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RESEARCH ARTICLE

PRESATURATION METHOD FOR DIMINISHING SOIL SWELLING POTENTIAL

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ABSTRACT

Expansive soils have caused significant damage in pavements and households; this damage leads to substantial economic loss in the world. In Mexico, around 12% of the territory is made of expansive soils and due to the problems that they cause, various techniques have been developed so as to stabilize them, which include mechanical and chemical methods, among others. One proposed technique to diminish expansion problems is the presaturation method which consists in provoking soil expansion by adding water to produce swelling prior to the structure's construction, reaching a degree of saturation higher than 80%. In this article, a literature review about the efficiency of the implementation of quick and inexpensive stabilization of expansive soils applying the presaturation technique is made.

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INTRODUCTION

Nowadays, expansive soils are sources of damage to various structures, among them are highways, roads and households (Evans and McManus, 1999; Phanikumar, 2009; Hasan *et al.*, 2016). In the particular case of Mexico, expansive soils cover around 12% of all the territory, causing severe damage to the Mexican highway network (Cervantes, 2002). Up to today, Mexico has not quantified the produced damage by expansive soils, whereas in the United States of America, Steinberg (1989) expounds that the damage caused due to expansive soils exceeds 10 billion dollars every year, amount that surpasses the damage caused by floods, hurricanes, earthquakes and tornados. The cost of substituting the expansive material is high, therefore, it is important to incur to diverse methods for its stabilization (Rosales, 2014). A technique to treat expansive soils is "presaturation" (see Figure 1); this method avoids big movements of dirt roads, reduction in the construction time and economical savings (McDonald, 1973). The technique has been used since 1930 in Texas, USA and consists of hydrating a clay soil so as to stimulate the expansion prior to constructing a structure (Wise and Ronald, 1971). %. In this article, a literature review about the efficiency of the implementation of quick and inexpensive stabilization of expansive soils applying the presaturation technique is made.

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Expansive soils

Volumetric changes cause that pavements or constructions are subject to significant deformations, these changes are a result of an increase or reduction of the water content. Humidity variation of a soil can occur when grass or trees are cut or when gardens are irrigated (Fredlund and Rahardjo, 1993; Labib and Nashed, 2013; Adem and Vanapalli, 2015; Dang *et al.*, 2016). Moreover, environmental conditions play a crucial role in expansive soils' behavior (Snethen, 2001; Chen and Bulut, 2016), in semiarid regions, the water content in an expansive material tends to change depending on the season (see Figure 2), this with regard to their equilibrium value (Terzaghi *et al.,* 1996; Estabragh *et al.,* 2015).

Aubeny and Lytton (2002) describe the process which causes the expansion of a non-saturated soil as follows:

- During ground water recession flow season, cracks are developed on the ground's surface; these are dependent on the intensity and length of the drought season.
- During rain season, water seeps through the cracks, increasing humidity and reducing ground suction.
- Suction reduction leads to a decrement in the strength of the material, additionally, the ground undergoes noteworthy volumetric changes (expansion).

Active Zone

The active zone is where the ground has a swelling potential, as a result of its humidity variation (Nelson *et al.,* 2001). The aforementioned variation is a product of temperature, climate conditions, adjoining constructions, vegetation, soil type, among others (Vipulanandan, 2011), in turn, the temperature effect influences in the water exchange (Nelson and Miller, 1992). In Figure 3, different idealized humidity profiles are shown: In profile (A) a dry soil is observed in a semiarid climate. Profile (B) shows an example of a stable-humidity soil. This reduces variations by temperature and humidity loss. Profile (C) is a result of winter conditions whereas profile (D) of summer conditions. Hamberg (1985) found that humidity variation in a soil profile in Colorado got reduced to 5.5 m, indicating the active zone thickness. Nelson *et al.,* (1994) performed humidity measurements for 596 days at Colorado State University, finding the active zone within 4.5 m. approximately. In another study, Vipulanandan (2011) measured humidity in the area of Houston from 2000 to 2007. He found significant variations of humidity in depths of 0.0 and 1.5 m, said variations substantially decreased from 1.5 to 3.0 m. In addition, precipitation affected the ground months after having gone by, the most significant fluctuations where observed within 1.2 m. William (2014) noticed important variations in the active zone in Texas, due to corn crops. Aubeny and Lytton (2002) mention that cracking increases the active zone's thickness, nevertheless, it is hard to quantify its effect.

Characterization of expansive soils

Free swell

The free swell test consists in measuring the expansion of a dry soil specimen with a defined volume; it is placed in a cylinder which will be filled with water, afterwards, the difference of initial volume and final volume after its expansion is measured (Nelson and Miller 1992).

Expansion measurement by means of the oedometer test

One of the most used techniques for measuring soil expansion is the unidimensional oedometer test. The advantages of using the oedometer are that the results are highly reliable; however, the test's nature might lead to higher expansive values than the ones measured on field. The majority of literatures mentionthe use of unidimensional tests with oedometer to predict a soil's expansion (Nelson and Miller, 1992, Elbadry, 2016). The swell test consists in placing a specimen of known volume in an oedometer; after it is placed, the sample is flooded so as to determine the soil swelling magnitude. Jennings and Knight (1957) developed double oedometer tests, one with excess load and the other by means of a conventional test. Additionally, Jennings *et al.,* (1973) compared excess load tests with consolidation procedures. Likewise, Teng *et al.,* (1975) performed expansion tests in modified and not modified samples with overload pressures.

Unidimensional swell

Balu and Robinson (2006) performed free swell tests for soils with a 70% to 105% liquid limit, concluding that the final deformations were dependent on the water content and initial vacuum relation, therefore the existence of suction. They also found that the swelling was significantly reduced for a compacted soil 4% above the optimum humidity. For a free swell test it was found that a compacted soil with optimum humidity obtained a swell pressure of 240 kN/m^2 whereas the same soil with humidity 4% above the optimum point, obtained a swell pressure of 60 kN/m^2. Other researches such as Justo *et al*. (1984) reported significant expansions in low suction values. Abduljauwad *et al.,* (1984) mention that the soil's swell pressure is dependenton its initial suction. Day (1992) discovered that for different compacted clay samples, the secondary expansion ended when it reached a grade of saturation of 87.9% to 99.99%. Concluding that, the initial vacuum relation and compacting energy, influence on the soil's swell pressure.

Moreover, Day (1994) concludes that a compacted clay above the optimum humidity results in a lower expansion percentage than the same compacted clay with a water content below the optimum point. Justo *et al.,* (1984) analyzed that an initial excess load in the soil helped reduce soil swell. Likewise, Brackley (1980) observed the same behavior for unaltered and reshaped soils. Additionally, Habib *et al.,* (1993) observed that the vacuum relation was more influenced by vertical stress (overload), whereas the water content tended to be more influenced by the changes in the material's suction.

Soil presaturation method: Stabilization technique for expansive soils

In 1930, the presaturation technique was employed in the state of Texas, United States; this technique consists in hydrating a clay soil so as to initiate the soil's expansion (see Figure 4) before the construction of a structure or pavement (Wise and Hudson, 1971). The presaturation method or water ponding assumes that the high water content is maintained, therefore, there will not be a substantial change in the soil's volume (Nelson and Miller, 1992). One of the first presaturation projects was performed in Texas, 1932 in the interstate 10 highway, where embankments and fillings of 30 cm were made (see Figure 5). A Portland cement based hydraulic concrete pavement was placed directly in the clay's sub-grade course. Based on measurements, little variability was found in the water content within 36 inches under the pavement; also, no important irregularities were observed in the pavement (Gordon and Steinberg, 1927). Rockwell (1917) reported irrigation and pond tests in different soil types, which were covered with a concrete slab. During the following 18 months, the slab was slowly deformed, the settlement slowly continued for seven years. Even though excellent results were reported, no control in the ground sections existed; therefore, the expansion product due to ponding could not be determined. Felt (1953) in Nelson and Miller (1992) increased the humidity of fissured clay for a month, utilizing the presaturation method. Nonetheless, he found that when flooding the soil for 6 months more, the expansion kept on. Blight and deWet (1965) achieved 90% of the estimated expansion of clay, saturating it for two months, employing vertical sand wick drains so as to reduce the time that water takes to seep through the soil. Gordon and Steinberg (1972) performed measurements of a stabilized expansive soil by means of the presaturation method in a pavement in San Antonio, United States. Water was ponded in the expansive soil up to 0.90 m, the hydration developed during 45 days, after that, the surface was stabilized with lime to maintain the soil's humidity.

Figure 1. Expansive soils hydration by means of the "presaturation" method

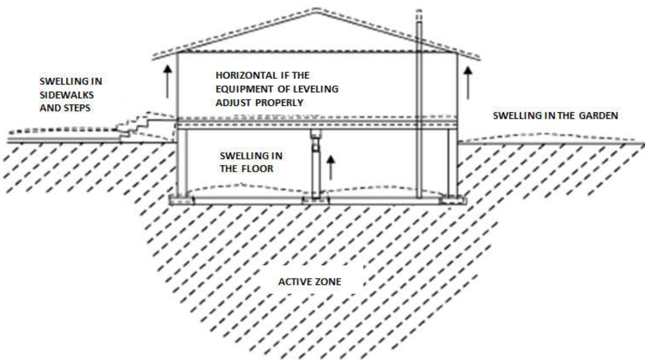

Figure 2. Ground movement associated to the construction of a shallow foundation over an expansive soil (Fredlund and Rahardjo, 1993)

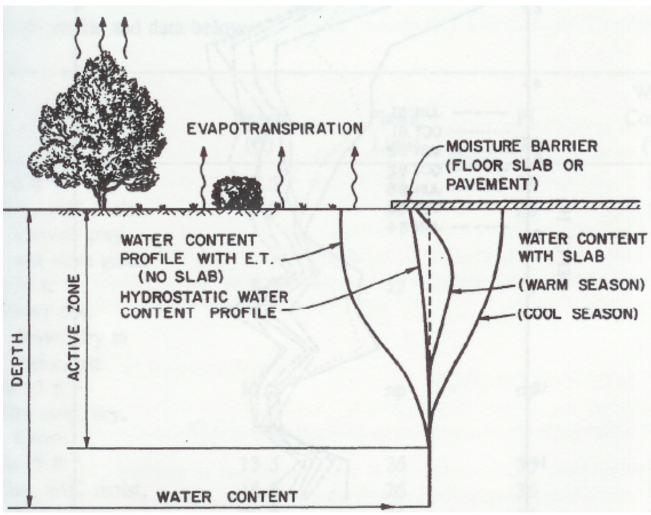

Figure 2. Water content profiles in the active zone (Nelson and Miller, 1992)

The measurements showed an expansion up to 1.2 m of the stabilized material's surface (after ponding), ponding increased the soil's humidity, such increase seemed to have been kept after humidifying, however, the soil's permeability didn't allow the water to seep through more than 0.90 m. Teng *et al.,* (1972) reported positive results of a ponding procedure in a clay soil in Mississippi. The soil was presaturated for 140 days, using sand drains of 6 meters of depth.

Figure 3. Expansive soil ponding by means of the "presaturation" method

McDonald (1973) analyzed if it was possible to maintain the water content of expansive materials in various test sections, employing geomembrane in the base course and vertical barriers in specific cross-sections, reporting good results. McKinney *et al.,* (1974) reported the results of the "Waco ponding project" where test sections were built so as to prove the efficacy of soil ponding and lime stabilization for the sub-grade course. Eighteen sections were selected, where the clay soil was humidified for 24 days, besides stabilizing the surface with lime to avoid water loss. The authors reached the following conclusions:

- Water did not go further than 1.2 m of the sub-grade course during the 24 day humidifying process.
- The measurements showed that the water contents below the pavement were kept constant for 13 years. There have been certain changes in the soil's humidity but they are not meaningful.

In both researches, results were satisfactory; nevertheless, the authors mention the problematic of the soil's low permeability, besides ensuring a uniform hydration of the expansive material. Poor (1978), quoted by Petry and Little (2002) analyzed the effects of presaturation and barriers to stabilize the subgrade of a slab, moreover, Tucker and Poor (1978) reported the factors that influenced humidity in different embankments. Said researchers found good results when the presaturation reached water contents of 2 to 3% above the soil's plastic limit, when constructing a foundation slab on the surface. Van der Merwer *et al* (1980), quoted by Nelson and Miller (1992) stabilized fissured soils with expansive nature for the construction of a pavement in South Africa. The soil was presaturated for 50 days, increasing the soil's grade of saturation up to a 1 m depth. Steinberg (1989) also executed the presaturation technique combined with impervious barriers, in two sections of the highway system in the state of Texas, United States, reaching a conclusion that the presaturation caused most of the estimated expansion prior to the construction after 1 month of saturation. Literature (Nelson and Miller, 1992) mentions diverse presaturation projects, where water ponding has been combined with the use of lime in the outermost layer. The purpose of combining such elements is to improve the working surface and avoid water loss of the expansive soil due to evaporation. Foreign literature mentions that the best presaturation method results have been reached in drought season. This is because water seeps through in a better way when the soil is fissured.

Figure 5. Interstate 10 Highway in the state of Texas (10highway)

Advantages and disadvantages of the "presaturation" method

To solve the expansive material problems, it is common to opt for the total substitution of the material or for a chemical stabilization of the expansive material. Even so, these methods can be expensive. The advantage that the presaturation method presents in comparison with other alternatives is its cost; this is due to not requiring specialized machinery or additional materials to stabilize the expansive soil. Another advantage of the presaturation method is the reduction of ground movement and material exploitation. These benefits help protecting the environment. Soil saturation may derive in shear strength and load capacity reduction, causing a problem in slopes and buildings. Water distribution after presaturating may continue to inferior layers, which may cause expansion deformations after the construction (Nelson and Miller, 1992).

Conclusion

Expansive soils have caused considerable damage in structures that have been founded over these expansive traits, therefore, it is imperative to know the different techniques of the expansive treatment which can be either a stabilizing product (lime, cement, grout) or in this case, presaturation. By knowing the soil's potential swell, different techniques can be applied so as to diminish the soil's expansive problem, for that, the presaturation technique is an inexpensive and quick alternative which also allows safety in the structural performance of the construction; nevertheless, more research about this topic is needed.

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