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RESEARCH ARTICLE

GAPS TECHNOLOGY TO MITIGATE THE GROWTH OF CLAYS

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ABSTRACT

Unstable clay land represent great cracking problem for light buildings over them because of volumetric instability caused by variations in moisture. A generalized solution has been to extract them and substituted by inert soil, thus they become construction trash. There are several foundation solutions to solve the problem of soil, one of which is inverted ribbed slab which generates hollow spaces between the soil and the slab in order to provide sufficient space for the soil movement to prevent damage to the construction. Based of the above concept, this work presents a sustainable and simple alternative for reducing growth of problem soils based on the inclusion of local natural gap material within its structure to reduce instability of clay land, with only previous determination of the void volume. After results, we conclude that gap material placed within the soil decreased their growth favorably and it depended on its natural void volume. In fact total vertical deformation of the soil (by volume) was decreased with only 65% of its value within the voids when the void volume theoretically should be equal to the vertical volume deformed. This is probably due growth pressure soil was redirected into the voids which probably generates greater density in the soil introduced.

INTRODUCTION

Many countries in the world have to deal with the problem of unstable clays such as Mexico, the USA, Australia, South-Africa, India and Israel among others. The constant growing of human settlements has provoked the urban stain to be extended up to agricultural lands, thus forcing to build on top of them. These soils show volumetric instability due to humidity variations. So they bring out fissures in light constructions above them (Chen, 1988). Because of the mentioned volume changes, either under or nearby to any type of foundation, the buildings may be subjected to various degrees of damages. Some of the most common problems include buckling of pavements, floor slab on grade cracking, differential movement and cracking of basement walls and buried pipes, wall cracking and even the collapse of one or more elements of the building (Kalantri, 1991). To know the growth potential of a soil is necessary wetting an undisturbed soil sample and measuring the volume increment. This test is carried out on a sample laterally subject and under normal pressure. The pressure necessary to prevent the growth of soil is known as growth pressure (Villalaz, 2004).

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Due to this problem soil, there are alternative solutions such as the removal of problematic soil to place inert material, chemical treatment of soils and construction of reinforced foundation structures capable of counteracting the effects of unstable soil (Chen, 1988). The application of high temperatures to clay land has been another treatment that has reduced the volume increase to temperatures greater than 100 ° C. This type of treatment produces a total loss of soil resistance at 400 °C (Abu-Zreig *et al.,* 2001). The introduction of polymers in soils has been another attempt to minimize growth. Such treatment reduces the growth of soil to 40% because it acts as a coating (López-Lara *et al.,* 2010). Fibers have also been used to reduce the growth of soil. Small dosage (0.25 and 0.5%) of these materials have been reduced 70% growth and was obtained with shorter fiber (Viswanadham *et al.,* 2009). Industrial waste materials mixed with other additives have also been applied to the improvement of unstable soils. This material achieved a reduction of 85% using lime (2%) and magnesium oxide (1%) (Seco *et al.,* 2011). Inverted ribbed slabs are a type of foundation that has been proposed to minimize the problem of these soils. This slab is constructed as raised floor (with void volume between the slab and the ground) and supported by beams which counteract the pressure of growth (Kalantri, 2012). The spacing between the raised slab and supports (girders placed on clay land) depends on the growth potential of the soil and the applied load. The voids provide the means of growth pressure relief. It has also proposed a flooring system with cavities, which has a lightweight section built with plastic tubes (middle section) that are located between the soil and the slab and are filled with sand or other material. Thus when the clay grows, its volume increase is accommodated into these spaces and thus the growth pressure is reduced. These types of foundations are expensive (Patrone and Prefumo, 2005). Based on the above, if we start from the void volume required by the problem unstable soil in inverted ribbed slab, we can say that theoretically this volume must be equal to the volume of the gap material placed within the soil. Then, in this research we use a gap natural material in order to present a simple solution to the instability of clays. In this work a universal natural earthy gap material was added into the soil with the aim of placing void spaces that can be filled when the growth appears and therefore, decrease the vertical volume increase. Porous solids include two types of porous bodies (i.e., natural and artificial). Natural porous solids can be found universally, such as bones that support the bodies and limbs of animals and human beings, plant leaves, wood, sponge, coral, pumice and lava. Lava is a sort of natural porous material that can be used in construction or for creating artwork. Artificial porous materials can be subclassified further into porous metals, porous ceramics and polymer foams (Liu and Chen, 2014). About earthy porous materials, scoria and pumice have several similarities. They are both volcanic rocks (often pyroclastic) and they contain vesicles. Vesicles in pumice are usually smaller and more irregularly shaped. Pumice is a very lightweight material that usually floats in water. Scoria is lightweight also but it sinks in water. Its vesicles can be much larger than vesicles in pumice are. Scoria is often glassy just as pumice. Fresh scoria can be distinctly pitch black and shiny. Older scoria is duller and brown or even reddish due to oxidized iron. Scoria contains much more iron than average pumice which contains more alkali metals (potassium, sodium). Iron gives black color to fresh scoria (Le Maitre, 2005). Pumice, scoria, tuff and volcanic cinders used for concrete lightweight aggregate are naturally occurring porous or vesicular lava and ash (Lamond and Pielert, 2006). Normally, the concrete aggregates are dry and absorb a significant amount of water from the matrix (up to 30% by weight for some types of aggregates) (Alexander *et al.,* 1999).

TESTS AND EXPERIMENTAL METHODS

Identification of the unstable clay land and gap material used*:* Geotechnical identification of the unstable clay land was made such as gradation test (ASTM D422-63, 2007). This was done to know the grain size distribution and the proportion of sizes of its constitutive particles. Then, the liquid and plastic limits were determined (ASTM D4318-10, 2010), as well as the Shrinkage limit (ASTM D 2427-04, 2008). With this information, the soil was classified by the Unified Soil Classification System (USCS) (ASTM D 2487-93, 1993). Its specific weight and specific gravity were obtained (ASTM D 2854-10, 2010). Soil moisture was obtained (ASTM D2216-10, 2010). After identifying the natural unstable soil we proceeded to obtain the particle size of the gap material (Figure 1). Gap materials (scoria) of sand size were used (ASTM D422-63, 2007). The size of gap material between 0.074 (200 mesh) and 4.76 mm (4 mesh) was used in this work. Dosages of gap material were 6, 10 and 15% on the dry weight of the clay land.

Experimental study*:* Then we proceeded to mix the unstable clay land with different dosages of gap material. After making the mixtures, the material was placed with the same specific weight and moisture of the natural unstable clay land within a test ring (Figure 2) for the assay of growth (ASTM D4546-03, 2003). The objective was to observe the decrease of the growth. In the same test we determine the growth of the natural soil (Figure 3). Then we proceeded to determine the approximate natural volume of voids of material used (ASTM C29/C29M-09, 2009). Gap material used was a natural volcanic aggregate (scoria). First, we obtained the dry gap material after placing in the oven to 100 degrees Celsius. After a certain amount of dry gap material (Ws) were placed in a volume chosen into a graduated cylinder. Then we introduce water into the cylinder in the volume occupied by the gap material and determine the weight of the gap material and water (Ws +Ww) (Figure 4). In theory, the difference in the two weights is the weight of water that occupies the void volume (Wv) of gap material plus the absorbed water weight (Wa) by the gap material (Alexander *et al.,* 1999), (Equation 1).

$$Ws+Ww - Ws = Wv + Wa \quad (1)$$

Then, to determine the amount of absorbed water (Wa), we tested the Absorption assay of void aggregate. Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the void spaces within the constituent particles, compared to the dry condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential (ASTM C127-12, 2010). In this test the material remained submerged for 24 h, then it was drained and its weight determined. So absorbed water (Wa) is the subtraction of drained and dry material weight (Ws). With the absorbed water (Wa) value we determined the amount of water that occupies the void volume of material (Wv) using equation 1.

RESULTS

Geotechnical properties of unstable clay land: By gradation analysis (ASTM D422-63, 2007), the clay land was a material with fines, since 98.55 % of its particles went through a sieve 200 (0.074 mm), and 1.45% of sands. The liquid limit was 72 % and the plastic limit of 30.6%, thus the plastic index was 41.4% (ASTM D4318-10, 2010). From these results, the clay land can be classified as high compressibility clay (CH) according to the Unified Soil Classification System (USCS), (ASTM D 2487-93, 1993). The volumetric shrinkage limit was 9.8% (ASTM D 2427-04, 2008), specific weight of 14.68 kN/m^3 and specific gravity of soil as 2.55 (ASTM D 2854-10, 2010) and natural moisture was 11.2% (ASTM D2216-10, 2010). Index properties of clay were of growth or expansive type (Chen, 1988).

Determination of the decrease of growth soil: Figure 5 shows the decrease in growth behavior. We observed that 6%, 10% and 15% of gap material decreased 1.75%, 2.8% and 3.45% respectively of natural growth clay land (16.4%). The average diameter and height of odometer used were 7.65cm and 2.0cm respectively (ASTM D4546-03, 2003), so volume of soil was 91.927cm^3. The dry weight of clay land used was 142.67g approximately.

Table 1. Calculation of the void volume of gap material (scoria)

Measured parameter	Result
a) weight of dry material (Ws) + cylinder (Wc)	99.32g
b) weight of water (Ww) + dry material (Ws) + cylinder (Wc)	118.37g
c) weight of cylinder (Wc)	41.59g
d) weight of dry material (Ws)=a-c	57.73g
e) volume occupied in the cylinder	47 ml
f) weight of gap material drained + cylinder	109.9g
g) weight of water (Ww) =b-a	19.05g
h) weight of water that occupies the void volume (Wv)=b-f	8.47g
i) weight of absorbed water (Wa)=f-a	10.58g

Table 2. Void volume of material vs vertical growth decrease

Gap material used (weight and dosage)	Volume material	Used Void volume material (14.67% of volume material)	Experimental Growth decrease (%)	Experimental Growth decrease (ml)
8.56g (6%)	6.96ml	1.02ml	1.75%	1.6ml
14.26g (10%)	11.6ml	1.7ml	2.8%	2.57ml
21.4g (15%)	17.42ml	2.55ml	3.45%	3.17ml

Figure 1. Natural gap material (scoria)

Figure 2. Gap material with unstable clay land within a consolidation ring

Figure 3. Growth test for unstable clay land with natural material

Figure 4. Weight of water and natural gap material in the volume occupied by the material

Determination of the void volume material: Table 1 shows the measured parameter of gap material to obtain their void volume and Absorption parameter. From the table 1 the Absorption (i/d) of gap material was 18.32%. It is very important to note that the water volume of voids was only 14.67% (h/e) of the total volume of gap material. Then in Table 2 we determine gap material volume used in each dosage (% amount of dry weight gap material) using the data in Table 1(dry weight and volume of total gap material used, "d" and "e" respectively), to obtain the void volume used (14.67% from volume gap material). In addition, we obtained the reduction of vertical growth volume (ml) based on the volume of the clay land (91.927cm^3) used. We started from the hypothesis that the increased soil volume was equal to the void volume and the results (Table 2) showed that the void volume occupied in the gap material was lower than vertical volume decreased for all dosages. This study shows that the decreased increased volume requires only 65% approximately of its value in holes. This is probably due growth pressure soil was redirected into the voids of the material placed which probably generates greater density in the soil introduced into the holes and thus less volume compared to the experimental vertical growth decrease volume of soil (without gap material). The study also shows that the volume of voids existing in the natural gap material was relatively low (14.67%), so if there is greater void volume in a material (natural or trash synthetic) have greater abatement for growth clay land. So considering for example the dosage of 10% material and a natural or synthetic void volume four times greater of 58.7% (14.67%x4), the growth abatement clay land will be 11.2% (2.8%x4).

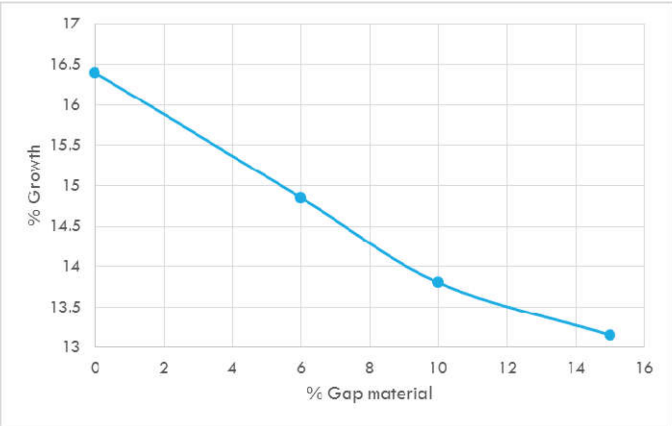

Figure 5. Decrease in growth clay land using gap material

Conclusion

We conclude that natural gap material placed within the unstable clay land decreased their growth favorably, whose magnitude depended on the void volume of structures. Even when the natural elongated vesicles of material (void space of approximately 14.67% of their total volume) are long, narrow and irregular, the reduction of vertical growth was significant. Above due probably growth pressure of clay land favored the introduction of clay land into small holes. In theory the reduced vertical growth of clay land would have to occupy the same volume within gap material however this study showed that the void volume occupied in the material was lower than vertical volume decreased of clay land for all dosages, namely the decreased increased volume requires only 65% approximately of its value in holes. This is probably due growth pressure soil was redirected into the voids of the material which probably generates greater density in the soil introduced into the holes and thus less volume compared to the experimental vertical growth decrease volume of clay land (without gap material). Therefore, according to the natural growth of the clay land we may include gap materials with the amount of void volume required for such growth. On the other hand, we note that if we previously determined the void volume of the material used, we can know approximately the maximum decrease of soil growth. Surely a more uniform particle size in natural gap material can provide more void volume. In this paper we demonstrate that the incorporation of natural gap materials in the unstable clay land can be a sustainable, reliable and simple solution for reducing growth. This research shows for the first time a Gaps Technology using a variety of local natural or trash synthetic gap materials to reduce instability of clay land, with only previous determination of the void volume, and so we do not waste clay land.

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