Effect Of Tsunami & Earthquake On Building In Coastal Region

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Abstract:*The seaside population has increased considerably over the past several decades. The increased seaside population led to increased seaside development, which causeto greater numbers of structures at risk from coastal hazards. Additionally, many of the residential buildings constructed today are larger and more valuable than those of the past, resulting in the potential for larger economic losses when disasters strike. In response to increased hazards and n lessons learned from past storms, regulatory requirements for construction in coastal areas have increased over the pastdecade.*
Living near the sea means living with the risk of a tsunami. A devastating tsunami was generated by the great Indonesia earthquake on 26th December 2004. This Indian Ocean Tsunami severely affected communities bordering the Indian Ocean and revealed the importance of constructing earthquake and tsunami-resistant structures in coastal regions. Hence, it is necessary to establish analytical methods for obtaining the response parameters and comparing them when structures are subjected to both earthquake and tsunamiforces.
In this study,four-storied (G+3) reinforced concrete frame structures are chosen for the analysis considering two different types of structural configurations subjected to a hydrodynamic force due to different levels of tsunami run-up and earthquake forces. A comparative study is made on the response of these structures. In this analysis, base shear values are determined using IS 1893(2002) seismic code and hydrodynamic forces are evaluated using FEMA"s Coastal Construction Manual. It is concluded that it is necessary to design critical structures and important infrastructure to survive tsunami effects. Well- designed and constructed structures survive the earthquake and the resulting tsunami with minimumdamage.
Key notes*: effect of tsunami, base shear, storey displacement.*

1. INTRODUCTION:

Tsunamis are rare events compared to other natural hazards. However, living near the sea means living with the risk of a tsunami. In some areas, such as the Pacific Rim countries, the risk is high the possibility of a significant tsunami occurs on a decadal scale in Japan. In the Indian Ocean, the risks are lower still, although tsunamis have occurred there in the past. According to the National Geographic Data Centre (NGDC, 2005), 63 tsunami events have occurred in the Indian Ocean since 1750.Besides that high death toll, the tsunami caused one of the worst nuclear disasters in history. The Fukushima nuclear power plant, located on the coast was hit by a 49 ft. tsunami wave that overtopped the tsunami protection walls that were only 19 feet high, and flooded the backup generators for the plant that were somehow placed on the first floor in a known tsunami zone.
Earthquake occurs due to sudden transient motion of the ground as a result of release of elastic energy in a matter of few seconds. The impact of the event is most traumatic because it affects large area, occurs all on a sudden and unpredictable. They can cause large scale loss of life and property.

P. Kodanda Rama Rao, K. Rama MohanaRao et al (2010)[51]In this paper a shelter building is chosen for the analysis considering different types of structural configurations and a comparative study is made on the response of these structures. In this analysis, seismic forces are determined using IS 1893(2002) seismic code and hydrodynamic forces are evaluated using FEMA"S CCM. The authors have also evaluated a useful guideline for demarcating the height of the building below which earthquake forces are predominant and above which tsunami forces are predominant..**Y. Nakano (2010)**[42]Tsunami shelters are of great importance to mitigate casualties by earthquake-induced killer waves. Although the proposed practical design formulae to calculate tsunami loads acting on shelters, it is derived primarily based on laboratory tests with scaled models but not on damage observations. It is therefore essential to examine the design loads through comparison between observed damage and structural strength. In December 2004, a huge scale Sumatra Earthquake caused extensive and catastrophic damage to 12 countries in the Indian Ocean. **IoanNistor, Dan Palermo et al (2010)**[44]The results of a comprehensive research program on tsunami-induced forces on infrastructure located in coastal areas are presented in this paper. The purpose of this research and engineering project is to elucidate the complex hydrodynamic mechanisms of the impact and extreme loadings on buildings and to properly quantify loads and further propose and derive new formulations for the design of structures located in the vicinity of the shoreline in tsunami-prone coastal areas. Prior to the 2004 Indian Ocean Tsunami, the design of structures against tsunami-induced forces was considered of minor importance when compared to the attention given to the tsunami warning systems. The author highlighted the fact that current structural design codes do not account for tsunami-induced forces and the impact of associated debris. Three parameters are essential for defining the magnitude and application of these forces: (1) inundation depth, (2) flow velocity, and (3) flow direction. The parameters mainly depend on: (a) tsunami wave height and wave period; (b) coast topography; and (c) roughness of the coastal inland. The force components suggested by Nistor et al. (2009), FEMA 55, CCH, and FEMA p646 were investigated by the authors in collaboration with the Canadian Hydraulics Centre of the National Research Council in

Ottawa,Canada. **YounesNouri, IoanNistor and Dan Palermo(2010)**[46]In this paper author has highlighted the deficiencies and discrepancies within tsunami- resistant design of typical buildings among the existing structural codes. Considering, analogies between a tsunami-induced bore and a dam-break wave in existing literature, in order to advance the existing understanding of bore-structure interactions, an experimental approach was taken where a dam-break flow, generated by the fast opening of a gate, impacts various free standing structures of different shapes located downstream of the gate. Experiments were carried out at the Canadian Hydraulics Centre, National Research Council of Canada, (NRC-CHC), in Ottawa. The pressures and forces exerted on all sides of thestructure, together with the bore height and the flow velocities in the flume were measured. The effect of upstream obstacles and flow constrictions was also investigated. In addition, to further understanding of debris impact during a tsunami, wooden logs were added to the bore in order to act as water borne missiles while the structure reactions were measured.This study provides a better qualitative and quantitative understanding of tsunami- induced forces and debris impact and is an effort to improve existing structural design of buildings that are located in the vicinity of the shoreline in tsunami prone areas..**Pimanmas A., Joyklad P. and Warnitchai P. (2010)**[49]In this paper, the design approaches for tsunami shelters are described. The shelters are classified into two categories: (1) shelter in the area where large debris is unlikely and (2) shelter in the area where large debris is likely. In the former case, a static load of a certain magnitude representing small-to medium debris is assumed to act at random points on the structure at the inundation depth. In the latter case, the work-energy principle is adopted to balance kinetic energy of large moving mass with the work done through energy-absorbing devices installed around the perimeter of the lower floors of the building. In both cases, the structure consists of a main inner structure and an outer protection structure. The function of the main structure is to provide usable spaces for evacuees, whereas the outer protection structure protects the inner structure from debris impact. The main structure is designed to be either elastic or with a low acceptable damage level..

1.1. Sources of tsunami:

A. Tsunami generated due to earthquake: Tsunami is generated by vertical displacement of overlaying water that is caused by earthquake causing abrupt deformation of sea floor. The displaced water attempts to regain its equilibrium position under the influence of gravity leads to the formation of waves

B. Tsunamis generated due to landslides: Probably the second most common cause of tsunami is landslide. A tsunami may be Generated by a landslide starting out above the sea level and then plunging into the sea, or by a landslide entirely occurringUnderwater**.**

c. Tsunami generated due to Volcanoes: The violent geologic activity associated with volcanic eruptions can also generate devastating tsunamis. Although volcanic tsunamis are much less frequent, they are often highly destructive**.**

1.2. Tsunami induced design forces

There is very little guidance provided by structural design codes for the forces induced by tsunami and their effects on coastal construction. A set of generalized equations were created from currently available building codes and published literatures, which contain information and recommended equations on flooding, breaking waves and tsunamis.

1.2.1. Tsunami-InducedForces

A broken tsunami wave running inland generates forces that affect structures located in its path. The parameters essential for defining the magnitude and application of these forces are: Inundation depth, Flow velocity and Flow direction.

These parameters mainly depend on

1. Tsunami wave height and waveperiod
2. Coastal topographyand
3. Roughness of the coastal inland

Forces associated with tsunami bores consistof

1. Hydrostaticforce,
2. Buoyant force,
3. Hydrodynamic (drag and impulse) force,
4. Surgeforce,
5. Impact of debrisand
6. Breaking waveforces

1.3. RC frames with masonry infilled walls

Due to the ease of construction and design Reinforced concrete frame structure is quite common in civil engineering field. Frames are often constructed with infill as partition wall. Lateral deflection of frame is considered as one of the principal design criteria for structural design of frame structures.In structural design process, such infills are considered as "nonstructural" members. Structure is assumed to carry horizontal loads only by the frame elements. Analytical and experimental studies show that infilled frames have greater strength and stiffness compared to bare frames. Understanding the behaviour of infilled frames and being capable of making a satisfactory modelling of infills during structural design process will help engineers to have more realistic and economical solutions.

2. METHODOLOGY:

2.1 Modeling of masonry infillwallsEquivalentsystem:

Several methods have been proposed in the literature for modelling masonry infills, such as, equivalent diagonal strut method, equivalent frame method, finite element method with masonry wall discritized into several elements, etc. On the other hand, the present national codes do not specify any method for analytical modelling of masonry infills in reinforced concrete (RC)buildings.It is observed that the single-strut model can be effectively used in cases where masonry infill walls are discontinued in the first-storey to generate parking space (for example, soft or open storey buildings). Infilled frame and the equivalent frame are shown in Figure 3.11. Figure 3.11 (a) shows Laterally Loaded Infilled Frame and Figure 3.11(b) shows EquivalentFrame.

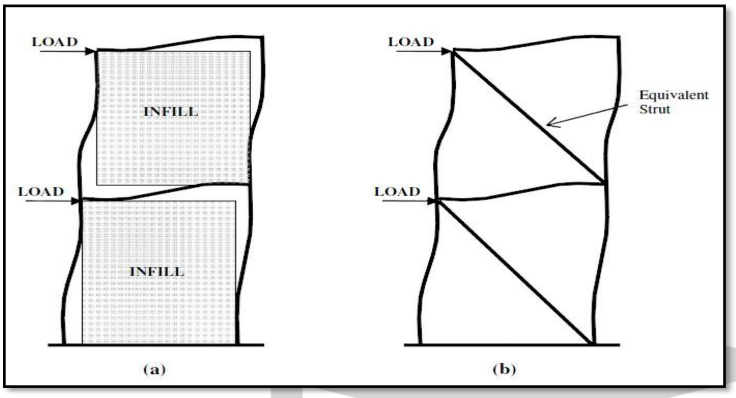


Figure 1:Idealization as Equivalent strut model

2.2. PROGRAMME APLLICATION TOSTRUCTURE

ETABS software is used for the analysis in present study. It is product of Computers and structures; Berkeley, USA. ETABS is used for analyzing general structures including bridges, stadiums, towers, industrial plants, offshore structures, buildings, dam, soils etc. Fully integrated program that allows model creation, modification, execution of analysis, design optimization, and results review from within a single interface. ETABS is a standalone finite element based program for the analysis and design of civil structures.

2.3 Input parameters in presentstudy

2.3.1 Materialproperties

2.3.1.1. Concreteproperties

Grade of concrete (all members) – M25 Grade of steel (all members) – Fe 415 Ec – 25000 N/mm^2

μ_c - 0.3

Density of concrete 25 kN/m^3

2.3.1.2. Brick masonryproperties:-

E_b – 11770 N/mm^2

Density of brick infill walls 20 kN/m^3

2.3.2. Building analysisdata

Building –Ground + 3 storey residential building

Structure - Reinforced concrete building with full and partial infill walls Height of building above ground - 12m

Live load on floor finish – As per IS:875 (Part 2) – 1987 Lateral Loads – Earthquake load as per IS:1893-20002

Tsunami loads as per FEMA P646 Earthquake analysis – Response spectrum analysis

Seismic zone - II, III, VI,V Damping for concrete – 5%

Response reduction factor – 3 (OMF)

2.4. Load combinations –

2.4.1. For Earthquake as per IS 456-2000, IS 1893-2002 Limit state of collapse

1. 1.5DL + 1.5 LL
2. 1.2 DL + 1.2 LL + 1.2 EQx
3. 1.2 DL + 1.2 LL + (-1.2) EQx
4. 1.2 DL + 1.2 LL + 1.2 EQy
5. 1.2 DL + 1.2 LL + (-1.2) EQy
6. 1.5 DL + 1.5 EQx
7. 1.5 DL + 1.5 EQy
8. 1.5 DL + (-1.5) EQx
9.1.5 DL + (-1.5) EQy
10. 0.9 DL + 1.5 EQx
11. 0.9 DL + (- 1.5) EQy
12. 0.9 DL + 1.5 EQx
13. 0.9 DL + (- 1.5) EQy

2.4.2. Limit state of serviceability

1.DL+LL
2.DL+EQx
3.DL+EQy
4.DL-EQx
5.DL-EQy
6. DL+0.8LL+0.88EQx
7. DL+0.8LL-0.88EQx
8. DL+0.8LL+0.88EQy
9. DL+0.8LL-0.88EQy

2.4.3. For Tsunami as per D. Palermo and I. Nistor (Tsunami load combinations)

1) T + 1.0 DL
2) T + 1.0 DL + 0.5 LL

2.5 Analysisprocedure

In this study a G+3 storied R.C. building is chosen and the analysis for response against both seismic and tsunami forces is carried out considering different types of structural configurations. Floor height is taken as 3.0m for all the floors. Foundation strata – soft soil.The different structural configurations that are considered in the present study are listed below.With shorter side along the shore line. The structural members beam of size 230mm X 450mm, column of size 230mm X 450mm and slab having thickness 150mm are used.

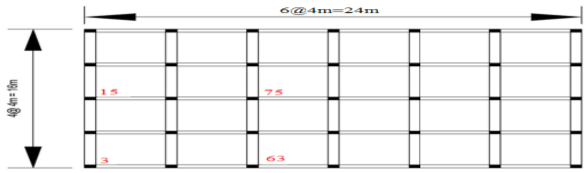


Figure 2: Plan for Ground+3 storey building showing joints considered for comparing displacement.

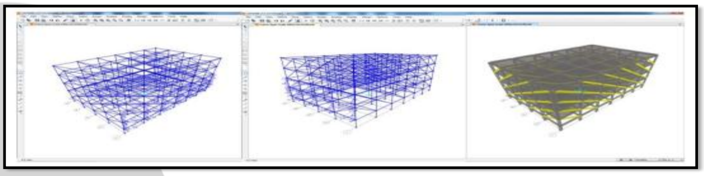


Figure 3:Modelling of G+4 building in sap2000 v17.0.1

Model 1 - All storey with inner and outer infill walls and shorter side facing sea shore.
Model 2 - All storey with inner and outer infill walls and longer side facing seashore.
Model 3 - Ground storey open, all other storey with inner and outer infill walls and shorter side facing seashore.
Model 4 - Ground storey open, all other storey with inner and outer infill walls and longer side facing seashore.
The building is used for residential purpose and is analyzed considering to be located in seismic zone II, III, VI and V of the Indian seismic zone map with isolated footing type foundation.

3. RESULTS ANDDISCUSSSION

As mentioned in previous chapter structures with two different configurations with fixed base assumption were analysed for earthquake by response spectrum method and tsunami induced hydrodynamic forces. The responses were calculated in terms of base shear, joint displacement, axial force, bending moment, shear force and storey drift force different levels of earthquake and tsunami loading. These results are plotted in terms of graphical plot and discussed.
The base shear in structure subjected to the hydrodynamic force due to tsunami of different height and earthquake force corresponding to different zones is as shown below.

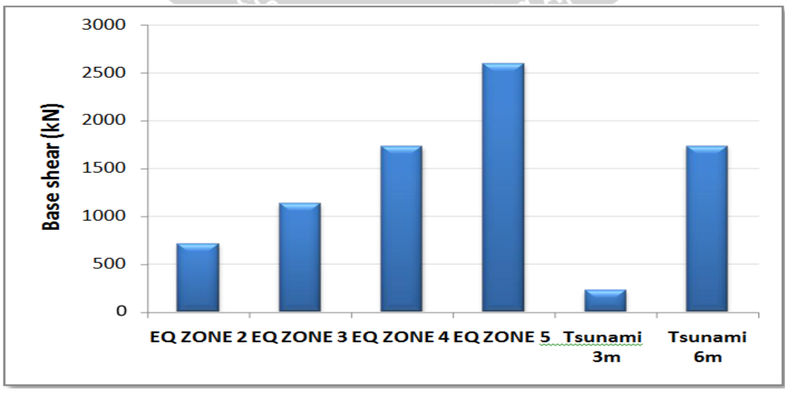
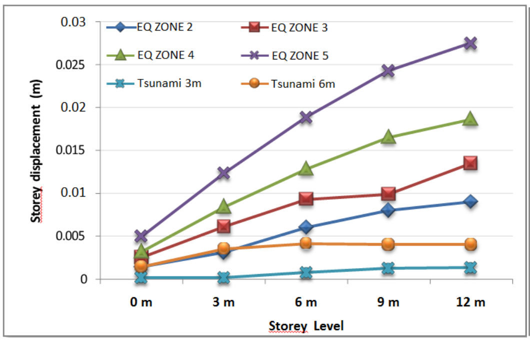


Figure 4. Base shear for all module

The base shear in structure subjected to the hydrodynamic force due to tsunami of different height and earthquake force corresponding to different zones is as shown below.



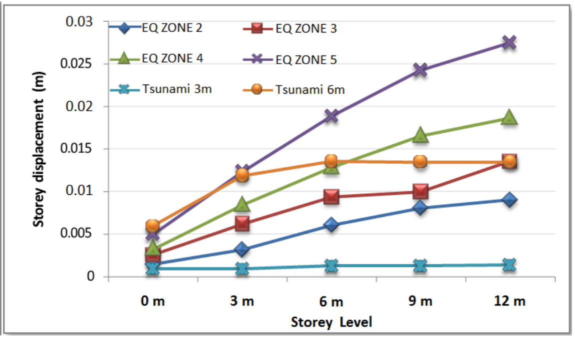
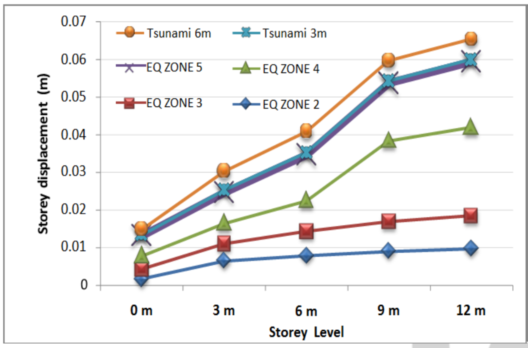


Figure 5.Storey displacement Model- IFigure 6: Storey displacement Model- II



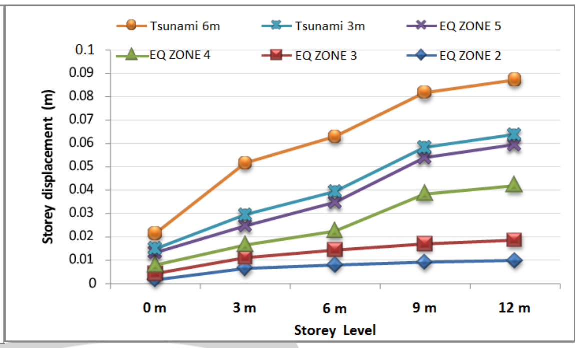


Figure 7: Storey displacement Model- III **Figure 8: Storey displacement Model- IV**

4. CONCLUSION:

Based on the observation and results obtained from comparison of analysis of buildings with two different structural configurations with longer side and shorter side facing the tsunami wave following is concluded.

[1] As most of the structures along the coast line of India are in earthquake zone II or III tsunami forces are predominant forces. Tsunami-induced loading should be considered for near-shoreline structures located in tsunami-proneareas.

[2] Structure in tsunami prone area should have shorter side facing tsunamiwave.

[3] Ground floor should be constructed with either all infill walls or proper provision should be made to increase the stiffness of open ground floor (i.e. diagonal bracing, cross bracing, Y bracing or shear walls should be provided)

[4] More guidance is required for structural engineers in order to estimate tsunami loads on structures as there are no guidelines give in Indian standard codes for tsunami loads onstructure.

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