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EFFECT OF ROCK FRAGMENTS ON ENGINEERING AND PHYSICAL BEHAVIORS OF CLAY SOILS

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ABSTRACT

Soils that contain rock fragments are widely distributed throughout the study area (Semel and Bakoz sites). Albeit, this component imposes profound effects on soil physical and engineering properties, its role is sporadically researched and there is contrasting response to this component. Consequently, the current study was proposed to quantitatively describe compressibility, water transport and water retention of soil rock mixtures prepared from two background clay soils and rock fragments of different rock characteristics in form of repacked soil columns or specimens. The results indicated that an increase in rock fragment content resulted in a decrease in soil void ratio and consequently caused a reduction in compression index. This parameter also tended to decrease with an increase in rock strength. It was also noticed that there is a fluctuating increasing trend in saturated hydraulic conductivity to a critical level of soil rock content. On the other hand, it was revealed that the rock fragment size had not an obvious effect on the values of the saturated hydraulic conductivity. Additionally, the results indicated at a fixed suction there is a steady decrease in retained amount of water with an increase in rock fragment contents from 0% to 50% regardless of the rock size. Furthermore, the ratio of transmitting pore to non-transmitting pores and that of macrospores to the sum of mesopores and microspores tended to increase with an increase in rock fragment to a certain limit.

***KEYWORDS*:** Rock Fragments, Compressibility, Soil Water Retention, Hydraulic Conductivity, Transmitting Macropores.

1.INTRODUCTION

Rock fragments are widespread in soils owing to soil-forming processes besides human activities. This soil constituent can be found in both erosive and sedimentary landforms. Hence, soils with large amounts of rock fragments really compose a significant part of the land resources (Niu et al. 2019). The compressibility of soil is a measure of the relative volume change as a response to a stress change and reflect the interaction of types and sizes of particles constituting the granular soil matrix. This interaction may be affected by the soil gradation, the content and type of the fine and the coarse particles together along with the void ratio (Fan et al., 2022; Yin et al., 2016; Chang and Yin 2011). With a gradual increase in soil coarse material content, the coarse particles dominate and the nature of the mixture will be governed by the coarse-grained particles. Contrary to this phenomenon, the influence of the fines on the mixture properties starts to weaken gradually (Li et al., 2022).

Watabe et al. (2011) performed odometer tests on scoured clay sand mixtures and observed that that the compression index (Cc) tended to increase with an increase in fines content over the range from 30% to 95%, and C_C remained stable for fines content smaller than 30%. For a soil rock mixture with a small amount of fines, the fine particles would fill the pores among the coarse particle, causing a less rock fragment breakage. Additionally, fine particles within the voids inhibit rock fragment slippage or rotation giving rise to lower compression index. In contrast, when the percent of fines becomes more than 20%, the rock particles will govern the soil rock mixture leading to higher compressibility index (Xu et al., 2009).

Kurnaz et al. (2016) reported that numerous empirical formulas were developed based on regression analysis to estimate the compressibility parameters depending on input parameters like natural water content, initial void ratio, liquid limit and plasticity index. Developed models will provide time saving and reduce the workload. Fan et al. (2022) elucidated that soil permeability along with soil compressibility are the key engineering properties which can affect seepage, consolidation rate, settlement, etc. Intuitively, the relationship between rock fragme ntsand soil hydrological processes is complicate and requires more international research efforts (zhang et al., 2016). They also reported that the influence of rock fragments on soil hydrologi cal processes are inconsistent.

For example, Wegehenkel et al. (2017) have noticed that presence of rock fragments in the soils, leads to a decrease in Ks values. On the other hand, Thoma et al. (2014) observed opposite trend. Furthermore, Khetdan et al. (2017) observed that even for the same soil, increasing and decreasing trends can be detected based on a threshold soil rock content.

Wu et al. (2021) unveiled that with an increase in the rock fragment content, the saturated hydraulic conductivity (Ks) exhibited an overall fluctuating downward trend over the range of soil rock mixture percentage from 0 to 40%. This parameter attained the lowest value. When the rock fragment content was 40%. In contrast, they observed that the rock fragment size had insignificant impact on Ks. Naturally, the presence of rock fragments can cause reduction in soil hydraulic conductivity through reducing the cross-sectional area available for water flow (Novak et al. 2011). However, rock fragments can create cavity (lacunar) pores at the rock fragment–fine earth interface that could become paths for preferential water flow and, as consequence it gives rise to an increase in soil water movement. (Sauer & Logsdon 2002). By contrast, numerous scholars revealed that an increase in rock fragment content gives rise to an increase in soil transmission pores and promoting the formation of preferential flow (Cheong et al. 2009).

Cousin et al. (2003) elucidated that the soil available water will be overestimated by 39% when the soil rock fragments content is not considered. One indirect influence of coarse rock fragments is reduction in small pores within the soil (Sekucia et al., 2020). They also concluded from their study that each of the permanent wilting point, field capacity and available water content were negatively correlated with soil rock fragment content. Gargiulo et al. (2016) observed from image analysis that the developed pore system showed a decrease and then an increase in soil porosity with an increase in soil rock content. They highlighted the threshold value at which there is a reverse in trend depends on soil type and soil swelling characteristics. Li et al. (2020) measured the soil moisture characteristic curve for different textures soils with soil rock content varying between 0 and 100%. Their findings indicated that the soil total porosity tended to decrease with increasing rock content. Like the total porosity, the fractions of storage decreased steadily, while the proportion of transmission pores showed opposite trend. As there is little reported research on the engineering properties of soil rock mixture, the current investigation was proposed to target the following objectives.

1) To describe the functional relationship between compressibility index and soil rock content
2) To assess the effect of rock fragments content and size on the saturated hydraulic conductivity of soil rock mixtures
3) To study the effect of rock fragments on pore size distribution and pore functional characteristics of two soils.

2. MATERIALS AND METHODS

2.1. Experiment I.

2.1.1. The study Factors and their Levels

This experiment was designed to study the effect of soil rock fragments content and rock fragment compressive strength of soil rock mixtures using two clay soils (Semel and Bakoz sites). The study factors encompassed the following levels:

1) Factor L (soil rock fragment percentage
L_1=0%; L_2=5%; L_3=12.5%; L4=25%; and L5= 37.5%;
2) Factor R (rock compressive strength):
R_1 = 17.6 MPa R_2= 67.4 MPa and R_3=119 MPa
3) Factor T (Type of soil) T_1 = silty clay soil and T_2= silty clay loam soil

2.1.2. Experiment Setup

1. For each treatment combination, a consolidation ring 7.5cm in diameter and 2 cm in height was taken and then its weight was recorded (Das, 2018)
2. The soil rock mixture was compacted at optimum water content using the modified compaction test and the specimen from the mould was ejected using a sample extractor. Thereafter, the ring was pressed to the ejected specimen such that the top and bottom surfaces were projected above and below the edges of the ring to facilitate trimming.

3. The specimen was assembled in consolidation cell by centering two soaked porous stones, on the top and bottom surfaces of the test specimen. Filter papers were also placed between the porous stones. The cell was filled with water for complete saturation.
4. The loading cap was placed on top porous stone. The dial gauge was then adjusted to a zero reading after adjusting the loading device.
5. The first load was applied to give a pressure intensity of kPa and the dial gauge reading was taken after equilibrium.
6. The loading process was repeated include loading pressures of 6.69, 11.097, 22.216, 44.388,110.97,221.94,332.91,443.88 and 554.85 kPa.
7. Upon completion of the final loading stage, the consolidometer was dismantled after the release of this load.
8. The soil specimen along with the ring were cleaned with a soft tissue to remove free water
9. The weight of the oven dried specimen was recorded after placing the specimen inside the ring in an oven.
10.The oven dry mass of the specimen along with the final soil water content for the specimen was (wf) calculated from the weight of the specimen before and after drying. It is commendable to mention that the focus was on compression index, therefore, time settlement curve was not established at a given loading stage. Additionally, when the maximum load was reached no unloading was carried out.

2.1.3. Calculations and Plotting

1)The height of the solid in the ring (Hs) was determined from:

$$Hs = \frac{W_s}{AGs\,\rho_w} \qquad \text{--------1}$$

where Ws = oven dry mass of the soil in the ring(g); A= ring area (cm^2)

2) The change sample height (ΔH) was determined during the first loading increment from the first two successive dial readings. The change in sample height was used to calculate the height of the sample under the loading at equilibrium according to:

Hf=Hi -ΔH -------2

3)The height of the voids under the first loading at equilibrium was calculated as follows:

Hv = Hf –Hs ------3

4) The void ratio that corresponded to the first applied load was calculated from:

$$e = \frac{Hv}{Hs} \qquad \text{-------4}$$

6) This step was repeated to find the void ratio against each applied load (P).

6)The graph of void ratio versus applied load is plotted on a semi logarithmic paper.

7) The compression index (Cc) was determined from the slope of linear (virgin) portion of the curve according to:

$$C_c = \frac{e_1 - e_2}{\log(\frac{P_2}{P_1})} \qquad \text{-------5}$$

8) From the point where the curve curvature was maximum, a tangent and a horizontal line were drawn and the resulting angle was bisected. Thereafter, the linear portion of the curve was projected backward. The point of intersection of the bisector and the projected line gave the pre-compression stress.

2.2. Experiment II: Water Transport Study

2.2.1. The Study Factors and their Levels

This experiment was designed to study the effect of soil rock fragment content and rock fragment size on saturated hydraulic conductivity of two background soils using constant –head methods. The study factors encompassed the following levels:

1) Factor L (soil rock fragment percent)

L_1=0%; L_2=5%; L_3=12.5%; L_4=25%; L_5= 37.5%; and L_6= 50%

2) Factor S (rock size):

S_1 = 4.75 – 9.0 mm and S_2= 9-20 mm

3) Factor T (Type of soil):

T_1= silty clay soil and T_2 = silty clay loam soil

2.2.2. Experimental Setup

Bulk soil samples were collected from the surface layer (0.0 -0.50 m) of two clay soils namely Semel (36o 24 20N and 44o 34 11E), and Bakoz village (36o 55 49.63N,43o 01 25.38E), sites in Duhok province. (Fig.1)

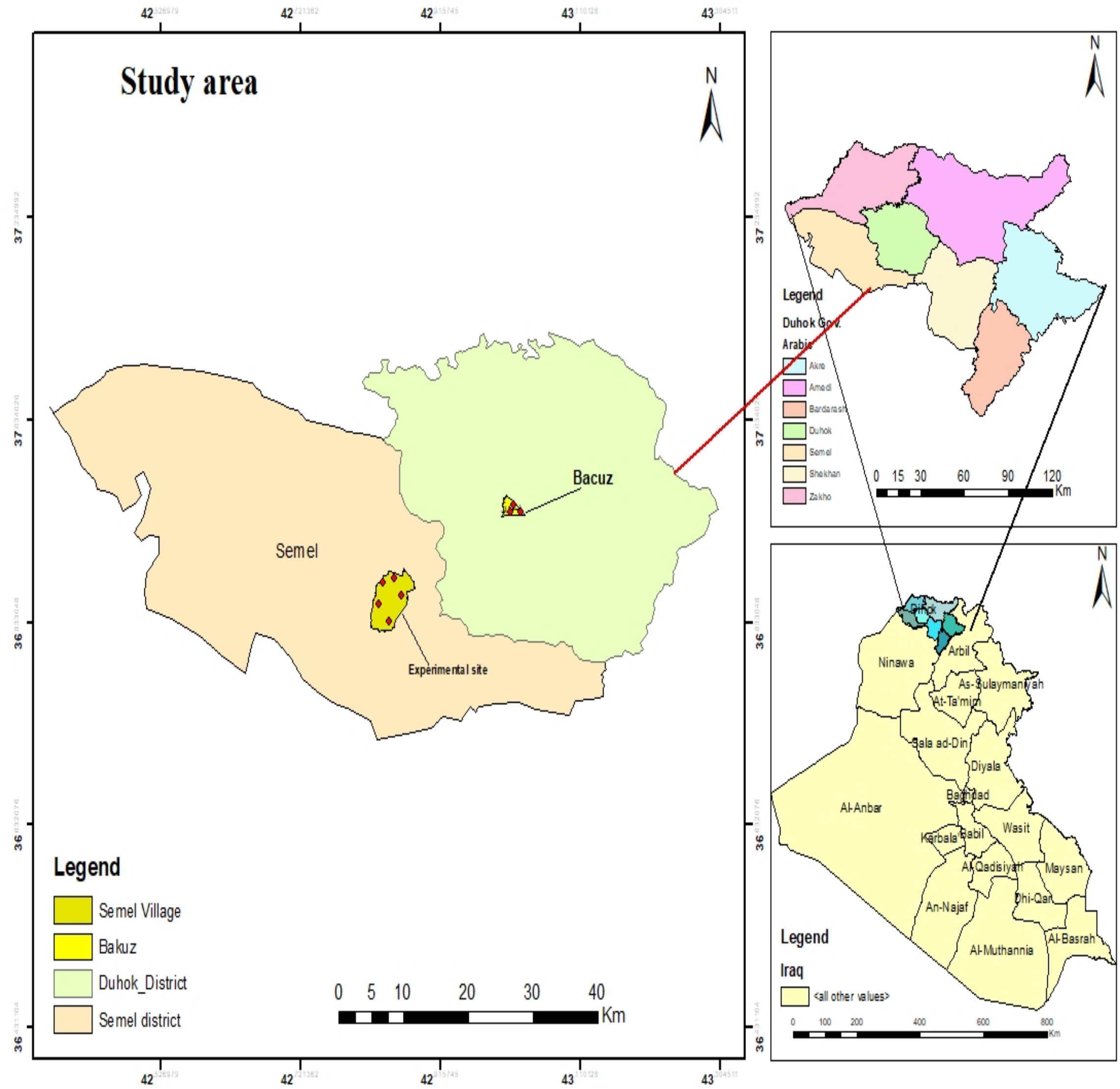

Fig. (1): Map of study sites.

Table 1 presented some selected physical and chemical properties of the soils under investigation. The soil sample from each location was air dried and ground gently to pass through a 4.75- mm sieve and kept until use. In the meantime, bulk samples of rock fragments with a diameter ranging from 4.75 to 20mm were collected from the surrounding sites to prepare soil rock fragment mixtures.

Each soils was mixed with predetermined quantity of the rock fragments to give four rock fragment contents (0, 12.5, 25, and 37.5%) on mass basis. Table 1and 2 presented some selected physical and chemical properties of the background soils and the rock sample under investigation.

Table (1): some selected physical and chemical properties of the investigated-soils

Properties		Unit	Average measured values	
			T1	T2
Particle size distribution	Clay	g kg^{1}	526	281
	Silt	g kg^{1}	400	545
	Sand	g kg^{1}	74	174
	Textural Name	-	Silty Clay	Silty Clay Loam
Soil bulk Density		Mg m^{-3}	1.37	1.151
PH		-	7.95	7.94
EC		dSm^{-1}	0.223	0.275
Organic Matter		g kg^{-1}	10.29	31.2
Calcium carbonate equivalent		g kg^{-1}	166.202	305.98

Table (2): some selected properties of the rock sample under investigation.

Properties	Unit	Average measured values		
		R1	R2	R3
Rock type	-	Limestone	Limestone	Limestone
Uniaxial compressive strength	MPa	17.6	67.4	119
Dry density	Kgm^{-3}	2127	2681	2680
Water absorption	(%)	8.89	0.24	0.27

Prior to the experiment, metallic columns containing soil were prepared, each having a diameter of 100 mm and a height of 400 mm. A perforated metallic base was attached firmly to the lower end of each column. The columns were held in upright position with the aid of wooden frame manufactured for this purpose. Overflow technique was used to maintain a constant head of 80 mm above the soil surface. The soil rock mixture was then packed in the plastic tube in form of three increments with the aid of a special hammer constructed for this purpose, the idea was to restore the fine materials its insitue density Circles of filter paper was laid of the soil surface and its bottom to keep the soil surface undisturbed and to avoid migration of soil particles from the bottom The columns were subjected to a series of wetting of wetting and dry cycles to allow the fine materials to restore its natural structure and bulk density partially. After the wetting front has reached the base of the columns, the effluent was collected every 30 minutes and the volume measured until the flow rate became nearly constant.

2.2.3. Calculations

The saturated hydraulic conductivity under each treatment was determined by applying the Darcy's law:

$$K \frac{QL}{A \Delta H} \qquad \text{-------------6}$$

Where:-

K = the soil hydraulic conductivity of the soil-rock fragment mixture (cm hr^{-1}); Q = the flow rate (cm^{3} hr.$^{-1}$)

L = the length of the soil column (cm)

A = the cross-sectional area of the soil column (cm^{2})

ΔH = Difference in hydraulic head of the upstream and downstream faces (cm)

The mean value of the soil hydraulic conductivity was corrected for temperature according to:

$$K_{25^\circ c} = \frac{K_{T^\circ c}\ \eta_t}{\eta_{25^\circ c}} \quad \text{...........7}$$

Where η_t and η_{25} is the viscosity of the permeant at the temperature of measurement (T) and at a standard temperature of 25 ^oC.

2.3. Soil Water Retention

2.3.1. The Study Factors and their Levels

This experiment was conducted to study the impact of soil rock content, rock size on water retention of two studied Clay soils (from Semel and Bakoz sites). Hanging water column was used to construct the drying curve for different soil rock mixtures over a range of soil moisture tension from 0 to 10 kPa. The treatment combinations encompassed two base soils (T1=silty clay and T2 =silty clay loam rock content (L1=0%; L2=5 %; L3 = 12.5%, L4=25%; L5 = 37.5% and L6 =50%) and two sizes of rocks (S1=4.75 – 9.5 mm and S2 = 9.5 – 20 mm). The source of rock fragments was crushed limestone of medium strength. Tables 1 and 2 describe some selected properties of the investigated soils and the rock fragments employed in the experiment.

2.3.2. Experimental Setup

The hanging water column system was composed of a fritted glass funnel having a top diameter of 10 cm and average pore diameter of 5 μm, which was connected to an outflow burette. Disturbed soil rock mixture was packed in the funnel to depth of 4 cm and consolidated by using the same number of tapping. Before imposing matric potential, the specimen was saturated with distilled and deaerated water via raising the open end of the tygon tube to the center of the sample until equilibrium was reached. Thereafter the specimen was subjected to a series of matric potential in the range of 0 -10 kPa. Under each suction, the open end of the tube was lowered to a height equivalent to the imposed matric potential to allow drainage of soil water. When soil water stopped flowing, the soil was removed for soil moisture determination and another sample was used for imposing a new tension. This step was repeated before the matric potential exceeds the porous plate air entry value. By this procedure a set of datasets were obtained to plot water content versus matric potential. The test was performed in duplicate and the average values were reported.

3.3.3. Calculations

The equivalent pore diameter for soil rock mixture with different sizes and different rock content was calculated as follows (Li et al., 2020)

$$S = \frac{300}{d} \quad \text{..........8}$$

Where S= matric potential in Pascal (1 bar=100000 Pa)

d=Equivalent pore diameter (mm)

Based on the above equation the effect of the rock fragments on proportions of transmitting pores (> 30 μm), non-transmitting pores (<30 μm), macropores (> 60 μm), and sum of mesopores and micropores (< 60μm) were studied.

4. RESULTS AND DISCUSSION

4.1. Compression behavior of soil rock mixtures

In the current study the compression index was utilized to describe the compression behavior of soil rock mixtures. The investigate soils were two soils with a wide range of clay content, Namely Bakoz soil (Clay= =28.1%) and Semel soil (Clay=52.6%). These soils were examined for their compression behavior with rock fragments size in the range of 4.5 -9.0 mm at different ratios (0%, 5%, 12.5%, 25% and 37.5%).

Prior to the odometer test, the soil rock mixture was mixed with the optimum water content, then compacted following modified proctor test. For each treatment combination, the void ratio of the specimen was plotted versus the applied vertical stress on a semi logarithmic paper. Irrespective of the soil rock content, the relation between void ratio and the applied stress was described by an exponential mode. The coefficient of determination exceeded 98% in most cases. As stated earlier, the compression index (Cc) was determined from the slope of linear (virgin) portion of the curve and the results were displayed in Figs.2 and 3.

As can be seen in Figs 2 and 3, with one exception the two host soils (control treatments) exhibited a higher compression index compared to the soil rock mixtures with rock content in the range of 5-37.5%. An increase in soil rock content results in a decrease in soil void ratio and consequently causes a reduction in compression index. These results seem to be in line with the study of Cabalar et al (2021). In a similar study Kaothon et al. (2022) have noticed that an increase in fines content caused an increase in both void ratio and compression index.

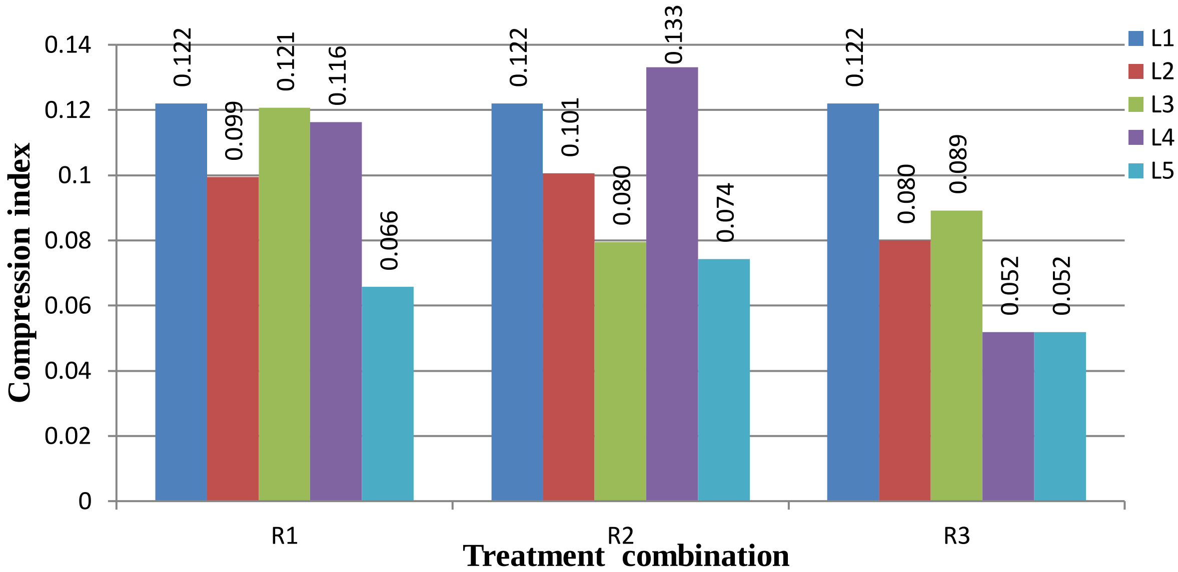

Fig. (2): Compression index of the Bakoz silty clay loam soil as affected by rock fragment content and rock strength

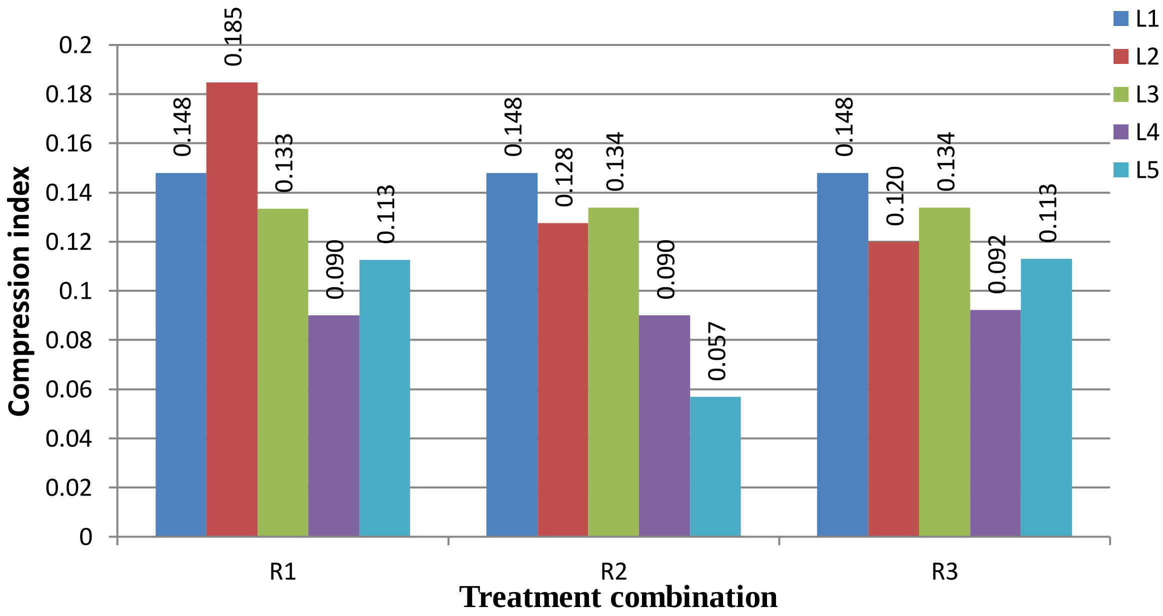

Fig. (2): Compression index of the Semel silty clay soil as affected by rock fragment content and rock strength

Based on the obtained results from oedometer test, the soil rock content of 37.5% is the most appropriate soil rock content for giving the lowest amount of settlement. It is of vital importance to take benefit from these results to select the most suitable materials for embankment construction to get the lowest amount of deformation. It is also recommended to examine the compression behavior of soil rock mixture with rock content beyond 37.5.% to show the possibility of obtaining a smaller value for compression index.

It can also be elucidated from the presented results of Figs 2 and 3 that the compression index of the soil rock mixture was affected by strength of the coarse fragments under the same level of soil rock content. The compression index tended to decrease with an increase rock fragment strength. The rock fragments with a low strength have a higher tendency to crush to smaller particles compared to rock fragments of higher strength. The particle size distribution of the soil rock mixture with low rock strength will be more modified leading to relative rearrangement and displacement of the particles. These finding are in line with results of Cai et al. (2020), who observed that change in particle size distribution is highly influenced by the stability of the soil.

4.2. Effect of Rock Fragment Content and Size on Soil Saturated Hydraulic Conductivity

Figs.4 and 5 show, the saturated hydraulic conductivity for remolded soil columns prepared by mixing predetermined quantities of rock fragments with the fine soil texture of Bakoz (T1) and Semel(T2) respectively. The idea behind this process was to attain 6 levels of soil rock content in the range of 0% to 50%. At each level, two sizes of rocks were used (S1: 4.75-9 mm and S2= 9- 20 mm). As stated earlier, the soil rock mixture columns were subjected to 5 cycles of wetting and drying to restore its natural condition.

As can be seen from presented results that these is not a steady change in saturated hydraulic conductivity over the entire range of the soil rock content. Overall, there is a fluctuating increasing trend in saturated hydraulic conductivity to a critical level of soil rock content. These results are consistent with the findings of Wu et al. (2021) who, found that the measured saturated hydraulic conductivity did not increase or decrease uniformly with an increase in the rock fragment content over a range of soil rock content ranging in between 0% and 40%.

The critical levels were 5%, 12.5%, 25% and 37.5% under treatment combinations of T1S1, T1S2, T2S1 and T2S2 respectively. The increase in saturated hydraulic conductivity with soil rock content up to 37.5% may be due to an increase in the proportion of macropores. These findings support the results of Chow et al. (2007), who observed that rock fragment treatment had 21.5% pores > 148μm in diameter, as compared with 17.6% under the control treatment. The increase in macropores may have been responsible for the significant increase in saturated hydraulic conductivity. It is commendable to point out to the fact that theoretically, naturally, the presence of rock fragments lessens the cross-sectional area available for the water flow, thus causing reduction in the hydraulic conductivity (Novak et al. 2011). Unlike this concept, rock fragments can create lacunar pores at the rock fragment–fine earth interface that could become paths for preferential water flow and, thus, increase the soil-water movement (Verbist et al. 2009).

With no exception, under 50% of soil rock content, all the treatment combinations exhibited the smallest value for saturated hydraulic conductivity. In a similar study by Wu et al., (2021), the saturated hydraulic conductivity of soil rock mixtures attained the lowest value at a soil rock content of 40%. The reduction in saturated hydraulic conductivity at this level of soil rock content can be attributed to a decrease in cross section area available for water transmission. In this context, Ravina and Magier (1984) demonstrated that increasing soil rock fragments content causes reductions in the water-conducting area available for water transmission and as a result there will be a drop in the value of saturated hydraulic conductivity.

Furthermore, the results of the current study indicated that the rock fragment size had not an obvious effect of the values of the saturated hydraulic conductivity. It was observed that this finding is in concordance with the findings of numerous researchers (Ma et al. 2010; Gargiulo et al. 2016).

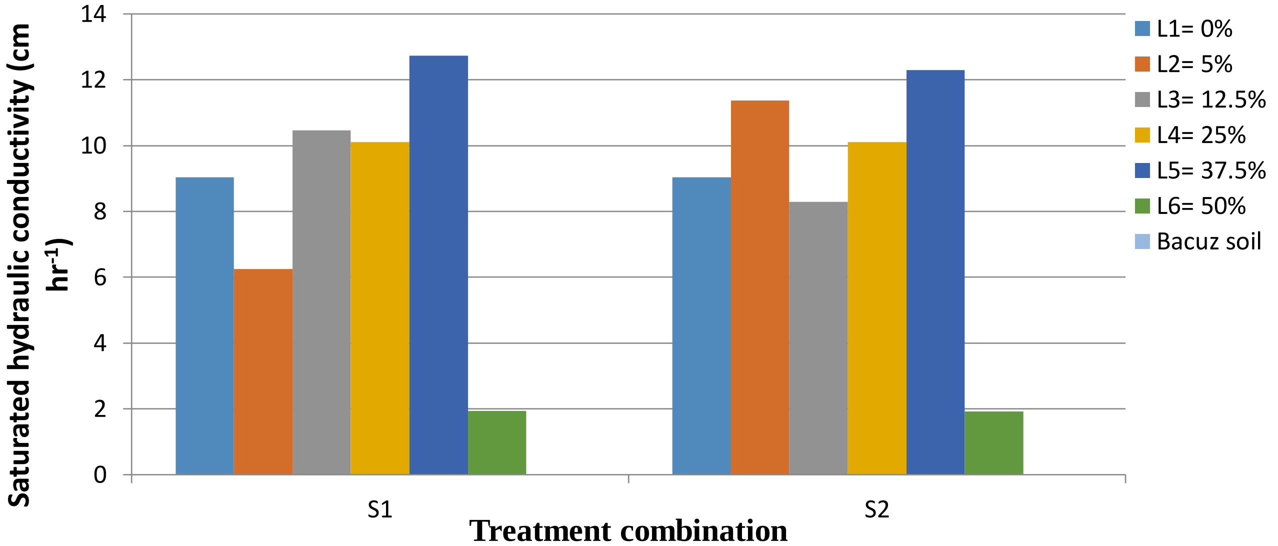

Fig. (4): Saturated hydraulic conductivity of remolded Bakoz background soil affected by rock fragment content and rock fragment size

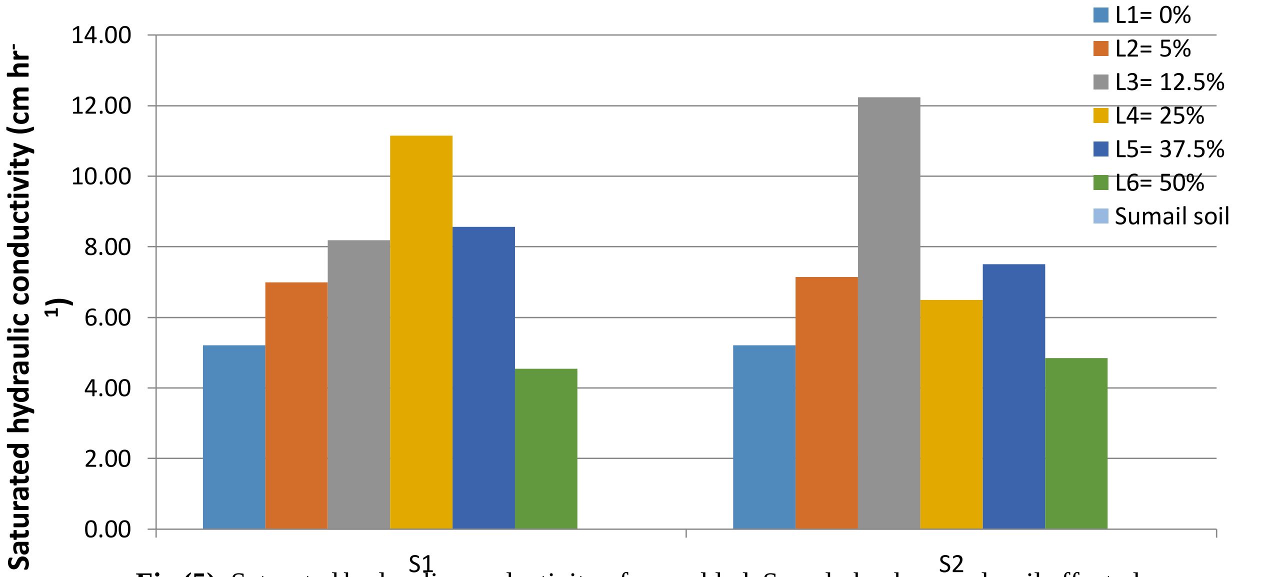

Fig.(5): Saturated hydraulic conductivity of remolded Semel background soil affected by rock fragment content and rock fragment size

4.3. Soil Moisture Retention at Low Suctions

Fig.6 portrays the impact of rock fragment contents and rock fragment sizes on water retention of two soils at low suctions in the range of 0 – 100 cm H_2O (0 to 10 kPa). As the figure shows, at a fixed suction there is a steady decrease in retained amount of water with an increase in rock fragment contents from 0% to 50%. Furthermore, the curves belonging to different suctions tend to converge with an increase in rock fragment contents. For the Semel soil, there is a sharper drop in water retention at a given suction due to changes in rock fragment content compared to the clay loam soil. The higher soil porosity for the former soil compared to the latter may be responsible for this phenomenon. It is also praiseworthy to mention that rock fragment sizes (4.75 - 9 mm and 9 – 20 mm did not exhibit noticeable trends.

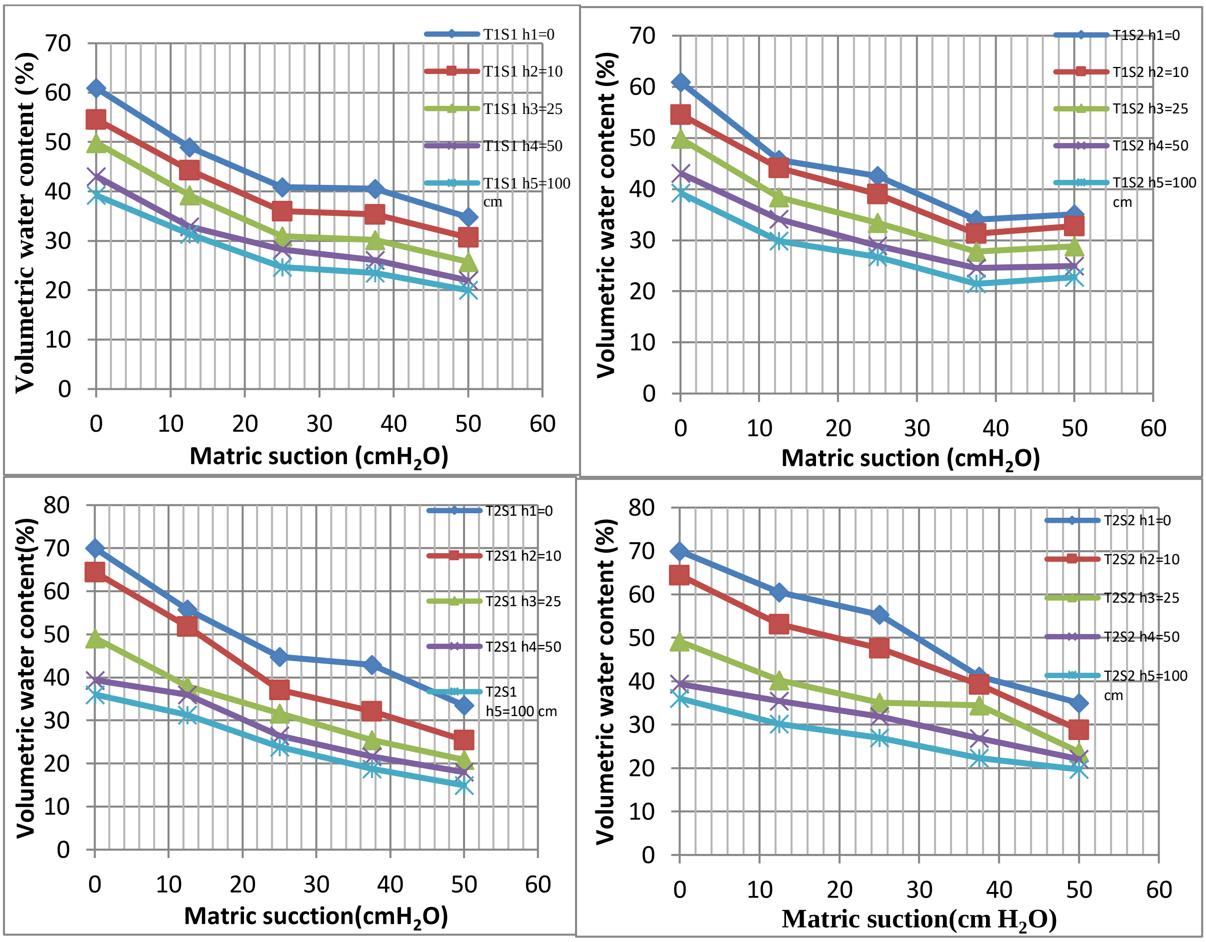

Fig. (6): Soil water retention of two background soils as affected by rock fragment content and rock fragment sizes

The results presented in Fig.7 indicate that there is a gradual decrease in soil porosity with an increase in rock fragment content in both soils and with the two rock sizes. The low porosity of the incorporated rock fragments (about 2%) may be a plausible reason for this phenomenon. This result is in accordance with finding of Parajuli et al., 2017, who observed that rock fragments have a low ability to retain water, causing stony soils to exhibit low holding capacity. Although the rock fragments content was changed by equal increments, the reduction in soil porosity was not linear in response to increasing rock fragments by equal increments. This discloses that the low porosity of the rock fragments is not the only factor governing the total porosity of soil rock mixtures. The rearrangement of soil particles may be an additional factor affecting pore size distribution. Under certain conditions, coarse fragments can generate new pores at the boundary between soil matrix and coarse fragments (Tokunaga et al., 2003).

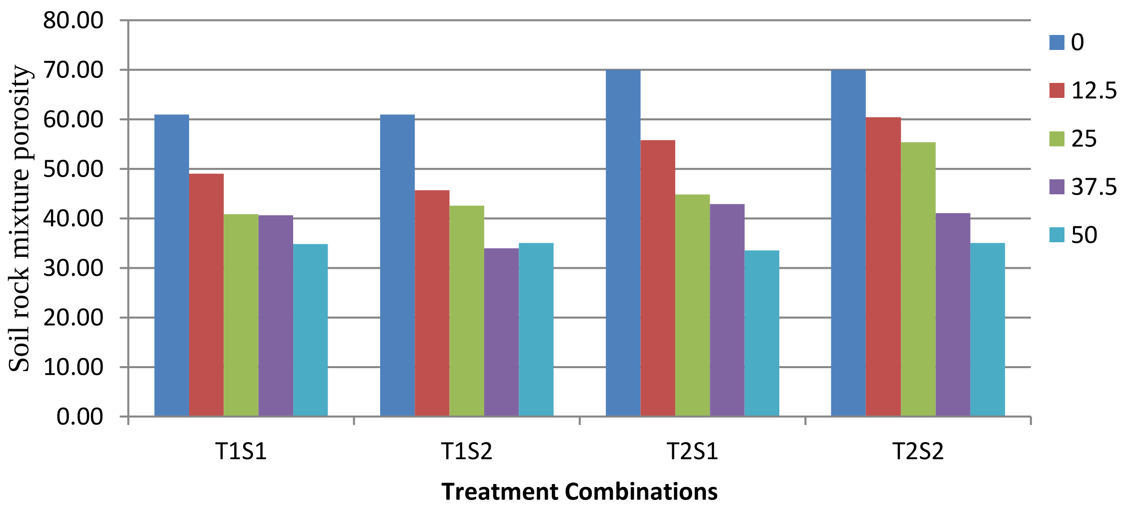

Fig. (7): Effects of rock fragment content and rock fragment size on porosity of two background soils.

Fig.8. illustrates the effect of content and size of coarse fragments on ratio of transmitting pores (d >30 µm) to non-transmitting pores (d <30 µm) of two studied soils. As can be seen in Fig. 8, that the ratio of transmitting pores to non-transmitting pores responded differently to the applied treatment combinations. There is a steady increase in the ratio with an increase in rock fragment content under T1S1, while this ratio tended to increase with an increase in rock fragment up to 25% under T1S2 and T2S2, beyond which started to decline. However, the overall results under most of the applied treatments indicate the ratio of transmitting pore to non-transmitting pores tended to increase with an increase in rock fragment to a certain limit, meaning thereby, rock fragment incorporation is encouraging soil aeration and soil water movement to a certain limit. These results disagree with findings of Jiangwen et al., 2020, who observed that the incorporation of coarse fragments to background soils can encourage the development of soil transmission pores and decrease the proportions of soil storage pores besides residual-bonding pores gradually. The difference in degree of compaction of the tested specimens may responsible for contrasting soil water retention behavior may be due difference in sate of compaction. For instance, Ravina and Magier (1984) reported that increasing rock fragments causes a decrease in soil saturated hydraulic conductivity in uncompacted state, whereas the opposite trend can be found under a compacted state.

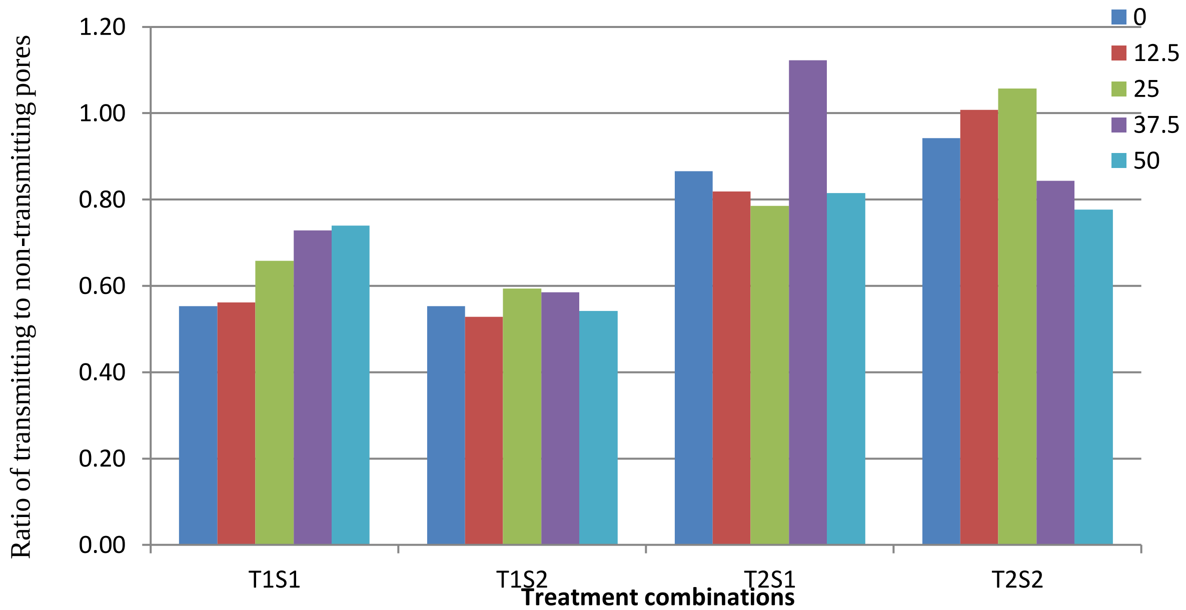

Fig. (8): Effects of content and size of coarse fragments on ratio of transmitting pores to non-transmitting pores in two background soils

Like soil porosity, the ratio of transmitting pores to non-transmitting pores did not respond obviously to rock fragment sizes. To confirm the impact of rock fragment contents and rock fragment sizes on pore size distribution, the ratio of macropores (d > 60 µm) to mesopores and micropores (d < 60 µm) were also calculated under different treatment combinations and the results are displayed in Fig.9. As can be noticed in Fig.9 the ratio of transmitted to non-transmitting pores and the ratio macropores to mesopores + micropores exhibited similar treatments with minor deviations. It is interesting to note that the rock fragments are overlooked, the soil moisture retained at a given suction will be overestimated and gives rise to misleading results. This situation is particularly sound when the rock fragment has a very low porosity.

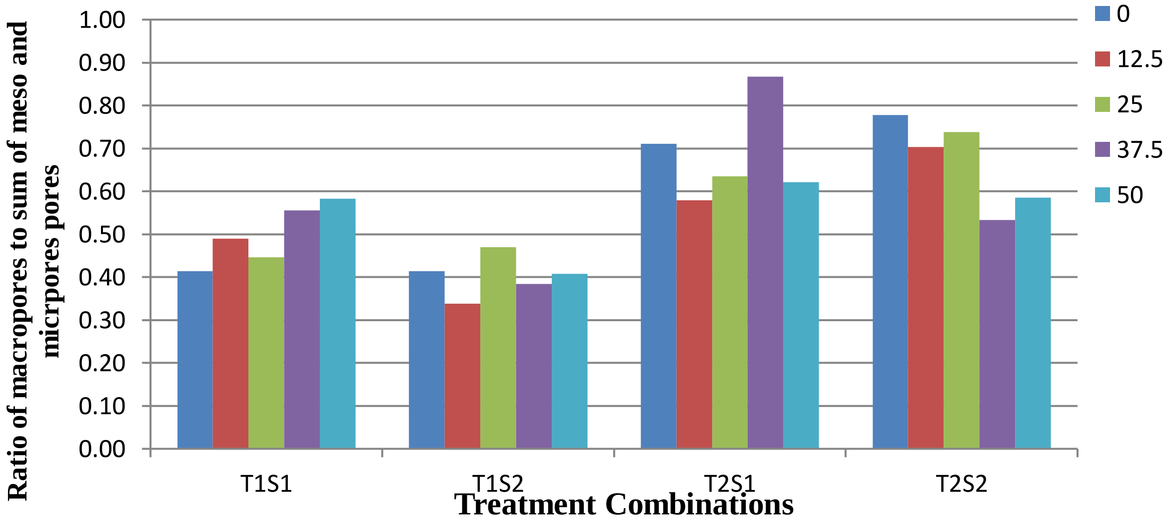

Fig. (9): Effects of content and size of coarse fragments on ratio of macropores to sum of meso and micrpores pores in two background soils.

5. CONCLUSIONS

Rock fragments characteristics impose profound effects on soil physical and engineering properties. There is an inverse relationship between rock fragment content and each of compression index and soil water retention under a given suction regardless of rock size.

The relationship between rock fragments and soil hydrological processes is complicate and requires more research efforts. Further, upon overlooking rock fragment component the soil water retention will be exaggerated.

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تأثير فتات الصخور في السلوك الهندسي والفيزيائي للترب الطينية

الخلاصة

تتوزع التربة التي تحتوي على فتات صخرية على نطاق واسع في جميع أنحاء منطقة الدراسة. وعلى الرغم من أن هذا المكون يفرض تأثيرات عميقة على الخصائص الفيزيائية والهندسية للتربة، إلا أن دوره يتم بحثه بشكل متقطع وهناك استجابة متناقضة لهذا المكون. وبالتالي، تم اقتراح الدراسة الحالية للوصف الكمي للانضغاط ونقل المياه واحتباس الماء لمخاليط صخور التربة المحضرة من تربتين طينيتين ومختلفيتين فتات الصخور ذات خصائص صخرية مختلفة في شكل أعمدة أو عينات تربة معاد تعبئتها. أشارت النتائج إلى أن زيادة محتوى الشظايا الصخرية أدى إلى انخفاض نسبة فراغ التربة وبالتالي انخفاض معامل الانضغاط. تميل هذه المعاملة أيضًا إلى الانخفاض مع زيادة قوة الصخور. ولوحظ أيضًا أن هناك اتجاهًا متزايدًا متقلبًا في الايصالية المائية المشبعة-لى مستوى حرج من محتوى صخور التربة. ومن ناحية أخرى تبين أن حجم مفصولات الصخور لم يكن له تأثير واضح على قيم التوصيل الهيدروليكي المشبع. بالإضافة إلى ذلك، أشارت النتائج عند الشفط الثابت إلى وجود انخفاض ثابت في كمية المياه المحتجزة مع زيادة في محتويات فتات الصخور من 0% إلى 50% بغض النظر عن حجم الصخر. علاوة على ذلك، فإن نسبة المسام الناقلة إلى المسام غير الناقلة ونسبة الأبواغ الكبيرة إلى مجموع المسام المتوسطة والأبواغ الدقيقة تميل إلى الزيادة مع زيادة شظايا الصخور إلى حد معين.

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پوختە

ئەو ئاخا هویرە بەر تیدا هەین بشیوەیەکی بەر فرەهـ یی بەر بەلاڤە ل جهی ڤەکولینێ. هەر جەندە ئەڤی بیکهاتی کارتیکرنەکا مەزن یا هەیی لسەر سالوخەتین فیزیکی وئەندازیاری ین ئاخی , لێ رولی وی تنی بجارەکی ل لیکولینن هاتین کرن وبەرسڤین ناکوژی بو ڤ بیکهاتیی هەی . ژبەر ڤی یەکی ئەڤ لیکولینە هاتیە پیشنیار کرن کو برەنگەکی مقدارکری و ڤەگوهاستنا ئاڤی و راگرتنا ئاڤا تیکەلا کەڤری وئاخی ئەوا هاتیە بیکئینان ژدوو ئاخین جیاواز وهویرە بەرا بتایبەتمەندین بەرا ین جیاواز ب پرکرنا ستوینن . ئەنجامان دیارکر کو بزیدەبونا باچین زناران بو ئەکەری کیمبونا فالاهیان ئاخی و بڤی رەنگی کیمبونا compression index. هەر کو هیزا کەڤرا زیدەدبیت ئەڤ دەرئەنجامە کیم دبیت دهەمان دەمدا هاتیە دیتن د ڤەکوهازتنا هیدرولیکا تێر بوی دا saturated hydraulic conductivity هەیە ئاستەك کریتیك د تیکەلا ئاخ وهێرە بەرا .ژلایەکی دیڤە هاتیە دیتن کو مەزناهیا باچین کەڤران کارتیکرنەکا زەلال لسەر saturated hydraulic conductivity نەبوو. دگەل ڤێ یەکی ئەنجامین ڤەکیشانەکا دومدەردا یو ئەکەری کیمبونەکا دومدەردا د چەندیا ئاڤا هیشتی