Soil collapsibility of Kerman city

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Abstract
The results obtained from 60 SPT tests on samples from the soil of the city of Kerman indicate that any increase in the SPT number would increase the probability of the soil collapsibility. All the studies have also shown that any reduction in the plasticity, moisture content, or specific weight would increase the SPT number and eventually the soil collapsibility. Through this study, it was found out that the soil of the area under investigation was, based on the Unified classification, clay with low plasticity and in some parts mud also with low plasticity. Also some amount of salt has been noticed in the texture of the soil which can affect the SPT drastically.

Key words: *collapsibility, standard penetration test, Kerman, plastisity*

Introduction
According to the field observations, the SPT tests results, and the laboratory tests, Kerman has collapsible soil. Since soil collapsibility is an instantaneous phenomenon which can be varied with any change in the soil condition, it can be increased in higher moisture content. If any construction is built on such soils, a large collapse will be predictable (Borja 2006).
Collapsibility can be defined as the sudden fall of the soil due to loss of the connecting strength between the soil particles (Bell 2002). The degree of the collapsibility depends on the initial soil porosity (Jennings & knight 1975) and also any change in the percentage of the soil saturation depends on the changes of the effective tension of the soil (Gao et al. 2007). From the point of view of geological engineering and geotechnique, collapsible soils, which are reported to exist in five continents of the earth, are categorized as difficult soils. These collapsible soils cover about 16 percent of the earth's surface (Reznik 2000). Their volume can be extremely expanded after they are saturated.
The city of Kerman has suffered from the problems of the soil collapse. In recent years, the constructions of high-rise buildings have been developed in this city and also the population, which is about 700000 at the present, is increasing (Planning and funding Organization 1995). The SPT test is a simple measure which its application is becoming more these days. The purpose of this study is determining the relation between the SPT number and the extent of collapsibility in the field and also other geotechnique parameters of the soil. During the initial investigations and after conducting about 60 SPT tests, the dependence of the collapsibility of the city soil on other parameters has been specified.

Geographical and geological setting
The city of Kerman, which is the center of the Kerman province (figure 1), is connected, through a network of asphalt roads, to the provinces of Hormozgan, Sistan and Baluchistan, Yazd, and Southern Khorasan from its southern, eastern, north western, and north eastern boarders respectively. Moreover, the railway in the south eastern parts of Iran passes Kerman.

The city is located on a quite high plain with a height of 1740 meters above the sea level which is surrounded by Joupar Mountains on its south, Balabane Mountains on its north, Seyedi and Taq Ali Mountains on its east, and finally Bad Amouiyeh Mountain on its west.

Figure 1. The geographical location of the city of Kerman in Kerman province

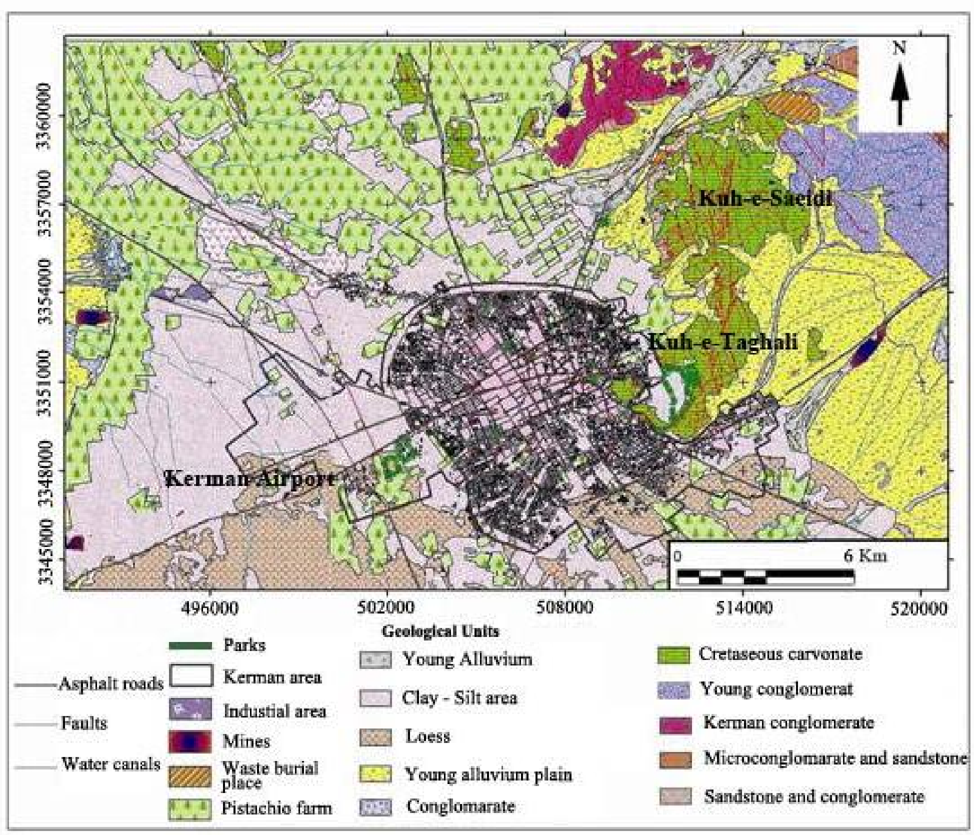

Figure 2. The geological map of Kerman (extracted and modified from Atapour, 2000)

Clastic sediments and quaternary alluvial with old and young alluvial fans have filled the graben between the heights. The old alluvial fans which can be observed as vertical walls in some parts are composed of particles of gravel, cobblestone, sand, and silt. The younger alluvial fans have been deposited in the area between the heights and the plain center. New alluvia, composed of well rounded sand and gravel, and also sand and hills, has stretched on river beds, river valleys, and central areas of the plain from the south of Kerman, to near Mahan and Joupar.

The basement of Kerman is reef limestone in most parts (figure 2). The alluvial sediments are stretched in the east and south east of Kerman. The playa sediments have been expanded in most parts of Kerman except the south and west southern of the Kerman plain and also in eastern parts of the city where wind sediments are covering alluvial sediments.

The purity degree of the limestone around the city of Kerman is higher comparing to the universal average (Atapour& Aftabi 2002). Therefore, since these rocks can be dissolved and form Karsts, they may rise the risk of collapses (Hamzeh 2006, Atapour & Aftabi 2002).

According to the investigations carried out by Roustaian (2000), the alluvia is predicted to be about 150 meters in the north of Zangi Abad, 170 to 200 meters in the area of Kerman Airport, 180 meters in the distance between Baqeyn and Saa'di, and 200 meters in the area 5 kilometers to south of Baqeyn thick. The changes of these alluvial thicknesses are estimated to be between 50 and 300 meters.

Hydrogeology and the hydrology of the area

The average precipitation of Kerman is 158mm (Atapour& Aftabi 2002), the humidity is 31 percent and the temperature is varying between -4 and 40 degrees centigrade (Planning and Funding Organization 1996). Therefore, this city can be regarded as a semi-dry or dry area. The wind blow is mostly from the North West or the west.

Considering the condition of the sewage system and underground water, the city of Kerman is in a critical state to the point that the depth of the underground water has reached 4 meters in some spots. The rise of the underground water and the existence of saturated clay layers can be a threat to the constructions. The sewage of the city of Kerman has been traditionally transferred to the underground aquifers through the absorbing wells and, therefore, resulted in the rise of the underground water, contamination of these water, and also epidemic of some diseases. Also there is a danger that the constructions may be damaged severely in case of earthquakes due to liquefaction. Since there is no urban sewage system and therefore the level of underground water rises, the weak layer of saturated sandstones could collapse or tilt the constructions in case of earthquakes. The most effective measure to prevent this is constructing and completing the urban sewage system and lowering the underground water.

Field studies of the phenomenon of collapsibility

At initial stages it was found out Kerman has collapsible soil (figure3). In the comprehensive detection stage, numerous regions with different depths have been dug to obtain both disturbed and undisturbed samples for laboratory observations and tests.

Figure 3. The observed cavities and cracks in Kerman's buff colored soil

Grain size distribution using hydrometer analysis

The results show that the soil of Kerman, based on Unified classification system, is mostly clay and mud, both with low plasticity. The grain size distribution curve of some soil samples, gathered from different parts of Kerman is demonstrated in figure 4.

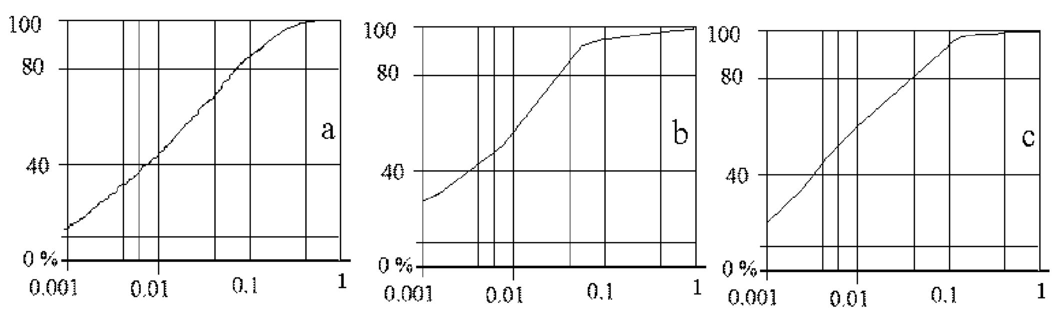

Figure 4. The grain size distribution curve of soil samples in three regions namely Shafa street (a), Stadium (b), and Shahrak-E-Motahari (c)

Relation between the SPT number and moisture content of the soil

The results of this part indicate that with the decrease in moisture content (non-saturated or semi saturated), the SPT number increases. When the soil is subjected to humidity, the phenomenon of collapsibility occurs.

The SPT test on the location

The Standard Penetration Test is one of the most common field tests to determine the features of soil layers. The results of this test can be employed to evaluate the relation between the SPT number and other parameters of clay soils. The results obtained from this test in different depths are shown in figure 5.

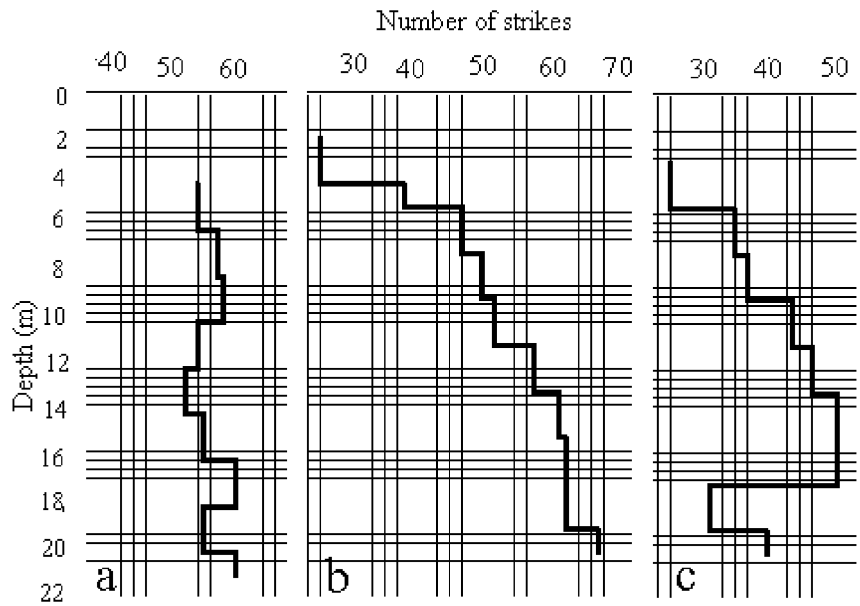

Figure 5. Three diagrams of the number of SPT strikes toward the samples depth in three regions namely Shafa street (a), Stadium (b), and Shahrak-E-Motahari (c)

Conclusion

It was found out, during this research, that the liquid limit is between 21 to 38, the plasticity is between 12 to 21, and the plasticity index (PI) is between 9 to 17 in the city of Kerman. The soil under investigation based on the Unified Classification System is clay and mud, both with low plasticity. The collapsibility of the soil elevates with any increase in moisture and with any other condition imposed on the soil. According to the investigations, the increase of the SPT number means the increase of the collapsibility of the soil. The reduction in the parameters of plasticity, moisture, and specific weight and also any increase in the parameters of the amount of clay in the soil and the porosity of clay-silt soils will lead to the increase of the SPT number and, resultantly, the increase of the soil collapsibility. The studied soil has strong cementation and some proportions of salt, thus, the SPT number is high. Based on the aforementioned standards, the soil of the city of Kerman is mainly categorized under the group of soils with high or very high degree of collapsibility. One solution to prevent the water rise and direct it towards the city exists, is digging canals, 8 meters deep, and carrying out the drainage approach.

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