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Comparative Study of Tsunami and Seismic Effect on Multistoried Building

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***Abstract*: This Paper is concerned with the effects of Tsunami and Seismic Response of Multistoried structure. It aims to carry out a comprehensive investigation on tsunami & seismic effect of high-rise structures vertically irregular with lower level designed as Stilt. Two types of structures, with stilt and without stilt were considered, Comparison of the results of these models was also done. Modelling and analysis was done on STAAD.Pro V8 software and of the G+25 structures were considered. The main influencing parameters considered for this study were Lateral Displacement, Story-drift, Base shear, Bending Moment.**

***Keywords*: Tsunami Effects, Seismic effects, Lateral Displacement, Storey-drift, Base shear, Bending Moment, STAAD.Pro V8.**

1. Introduction

While Earthquake and tsunamis are inevitable forces of nature, it is possible to better be prepared for them so that the damage to infrastructure can be minimized. It has been observed that buildings constructed according to local seismic codes have shown excellent seismic proof characteristics; however, tsunami proof design codes and concepts are not yet systematic. The scope of this topic is to understand the tsunami and design the structures accordingly so that in a natural calamity of tsunami, the structure would be able to withstand the forces saving devastation or at least reducing it. Not much research has been done on High rise Tsunami Resistant Structure. Here, I have taken a G + 25 Structure, where in the lower most 3 Floors, i.e. Ground, First & Second Floor are Floors with breakable walls. In case of a Tsunami these walls will break creating passage for the flow of water instead of creating an obstruction for the same. These Floors will allow the necessary passage for Water to pass, reducing the Hydrostatic Force considerably which will help the structure during Tsunami. Also the weight of the water will help in Stability requirements for the Foundation design. For this project two models have been created one for Seismic Loading and one for Tsunami Loading. Analysis and design have been performed for both. The results for Analysis and design have been compared for Economic Viability. It is found that for a G + 25, Seismic Forces are more governing provided that there is a Stilt provision on the lower floors. It also implies that if a Stilt Structure is well designed for Earthquake would be able to perform and withstand Tsunami Loads as well. The Foundation design would require special consideration for Seismic as well as Tsunami consideration. Raft foundations would be suitable for withstanding both these Forces.

Fig. 1. Aerial view of the la farge cement plant

2. Literature review

Qin Rong (2012) made a study pointing out that Earthquake study and understanding has developed excellently to create Earthquake resistant structures. The aim of the paper was to understand the tsunami resistant structures by performing experiments, analyzing and studying the damages due to Tsunami to homes. The paper covered the Tsunami design target which excluded houses located close to coastal region and less than 10 m from the shore. These structures cannot withstand Tsunami and protect the inhabitants. The paper concluded with alternate solutions for reducing Tsunami loads like planting Mangroves on the coast, building reinforced concrete sea wall and that the development of Tsunami proof design is critical and required further efforts to regulate these which are also easily available to designers.

Christopher Koutitas et al. (2005) presented a paper emphasizing on organisation of design codes and engineering practices. The aim was to perform number of numerical experiments to understand the effect of Structure orientation with respect to propagation of waves. For this understanding a computational model was created and nonlinear shallow water equations were applied. The paper concluded the building orientation, partial or total collapse may favour or adverse the effect of Tsunami on the structure. The paper also gave scope for studying the effect of Entrance, staircase etc. on the structural performance in case of Tsunami.

Abdullah Keyvani and Leila Keyvaniin (2013) in their paper studied the progressive collapse of RC frame Structure during Tsunami because of the heavy impact loads induced by Wave. The aim was to study the progressive collapse. For this a four bay and eight storey RC frame structure is modeled and the middle column was removed. A comparison was made between experimental results, FEMA Model and FEH Model. The deflections observed from FEH were close (80%) to the ones observed experimentally, however the ones observed from FEMA were twice as observed experimentally. Also the reinforcing bar strain as per FEH model (value is 25mm) was found compatible to about 100% with the experimental model (value is 0-25 mm). Another comparison made was for the rupture of the reinforcing bars for the FEH model which occurred at a displacement of 450.2 mm which was compatible to experimental results, results for the FEMA analysis was not available. The paper concluded that the FEH method gives more accurate results than FEM since it considers the catenary actions, P-M (Axial force – Bending Moment) for considering Non linearity.

Ahmed Ghobarah, Murat Saatcioglu, Ioan Nistor (2005) studied the effects of Earthquake and Tsunami which occurred on 26th December 2004 on various structures in Thailand and Indonesia. The paper discussed the various types of structures that were affected by Earthquake and Tsunami namely residential wood houses with tile or corrugated steel sheet roof, non-engineered concrete construction and Engineered concrete construction. The paper concluded that structures which exhibited failure due to Earthquake were mainly due to soft storey formation, open spaces leads to formation of less floor stiffness leading to failure. The structures that survived this failure was because of the formation of ductile behavior of hinges. Another reason of collapse was due to strong column-weak beam junctions, short columns and lack of shear reinforcement in exterior beam-column junctions.

V. M. Patel, H. S. Patel and A. P. Singh (2011) made a comparative Study between Earthquake resistant Structure to Tsunami Resistant Structure and the location and Design of Vertical Evacuation System at Dwarka Temple, West Gujarat. Structural Models have been analysed for Earthquake as well as Tsunami Loads. The study shows that the Axial Force of columns is about 22% Lower than the Force obtained in Earthquake Analysis. In the columns directly being affected by Tsunami i.e the frontal exposed Columns, the Shear force increases by 2400% at the Tsunami height and in rest of the Columns it increases by 1100%. The Moments above and below the Tsunami Level are lower and Higher by 6% and 300 % compared to Earthquake induced Moments. Moments in Columns are found to be 450% higher. The paper concludes that with these higher Moments for a Tsunami height of 3.28 m for Gujarat, it is extremely very important to design the lower Beams, Columns and Foundations for higher Moments and Shear for Tsunami. The paper also states that the load combinations due to water born debris are the most critical Load Combination and should be critically examined for the Design.

Kavinda Manoj Madurapperuma and Anil C. Wijeyewickrema (2008) studied the effect of Impact of Water Borne Boats and Containers due to Tsunami. The aim of the paper is to study Tsunami resistant structures with elevated lower level having columns exposed to Tsunami directly, the effect of water borne induced deflections, Shear Force, Moments and Moment Curvature, the stress strain behavior of cover concrete, core concrete and Tension Reinforcement at the impact section. The model used for this analysis is a Finite Element Model. Two models namely Ordinary Moment Resisting Frame and Special Moment Resisting frame are analyzed. These models are analyzed for the same Impact Load of 2 Ships at different elevations of 2 and 2.5 m. This paper concludes that the Special Moment resisting frame performs better under the impact of Tsunami borne massive objects compared to Ordinary Moment resisting frame.

3. Objectives

- Study, Analysis and Design of Tsunami resistant structure to understand the behavior would be the prime objective of the project.
- The Lateral Displacement, Storey drift, Base shear, Bending Moment of the tsunami resistant structure will be compared to conventional designed structures.
- The design of the tsunami resistant structure shall be compared to that of conventional designed structure summarizing the economically viability.

4. Description of structural model

- Model M1: This is G+25 structure with stilt.
- Model M2: This is G+25 structure without stilt.

Table 1
Dead and live loads considered

Dead load	Self-weight of slab, beam, column, and parapet wall
Live load	For intermediate floor=2 & 3kN/m²
	For terrace floor=1.5 kN/m²
Floor finish	For intermediate floor=1kN/m²
	For terrace floor=1.5 kN/m²

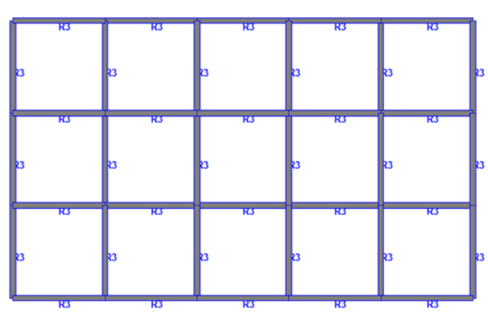
Fig. 2. Ground floor plan of building in STAAD software

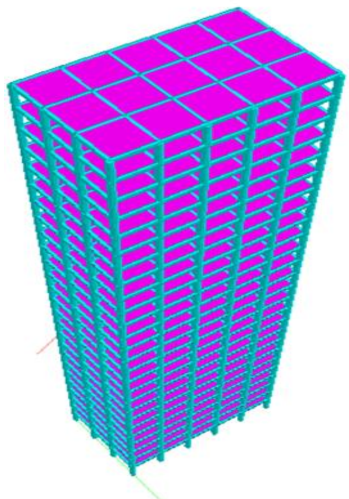

Fig. 3. 3-D model of building in STAAD software

5. Results and discussions

As analysis of G+25 building is done by using STAAD software using Response spectrum analysis method and the following results are obtained. As shown in Tabular form and represented graphically for M1, M2 Model by using STAAD software. Story Forces, Story Displacement, Story Drift and Moment at each floor are obtained and are Graphically represented to compare results with different conditions which are as follows:

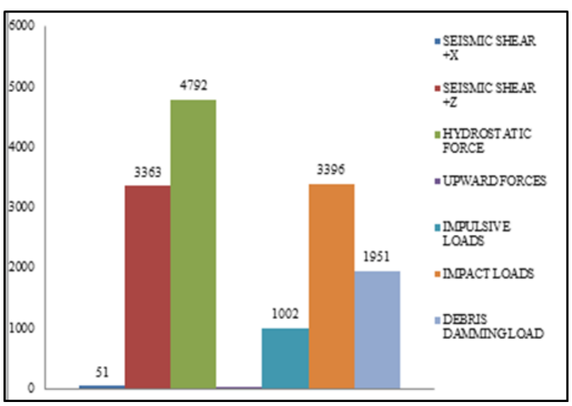

Fig. 4. G+25 Building (variation of horizontal force)

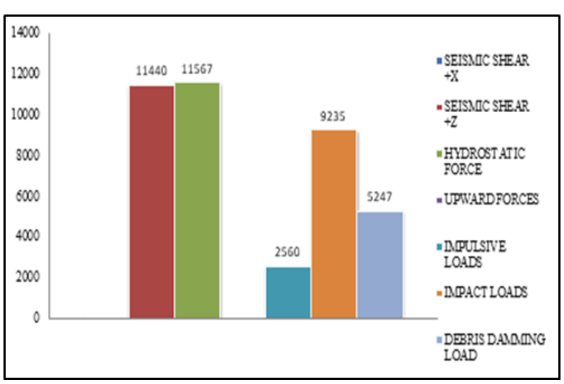

Fig. 5. G+25 Building (variation of moment)

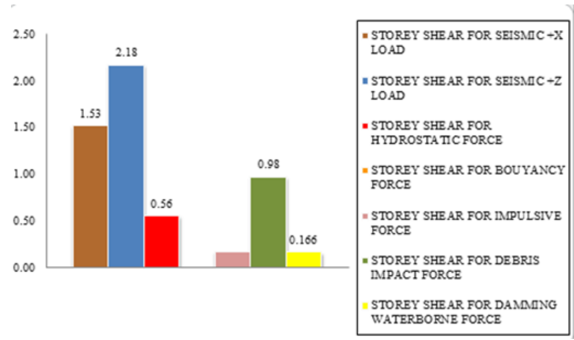

Fig. 6. G+25 Building (storey shear)

6. Conclusion

The Moment produced at the support due to Tsunami Loading is approximately 100% of Base shear produced due to Earthquake. The Shear produced in column due to Tsunami Loading is 200% higher than Shear produced due to Earthquake. The Moments produced in column due to Tsunami Loading is approximately 100% of Shear produced due to Earthquake. The Axial Force produced in beam due to Tsunami Loading is 200% higher than axial force produced due to Earthquake. It is found that for a G+25, Seismic Forces are more governing provided that there is a Stilt provision on the lower floors. It also implies that if a Stilt Structure is well designed for Earthquake would be able to perform and withstand Tsunami Loads as well. The Foundation design would require special consideration for Seismic as well as Tsunami consideration. Raft foundations would be suitable for withstanding both these Forces.

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