ASSESSMENT OF SOIL MIXING WITH CEMENT KILN DUST TO REDUCE SOIL LATERAL PRESSURE COMPARED TO OTHER SOIL IMPROVEMENT METHODS

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ABSTRACT

The soil lateral earth pressure acting on retaining or wing walls of hydraulic structures is considered the most influential loads in its structural design. The general properties of the soil foundation and backfill soil are the factors that control the cost of engineering design of these retaining or wing walls. In order to improve the mechanical properties of the backfill soil, which is reflected on the cost of new buildings or addresses soil problems of existing structures, this research compares between different soil improvement methods, to select the most effective method can easily be applied for these kinds of structures.

Many field tests were carried out to compare the retaining wall lateral resistance to backfill soil using medium sand soils as backfill material processed in all examined cases. These cases are filling sand using common compaction specifications, sand filled gabions, geogrid soil reinforcement and soil mixing with cement kiln dust.

The results of experiments showed that, using gabions is the most efficient solutions compared to other studied methods to optimize retaining walls design. In addition, soil- cement dust mix can also be used as an efficient solution with the advantage of improving soil backfill of existing retaining walls.

Keywords: Soil Improvement; Soil Mixing; Hydraulic Structures.

1. Introduction

Most of barrages in Egypt have been built many years ago using masonry bricks without reinforcement. The main problem of the masonry structures is their low resistance to tensile stresses, which appears in the sensitivity of the abutment structures to lateral earth pressure load. It is essential to protect the barrage structures due to their importance in the Egyptian irrigation system from the risk of failure due to excessive lateral earth pressure. Soil improvement is one of the most economical engineering solutions to overcome most of soil problems. Soils may be improved through mechanical effort or addition of chemical or cementitious additives. Soil mixing is considered one of the most promising soil improvement techniques. The importance of this technique will be increased especially when using waste of some industrial materials to be mixed with natural soil. **C**ement **K**lin **D**ust (CKD) can be used as a cementious material with a variety of soils to improve their engineering properties. This research assesses the reduction in the lateral earth pressure of soil mixed with cement dust compared to the induced of soil improved by compaction or geogrid reinforcement or packing in gabions.

Many researchers have studied the effect of mixing soils with CKD. IEEE-IAS Cement Industry Committee [1] stated that the CKD has been used extensively as a binder in soil stabilized base and sub-base pavement applications. It was found that the compaction characteristic of the sand was improved by adding CKD [2]. Considering the seepage control and compressive strength, cement dust was proved to have more pronounced effect on the reduction of the sand permeability and enhance its compressive strength.

The CKD can be utilized in the pavement construction as the CBR of the CKD soil mix was significant even in soaked condition. Fibers greatly affected the stress strain behavior of the CKD soil mix. The plasticity index of the soil was also reduced significantly with the addition of CKD [3-4].

The results from this research present further credibility to using CKD for soil improvement. The proposed method also can be applied for the new structures and can be used to reduce the impacts of the lateral earth pressure on the retaining walls.

2. Experimental Work & Results

Field experimental program was designed to assess the effectiveness of the suggested method compared to other common methods. Four field tests were carried out to measure the effect of backfill soil improvement method on a retaining wall. Strain due to wall bending was the indicator of the value of the backfill lateral earth pressure. The maximum strain was measured near the wall base and recorded during the filling stages. The following sections describe the properties of materials that used to compose the backfill and the retaining wall model properties.

2.1. Determination of the used material properties

Laboratory tests were done to determine the properties of the used material (sand, cement kiln dust, geotextile, geonet) as following:

2.1.1. Specific gravity

The specific gravity of sand was determined according to ASTM-C127 while the specific gravity of cement dust was determined by means of a Le Chatelier flask as described by ASTM C 188-95 (Standard Test Method for Density of Hydraulic Cement). The results are found to be 2.70 and 3.12 respectively, which indicates that the specific gravity of the used sand soil-CKD mix will be higher than the natural sand soil.

2.1.2. Grain size distribution

Grain size distribution test was performed in accordance with the ASTM-D422 test method for particle size analysis of soils. Soil is classified according to the Unified Soil Classification System (USCS) (test method for classification of soils for engineering purposes). Figure 1 shows the grain size distributions of the used sand. The Uniformity Coefficient (Cu) and The Coefficient of Gradation (Cc) are found to be 3.0 and 1.47 respectively. The used soil is classified as poor graded sand. It can be also noticed from grain size distribution curve that the CKD particles are in the silt size zone.

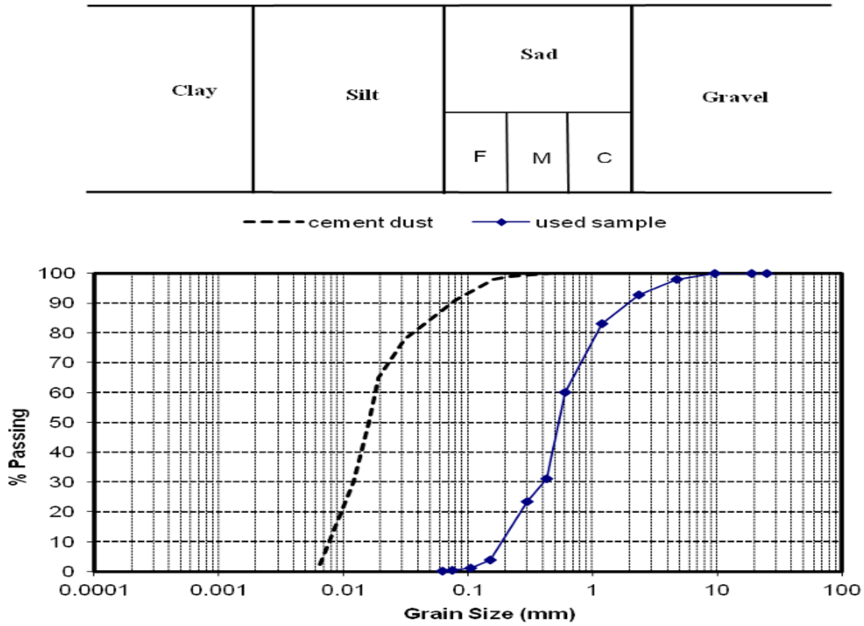


Fig. 1. Grain size distribution curves

2.1.3. Compaction test

The maximum dry density for sand used in experiments was determined using the modified proctor compaction test standard ASTM-D1557. The maximum dry density and the corresponding optimum moisture content (OMC) were found to be 1.978 gm/cm^3 and 10.45% respectively as can be noticed from Figure 2. Compaction test for soil mix has no meaning for this application because the CKD converts the used soil to a cohesion soil after setting time.

2.1.4. California bearing ratio

The CBR test generally is used for a particular soil subgrade to determine the road pavement required design parameters. Figure 3 shows the CBR values of the used sand and soil mix with 30% cement dust ratio [2]. The results of CBR were 17% and 165% respectively.

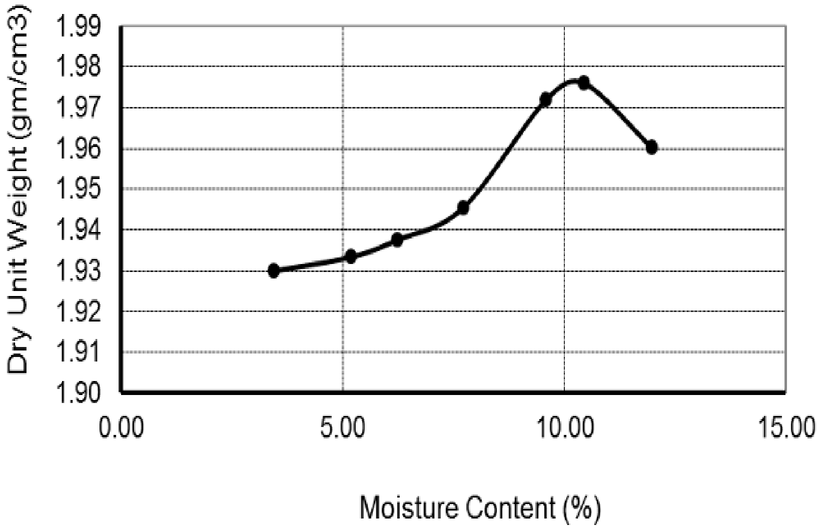


Fig.2. Compaction test results.

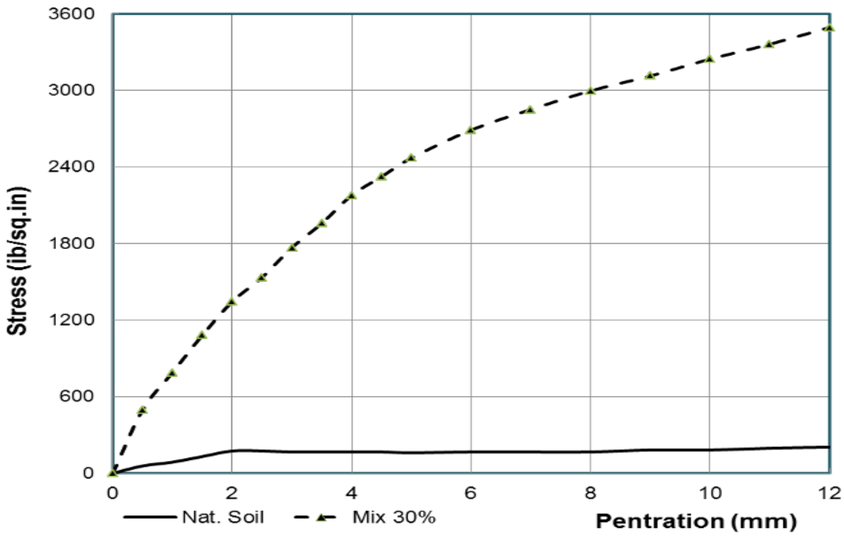


Fig. 3. CBR test results.

2.1.5. Unconfined compression test

The common indicator of soil improvement is the compressive strength. The unconfined compressive stress of the soil mix was determined at different ages. All specimens were not cured and were tested after 3, 7 and 28 days. The dimension of the tested specimen was 3.50 cm in diameter and with 7.00 cm height. The maximum strength was 4.34 kg /cm^2 at

28 days. Figure 4 displays the value of unconfined compression strength and it is clear that as the time increases, the unconfined compressive strength increases.

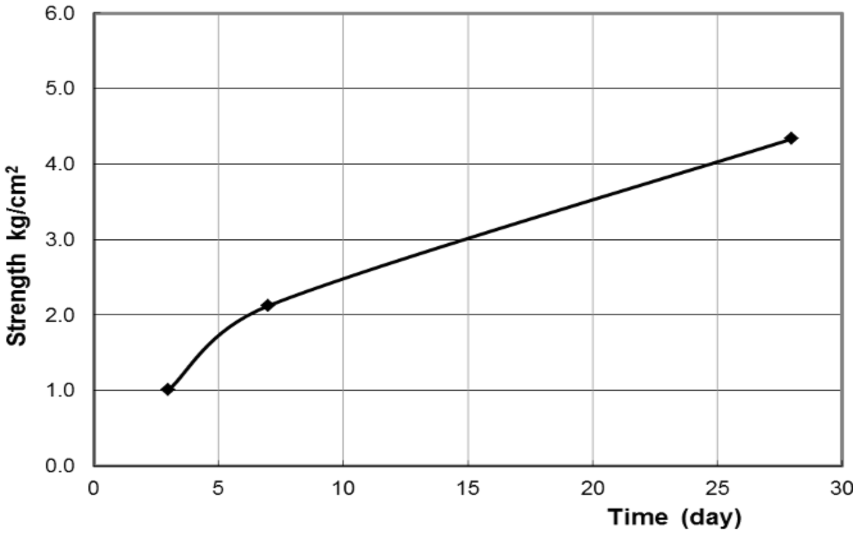


Fig. 4. Unconfined compression strength for soil mix.

2.1.6. Geotextile properties

Figure 5 and Table 1 shows the results of laboratory tests that were carried out to determine the used geotextile mesh properties; mass per unit area, nominal thickness, wide-width strength, and grab tensile strength according to ASTM test methods.

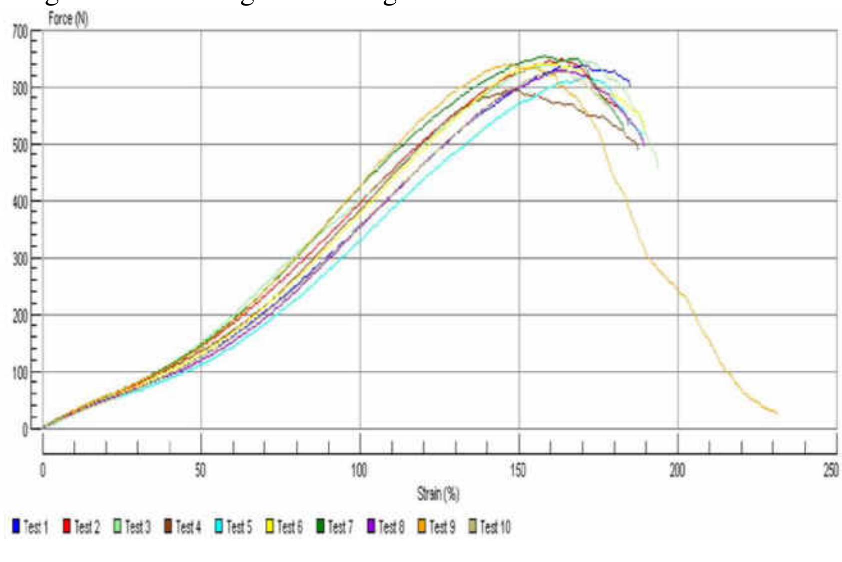


Fig. 5. Geotextiles force strain test results (M.D) direction.

Table 1.
Test results of geotextile mesh products.

Property	Units	Test Result
Mass per Unit Area	g/m^2	454.2
Thickness	mm	3.35
Wide-Width (M.D)	N/m	7391.9
Wide-Width (X.D)	N/m	8815.6
Grab Load (M.D)	N	633.01
Grab Load (X.D)	N	744.8

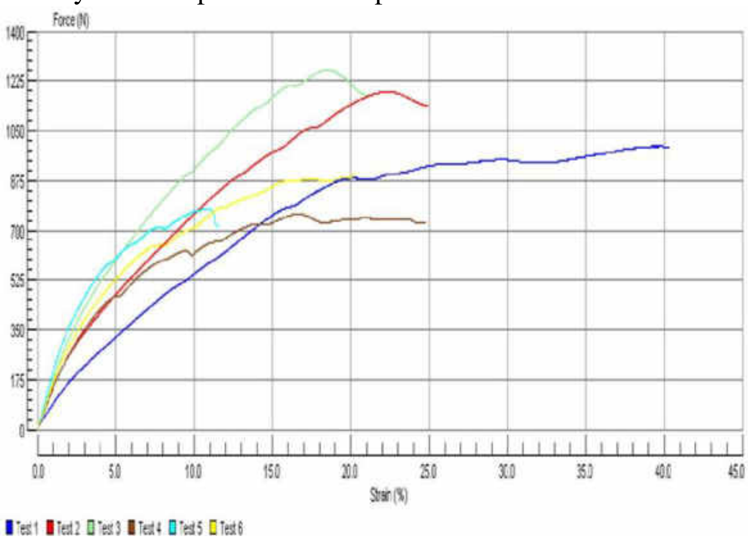
2.1.7. Geonet properties

The geonet is produced locally in Egypt. The laboratory tests were carried out for geonet products to determine the nominal thickness and wide-width strength. The results of the mentioned tests are presented in Table 2. Figures 6 shows considerable variation in the test results.

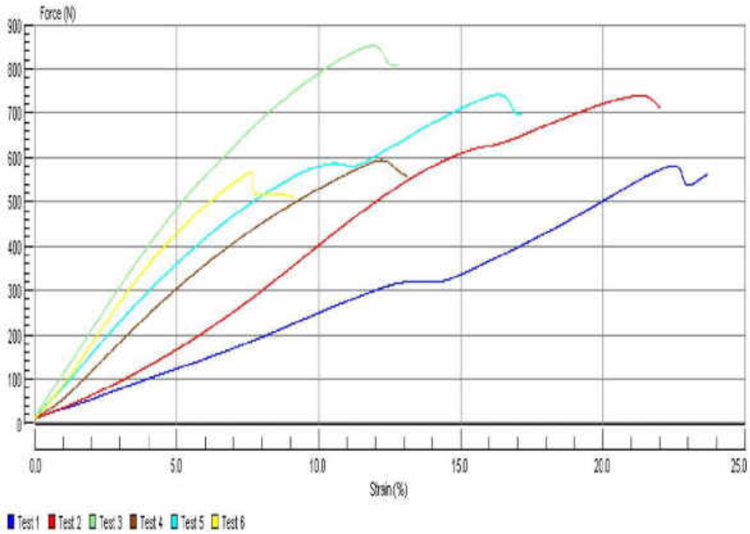
Table 2.
Test results of geonet products

Property	Large Sized Geonet	Small Sized Geonet
Thickness (mm)	8.67	4.75
Wide-Width (M.D) (N/m)	3395.41	4886.83

This variation is related to the quality of the local geonet. On the other hand, the local material price is very low compared to the imported one.



a) Small size geonet

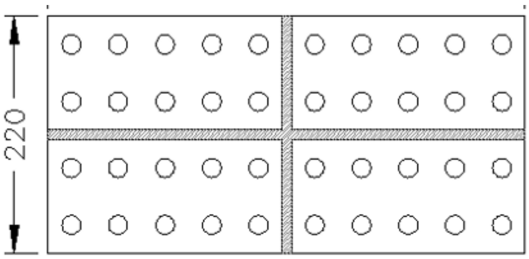


b) Large size geonet

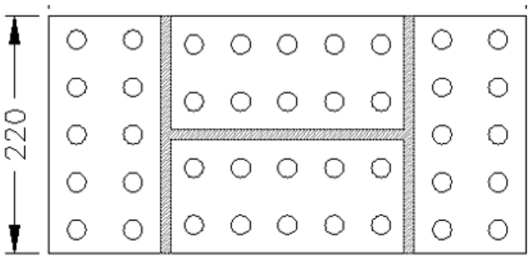
Fig. 6. Geonet force-strain test results.

2.2. Field retaining wall models

Four masonry retaining walls were built in the field using commercial clay hollow bricks to model the hydraulic structure wing walls and also using ordinary techniques for masonry buildings. The bricks were arranged as shown in Fig. 7. The length, breadth, and height of each wall were 150 cm, 22 cm, and 150 cm, respectively. The masonry walls were built on a foundation layer consisting of plain concrete with 20 cm thickness. Figure 8-a shows schematic drawings for typical wall, while Fig. 8-b displays one of the built wall.

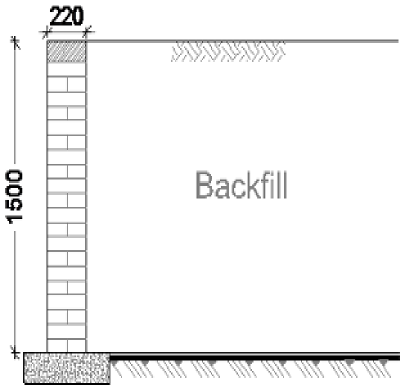


a) Course No. 1



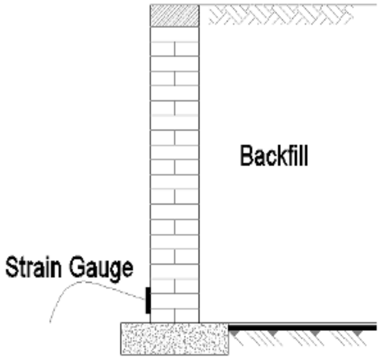
b) Course No. 2

Fig. 7. Brick arrangement used in piers construction.



a) Typical retaining wall

One of the tested wall



Strain gauge location

Fig. 8. The Brick Retaining Wall Model.

As shown in Fig. 9 the first wall was tested with traditional soil backfill compaction. The second wall was tested using soil backfill in gabions. Geogrid layers were inserted during construction of the third wall, which was tested using reinforced backfill soil. The last wall was tested with mixed soil-cement dust backfill. Strain gauge was fixed at the most stressed section of the retaining. Figure 8.c. showing schematic drawings for strain gauge location, that was fixed at the bottom of the front face of the retaining wall model. The used wall model was cantilever type. The maximum strain was measured and recorded during the filling process and at the end of completion of each layer.

2.2.1. Compacted soil backfill

The backfill soil was filled in layers, 25 cm thick each. A plate compactor was used to compact low layers of soil then manual compaction was used for the top layers. Compaction effort was designed to reach not less than 85% of relative density. The strain gauge readings were recorded at end of compaction process of each layer. Figure 9 displays the compaction process for the first wall.

Fig. 9. Backfill with traditional compaction technique.

Figure 10 shows the readings of strain gauges against the wall height, which indicate that as the height of the backfill increases the strain increases. The maximum measured strain is about 175(µ-strain) at backfill height equal to 100 cm.

2.2.2. Reinforced soil backfill

Two geogrid mesh reinforced layers were used at a spacing in-between equal to 50 cm. The first geogrid reinforced layer was placed at level (+00.25) from ground zero level. The backfill soil was layers, 25cm thick each. Manual compaction was used for compacting all layers. The compaction effort was designed to reach not less than 85% of relative density. The strain gauge readings were recorded at the end of compacting each layer. Figure 11 displays the backfill technique while Fig. 12 shows the readings of strain gauges against the wall height. As the height of the backfill increases, the strain increases. At the same height the reinforced sand causes less strain compared to the sand compacted backfill (35 µ-strain) at backfill height equal to 100 cm.

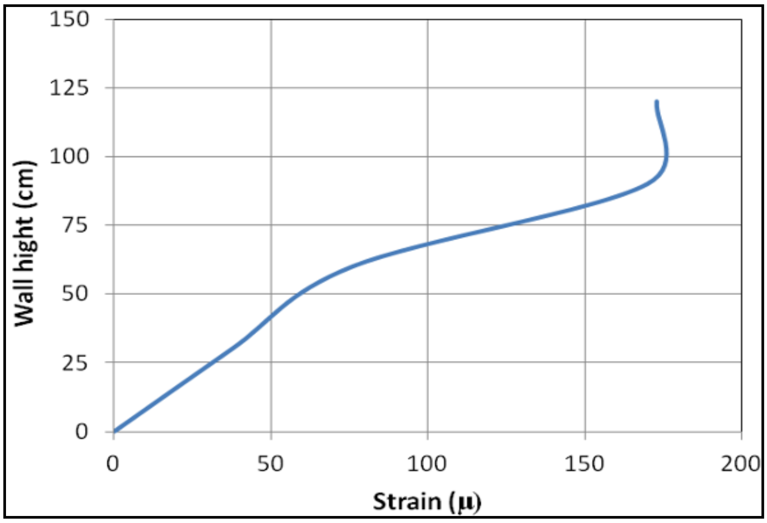


Fig. 10. Relation between Strain of retaining wall and backfill height.

Fig.11. Backfill with geogrid reinforced soil

2.2.3. Gabions filled with soil backfill

Six rows of gabion boxes formed and filled with sand were installed to be used as backfill. Two adjacent boxes were used in each row. All boxes were lined with geotextile membrane to keep sand inside the box. Each box contains a sand layer, 25.0 cm thick. The boxes were putted behind the wall empty and filled with sand. Manual compaction was used for compacting sand inside the boxes. The open side of the box was warped from all sides after compaction completion with woven geotextile ropes and then joined to the above empty box. The compaction effort was designed to reach not less than 85% of relative density. The strain gauge readings were recorded at the end of compacting each layer. Figure 13 displays the backfill technique while Fig. 14 shows the readings of strain gauges against the wall height.

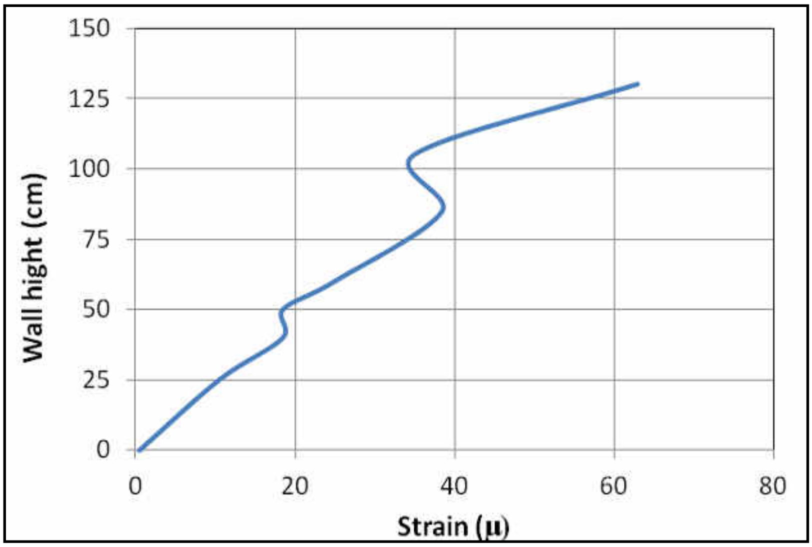


Fig. 12. Relation between strain of retaining wall and backfill height.

Fig.13. Backfill with gabions boxes filled with sand

It is clear from Figure 14 that the strain in the retaining wall with gabions case backfill is smaller than the other cases. In addition, as the height of the backfill increases, the strain decreases.

The behavior of this case indicates that the gabions not only carrying each other but also its base surface work as soil reinforcement layer and decrease the lateral pressure on the wall.

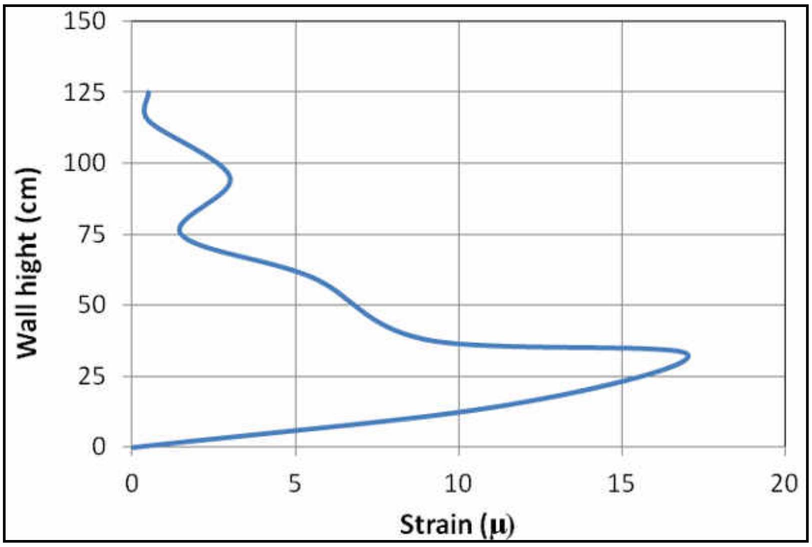


Fig.14. Relation between strain of retaining wall and backfill height.

2.2.4. Soil backfill mixed with CKD

Sand soil mixed with cement dust was used as a backfill soil. The cement dust was used with a ratio of 30% by weight referring to the sand soil. The used mix technique was introduced to explain that the proposed technique can be used in new structures as simple as traditional concrete work. In addition, the proposed technique can be executed like the common soil mix technique in case of existing structures. The fill was added in layers, 25.0 cm thick each. Each layer was placed and then compacted using manual effort. A waiting period after casting two layers was necessary for mix setting. The work was repeated in the same manner until reaching the required height. Some control tests were carried out to determine the mix setting time and mix strength. Figure 15 displays the backfill technique while Fig. 16 shows the readings of strain gauges against the wall height.

Fig. 15. Backfill with soil mixes with cement dust

Figure. 16 clarifies that the strain increases at the time of casting, then after casting the mixture hardening starts and the strain decreases. The final strain is very small compared to the other cases except the gabions case.

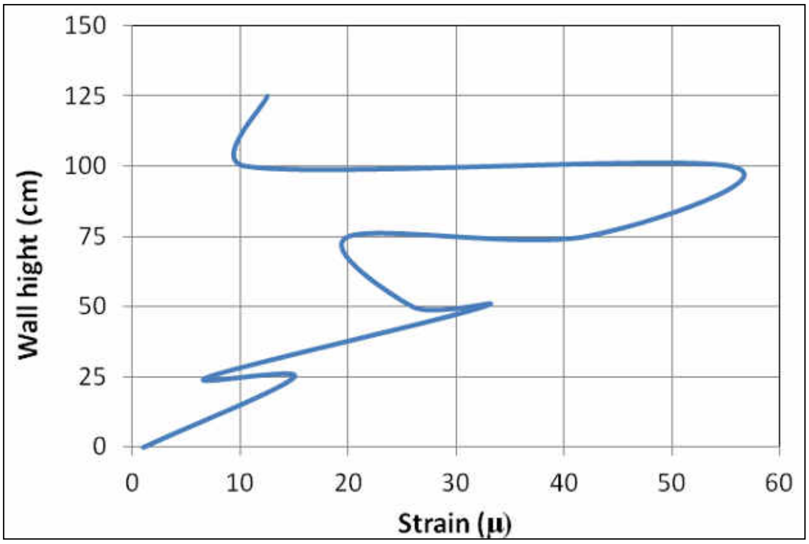


Fig. 16. Relation between strain of retaining wall and backfill height.

3. Discussion

The results for each improvement method are plotted in the same chart for the purpose of comparison as displayed in Fig. 17. From the plotted results it is noted clearly that the traditional compaction method is the poorest solution referring to other techniques. Using gabions is considered the most efficient method to reduce the active earth pressure on the retaining wall model. Therefore, the technique of gabions is the best amongst all tested techniques.

The final results of soil mix with cement dust technique are the nearest to the results for gabions. The mix curve shows sudden changes in wall strains at the same levels because strain readings were recorded at the end of casting mix layer after compaction and before setting. The active pressure for soil mix changed according to mix liquidity. The active earth pressure dropped significantly after layer setting. The results of soil mix can be improved by using temporary lateral supports until reaching acceptable setting.

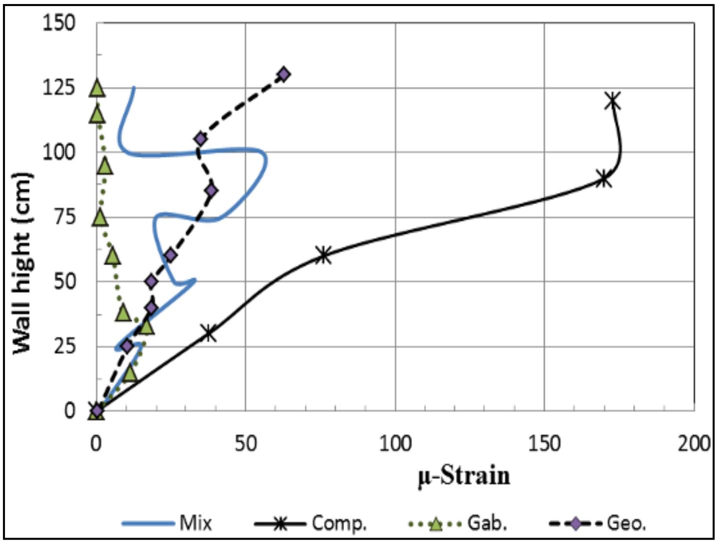


Fig.17. Relation between Strain of retaining wall and backfill height.

On the other hand, the soil reinforcement technique can reduce lateral earth pressure by considerable amount compared to the traditional compaction method. The soil reinforcement techniques are slightly complicated than soil mix and gabion methods considering execution of work.

4. Conclusions

The lateral earth pressure was controlled effectively by using the soil mixed with cement kiln dust approach. In addition, gabions provide the most competitive solution for reducing earth pressure. Based on the results of this research it is recommended to carry out further studies for the economic evaluation of soil mixed with cement dust and gabion techniques. This study leads to the following conclusions:

- The use of soil mix with cement dust to reduce lateral earth pressure can be used as one of the most efficient solutions to optimize retaining walls design.
- The use of gabions in backfill to reduce lateral earth pressure is the most efficient solution compared to other studied methods to optimize retaining walls design.
- The use of soil mix with cement dust could be used for new structures and for upgrading or strengthening existing structures while gabions method is suitable only for new structures.
- Soil mix method uses cement industry waste material and gabions also can be filled with construction waste materials.

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تقييم طرق تحسين التربة المختلفة لتقليل الضغط الجانبى للتربة

الملخص العربى

المنشأت الساندة تتأثر بنوعية التربة خلفها حيث أن معظم القوى الخارجية تأتى من خلال ضغط التربة الجانبي وكلما زاد ارتفاع الحائط زاد ضغط التربة خلفه وبذلك تزداد أبعاده التصميمية. فى هذا البحث تم دراسة تقليل ضغط التربة على الحائط من خلال طرق تحسين التربة المختلفة. فقد تم قياس الإجهادات والإزاحات على حائط تم وضع خلفه ردم بإستخدام رمال مدموكة على طبقات سمك كل طبقة يساوى 25 سم وتعتبر هذه الحالة التقليدية فى الإنشاء وتم قياس الإجهادات والإزاحات خلال عملية الإنشاء وبعد تمام الإنشاء. والطريقه الثانية وهى تسليح التربة من خلال تثبيت شرائح من الجيونت بالحائط على مسافات بينية رأسية تساوى 50 سم وتم الردم على طبقات وتم قياس الإزاحات والإجهادات الداخلية للحائط. وفى الطريقة الثالثة تم تفصيل صناديق الجبيونات بأبعاد لها نفس عرض الحائط وإرتفاع يساوى 25 سم وعمودى على الحائط بطول 2.00 مترا وتم ملؤها بالرمل مع الدمك ورصها بإرتفاع الحائط وتم قياس الإزاحات والإنفعالات الداخلية للحائط. وتم التحسين الأخير من خلال خلط نسبة 30% من غبار الأسمنت مع الرمل وصب الخليط على طبقات بسمك لكل طبقه يساوى 25 سم وتركها لمدة 24 ساعة لتجف. وقد وجد أن أفضل طرق التحسين هى الجبيونات وتليها خلط التربة مع غبار الأسمنت.