Application of Geotechnical Technique in Urban Design.

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ABSTRACT

One of the Earth's natural phenomenon are earthquakes and the occasional subsequent liquefaction in the sandy subsoil territory. Geotechnical engineering makes an attempt to understand of nature and mitigation of liquefaction. This research paper investigated the application of geotechnical data in urban design for controlling and mitigating liquefaction. The result of embankment modeling revealed the possibility of controlling and mitigating liquefaction through the use of structure self weight in the urban design. This method is called liquefaction mitigation modeling. This technique has not yet been extensively used in designing urban settlements.

(Keywords: deformation, structure self weight, mitigation, liquefaction, sandy subsoil)

INTRODUCTION

An earthquake is a natural phenomenon in which the surface of the earth vibrates mildly or violently for durations ranging from a fraction of a second to a few minutes. Its effects depend on the intensity of the vibration. They can range from barely perceivable to large-scale damage or destruction of man-made structures.

The Indian Plate is fused to the Australian Plate to form the major Indo-Australian Plate, while the rest of Asia and Europe form parts of the Eurasian and the Arabian plates. These plates float on the softer (liquefied) rock below. As they float, moving at a few millimeters per year, they push or rub against each other at the faults. In doing so they build up huge amounts of energy that is stored along the fault lines. When the amount of this stored energy at any point exceeds the capacity of the fault to withstand it, it is suddenly released in a major upheaval. This causes shock waves or a tremor, which makes the ground tremble during an earthquake [1].

Although nothing can be done to prevent earthquakes, precautions can be taken to mitigate their destructive effects. In order to reduce the damage caused by seismic events, civil engineers incorporate a variety of technology into modern structures. Many techniques can be used either individually or in combination to reduce the effects of external forces and to control deformation caused by earthquake.

Soil structures such as river dykes, highway embankments, and earthen dams have to be designed for resisting all sorts of external and internal forces acting on them to offer serviceability during their life time. Almost all external forces encountered during natural disasters are time dependent and they are dynamic in nature. For example, volcanic forces, cyclic effects, floods, and earthquake forces act for a short duration of time and are dynamic in nature. The analysis of soil structures considering the dynamic forces requires more rigorous treatment because of the additional parameter of time that has to be incorporated.

Earthquakes have been found to be the most devastating of all natural disasters because of the potential magnitude of damage, the spread the damage occurs, and the uncertainties involved. Often wide spread damage occurs because of liquefaction of sand under the vibrations. During liquefaction a large number of parameters are involved and the problem is a complex one, even though significant information is available. Though present day researchers are trying to bridge the gap between static and dynamic characteristics of soil, it has been observed that the strength of soil reduces during shaking.

Around the world, a large number of earthquakes occur every day. Most of these are of such low magnitude that they can only be recorded by sensitive instruments and are not felt by people. Many of them occur on the floor of oceans (which accounts for more than two-thirds of the Earth's surface and affects people only if they cause tidal waves which reach coastal areas). Several quakes occur in areas with low population density and are neither readily noticed nor very destructive. The following chart gives an idea of the occurrence of earthquakes worldwide [2].

Table 1: Probability of Earthquake Occurrence [2].

Annual Average	Description	Magnitude
1	8.0 or higher	Great
18	7.0-7.9	Major
120	6.0-6.9	Strong
800	5.0-5.9	Moderate
6,200	4.0-4.9	Light
49,000	3.0-3.9	Minor
3,285	1.0-3.0	Very Minor

The phenomenon of liquefaction is one of the most influencing factors during an earthquake. Liquefaction represents a condition where soil gets subjected to continuous deformation at a constant low residual stress or with no residual resistance, due to the generation of high pore water pressure which reduces effective confining pressure to a very low value. Pore pressure builds-up leading to true liquefaction which may be due either to static or cyclic stress applications.

The first explanation of the phenomenon of liquefaction was published by Terzaghi in 1925 in his classic book "Erdbaumechank". According to Terzaghi, if the soil is saturated and is at the instant of collapse, the weight of soil particles is temporarily transferred to the water through the points of contact with the neighboring particles.

The next contribution to the study of liquefaction was made by Casagrande in 1935. He stated that sand may undergo liquefaction if it occurs at a void ratio more than the critical void ratio. It was pointed out later by Taylor in 1948 that the critical void ratio is not a unique property of sand and the effect of vibrations are not taken into account in tests done for determining critical void ratio [3].

An example of the effects of liquefaction can be seen in the 2001 Bhachau Taluka earthquake in India. The earthquake was felt in most parts of the country and a large area sustained damages. About 20 districts in the state of Gujarat sustained damage. The entire Kutch region of Gujarat, enclosed on three sides by the Great Runn of Kutch, the Little Runn of Kutch, and the Arabian Sea, sustained the greatest damage with maximum intensity of shaking as high as X on the Medvedev-Sponheuer-Karnik (MSK) intensity scale.

Several towns and large villages, like Bhuj, Anjaar, Vondh, and Bhachau sustained widespread destruction [4]. The strong motion records obtained by the University of Roorkee at the Passport Office Building under construction in Ahmedabad City indicated a peak ground acceleration of about 0.11g.

The State of Gujarat is the heartland of Indian industries like petroleum, power, and steel. Indeed, this M7.9 earthquake is the first to hit metropolitan cities of India in recent times; affecting modern industrial constructions. Therefore, the performance of structures in this area will offer important lessons particularly from the points of view of efficacy of Indian codes and construction practices. The damage now seen and documented in the Kutch area would serve as excellent evidence for the Indian civil engineering community on the performance of its own traditional and modern construction.

The earthquake produced excellent examples of large-scale liquefaction. The Great Runn of Kutch, the Arabian Sea, and the Little Runn of Kutch locked the affected area on its three sides [5]. Figure 1 indicated the area affected by the earthquake.

Figure 1: Bhachau Taluka Earthquake [1].

METHODOLOGY AND EXPERIMENTS

In this research work an attempt was made to use of Liquefaction Mitigation Method and other geological mitigation in designing urban settlements. In this regard, soil properties and the level of underground water were considered as main factors in the designing urban settlements. We evaluated the best economical method of designing a city which may be vulnerable for liquefaction. This research used computer aided evaluations as well as the application of geological data in urban settlement design.

RESULTS AND DISCUSSION

From 1930 to 1985, the seismicity analysis of Iran was conducted by Wilson (1930), Niazi and Basford (1968), Nowroozi (1972, 1976), Banisadr (1971), Ambraseys and Moinfar (1973), Berberian (1973), and Tchalenko (1975) [6-12]. It is now agreed by several investigators that the seismicity in Iran is related to the local surface geology and tectonics.

Many destructive earthquakes such as Silakhor (Ms=7.4, 1909), Salmas (Ms=7.4, 1930), Torud (Ms=6.4, 1953), Lar (Ms=6.7, 1960), Buyin Zahra (Ms=7.2, 1962), Dasht-e-Bayaz (Ms=7.4, 1968), Qir (Ms=6.9, 1972), Khorgu (Ms=7, 1977), Tabas (Ms=7.7, 1978), Qayen (Ms=7.1, 1979), Rudbar-Manjil (Ms=7.2, 1990), and Birjand (Ms=7.3, 1997) confirm this phenomenon in Iran. It is clear that the Iranian plateau is one of the more seismically active areas of the world and frequently suffers destructive and catastrophic earthquakes that cause heavy loss of human life and widespread damage. Earthquakes larger than Ms=7.0 have been experienced in the Zagros region during the 20th century, but shocks of magnitude over Ms=7.0 have occurred in central and eastern Iran [13].

Liquefaction is always resulted from settlement and differential settlement, deformation, and differential deformation of soil foundations depend on soil geological characteristics. Understanding liquefaction is essential for geological and geotechnical investigation and the identification of a potential urban site. Urban designers need to understand the impact of structural load to the neighboring structure and to the whole site and the influence of load in the acceleration or control of liquefaction.

It is reported that the control of liquefaction under the embankment sandy model with a minimum of deformation and maximum pore water pressure under the embankment at the center of subsoil was observed and the seismic force in the center of subsoil by weight of embankment was controlled (Figures 2-5)[14].

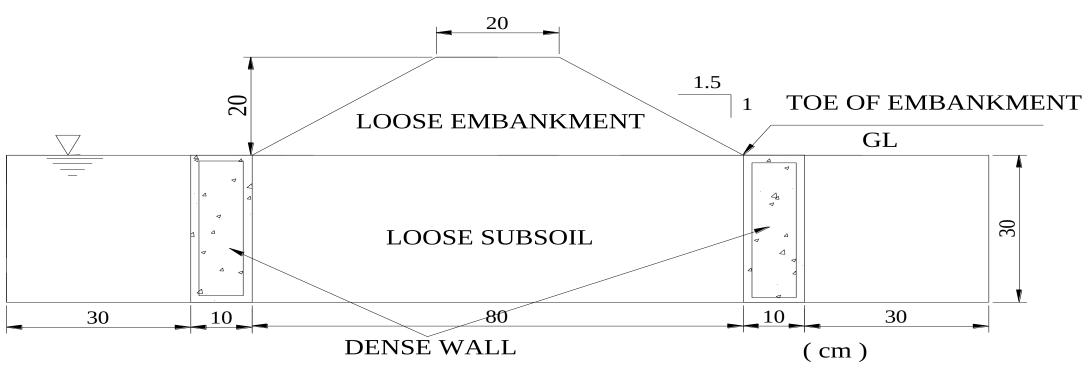


Figure 2: Model of Moist Loose Embankment and Loose Subsoil Fully Saturated with a Dense Wall made from Composite (60 % sand and 40 % gravel) Confined in Geo-textile Placed on the Outside of the Toe of the Embankment [14].

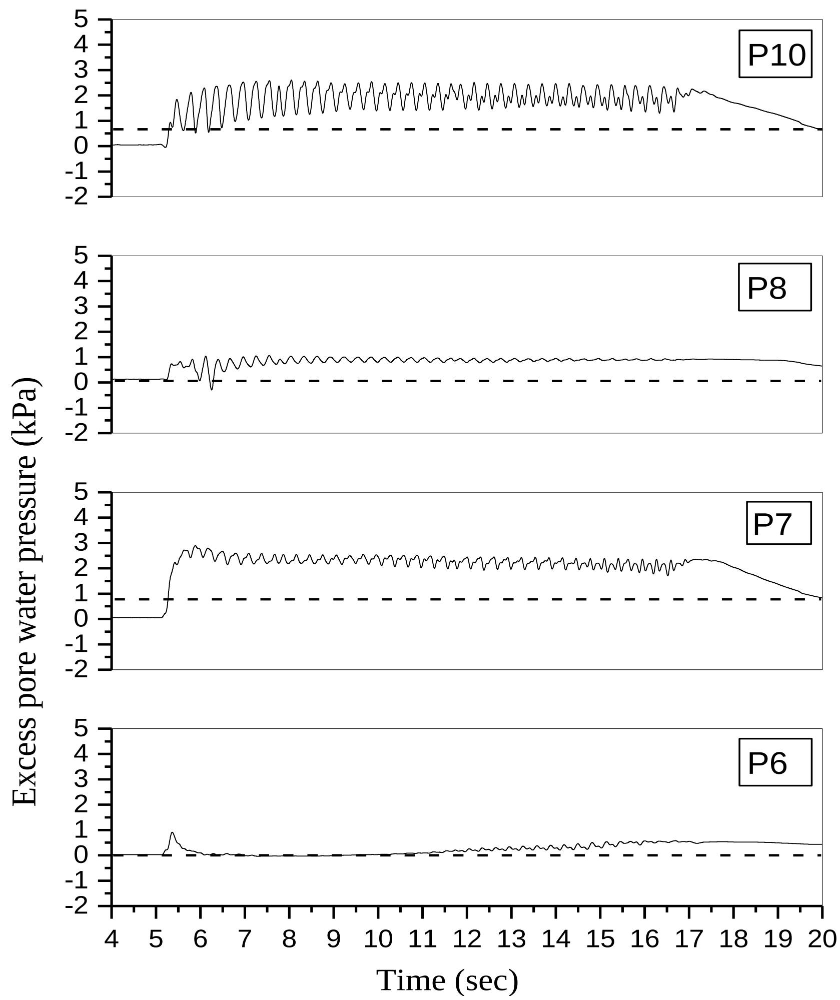


Figure 3: Time Histories of Excess Pore Water Pressure [14].

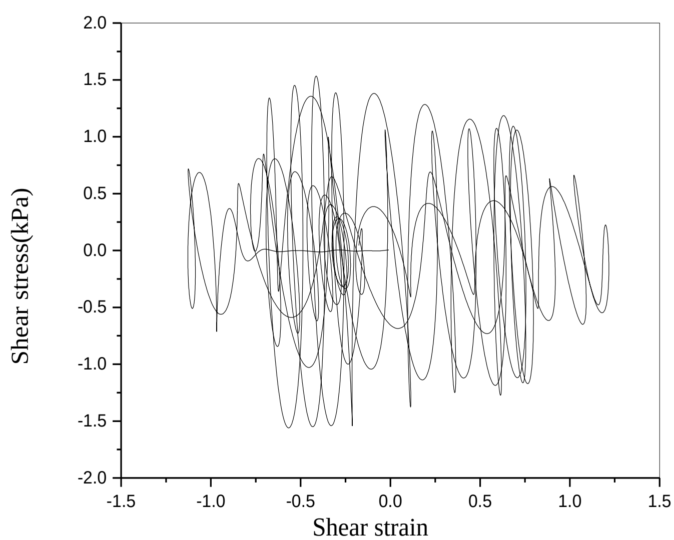
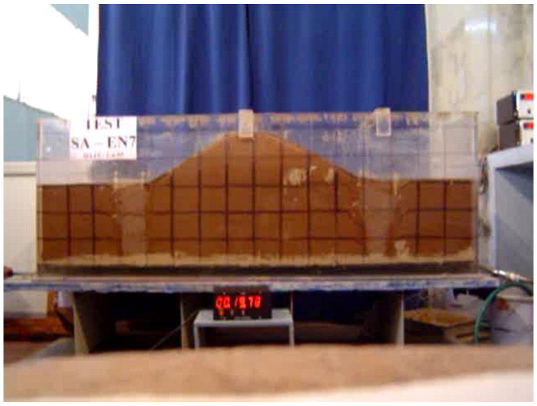
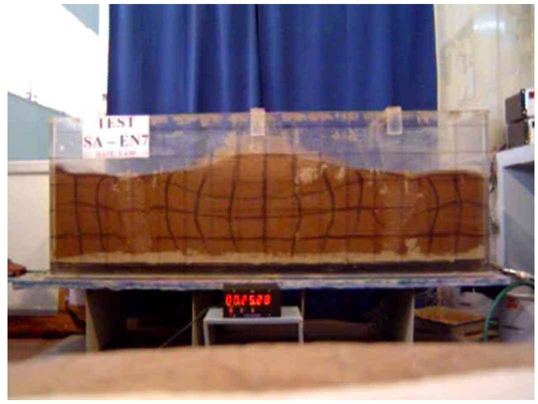


Figure 4: Stress Strain History in the Subsoil below Embankment [14].



Initial Condition



After one Second

After Two Seconds

After Three Seconds

After Four Seconds

After Five Seconds

Figure 3: Deformation Shape of Embankment-Subsoil System at Different Instants of Time [14].

The aspects mentioned here could be applied in urban design if structures are arranged as a body which is a mirror on city construction. This information may help a site to overcome risk associated with liquefaction. This aspect of geotechnical engineering could be regularly applied in urban design. The weight of a structure on site could be a positive force for the control and mitigation of liquefaction if its nature and behavior are well understood in urban design. A second advantage of this urban designing method is to employ the self weight of the structure at the site for the densification of subsoil. In civil engineering the weight of a structure seldom an interesting factor, but from this urban design method the use of the structure self weight could be a technique for mitigation of liquefaction.

CONCLUSION

- It is essential to apply geological and geotechnical investigations and identification in the selection of an urban site.
- Urban designers need to understand the potential impacts of structure self load in the acceleration or controlling of liquefaction.
- In urban design, if structures are arranged of as a body which is a mirror on city in construction, it is could mitigate liquefaction.
- The weight of a structure on the site could be a positive force for the control and mitigation of liquefaction if it is well understood in the urban design.
- The self weight of a structure could be used in subsoil densification.

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