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# TERRAIN EVALUATION AND SEISMIC RESPONSE OF MULTI-STORIED BUILDINGS UNDER DIFFERENT SOIL CONDITIONS IN AMARAVATHI REGION, ANDHRA PRADESH

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*Abstract :*

The new state of Andhra Pradesh has identified the region spanning the Guntur and Krishna Districts for developing a new capital. The development of the core is proposed on a green field site in the flood plain of Krishna River on Guntur side adjoining the existing settlement of Amaravathi. Being a highly productive land, yielding three irrigated crops a year, land acquisition has been quite expensive for the state. As such, the urban design has considered compact with high rise developments. In view of the heavy investment involved in the development of the capital, it is imperative to plan and protect these developments from natural and manmade disasters. The project aims at evaluating the terrain Amaravathi region and carrying out the seismic response of multi-storied structures resting on different types of soils. Spatial database has been prepared to carry out integrated spatial analysis and to identify the vulnerable zones in the study region in the event of an earthquake. Terrain evaluation is carried out by creating various thematic maps for soil & rock types, and seismo-tectonics of the study area at a high-resolution scale. After obtaining details of terrain evaluation, geotechnical and seismic analyses are carried out when a similar multi-storied building rests on different soils. The base shear and displacement parameters are also worked out and compared with the results obtained when the structure is assumed to be fixed at the base. Based on the insights gained through the evaluation of these multiple variables, the responses of multi-storied structures to various seismic scenarios are evaluated. The results indicate the necessity to consider soil-structure interaction while designing structures particularly when it rests on loose soils. It can be concluded that structures resting on stiff soils or rock behave well than structures resting on loose soils during an earthquake.

KEY WORDS: Terrain Evaluation, Earthquake, Soil-structure Interaction, Time Period, Base Shear, Displacement. **Introduction**

## 1.1 General

Terrain or land relief is the vertical and horizontal dimension of land surface. Geomorphic resources are the natural phenomena on the earth‟s surface, which have originated due to the active geomorphic processes. The resources directly or indirectly control various anthropogenic activities to a great extent. Geomorphic resource study and analysis are very much essential to understand the availability of natural resources which in turn influence the probability of economic and social development of the region. Evaluations of these resources are considered essential for implementation of any type of regional and economic planning. Terrain evaluation is very important for land use planning as it depicts the land suitability, e.g. while agriculture tends to favours flat fertile areas of little aesthetic charm, recreational and residential developments prefer the proximity of hilly or rocky areas.

Earthquakes are the most catastrophic natural hazards related to on-going tectonic processes which occur sudden and destruction takes place in few minutes. Usually, when earthquake originates from focus, seismic waves travel through different rock / soil media and when they reach the foundation, the structure vibrates. Shear wave velocity varies from low value in case of flexible soils to a higher value for stiff soil / rock and hence the geo-technical properties of different geomorphic

## 1.2 General Considerations:

- The structure consists of twelve storeys (2 soft +10) which is intended to serve residential purpose.
- The floor diaphragms are assumed to be rigid.

- Preliminary sizes of structural components are calculated for gravity loads only.
- Ground vibrates in all directions during earthquakes. The horizontal component of the ground motion is generally more predominant than that of vertical components during strong earthquakes. Hence, for analysis purpose,

## **1.3** Principles of Earthquake Resistant Design

- Structures should not be brittle or collapse suddenly. Rather, they should be tough, able to deflect or deform a considerable amount.
- Resisting elements, such as bracing or shear walls, must be provided evenly throughout the building, in both directions side-to-side, as well as top to bottom.
- All elements, such as walls and the roof, should be tied together so as to act as an integrated unit during earthquake shaking, transferring forces across connections and preventing separation.
- The building must be well connected to a good foundation and the earth. Wet and soft soils should be avoided, and the foundation must be well tied together, as well as tied to the wall. Where soft soils cannot be avoided, special strengthening measures must be provided..

## **1.4.** Design criteria and Earthquake resistant design

- ➢ To have structures that will behave elastically & survive without collapse under major Earthquakes, that might occur during the life time of the building.
- ➢ To avoid collapse during major earthquakes, members and structures must be ductile enough to absorb and dissipate energy by post elastic deformations.
- ➢ Yielding should be confined to beams while columns remain elastic. This is known as strong column-weak beam approach.

## LITERATURE STUDY

Response of structures against earthquake forces considering the effect of soil- structure interaction was carried out by several authors earlier some of the investigations including soil structure interaction presented below.

*S.R.K.Reddy, et al, "Terrain evaluation and influence of soil-structure* **interaction on seismic response of structures in urban environs" proc of 3rd International conference (2006) Venice, Italy, pp235-242** There are about 160 super cities worldwide of which 70% are in seismic zones; the majority of them being along the coastal belts, tat rim the pacific and cross southern Asia and Middle East.

**Whitman. R.V, Richart.F.E, "Design procedure for dynamically loaded foundations" journal of soil mechanics and foundation engg. Division, ASCE 93, 1967, pp167-191** Assuming the foundation of the structure with isolated footings, translational and rocking stiffness formulas are suggested and also a fictitious mass to be added to the soil-structure model in time domain to reduce the error caused by frequency dependent nature of the response.

**V.K.Puri and Shamsher Prakash "Foundations for Dynamic loads**" Design of foundations in earthquake prone areas needs special considerations. Shallow foundations may experience a reduction in bearing capacity and increase in settlement and tilt due to seismic loading

# CHAPTER 3

## TERRAIN EVALUATION & PREPARATION OF THEMATIC MAPS

### *3.1 General*

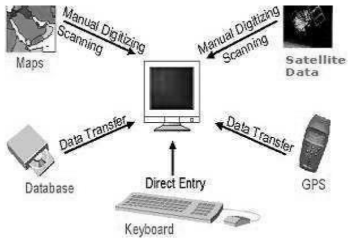
The study of terrain evaluation requires basic knowledge of what is remote sensing? And what is GIS? Geographical Information System coupled with Remote Sensing has proved a powerful tool in the field of land evaluation and management. Various studies have been reported across the world, illustrating the application of GIS in the evaluation and management of landform, soil, and water resources. The spatial pattern of relief yields the topographic mosaic of a terrain and is normally extracted from the topographical maps which are available at various scales and are rarely good inputs for terrain analysis. Survey of India topographical maps, at a variety of map-scales are the most readily available data source for terrain analysis.

### **3.2** Basic Concepts of Remote Sensing and GIS

#### **3.2.1** Remote Sensing

Remote sensing, in the simplest words, means acquiring information about an object without touching the object itself. Conveniently, however, remote sensing has become to imply that the sensor and target are located remotely apart and the electromagnetic radiation serves as a link between sensor and the object, the sun being the major source of energy illuminating the earth. The pat of this energy is reflected, absorbed.

The data storage and retrieval subsystem organizes the data, spatial and attribute in the form which permits it to be quickly retrieved by the user for analysis and permits rapid and accurate updates to be made to the database. This component usually involves use of a database management system (DBMS) for maintaining attribute data. Spatial data is usually encoded and maintained in proprietary format.



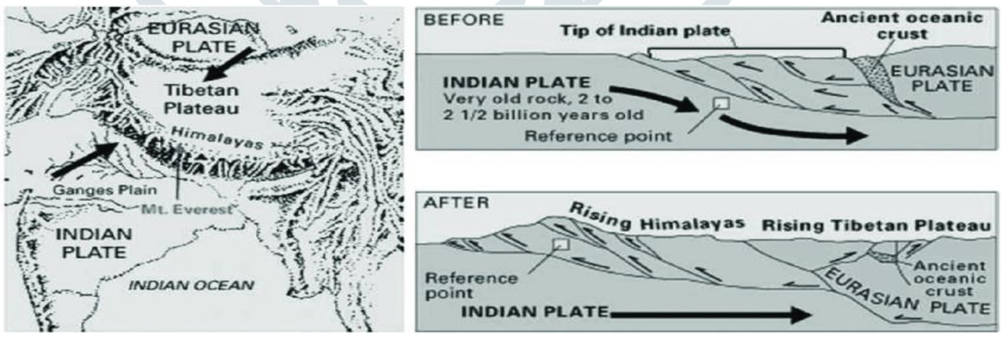

**SEISMOTECTONICS**

## General:

The study of seismology requires an understanding of internal structure and behavior of earth, particularly as they relate to earthquake occurrences. The seismicity depends mainly on the aspects of geology, which is the science of the earth‟s crust and also calls upon knowledge of the physics of the earth as a whole i.e. Geophysics. The particular aspect of geology which sheds more light on the source of earthquake is tectonics, which concerns the structure and deformations of the crust and the processes that accompany it. The relevant aspect of tectonics is now often referred to as Seismo-tectonics.

## Sesismotectonics of the Indian subcontinent:

Interestingly the drifting still continues at the rate of few centimetres a year and has been the major force in creating mountains, volcanoes and earth quakes on the earth surface. Indian plate has struck the Eurasian plate and the boundary between these two plates is the great Himalayan Range. This Himalayan Range is seismically active and a large number of earth quakes occurred here. The collision of Indian plate with Eurasian plate and rising of Himalayas.




**MECHANISM & EFFECTS OF EARTHQUAKE**

## General

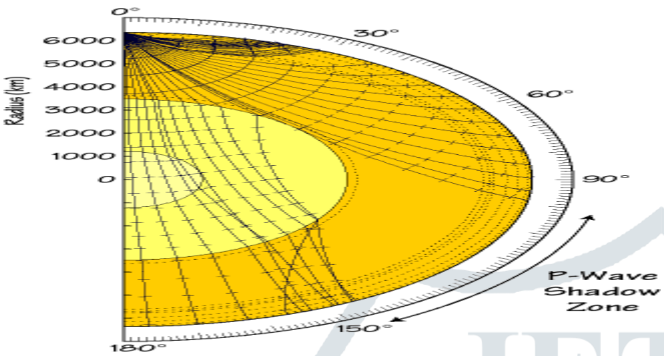
A spurt in the related professional activities in India during recent times shows that 2001 Bhuj and 2014 Indonesia earthquakes have significantly enhanced the awareness among the Engineering Community towards the earthquake problem. However, there is a need to channelize various aspects in earthquake resistant design problems and it must be implemented. The response of structure to earthquake induced vibrations is a function of the nature of foundation soil/rock, form, size and materials of the structure, construction quality and the duration and characteristics of the ground motion. As the study area is composed of various types in geomorphic units, the seismic response of similar structure behaves differently in different units.

## P-waves in earth

The mathematics behind wave propagation is elegant and relatively simple, considering the fact that similar mathematical tools are useful for studying light, sound, and seismic waves. We can solve these equations or an

| Elevation | Load from Beam H4H5 | Load from Beam G4H4 | Load from Beam H3H4 | Load from Beam | Point Load | Self-Weigh t | Total Load | Grand Total |
|---|---|---|---|---|---|---|---|---|
| 39.7 | 18.7 | 25.34 | 35.36 | - | - | 2.875 | 82.275 | 82.275 |
| 36.5 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 217.35 |

appropriate approximation to them to compute the paths that seismic waves follow in Earth. The diagram below is an example of the paths P-waves generated by an earthquake near Earth's surface would follow in figure 5.10.




### 9.1.1 *Preliminary data*

| ***Parameter*** | ***Dimension/s*** |
|---|---|
| Height of the building | 39.7m |
| Size of building | 25.0m x 18.16m |
| Height of each storey & function hall | 3.2 m &4.5m |
| Number of stories | 12(2 soft +10 ) |
| External Column size<br>Internal Column size | 0.3m x 0.6m<br>0.3m x 0.75m |
| Longitudinal, transverse & plinth Beams size For spans <5.0m | 0.23m x 0.42m |
| Transverse beams size For spans >5.0m | 0.23m x 0.72m |
| Slab thickness | 0.12m |
| Exterior wall thickness<br>Interior wall thickness | 0.23 m<br>0.115m |
| Parapet wall height | 1m |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 33.3 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 352.42 |
| 30.1 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 487.5 |
| 26.9 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 622.57 |
| 23.7 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 757.65 |
| 20.5 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 892.725 |
| 16.0 | 40.8 | 57.92 | 37.95 | - | - | 2.875 | 141.265 | 1033.99 |
| 12.8 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 1169.06 |
| 9.6 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 1304.14 |
| 6.4 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 1439.21 |
| 3.2 | 39.95 | 54.3 | 37.95 | - | - | 2.875 | 135.075 | 1574.29 |

Load calculation sheets prepared for critical column H4

| ***Component*** | ***Weight(kN)*** |
|---|---|
| Weight of column<br>=(24x0.3x0.6x((3.2-0.72)/2+(24x0.3x0.6x((4.5-0.72)/2+12x0.3x0.75x((3.2-0.72)/2+12x0.3x0.75x((4.5-0.72)/2)x25 | 554.89 |
| Weight of transverse beam<br>=(12x7.58x0.23(0.72-0.12)x25) | 313.812 |
| Weight of longitudinal beam<br>=(154.72x0.23(0.42-0.12)x25) | 266.89 |
| Weight of exterior infill wall<br>=(134.58x0.23x(3.2-0.72)/2)x20+(126 2x0..23x(4.5-0.72)/2)x20 | 1865.4 |
| Weight of interior infill wall<br>=20x49.84x0.115x(3.2-0.42)/2 | 159.33 |
| Weight of slab<br>=(0.12x25.10x18.16x25)-(2x(7.58x3)x25) | 1231 |
| Weight of floor finish=18.16x25.10 | 410.336 |
| Weight of live load<br>=18.16x25.10x0.25x3 | 307.75 |
| Seismic weight of floor level storey ($W_6$) | 5109.4 |

## CONCLUSIONS

In spite of many scientific and research advancements during last century, the threat of natural disasters, particularly earthquake and cyclones has remained untamed. Previous geological evidences and failure examples show that rate of occurrence of such events will increase in future. Rapid growth of population in capitals and other cities situated in seismic regions, the potential for massive destruction increases against future earthquakes.

From the results obtained, the following conclusions are presented below.

- The shear wave velocity influences significantly in changing the shear modulus of different soils from static to dynamic state. It is noticed that dynamic shear modulus exponentially increases with the increase of shear wave velocity.
- The horizontal and rocking soil spring constant values increase when type of soil varies from loose soil to hard rock. It is also noticed that these values are high in case of isolated footings when compared to the pile foundation.

- Fundamental time period of the building invariably decreases with the increase of soil stiffness. In loose soils like silty clay and silty sand, where normally pile foundations are preferred, these time period values decrease compared to the values obtained when isolated footing type foundation is provided.

- It is found that base shears at ground level increase with increase of soil stiffness and also noticed that loose soils absorb more shears compared to stiff soils/hard rock.
- The base shear values obtained are the lateral shears transferred from soil to the base of the structure due to effect of soil – structure interaction.
- It is noticed that the displacements are high in case of loose soils compared to those of very stiff/ hard soils.
- When pile or mat foundations are used in place of isolated footing, these values are observed decreasing.
- It is also noticed that the increase in displacements with the decrease of soil stiffness is mainly due to the contribution from rocking spring constant compared to horizontal spring constant values of soil.
- In general, it can be concluded that structure resting on stiff soils or rock behave well during earthquake than structures resting on loose soils.

## FUTURE SCOPE

In this experimental study a multi storey building rests on different soil conditions (hard rock granite, coarse gravel, Silty clay) have been considered, for further experimental investigations different combinations of soil conditions can be carried out. In this present study the soil in and around the foundation has been considered as a spring one in horizontal and rocking mode, for further study spring can modelled including torsion effects this can modelled as used in different software like ANSYS,SAP200, and ETABS or inelastic continuum method . The soil is considered as single media but layered soil types exist below is not single, so different linear equilibrium effects can also be considered.

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