shear forces.

COLUMN DESIGN

Columns are designed for axial forces and biaxial moments per IS 456:2000. Columns are also designed for shear forces. All major criteria for selecting longitudinal and transverse reinforcement as stipulated by IS: 456 have been taken care of in the column design of STAAD. However following clauses have been satisfied to incorporate provisions of IS 13920:

The least quality of concrete shall ideally be M20.

- Steel reinforcements of quality Fe415 or even much less simply shall be worn.
- The least dimension of column part shan't be a bit less compared to 200 mm. For columns owning unsupported measurements exceeding 4m, the least dimension of column shan't be a bit less compared to 300 mm .The ratio of least cross-sectional dimension to the perpendicular dimension shall ideally be not under zero.
- The spacing of hoops shan't go beyond fifty percent the very least lateral dimension of this column, with the exception of the place extraordinary confining reinforcement is actually supplied.
- Special confining reinforcement shall be offered with measurements lo via every joint facial skin, towards mid span, as well as on each side of every axial, in which flexural yielding could happen. The measurements lo shan't be a bit less compared to a) bigger lateral dimension of this part on the axial in which yielding happens, b) 1/6 of the distinct span of this part, as well as c) 450 mm.
- The spacing of hoops employed as exclusive confining reinforcement shan't go over ¼ of least part dimension but doesn't have to be a bit less compared to seventy-five mm neither over hundred mm.

ANALYSIS METHODS
STRUCTURAL MODELLING
SPECIFICATIONS

Live Load	3.0 kN/m^2
Density of RCC considered:	25.00 kN/m^3
Thickness of slab	150 mm
Depth of beam	800 mm
Width of beam	300 mm
Dimension of column	300x800 mm
Density of infill	20 kN/m^3
Thickness of outside wall	250 mm
Thickness of inner partition wall	150 mm
Height of each floor	3.5 m
Earthquake Zone	IV
Damping Ratio	5%
Importance factor	1
Type of Soil	Rocky
Type of structure	Ordinary Moment Resisting Frame
Response Reduction Factor	3

Four types of Irregular buildings were considered, Regular structure, Mass irregular structure, structure with ground storey as the soft storey and vertically geometric irregular building. The first three structures were 10 storeyed.

1. **Regular structure (10 storeys):**

Mass Irregular Structure (10 storeys): The structure is modeled as same as that of regular structure except the loading due to swimming pool is provide in the fourth and Eighth floor.
Height of swimming pool considered - 1.80 m
Loading due to swimming pool - 18.00 kN/m^2

2. **Stiffness Irregular Structure (Soft Storey):** The structure is same as that of regular structure but the ground storey has a height of 4.5 m and doesn't have brick infill.
   Stiffness of each column= $12EI/L^3$
   Therefore,
   Stiffness of ground floor/stiffness of other floors= $(3.5/4.5)^3 = 0.47 < 0.7$
   Hence as per IS 1893 part 1 the structure is stiffness irregular.

3. **Vertically Geometric Irregular**- The structure is 14 storeyed with steps in 5th and 10th floor. The setback is along X direction.

Width of top storey= 20m Width of ground storey = 40 40/20 = 2 > 1.5

SPECIFICATION

Live Load	**3.00 kN/m^2**
Density of RCC considered:	25.00 kN/m^3
Thickness of slab	150 mm
Depth of beam	800 mm
Width of beam	500 mm
Dimension of column	300x800 mm
Density of infill	20 kN/m^3
Thickness of outside wall	250.00 mm
Thickness of inner partition wall	150 mm
Height of each floor	3.50 m
Force Amplitude factor	9.81

TIME HISTORY ANALYSIS
INTRODUCTION TO IS CODE GROUND MOTION USED

Regular and various types of irregular buildings were analyzed using THA and the response of each irregular structure was compared with that of regular structure for IS code Ground motion. The IS code ground motion used for the analysis had PGA of 0.2g and duration of 40 seconds

CONCLUSION

Three kinds of problems specifically mass irregularity, vertical geometry as well as stiffness irregularity had been regarded. All three types of unusual RC setting up frames had strategy symmetry. "Reaction Spectrum Evaluation" was done for every kind of irregularity and also the storey shear forces received ended up being in contrast to this of a typical framework.

Time history analysis (THA) was conducted for each type of irregularity corresponding to the above-mentioned ground motions and nodal displacements were compared. Finally, the design of above-mentioned irregular building frames was carried out using IS 13920 corresponding to Equivalent static analysis (ESA) and Time history analysis (THA) and the results were compared. Our results can be summarized as follows-

"Time History Analysis" was done for every kind of irregularity corresponding to the above described ground movements as well as nodal displacements had been when compared. Last but not least, style of previously named abnormal developing frames was carried through working with IS 13920 corresponding to "Equivalent Static Analysis "as well as "Time History Analysis" and also the outcomes had been when compared. The outcomes of ours could be summarized as follows-

- According to outcomes of RSA, the storey shear pressure was discovered to become optimum for your very first storey and this decreased to a bare minimum within the leading storey in all of the instances.
- According to outcomes of RSA, it was actually discovered the mass abnormal construction frames encounter bigger foundation shear compared to corresponding typical developing frames.
- According to outcomes of RSM, the stiffness abnormal developing encountered smaller foundation shear and possesses bigger inter-storey drifts.
- The complete displacements from precious time historical past evaluation of geometry abnormal putting together from respective nodes had been discovered to become in excess of this in the event of typical putting together for top accounts but steadily as we shift to reduced accounts displacements within the two components tended to converge. This 's simply because inside a geometry abnormal framework top accounts have reduced stiffness (due to L shape) as opposed to the reduced accounts. Reduced stiffness leads to larger displacements of top accounts.
- In the situation of a mass abnormal framework, Time historical past evaluation yielded somewhat greater displacement for top accounts compared to this for normal structure, while as down, is moved by us lower stories showed higher displacements as compared to that in regular structures.
- When time history analysis was done for regular as well as stiffness irregular building (soft storey), it was found that displacements of upper stories did not vary much from each other but as we moved down to lower stories the absolute displacement in case of soft storey were higher compared to respective stories in regular building.

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