World Academy of Science, Engineering and Technology
International Journal of Geological and Environmental Engineering
Vol:12, No:5, 2018

Analysis and Modeling of Stresses and Creeps Resulting from Soil Mechanics in Southern Plains of Kerman Province

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***Abstract*—**Many of the engineering materials, such as behavioral metals, have at least a certain level of linear behavior. It means that if the stresses are doubled, the deformations would be also doubled. In fact, these materials have linear elastic properties. Soils do not follow this law, for example, when compressed, soils become gradually tighter. On the surface of the ground, the sand can be easily deformed with a finger, but in high compressive stresses, they gain considerable hardness and strength. This is mainly due to the increase in the forces among the separate particles. Creeps also deform the soils under a constant load over time. Clay and peat soils have creep behavior. As a result of this phenomenon, structures constructed on such soils will continue their collapse over time. In this paper, the researchers analyzed and modeled the stresses and creeps in the southern plains of Kerman province in Iran through library-documentary, quantitative and software techniques, and field survey. The results of the modeling showed that these plains experienced severe stresses and had a collapse of about 26 cm in the last 15 years and also creep evidence was discovered in an area with a gradient of 3-6 degrees.

Keywords—Stress, creep, surface runoff.

I. Introduction

EFFECTIVE stress is a stress tolerated by the body of the soil (skeleton of the soil). In 1936, Carl von Trazaghi for the first time proposed effective stress equations [1]. As this calculated stress is effective in soil movement and it is the agent of deformations in soil, the term "effective" is used for it. Effective stress is a stress tolerated by the body of the soil (skeleton of the soil).

Effective stress 'σ is obtained by using two terms of total stress or σ and the pore water pressure or u:

$$q1=q-u$$

The amount of total stress and pore water pressure in problems that does not have complexity is obtained from the following equation: q = Hsoil γsoil

$$u = \text{Hw } \gamma\text{w}$$

The concept of effective stress is more like the concept of stress itself, and its equation has been developed on this basis. If we want to consider the behavior of a soil grains individually, the relationship of effective stress will be much more complex. Soil creep is a very slow mass movement of soil [2]. Creep is a slow movement of the soil and rock, which cannot be seen, but the effects of this movement can be observed. These effects include the removal of fences from the regular mode or the movement of phone cables downwards of the slope [3].

This soil displacement occurs in areas, which are affected by melting and freezing cycles. The freezing takes the soil and rock particles, and when the ice melts, these particles are collapsed, but not in the previous site. Gravity always causes rock and soil to collapse slightly farer and downwards the slope. This slow movement is called creep [3]. In areas, which have periodically wet and dry periods, creep is observed and acts like a melting and freezing cycle. As this process is very slow, it can be recorded as flow and over a long period of time [4].

In places, where materials of the mass have mechanical properties of a dough substance, they are thick or a true liquid.

The mass movements can be in flow form. In an unfinished flow, the particles of the object are displaced. Flows may occur at any speed, and the generator involved in the movement may have varying water values [5]. The speed of movement in a flow depends on the amount of water, slope of domain, type of material involved and weather conditions. Creep in rock and soil, avalanches, rubbles, mud flow, sand flow, gravity flows in the sea beds and ocean beds, and river flows are examples of flow movements. When the soil undergoes constant loading, it undergoes deformations over time, known as 'secondary compression' or 'creep'. Time-dependent deformations, especially in long-term deformations, are very important in geotechnical engineering. Some of these deformations include structure collapse on compressible lands, natural slope movements, compression of soft soils around the tunnel, and so on [6].

The history of the studying the creep behavior of clay soils backs to the 19^{th} century. The first research on secondary compression was performed about a decade after the theory of Terzaghi indicating the compression of clay soils due to waste of pore water pressure [7]. In addition, the laboratory studies carried out by Wang indicate the effect of clay on clay compressibility [8]. Buirman stated the time logarithm collapse equation under constant stress scientifically for clay soils [9]. Sjoberg for the first time presented a time-dependent model to describe the creep behavior of clay soils, in which initial consolidation and NAO compression were considered as two distinct processes [10].

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Zipf introduced a model in which primary consolidation and secondary compression have couple behavior in order to explain the creep behavior and the effects of over-consolidation [11]. Lambe introduced the outflow and depreciation of porous liquid from micro-pores as one of the reasons for secondary compression [12]. Kushwaha et al. concluded that the transfer of water from micro-pores to macro-pores is due to secondary compression, and in stable effective stresses, the average collision of particles during the creep stage should be constant [13]. The clay contains small particles smaller than 2 microns, which negative loads cover its surface. Due to the nature of clay, particles are susceptible to physical and chemical processes. In dry mode, the clay particles absorb cations and when exposed to water, cations are separated in order to achieve equilibrium mode. As shown in Fig. 2, the negative loads of the clay surface and dispersed loads form a double layer of water in conditions in which clay is placed adjacent to the porous liquid containing the polar molecules, micro and macro pores are formed. Micro pores are formed as a result of absorption of surface water and macro pores are formed as a result of free water. The mechanism involved in the creep behavior of clay soils can be attributed to slide, contact, particle deformation, and pores compression [12].

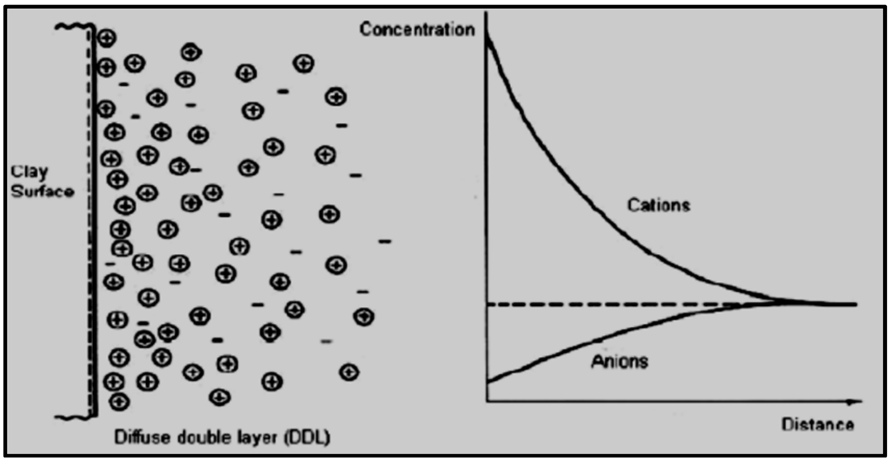

Fig. 1 A double layer of water formed on the clay surface

Soil Stresses and Creeps in Faryab Plain

Kerman province is the largest province in the country and covers 11.6 percent of Iran's territory. This province is one of the highest provinces of Iran, and its Faryab city with 2100 meters above sea level is one of the highest cities in the province. The Faryab city is located in the southwest of the province [14].

The presence of highlands in different parts of the city, locating of Kavir-e Lut in its northwest and low latitudes, has caused that this city to be divided into three areas in terms of climate, including desert and marginal desert, tropical and cold, temperate mountainous areas. The Faryab plain is located in this province, which are more fine-grained sediments called as claypan. Based on the geological map 1: 250,000, clay sediments are placed on the deposits of gypsum marls, sandstone, and conglomerate related to Pliocene period. In terms of hydrogeology, fine-grained clay sediments which are mixed with fine grained sand particles in some horizons form the aquifer of this plain and layers related Pliocene form stone of the plain floor [15].

II. Model Description

Considering the slope of the area and the surrounding lands, the northern and western parts are the main factors in producing the surface water flowing towards the Faryab Plain. However, the factor of presence of gardens and fields in the northern, northwest, and southern parts of the plain causes these waters to penetrate into the earth rather than flowing as flood on the earth surface. The penetration of these waters causes clay soils in the area to be saturated, providing the conditions for the creep phenomenon. Two fundamental factors should be considered for modeling the creep phenomenon, including very low slope and moisture which both of them were in the study area, and they led to the creep phenomenon. It was clearly observed in field studies. It should be explained that there is a series of soil science evidence in the environment to estimate the soil creep and stress, which this evidence can be stated as follows:

III. Tilting of Utility Poles and Trees

Creep: it is a slow flow of soil or rock, which does not move along the sliding surface and is displaced in a vertical direction. Creep is seen only on the surface layer of the earth. The degree of creep depends on the magnitude and duration of the stress applied to the surface layer. Creeps are divided into three categories:

1. Primary Creep: In this creep, the level of stress after a long period of time decreases from a high amount to a constant level.
2. Secondary creep: In this type of creep, the stress level after a period of time increases from one constant level to another level
3. Third creep: In this type of creep, the stress level increases from the constant level to its maximum level

and collapse occurs.

Based on the type of creep material, creeps are classified to earthy, debris, and rocky creeps and occur in temperate and tropical climates. Weathering, freezing, temperature variations, water absorption can provide conditions for creep. Sometimes the tilting of the lines of power transmission lines or tree trunks on the slopes indicates creep.

In the study area, utility poles have been displaced as a result of creep phenomena and have been transformed from vertical to angular form. Fig. 3 shows the displacement of the utility poles from vertical form in the field studies.

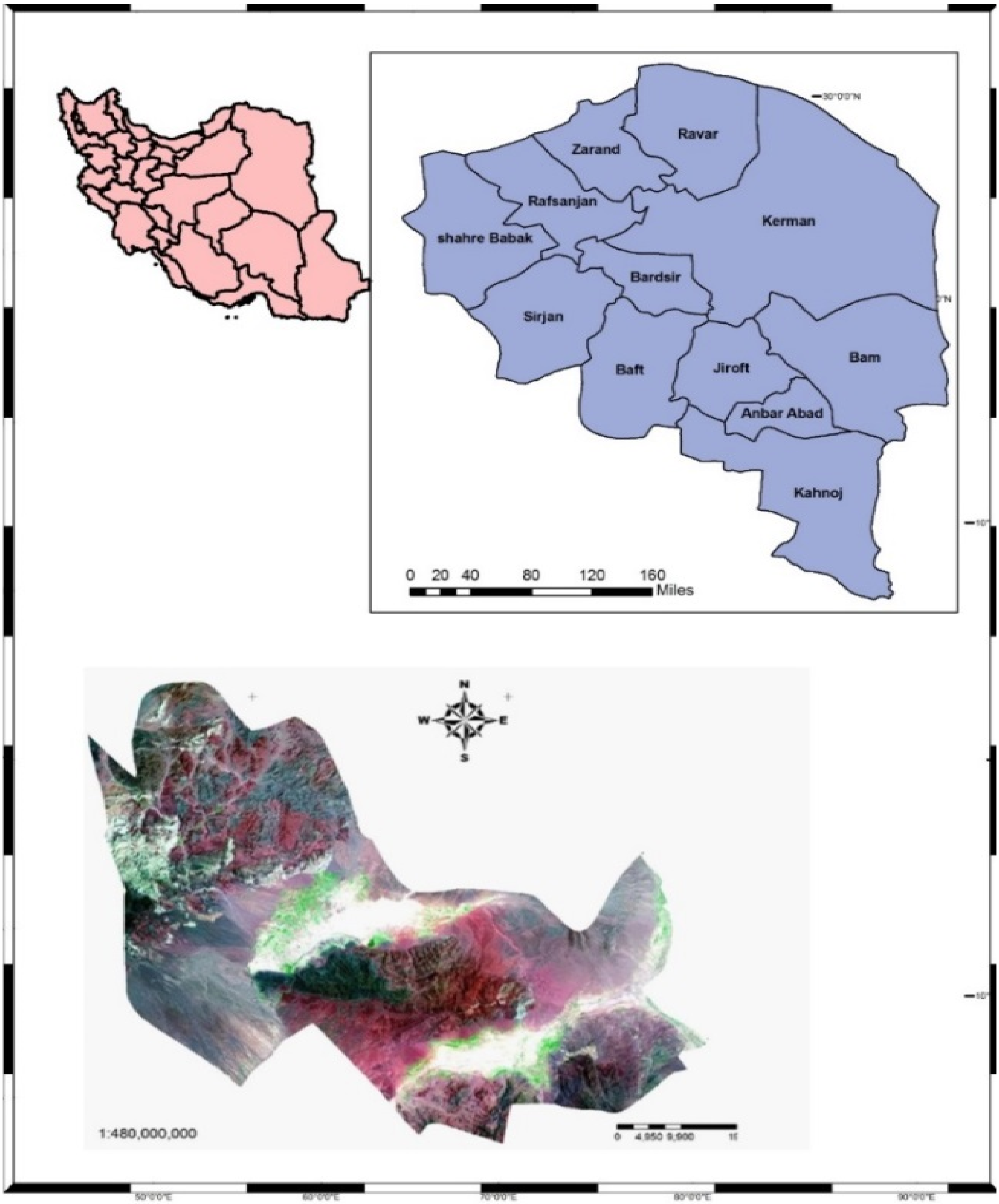

Fig. 2 Map of study area

Fig. 3 Displacement of utility poles from vertical form to inclined form as a result of creep phenomena in the study area

In general, the Faryab Plain lacks steep slopes due to being located in smooth lands. Based on the study of topographic maps, the maximum difference between the north and south and east and west of the plain is not significant. The slope of the area is about 20% on average. The highest slope is in northwest – southeast direction.

IV. Surface Runoff (Flood)

One of the most important factors causing the phenomenon of creep and soil stress is the increase in soil moisture content. As the land slope is lower and the amount of runoff resulting from precipitation is more, the soil would be under more stress. In Fig. 2, the increase in water volume and its recession and progression in the Faryab Plain have been modeled. These figures show that, in the early stages, with increasing runoff, soils, especially fine-grained soils such as clay, begin to swell. As a result of reduced precipitation, water begins to evaporate and the clay begins to break down due to its molecular properties.

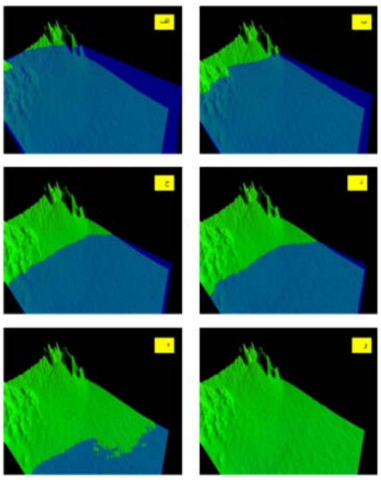

Fig. 4 Surface runoff recession steps in the study area (Darzadeh, Hamed, Telecommunication Office of Geology of Kerman)

Extraction of Liquids

Extraction of liquids, especially water, is the most important cause of collapse of the Earth's surface. Extraction of liquids reduces its pressure in underground reservoirs and directly leads to an increase in effective stresses and compacted compression. The fine-grained clay layers are very compressible, but regulating their porosity pressure is slow and time-dependent and permanent. Land collapse management is involved at least in three strategies.

First, the prediction of the location and the nature of the collapse before its occurrence, and the use of this knowledge to plan the development of surface affairs of land in the future in a safe place and preventing the collapse of previous development projects. Second, finding solution on the effects of collapse through the preservation and survival of the earth's surface or reducing the collapse or ground surface correction. Third, the effects of collapse resulting from the development of earth's surface affairs can be reduced by precise planning and conservative affairs.

In the study area, due to the boom of agriculture and planting crops such as watermelon, green cucumbers, and cereals such as wheat and barley, maize, palm, tomatoes, onions and citrus such as oranges, lemons, and grapefruits groundwater aquifers are used excessively. On the other hand, due to drilling deep and semi-deep wells, the groundwater resources of this plain are severely attacked and somehow plundered. Due to such action, the property of soil saturation on the Faryab plain has been reduced fine-grained soils have begun to break down, and due to stresses, numerous gaps and seams have been created in the study area.

As the study area is geologically a part of the Cenozoic volcanoes, evaporation sediments of the third geological period are mainly salt, gypsum and marl, which directly lead to salinity and poor water quality. The Faryab plain is located on new quaternary (new) sediments. These sediments have loose and erodible texture. The floor rock kind of the area is Plio-Quaternary sedimentary deposit, which is composed of loose conglomerate with layers of sand, silt and clay, located on green siltstones and thin lime layer.

Fig. 5 Number of gaps and damage caused by it during a field survey

It is also covered with clay and marl soils, which clay soils have more collapse due to more porosity and the level of the collapse increases with decreasing pore water pressure and increasing effective stress. In addition, from the geomorphic viewpoint, compaction and erosion pediments, along with many alluvial fans with a gentle slope end to ending parts of the plain. According to the available statistics and calculations performed on the groundwater level and considering that the sedimentary layer of the area which is clay and marl which is more sensitive compared to coarse grain sediments such as sand, it would experience more collapse. Land collapse has led to the creation of seam and gap in land and damage to residential buildings in the study area.

Fig. 6 Creating a gap and seam due to undue and uncontrolled use of groundwater

V. Conclusion

As Faryab plain is located on new quaternary (new) sediments and it has sediments with loose and erodible texture and as the floor rock kind of the area is Plio-Quaternary sedimentary deposit, it is so sensitive to stresses and creeps. Tilting of utility poles and the area trees as well as reduced level of underground aquifers were evidence in this regard (see research findings). The factors of reduced liquids and tilting of trees were the main evidence, and the reduced slope of land and surface runoffs were other factors involved in creation of the stress and creep in the soils of the study area.

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