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Utilizing the P-Delta Effect For Seismic Evaluation of Structures

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ABSTRACT

Earthquakes are the most devastating and unexpected natural disasters, inflicting havoc on both people and infrastructure. An earthquake's seismic stresses can cause severe damage to structural components, and in certain cases, they may fail. Urbanization is also rapidly rising, making accessible development land increasingly scarce. Hence, the attractiveness of big structures is expanding. P-delta evaluation is another iterative method necessary when researching tall structures in compliance with IS 16700-2017 specifications. If an axial force is given to a member and it maintains its original position, just the lateral load generates a moment. When a member deflects by Δ, both the original moment and the P-Delta effect begin to work on it. The dynamic phenomenon known as P-delta occurs in the majority of structures, including components subjected to axial loads. Higher building heights cause more transverse stress from earthquakes. As the structure's height grows, the P-delta impact becomes more significant. This project utilizes three RC model constructions from East Delhi's G+4, G+10, and G+22-story residential towers. All three types have identical slab, column, and beam measurements. There are two steps to the work: The P-delta effect is ignored in the study's first phase, but it is addressed in the second half. We documented storey displacement and drift for all three models in both conditions. The P-delta effect is omitted from the first phase of the study before being included in the second. We included the number of floors in all three models, as well as floor movement and drift in both situations. In terms of storey displacement, the P-delta effect surpasses storey drift. A correlation study is carried out, and relevant parameters are identified for future usage.

Keywords: *P-Delta Analysis, IS 16700:2017, Seismic Forces and Wind loads, Interaction Factor*

INTRODUCTION

A disaster, according to the United Nations Office for Disaster Risk Reduction (UNISDR), is "a serious disruption of the functioning of a community or society involving widespread human, material, economic, or environmental losses and impacts, which exceeds the affected community's or society's ability to cope with using its own resources." It is considered that such tragedies are becoming increasingly prevalent. However, with advancements in technology and science, forecasting of many sorts of disasters is now feasible, and the impact of these disasters may be considerably reduced by providing appropriate and timely warnings and cautionary messages. From 1950 to 2011, it was determined that the incidence of disasters increased.

Figure 1.1 displays the global increase in various kinds of catastrophes resulting from nature between 1980 and 2019.

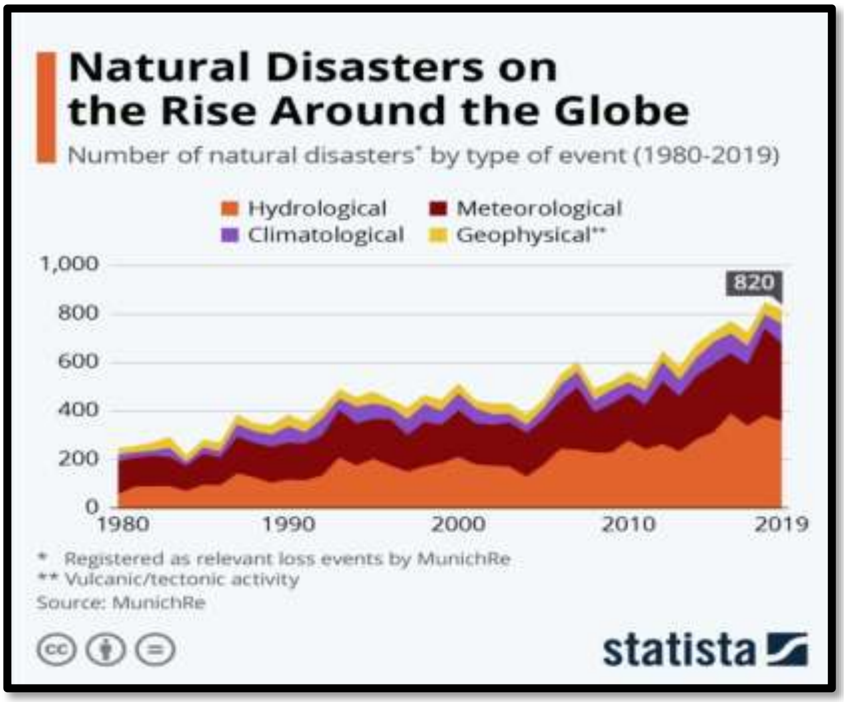
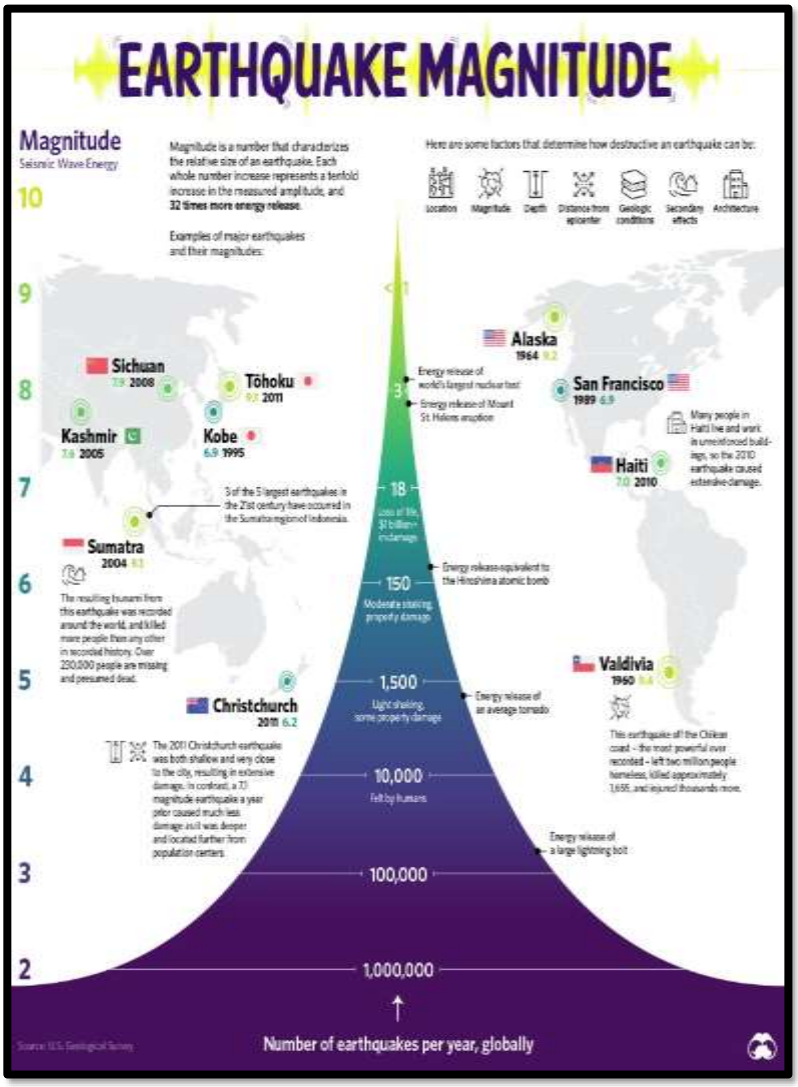


Figure 1.1: Natural Disasters on the Rise Across the Globe

According to statistics from the World Economic Forum, the frequency of natural disasters such as hydrological, climatological, meteorological, and geophysical disasters is rapidly increasing worldwide. Furthermore, from 1980 to 2019, geophysical catastrophe incidents outnumbered all other types of disasters. The frequency of natural disasters has also increased.

Figure 1.2 shows that the strength of earthquakes is increasing year after year.



A different approach to data presented by the World Economic Forum highlighted the rising intensity of earthquakes. According to the most current analysis in 2019, there were over 180 earthquake events worldwide with a Richter scale equivalent to or greater than 6. An earthquake is one of the most destructive natural disasters due to its irregular nature and tremendous potential for destruction. Earthquakes do not directly kill people; instead, the destruction of structures and other buildings causes a massive loss of human life and property. As a result, structures must be protected from the devastation caused by earthquakes across the world.

India is a big country with distinctive geographical features. IS:1893(Part 1)-2016 is the Indian Standard Codal Provision for assessing the earthquake's impact on any structure. IS:1893 (Part 10): 2016 splits India into four seismic zones based on geographical criteria, starting with Zone II and progressing to Zone III, Zone IV, and Zone V, which have the deadliest and most violent earthquakes.

Figure 1.3 depicts several earthquake zones in India.

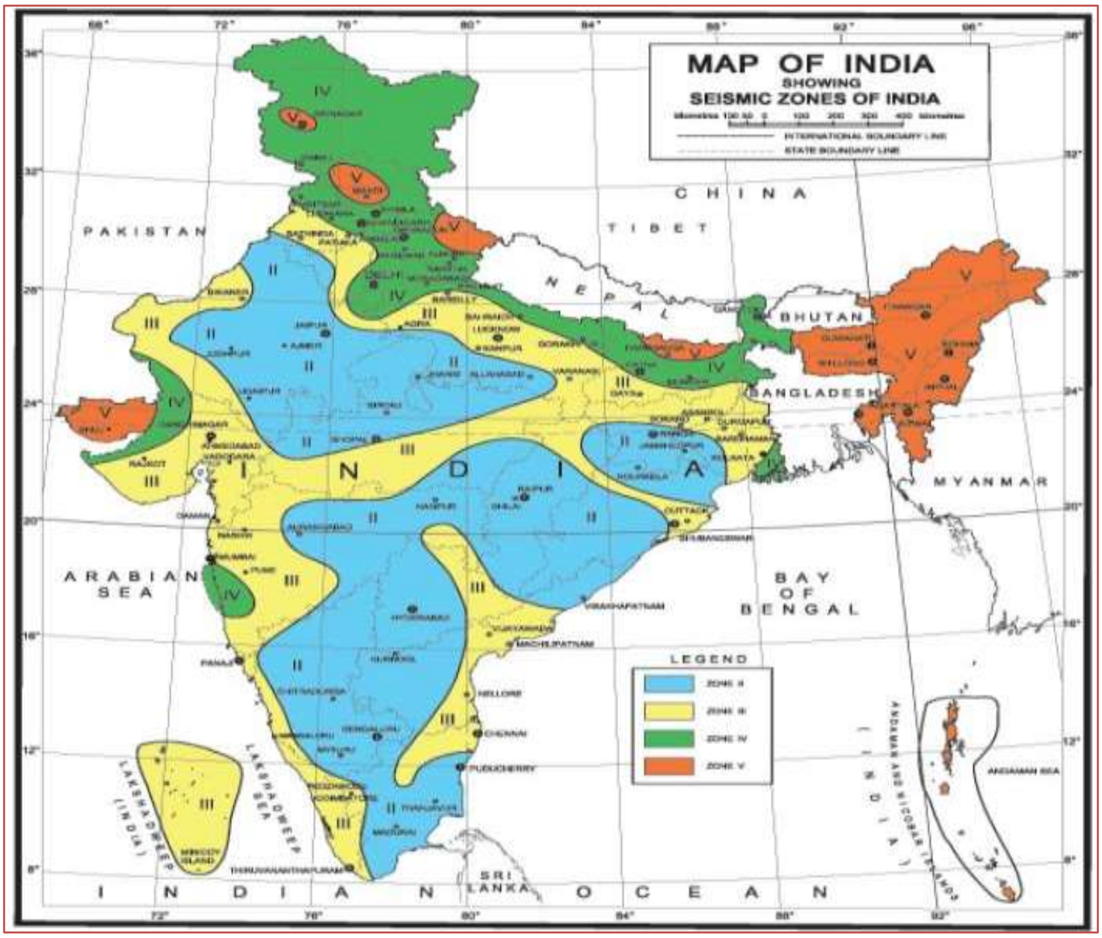


Figure 1.3: Earthquake Zones in India (source: IS 1893:2016)

Code Guidelines, IS: 1893(Part 1)-2016. However, the problem is with buildings constructed prior to the change in IS codal standards. With the increasing frequency of earthquakes, post-disaster management is critical, as is the deployment of various disaster risk reduction techniques. The United Nations Office for Disaster Risk Reduction (UNISDR) declares that its goal is to reduce the devastation caused by natural disasters such as cyclones, earthquakes, droughts, and floods through the implementation of a preventative code. Disasters are frequently associated with natural risks. A disaster's size is determined by the harm it presents to the environment and society. As a result, there is an urgent need for novel approaches to predicting natural disasters. As technology advances, researchers can develop a system to detect on-surface natural disasters such as landslides, hurricanes, tornadoes, and tsunamis. Scientists are now working on establishing a comparable strategy for subsurface calamities like earthquakes and landslides. Earthquakes are regarded as one of the most catastrophic natural disasters because they can trigger the occurrence of other calamities such as tsunamis, avalanches, landslides, and floods.

The aftermath of an earthquake causes significant property and human life loss. When the structures are short in height, the destructive effect of earthquakes is lessened, but it grows as the structures' height increases.

1.Tall Structures and Recommendations:

A tall building, according to the Indian Standard Codal Provision of IS 16700:2017, is one that is taller than 50 meters but less than 250 meters. A supertall skyscraper is one that is taller than 250 meters. For various structural systems, the maximum vertical length of buildings (in meters) shall not exceed the limit specified in Table 1.1

SI No.	Seismic Zone	Structural System					
		Moment frame	Structural wall		Structural wall + Moment frame	Structural Wall + Perimeter Frame	Structural Wall + Framed Tube
i)	V	NA	100	120	100	120	150
ii)	IV	NA	100	120	100	120	150
iii)	III	60	160	200	160	200	220
iv)	II	80	180	220	180	220	250

Table 1.1: the maximum allowable height, H, over the base stage for different buildings, in meters.

When considering seismic hazards on tall structures, it is necessary to consider both. An analytical model of a structure must capture the right behavior of both its components and the overall structure. There are various options accessible, including frame element modeling, finite element modeling, and a hybrid of the two. When an unfactored lateral load is applied to a reinforced concrete structure, lateral deflections are calculated using section properties for unfactored loads, whereas lateral deflections are estimated using section characteristics for factored loads. The final seismic zone (Zone V) experiences both horizontal and vertical shaking. A site-specific spectrum must be calculated and used for the construction of buildings in zones IV and V. When site-specific research yields an inflated safety estimate, the findings must be used.

When calculated loads are applied. To calculate lateral impacts on structures, assume they are fixed at their base. If a tall structure is being built in seismic zones IV and V, the following guidelines must be met:(IS 16700:2017)

1. The structural wall must not be shifted in or out of plane, and it must be continuous to the foundation.
2. The wall thickness should be at least 200mm.
3. Longitudinal and transverse reinforcement should contribute to at least 0.4% of the total cross-sectional area.
4. Arrange reinforcement in two curtains, one facing each direction.
5. To keep structural walls from wobbling, ensure that they are correctly fastened and attached to the base.
6. All openings on structural walls should be aligned vertically. Random openings in linked walls are allowed only if their impact is limited.

Previous research work completed:

Hassaballa A. E. et al. [17] performed a seismic study on a multi-story RC frame structure in Khartoum city to investigate the performance of existing buildings under earthquake loads. The frame was investigated using the response spectrum method to calculate stresses and seismic displacements in line with Sudan's earthquake provisions. The findings suggested that nodal displacements caused drifts that exceeded allowable limits. The horizontal motion significantly affects the axial compression force on the exterior columns. Seismic loads produce much higher bending moments in beams and columns than static loads. The frame was unable to resist the prescribed earthquake load.

Dinar Y. et al. [7] conducted linear static analysis and P-delta analysis on six RC structures ranging from G+5 to G+30 storeys, with a 5-storey variation in each model. The findings were compared. According to the P-Delta study, displacement and axial force varied exponentially as height increased. Moments reduced as the tale height increased.

Patil S.S. et al. [15] conducted seismic analysis on a high-rise structure utilizing various lateral stiffness systems using StaadPro. Some variants are brace frames, while others are bare frames or shear wall frames. The analytical approach is the response spectrum approach. The authors concluded that buildings with short periods have higher acceleration but lower displacement. Structures having shear walls situated at the outer frame of the X and Z directions along the height have been shown to be particularly effective in handling lateral stresses. Lateral stiffness rose significantly in the braced model compared to another model.

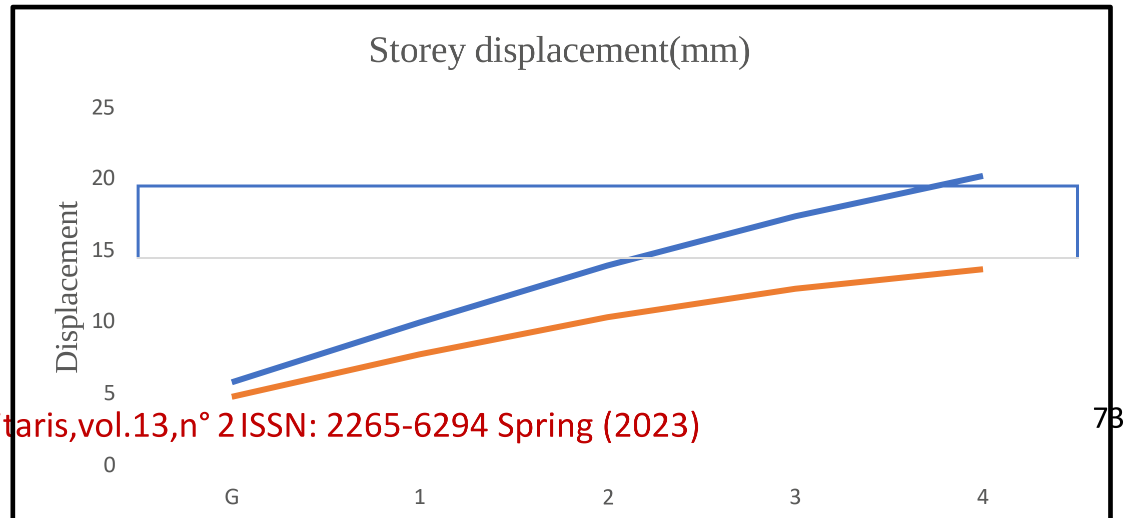
WIN N.N. et al. [20] investigated a G+11 story RC structure using ETabs. The structure is examined statistically using the response spectrum approach. The findings of the static and dynamic methods are used to conduct a parametric investigation. In this study, factors such as storey shear, displacement, storey drift, and storey moment in the X and Y directions are compared for response spectrum and static analysis. Static analysis yields fewer displacements than response spectrum analysis. Furthermore, static analysis yields smaller displacements than response spectrum analysis. The level shift in each direction is modest. High-rise buildings require dynamic analysis since static analysis is insufficient.

Mallikarjuna B.N. et al. [10] have compared P-Delta evaluation to linear static analysis. An 18-story steel frame building model is examined using the P-delta effect. The model is analyzed using StaadPro. The wind load analysis for the framed multistory building was performed in accordance with IS 875 (Part 3): 1987. Following analysis, a comparison is made between maximum storey displacement and axial force for P-delta and linear static analysis. P-delta analysis shows that storey displacements are rising at all levels of the building. P-delta analysis provided twice as much axial force as static analysis.

WITHOUT P-DELTA ANALYSIS:

G+4 MODEL:

- The Maximum Storey Displacement is found to be ***20.137 mm*** in **X – direction** and ***13.631 mm*** in **Z – direction**



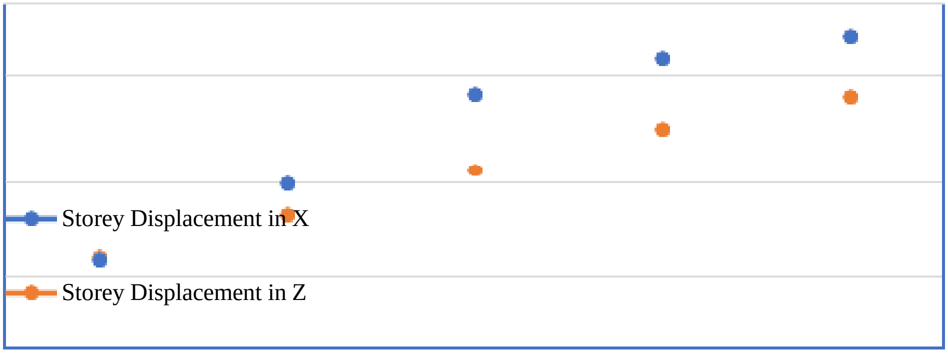


Fig 4.11: Storey Displacement for G+4 Model

We can see from Storey Displacement for G+4 Model graph that the value of storey displacement has increased from ground storey towards the 4th storey and is highest on top most storey. Also, storey displaces more in X-direction and comparatively lesser in Z-direction.

The magnitude for Maximum Storey Drift is found to be ***4.167 mm*** in **X –direction** and ***2.962 mm*** in **Z – direction.**

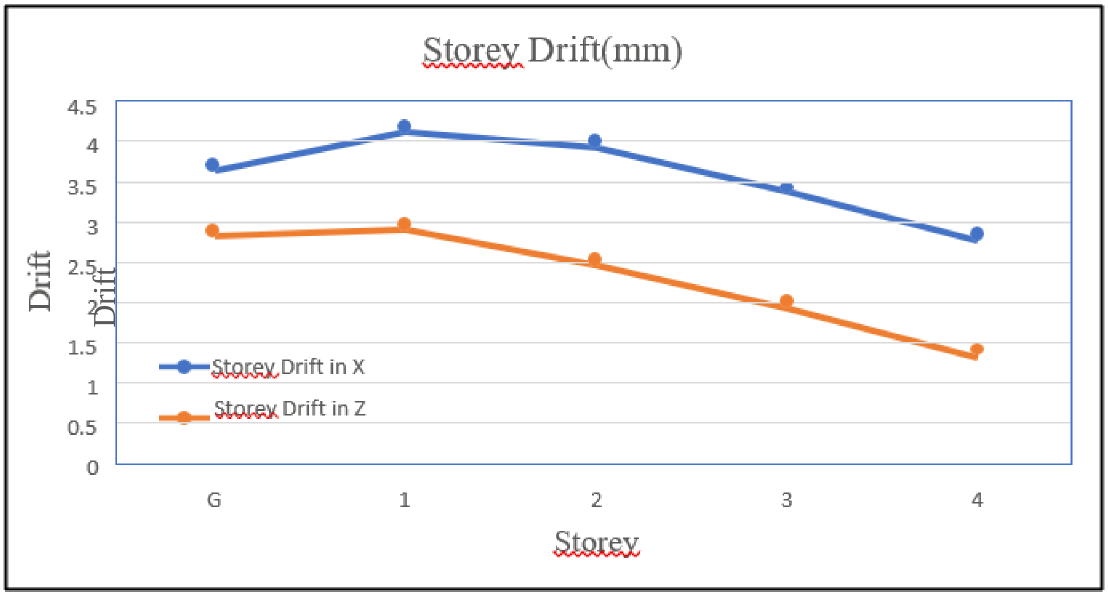


Fig 4.12: Storey Drift for G+4 Model

We can see from Storey Drift for G+4 Model graph that the drift increases initially from ground storey towards 1st storey, but again starts to decline towards the 4th storey, with maximum storey drift on 1st storey.

4.1.2 G+10 MODEL:

- The Maximum Storey Displacement is found to be ***44.958 mm*** in **X – direction** and ***29.044 mm*** in **Z – direction.**
- The maximum storey displacement is on top most storey in both directions.

The magnitude for Maximum Storey Drift is found to be ***5.053 mm*** in **X – direction** and ***3.421 mm*** in **Z – direction.**

CONCLUSION

Earthquakes are regarded as one of the calamities that result in widespread losses of human lives and property. As a result, all new structures must be constructed and evaluated in accordance with the most recent revisions to the standard codal rules. Furthermore, existing structures must be analyzed so that their behavior can be observed, and appropriate rehabilitation or retrofitting procedures must be used to re-strengthen the structure.

his study analyzes three models of existing structures in a high seismic zone using StaadPro and the P-Δ analysis. The following information is documented:

1) **Maximum Displacement:**

a) The G+4 model results in a maximum storey displacement of 20.382 mm in the X and 13.676 mm in the Z direction. The P-Delta study indicated a 1.22% increase in maximum storey displacement.

b) The G+10 Model shows a maximum storey displacement of 43.379 mm in X and 29.516 mm in Z directions. The P-Delta research revealed a 3.16 percent increase in maximum storey displacement.

c) The G+22 Model shows a maximum storey displacement of 356.969 mm in the x and 139.93 mm in the z direction. The P-Delta study indicated a 19.29% increase in maximum storey displacement.

2) Maximum Storey Drift:

a) The G+4 model shows a maximum storey drift of 4.225 mm in the X and 2.977 mm in the Z directions.
b) The G+10 model shows a maximum storey drift of 5.274 mm in the X and 3.496 mm in the Z direction.
c) The G+22 Model shows a maximum storey drift of 10.79 mm in X and 4.023 mm in Z.

FUTURE SCOPE

When a structure encounters seismic stresses, it is subjected to a lateral force that can originate from any direction, causing the structure to oscillate while remaining stationary at the base. Thus, competent management is essential to at least secure the structure so that people may be evacuated from the structures while no injuries are reported as a result of their demolition.

Such structural examination, particularly on older structures, should be made mandatory in light of the present global trend of increasing earthquake frequency. Once these structures have been analyzed, if any of the structural components fail the "Building Performance Level" criterion, those structural members must be rehabilitated or modified based on the building's normal performance level.

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