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Influence of Vertical Irregularities of Various Steel Framed Structures During Seismic Response

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ABSTRACT

Severe torsion forces, in addition to lateral forces, are exerted on buildings that are vertically irregular, asymmetric in plan and elevation, or both, by the action of earthquakes. Plan and elevation views of buildings with vertical irregularities are highly asymmetrical because the centers of mass and stiffness of individual floors are not all on the same vertical axis. The steel construction industry is vital to the building sector. Earthquakes in India's past have demonstrated the importance of designing engineered structures to withstand seismic forces. Adding steel bracings to the structural system of a steel moment-resisting frame improves the frame's response. A significant factor influencing structural responses to seismic loads is irregularity.

METHODOLOGY AND EXPLANATION

The purpose of this research is to analyze the seismic responses of steel buildings for two types of vertical irregular buildings: vertical irregularity associated with steps in the building plan area (Brace system with full height and frames that have more bays at the base of the building than at the top) and (ii) vertical irregularity associated with Brace system that stops around mid-height of the building. Using linear static analysis, we compared the behavior of low-rise and high-rise steel buildings with vertical irregularity and identical bay lengths. To further investigate the nonlinear response of all structures to the Chamoli earthquake, a nonlinear time history analysis is performed.

Keywords: Seismic loads, vertical irregularities, steel buildings, and steel-braced structures are some of the terms used to describe these factors.

I. INTRODUCTION

The term "earthquake" is used to describe any seismic event, natural or man-made, that has the potential to affect the local seismic environment. Geological faults within the Earth often rupture, but volcanic activity, landslides, mine explosions, and nuclear tests can also trigger earthquakes.

Shaking of the earth's surface, known as an earthquake, can be felt and is often strong enough to cause extensive damage and the loss of life. As far as natural disasters go, earthquakes are widely regarded as the most dangerous and unexpected. As a result, it is challenging to over-engineer against it to save properties and life. When it comes to natural disasters, India consistently ranks among the world's worst. Despite all the research that has gone into understanding earthquakes, scientists still can't say for sure where or when a quake will occur.

To address these problems, it is necessary to determine the seismic performance of the buildings through the creation of several analytical procedures that will guarantee the buildings will remain standing even when subjected to frequent minor earthquakes and enough protection when subjected to major earthquakes. A building's ability to withstand earthquake forces depends on several characteristics, including its rigidity, lateral strength, ductility, and regular, straightforward layout. Normal buildings are less damaged than irregular ones because of their regular geometry, evenly distributed mass, and planar and vertical stiffness. Abrupt shifts in geometry, uneven mass distribution, breaks in load paths, and gaps in stiffness and strength are all possible causes of a configuration's irregularity. The demands of the modern era and the growing population, however, have pushed architects and engineers inexorably toward more unconventional layouts.

II. CONTEXTUAL HISTORY

Due to its relative simplicity and consideration of post-elastic behavior, nonlinear static analysis, also known as pushover analysis, has become the most sought-after analysis procedure for design and seismic performance evaluation purposes over the past twenty years. Nonetheless, there is always bound to be some variation in the process, as is to be expected in any non-linear analysis for predicting seismic demand.

Due to its prevalence in the design and seismic performance evaluation processes, understanding the factors that influence pushover predictions is crucial. This means that issues like modelling nonlinear member behavior, the computational scheme of the procedure, differences in the predictions of different lateral load patterns used in conventional pushover analysis, and the efficacy of invariant lateral load patterns in representing higher mode effects and accurate estimation should be explored to determine whether or not pushover analysis is useful for predicting seismic demands for low-, medium-, and high-rise structures.

In the last two decades, the pushover analysis method has gone through numerous iterations and has been developed by a wide range of people. Inelastic Response of Reinforced Concrete Structures to Earthquake Ground Motions was a topic of research for Gulkan and Sozen in 1974. Nonlinear seismic analysis of reinforced concrete buildings was the subject of Fajfar and Fischinger's 1987 research. The pushover analysis relies on the Applied Technology Council's ATC 40: Seismic evaluation and retrofit of concrete buildings, which was published in 1996. Additionally, the American Society of Civil Engineers has developed FEMA 273 (1997) and FEMA 356 (2000), both of which are guidelines for seismically rehabilitating buildings (ASCE). Seismic pushover analysis is an area where Anil K. Chopra has made significant contributions. Since non-linear analysis is required to capture the behavior of the structure under seismic effects, inelastic behavior is intended in most structures subjected to infrequent earthquake loading. The non-linear static procedure is widely used in structural engineering because of its ease of use.

III. RELEVANCE OF THE STUDY

The performance of a structure under the action of these loads is usually doubted when it is designed, even though the structure may be subjected to earthquakes in the near or distant future. Despite the rarity of earthquakes, it is still necessary to foresee how a building will fare during one. Loss of property and, more importantly, loss of life can be avoided if the building is built to withstand earthquake loads, and the problem is made worse by any structural irregularities.

Seismic loads are barely considered during the design process, so it is impossible to guarantee that buildings in India will withstand an earthquake. Because of this, it is crucial to assess the buildings' susceptibility to earthquakes and verify that they can withstand the resulting forces.

Engineers often resort to empirical formulas to make sense of the structure's non-linear behavior. No building can be completely earthquake-proof because neither the magnitude nor the direction of an earthquake can be predicted with any degree of certainty, but buildings can be reinforced to the point where only minor damage is sustained. Non-linear static analysis, also known as pushover analysis, is one method that can be used to account for the structure's performance under such loads. It can be used on a structure that exhibits non-linear behavior under these loads, pinpointing its weak points so that existing components can be strengthened with minimal disruption.

Shaking table tests can be used for the scaled model, but the results are highly debatable and have some limitations, and there is no experimental method that exactly contemplates the behavior of steel framed structures, which means that these tests cannot be used for the analysis of real structures. Thus, the behavior of the structure can be understood with the help of certain finite element packages, whose results are quite reliable up to a certain level.

IV. OBJECTIVES

The following goals have been established for this study, and they were determined after reviewing the relevant literature.

- Multi-story steel-framed buildings with vertical geometrical irregularities will be analyzed for their behavior.
- Non-linear static analysis will be utilized to assess the performance of the structure at a G+20 story height with a variety of bracings.
- Evaluate how the structure performs with and without additional full and half bracings.
- Displacements, overturning moments, base shear, and storey drifts are being analyzed with the help of ETABS, and the results are being compared.

V. SCOPE OF WORK

The analysis takes into account steel-framed buildings in seismic zone II with a response reduction factor of 3, an important factor of 1, and damping of 2%. For tall buildings with angular irregularities in every direction, a non-linear static analysis has been performed. A G+20 building would have a maximum bay width of 6 meters in both directions and a maximum storey height of 3 meters.

The vertically irregular structures with full and half x steel bracings have been subjected to seismic forces following the standards of IS 1893 2002 load patterns. Finite element analysis software ETABS 2016 will be used to make predictions about the structure's behavior.

Chamoli earthquake data is analyzed non-linearly over time, and the resulting plots are recorded in terms of displacements and storey shears.

The structure's performance levels under varying conditions are determined by carefully examining the analysis's findings.

VI. LITERATURE REVIEW

To learn how buildings with setbacks react during earthquakes, Shahrooz and Moehle (1990) conducted an experimental and analytical study. A quarter-scale model of a multi-story, reinforced concrete, setback frame was designed, built, and tested in an earthquake simulation. Several multi-story frames with varying setbacks were designed and inelastically analyzed as part of the analytical studies. Some of the topics covered include:

- How failures shape reactions in the face of change;
- Design strategies for enhancing the responsiveness of buildings with setbacks.
- According to Moehle, standard limit analysis and static inelastic analysis are reliable tools for

assessing durability and deformation properties in the face of intense earthquake shaking.

- Increased seismic demand for buildings with discontinuous distributions of mass, strength, and stiffness was also agreed upon by Devesh et al. (2006), as was the increased drift demand in the tower portion of set-back structures. It was discovered that the combined stiffness and strength irregularity posed the greatest seismic demand.
- Model choices were found to affect seismic behavior.

To compare the seismic response characteristics of three models of 17-story RC wall buildings with different types of irregularity at the bottom two stories, Lee and Ko (2007) subjected them to the same series of simulated earthquake excitations. Model 1 featured a symmetrical moment-resisting frame, Model 2 included an infilled shear wall in the central frame, and Model 3 featured an infilled shear wall in only one of the exterior frames at the bottom two stories. No matter if a shear wall is present or not, the total amount of energy absorbed due to damage is the same. Overturning absorbed the most power, followed by shear deformation.

Babu, and C. M. Ravikumar To paraphrase: Narayan K S (2012) As a pushover, ETABS 6.0 is used to investigate the seismic requirements of a variety of non-rectangular reinforced concrete (R.C) buildings in India's seismic zone V (hard rock). The plan's layout features 5m-long bays that are 4m on each side. The structures under consideration are three-story, irregularly-shaped, ordinary-moment-resisting frame buildings made of Reinforced concrete. In this case, the nonlinear behavior of seismic demands is not taken into consideration, and neither is the stiffness of the infill.

When it comes to life safety and collapse prevention, all models except two fall somewhere in the middle when tested on sloped ground. This demonstrates that structures situated on the sloped ground are more prone to damage during earthquakes.

Anwaruddin Mohammed (2013) Using non-linear static analysis, the efficiency of a structural system can be measured. Estimating the structural strength and deformation demands and comparing them to available capacities at target performance levels is part of this process. The purpose of this research is to compare and contrast the responses of five different reinforced concrete building systems by employing nonlinear static procedures and described acceptance criteria, as outlined in the ATC-40. Using the IS 456-2000 and PBD guidelines, the methodology is applied to a three-story frame system with and without vertical irregularity.

The lateral load capacity increases without vertical irregularities in a bare frame. However, as vertical irregularity increases, the building's lateral displacement decreases. The values of the story shear rarely deviate from a range of 2% to 5%.

VII. METHODOLOGY

REGUALR AND IRREGULAR STRUCTURE

Four main characteristics should be present in a building for it to fare well in an earthquake: simple regular configuration; sufficient lateral strength; sufficient stiffness; and sufficient ductility. It has been observed that buildings with regular configurations, in which mass and stiffness are distributed uniformly in plan and geometry, fare better in the event of a natural disaster. If a building does not meet even one of these criteria, it is considered irregular.

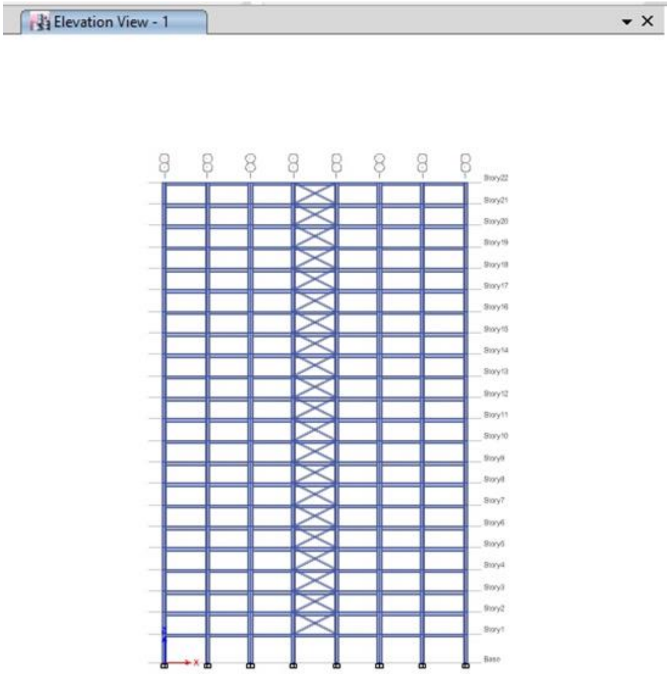
Lateral load or seismic force describes the horizontal loading experienced by a building during an earthquake, as opposed to the vertical loading exerted by the building's weight due to gravity. While the structure as a whole shift around with the ground, the roof typically maintains its place. However, since the walls and columns are attached to them, the roof moves with them. The force developed as a result of the slab's inertia to remain in its original position is also called inertia force. The analysis assumes masses are concentrated at a few points; it acts like a vertical cantilever, with greater gyrations caused by a greater mass at the top. The inverse relationship between structure stiffness and flexibility means that less flexible structures have higher levels of stiffness.

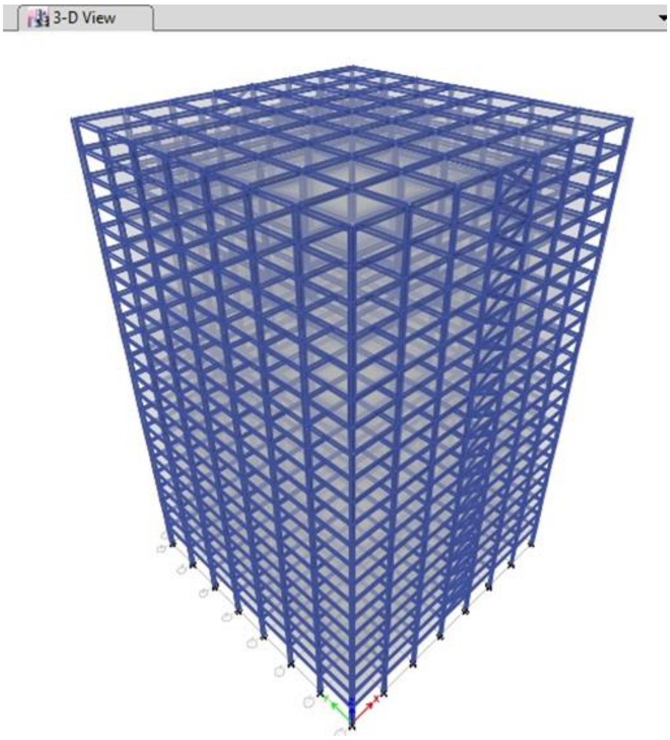
It is preferable to avoid irregular structures during earthquakes because of the better and more predictable behavior of regular structures. However, irregularity of a structure becomes unavoidable due to architectural and aesthetical considerations. The irregular structure's response to extreme conditions is very difficult to predict.

As anyone who has seen a building perform can attest, a building's dynamic response can be affected by its shape due to how forces are distributed as they travel through the structure. There is a strong correlation between the building's performance and its geometry, structural member type, material, and connections. Because of their unique dynamic characteristics, load transfer, and stress concentration must be taken into account during the design process whenever there is a sudden change in structural resistance.

DETAILS OF MODEL

Type of Structure	Steel moment resisting frames
Number of stories	G+20
No. of Bays in X- direction	7
No. of Bays in Y- direction	7
Bay width	6 m* 6m
Floor height	3 m
Bottom story height	3.5m
Depth of Slab	125 mm
Beam size (d mm x b mm)	ISMB 450
Column size (mm x mm)	ISWB 550-1
Size of bracings	ISMC 250
Concrete	M25
Steel	Fe 345, FE500
Density of Concrete	25 KN/m^3
Response reduction factor	3
Type of Soil	Medium
Damping	2 %
Zone	II
Zone factor	0.10





RESULTS AND DISCUSSIONS

DISPLACEMENTS

Story Response		THX		THY	
Story	**Elevation**	**X-Dir**	**X-Dir**	**Y-Dir**	**Y-Dir**
	m	full	half	full	half
Base	0	0	0	0	0
Story1	4	0.129	0.106	0.247	0.247
Story2	7	0.242	0.197	0.355	0.355
Story3	10	0.355	0.287	0.433	0.432
Story4	13	0.466	0.374	0.478	0.477
Story5	16	0.571	0.464	0.531	0.531
Story6	19	0.67	0.567	0.575	0.576
Story7	22	0.76	0.671	0.625	0.625
Story8	25	0.84	0.773	0.674	0.674
Story9	28	0.91	0.872	0.707	0.707
Story10	31	0.971	0.964	0.731	0.731
Story11	34	1.022	1.052	0.752	0.752
Story12	37	1.069	1.129	0.774	0.775
Story13	40	1.117	1.188	0.797	0.798
Story14	43	1.161	1.234	0.818	0.818
Story15	46	1.208	1.264	0.833	0.833
Story16	49	1.263	1.278	0.844	0.844
Story17	52	1.31	1.28	0.852	0.852
Story18	55	1.36	1.311	0.861	0.861
Story19	58	1.453	1.388	0.873	0.873
Story20	61	1.557	1.467	0.887	0.888
Story21	64	1.642	1.528	0.943	0.944
Story22	67	1.707	1.569	0.989	0.989

Table: Comparision of Displacements values of model 1 in time history x-dir and y-dir with full and half steel X bracings

TIME PERIODS COMPARISION

FULL BRACE					
mode	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
1	6.445	5.345	5.296	5.197	4.994
2	3.252	2.495	2.633	2.441	2.332
3	3.054	2.493	2.371	2.245	2.271
4	2.146	1.951	1.881	2.101	1.837
5	1.274	1.267	1.279	1.288	1.24
6	1.043	0.976	0.902	0.967	0.939

7	0.984	0.957	0.859	0.932	0.89
8	0.907	0.907	0.775	0.875	0.877
9	0.703	0.674	0.667	0.684	0.685
10	0.582	0.564	0.619	0.564	0.558
11	0.574	0.542	0.531	0.553	0.528
12	0.552	0.518	0.479	0.52	0.494

Table: Comparision of Time periods of all models in time history x-dir and y-dir with full steel X bracings

VIII. CONCLUSION

This paper aims to provide an efficient bracing system against lateral loads induced in the building by seismic forces. Bracing is a system installed to lessen the building's lateral movement. Braced frames are increasingly used in seismic design and buildings with multiple stories. Thus, the purpose of this thesis is to examine how steel bracing steel structures function. In this study, we analyze the effects of axial force and bending moment in column and story displacement on a steel building model.

- Steel bracing is a useful idea for strengthening compromised high-rise buildings by minimizing lateral movement.
- Full bracing, in comparison to half bracing and no bracing, significantly reduces lateral story displacements.
- Under the conditions of this research, full bracing has been determined to be the most effective method for regulating lateral displacement.
- The full-braced model shows a 27.9% reduction in lateral story displacements compared to the unbraced model with vertical irregularities in the x direction, while the half-braced model shows a 5.28% reduction.
- Overall, the full-braced building system outperformed the others in the study. When bracings are used to make a building more rigid, the structure's response is drastically dampened.
- Basic natural periods found for seismically-designed building simulations. Stiffness, as shown in the graph, is proportional to the building's natural frequency and, by extension, inversely proportional to its natural period. That is, the natural period keeps dropping as building stiffness improves. And because taller buildings are less stiff, the natural period keeps growing as the natural frequency decreases.

IX. FUTURE RESEARCH INDICATIONS

- The impact of brick infill can be accounted for in parametric studies of these buildings.
- The current research can be expanded upon by using a nonlinear approach to structural analysis.
- The adoption of multiple stiffness systems, such as the shear wall with bracings, allows for a more thorough analysis of the heights.
- With a different approach to structural analysis, the aforementioned structures can also add fragrance to time-history studies.

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