Ground Improvement Technique Using Geogrid Reinforcement with Additives (experimental study)

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Abstract: One of the main challenges that facing the construction engineers is soft soils with less bearing capability, so a lot of efforts must be done to creating an alternative ways for treating weak soils by using various kinds of supplements and stabilizers for reducing the costs supplements and improving the quality of weak soil. The current study aimed to adopting an experimental program to study the impact of two types of geogrids layers at different depths with and without environmental friendly enzyme called (permazyme) on the soil strength. California Bearing Ratio (CBR) was conducted to investigate the enhancement in soil strength. This research has been performed to investigate the engineering performance (CBR) for three kinds of subgrades soil (sand- clay- loam) strengthened with layers of two different geogrids (geo1-geo2) at depths (1.5cm- 3cm- 4.5cm) without additives. The obtained results have shown that GEO1 is better than GEO2. Therefore, GEO1 is better than GEO2. The test has been repeated for the same types of subgrade soil reinforced with layers of GEO1 at depths (1.5cm- 3cm- 4.5cm) and (2.3cm- 4.6cm- 6.9cm) without additives. The obtained results have shown that using of three layers at depth of (1.5cm- 3cm- 4.5cm) is better than Depth of (2.3cm- 4.6cm- 6.9cm). The test has been repeated for the same types of subgrade soil reinforced with GEO1 at depths (1.5cm- 3cm- 4.5cm) with permazyme modifier. The obtained results have shown that GEO1 without permazyme is better than using permazyme with GEO1. As laboratory tests have been applied, field tests have been applied also. Settlement of original soil differs from modified soil. Settlement test has been applied in field original soil, permazyme modified soil, Geogrid modified soil and Permazyme Geogrid modified soil to determine the best type of these modifiers in field.
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Keywords: CBR value, Geo-grid, Permazyme, Modified soil, Geogrid reinforced soil.

1-Introduction:

Soil is capable to convey merely compact and shear strengths. Therefore, soil constructions can be designed to convey tensile forces by the applying of geosynthetics as reinforcing materials.

Road embankment's designation on soft subgrade soils require using coarse grained soils as one of the selected substances in this aspect. Previous studies dealing with using of geosynthetics for improving the soft subgrades soils, where it improves their bearing resistance. Construction of roads on weak subgrades soil is one of the most important obstacles facing the engineers and investigators, they tried to find a suitable methods for reinforcement of such soft soils through what`s called geosynthetics & coarse fill for construction on these soils onsite. Though, from economic point view and insufficiency of seal substances, researchers tried to find alternative ways for using of locally available materials with less costly for treatment of weak soils. Disregarding construction problems such as real use is probable in projects of small scale in cases of enhanced engineering presentation. The advantages of soil improvement is the reduction in the costs through using of locally available materials in addition to reinforcement of weak soils.

AL-Sinaidi[1] & Ali[2], 2006, found that by using the geogrid-reinforcement, they obtained a the effective applicable results. The field observations verified that the very soft/soft soils can be improved efficiently through applying of the geogrid-reinforced system which enhanced and minimized the variance expenditure. Therefore, the benefits from using of the geogrid-reinforced system returned to less costly, good-looking and demonstrates higher performance than maximum of other techniques used for soil improvement and is optimal for rapid construction and/or strict total and differential settlements of the structure and/or a thick and newly placed fill.

There are several uses of granular soils in civil engineering works such as but not limited to under foundations structures, sub base course of roads, unpaved roads and soil embankments. (Mohammed Kadum Fakhraldin1, (2016) attempts to overcome the problems of low-quality (by means of strength) of granular soil by enhancing California Bearing Ratio

(CBR) test by utilizing geogrid. The research aim's to investigate the potential benefits of using the geogrid to improve CBR of granular soil. The results of tests showed that the granular soil under study was inferior than the materials comply on class C of Iraqi specifications for granular soil material. On the other hand, using of geogrid type Tensar SS2 at 0.15H (where H the total thickness of granular material samples) improves extremely the CBR value of the granular soil as it is increased by about three times in comparison with untreated ground.

Several authors tried to apply enzymatic preparations for stabilization of ground (Tingle & Santoni, 2003; Velasquez et al., 2006; Visser, 2007, Khan & Taha, 2015; Malko et al., 2015). It is known that enzymes are protein in nature, that acting as a catalytic in biological processes (Katz et al., 2001). The mode of action of enzymes in the biological system is through the augmentation of reactions and their roles ends with the end of reaction without entering in the products. Some investigators, reported that the water layer adhering to surfaces of soil are affected by the size of soil particles particularly the clay soil (Terzaghi, et al., 1996). The compressibility and swelling characteristics of the ground are influenced greatly by the thickness of water soil layer, where the soil engineering performances will improved in case of diminishing in the thickness of water layer (Tingle, et al., 2007). Several investigators tried to study the possibility of using the available commercial preparations of different enzymatic systems which present in the local market carrying different commercial names such as Earthzyme, Permazyme and Terrazyme for stabilization of the ground or soil. There are many factors which affecting on the harvested results like types of soil and enzymes, and exposure time, so, the results is varied greatly between the treatments according to the mentioned factors which ranged from modest to high improvement in the stability of soil (Layrea, 2003; Rajoria & Kaur, 2014; Khan & Taha, 2015).

Abou Khadra et al., 2018 studied the possibility of addition of some enzymes on the stability of different kinds of soils. The variety of soils used by the authors representing a wide range of particle sizes of the examined soils which treated with two kinds of enzymes. Different parameters including compaction characteristic, permeability and compressive strength of the soil for estimation of the degree of improvement are performed in the laboratory ().

Advanced techniques applying enzymatic systems for improving the stability of soil are achieving a good results represented in a significant improvement in California bearing ratio and loose compressive strength. The addition of enzymes to the loose soil improved greatly the properties of treated soils in comparison with the sandy soil. With respect to the degree of improvement in the fine soil, it reached 2.75 to 4.5 times more than that recorded in non-treated soil and 0.25%. is maximum level ratio is obtained in the experiments. In addition, a significant improvement in the permeability of soil is achieved due to high extent of stabilization induced by enzymes. Although, in the treated soil, the permeability coefficient were averaged 0.4 to 0.16 times in matching with untreated soil. Furthermore, increasing in the content of clay in the soil was associated with increasing in the soil permeability and soil strength. The same authors reported that an improvement in maximum dry density for fine soil was slight, while a non-significant elevation was observed in case of coarse soil (AbouKhadra et al., 2018).

Practically in the field, the using of enzymes for improvement of the soil properties required many steps must be performed for the succeeding of enzymatic systems in the soil. These procedures including: (a) tearing with a grader for facilitating moisture regulation and prevent the enzymatic solution from discharge during supplementation; (b) the pavement site is treated with dribble bar from a water cart for the purpose of rising in the content of moisture nearly similar to the optimum moisture content (OMC); (c) each enzymatic material is diluted according to the instructions of the manufacturer; (d) The selected added enzymes are diluted according to the manufacturer guidelines and sprayed over the pavement substance and mixed carefully using a stabilizer and (e) formula of the pavement is carried out by using smooth drum roller numerous times (Renjith et al., 2017).

We can suggested from the obtained data that the application of enzymatic preparations improved significantly the strength of smooth soil and the content of clay in the soil was linked with the degree of improvement (AbouKhadra et al., 2018). Permazyme is one of these enzymatic materials, so permazyme has been used as a soil improving material in laboratory and field tests.

2-Tests programming:

2-1-Modifiers preparation:

2-1-1- Geogrid preparation:

Two type of geo-grid, TX160 (Figure 1) with triangle aperture and SS20 (Figure 2) with rectangle aperture, ware used to reinforce the subgrade soil. The physical and mechanical properties of these reinforcements as provided by the manufacturers are listed in Table (1).

Table (1): Properties of Geo-grids (Properties from manufacturer's data)

Geo-grid type		TX160	SS20
Mass\ Unit area (kg\m^2)		0.22	0.22
Aperture size (mm) MDxTD		40x40	39x39
Min., rib width (mm)		1.2	2.2
Min., rib thickness (mm)		0.8	1.1
Tesileatrength (KN\m^2) @ 2% strain	MD	4.6	7
	TD	4.6	7
Tesileatrength (KN\m^2) @ 5% strain	MD	10.64	14
	TD	10.64	14

2-1-2- Permazyme preparation:

Enzymatic preparations commercially available in the market are labeled as safe preparations derived from natural sources, however, the exact chemical composition is not revealed for commercial reasons. It has been described in literature that the enzymatic preparations are acting on the surface properties of the soils rather than typical chemical changes and formation of new compounds as illustrated in case of other soil stabilizers (Rauch et al., 2002). For example, calcium dependent soil stabilizers stabilize soil particles via formation of hydration products such as calcium-silicate-hydrates (C-S-H), calcium-aluminate-hydrates (C-A-H) and calcium-aluminum-silicate-hydrates (C-A-S-H). One of the theories that explain the enzymatic-based soil stabilization is the activity on the surface charges of the soil particles. Most clayey soils have a molecular structure with a net negative charge. In order to maintain the electrical neutrality, the edges and surfaces of clay particles attracts cations (positively charged). These cations are called "exchangeable cations" because in most cases cations of one type may be exchanged with cationsof another type. When the cation charge in the clay structure is weak, the polarized water molecules are attracted by the remaining negative charge as well as the spaces of the clays structure is filled with ionized water. Enzymatic preparation are probably provides strong and soluble cations that can exchange with the weaker clay cations to eject the water from the clay structure. The loss of moisture leads to strengthening of the particle arrangement of the clay and also in a reduction of the particle size and plasticity in a soil as well as higher density and permanent structural change (Rauch et al., 2002). Furthermore, enzyme stabilizer improves the bonding that allows soil materials particles to become closer to each other and more densely compacted. The penetration of the enzymatic preparation active ingredients is aided by the wetting agents—the surfactants—found in the enzymatic preparations.

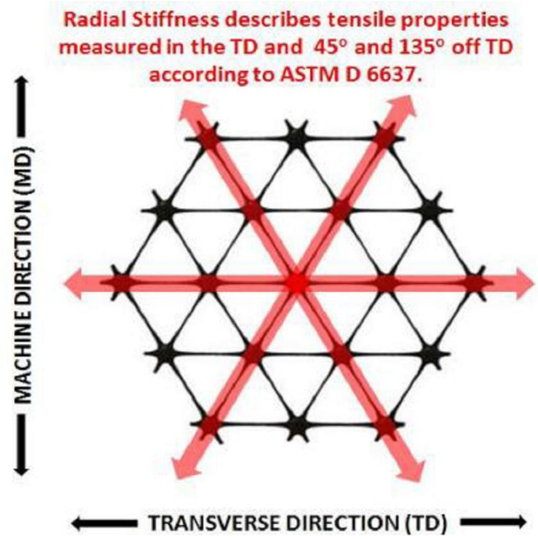

Figure (1): TX160 Geo-grid

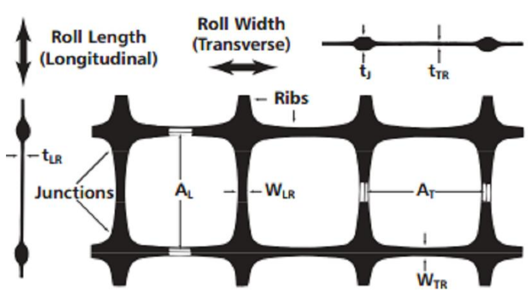

Figure (2): SS20 Geo-grid

2-2- 1-Laboratory tests:

California Bearing Ratio test has been conducted on sand, clay and loam in four stages:

1st step: CBR for untreated samples of each soil.

2nd step: CBR for two type's geogrid reinforced soil. Replacing one layer at depth 1.5 cm, two layer at depths (1.5- 3) cm and repeating the test after replacing three layers at (1.5- 3- 4.5) cm depths in each soil sample.

3rd step: using the geogrid which has the better effect on soil performance, but on other depths. Replacing one layer of geogrid at 2.3 cm, two layers at

(2.3- 4.6) cm and 3 layers at (2.3- 4.6- 6.9) cm depths then repeat CBR test.

4th step: Choosing the best type and depth of geogrid to replace it in permazyme treated soil.

2-2-2-Field test:

Plate loading test has been conducted in 4 stages, also. A plate with 30cm diameter has been used in test with 0.25 kg\cm^2 loading rate. The test has been conducted on native soil, permazyme treated soil, 10 cm depth geogrid reinforced soil and permazymegeogrid reinforced soil. Fig., (1) shows reinforcing soil by geogrid in field.

3-Results:

1-Results of laboratory tests:

Table (2): Results of (CBR) test after adding GEO1 and GEO2 at depths of (1.5- 3- 4.5) cm in sand, clay and loam without additives.

Sample	Sand		Clay		Loam	
	GEO1	GEO2	GEO1	GEO2	GEO1	GEO2
Original	28	28	3	3	2.26	2.26
One layer at depth 1.5cm	30	24	4.8	4	6.9	5.6
2 Layers at depths (1.5-3) cm	37	37	6.7	6	10.9	6.4
3 Layers at depths (1.5-3-4.5) cm	43	33	5.6	5.5	9.4	10

Fig., (3) reinforcing soil by geogrid in field.

Figure (4): the performance of sand strength after using two types of geogrid layers at different depths. When one layer of GEO1 has been located at depth 1.5 cm, (CBR) has been increased from 28% to 30%. When two layers of GEO1 have been located at depth 1.5 cm and 3cm, (CBR) has been increased from 28% to 37%. After using three layers of GEO1 at depths 1.5, 3 and 4.5 cm (CBR) has been increased from 28% to 43%.

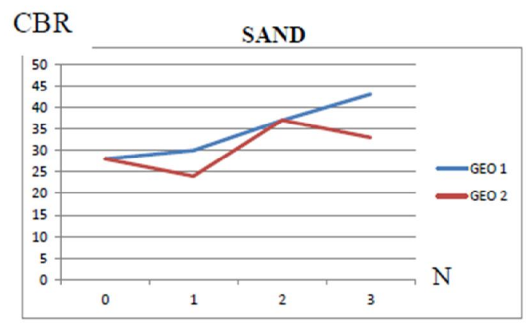

Figure (4): Effect of GEO1 and GEO2 on (CBR) sand test.

Sand performance suffered from fluctuation when GEO2 has been added at the same depths. When one layer of GEO2 has been located at depth 1.5 cm, (CBR) has been decreased from 28% to 24%. When two layers of GEO2 have been located at depth 1.5 cm and 3cm, (CBR) has been increased from 28% to 37%. After using three layers of GEO2 at depths 1.5, 3 and 4.5 cm (CBR) has been increased from 28% to 33%.

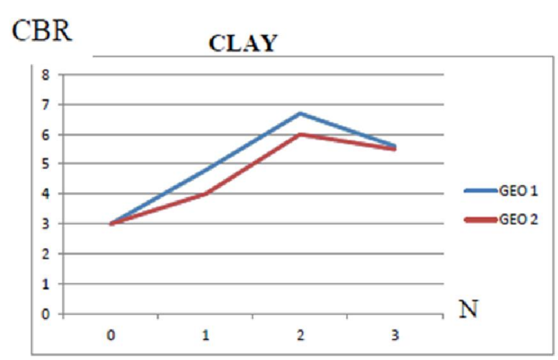

Figure (5): Effect of GEO1 and GEO2 on (CBR) clay test.

Figure (5): the fluctuation of clay strength after using two types of geogrid layers at different depths. When one layer of GEO1 has been located at depth 1.5 cm, (CBR) has been increased from 3% to 4.8%. When two layers of GEO1 have been located at depth 1.5 cm and 3cm, (CBR) has been increased from 3% to 6.7%. After using three layers of GEO1 at depths 1.5, 3 and 4.5 cm (CBR) has been increased from 3% to 5.6%.

When one layer of GEO2 has been located at depth 1.5 cm, (CBR) has been decreased from 3% to 4%. When two layers of GEO2 have been located at depth 1.5 cm and 3cm, (CBR) has been increased from 3% to 6%. After using three layers of GEO2 at depths 1.5, 3 and 4.5 cm (CBR) has been increased from 3% to 5.5%.

Figure (6): the fluctuation of loam strength after using two types of geogrid layers at different depths. When one layer of GEO1 has been located at depth 1.5 cm, (CBR) has been increased from 2.26% to 6.9%. When two layers of GEO1 have been located at depth 1.5 cm and 3cm, (CBR) has been increased from 2.26% to 10.9%. After using three layers of GEO1 at depths 1.5, 3 and 4.5 cm (CBR) has been increased from 2.26% to 9.4%.

When one layer of GEO2 has been located at depth 1.5 cm, (CBR) has been decreased from 2.26% to 5.6%. When two layers of GEO2 have been located at depth 1.5 cm and 3cm, (CBR) has been increased from 2.26% to 6.4%. After using three layers of GEO2 at depths 1.5, 3 and 4.5 cm (CBR) has been increased from 2.26% to 10%.

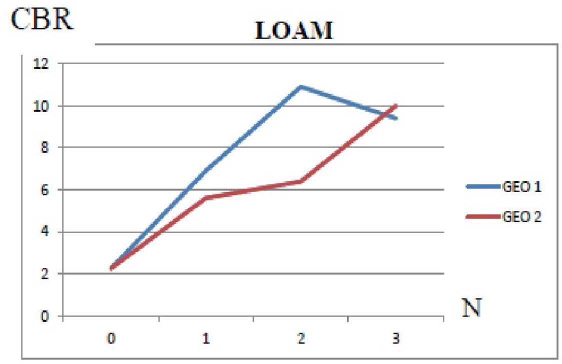

Figure (6): Effect of GEO1 and GEO2 on (CBR) loam test.

Table (3): Results of (CBR) test after adding GEO1 at depths of (1.5- 3- 4.5) cm and (2.3- 4.6- 6.9) cm in sand, clay and loam without additives.

Sample	Sand		Clay		Loam	
Depth	1.5cm & its multiples	2.3cm & its multiples	1.5cm & its multiples	2.3cm & its multiples	1.5cm & its multiples	2.3cm & its multiples
Original (without GEO)	28	28	3	3	2.26	2.26
One layer	30	28	4.8	4	6.9	4
2 Layers	37	22	6.7	4.5	10.9	4
3 Layers	43	22	5.6	4.5	9.4	4

Figure (7): that first layer of GEO1at depth 2.3cm didn't affect (CBR) value for sand, as the value still 28%. When two layers of GEO1 have been located at 2.3cm and 4.6cm depths, (CBR) has been decreased from 28% to 22%. Also, reinforced sand with three layers of GEO1at 2.3, 4.6 and 6.9cm depth isn't better than sand with two layers at 2.3, 4.6cm depth, as (CBR) value stayed 22% in both two layers and three layers.

Figure (8): that first layer of GEO1at depth 2.3cm increased (CBR) value of clay from 3% to 4%. When two layers of GEO1 have been located at 2.3cm and 4.6cm depths, (CBR) value has been improved from 3% to 4.5%. Also, reinforced clay with three layers of GEO1at 2.3, 4.6 and 6.9cm depth isn't better than clay with two layers at 2.3, 4.6cm depth, as (CBR) value stayed 4.5% in both two layers and three layers.

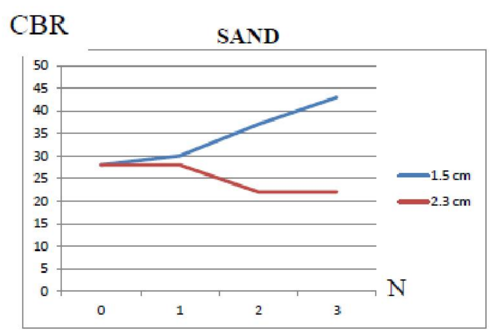

Figure (7): Effect of GEO1 at depth 1.5cm, 2.3cmand their multiples on (CBR) sand test.

Figure (9): that the first layer of GEO1at depth 2.3cm increased (CBR) value ofloam from 2.26% to 4%. Second and third layers at depth of 4.6cm and 6.9cm didn't affect the loam performance, as (CBR) value stayed 4% in both cases.

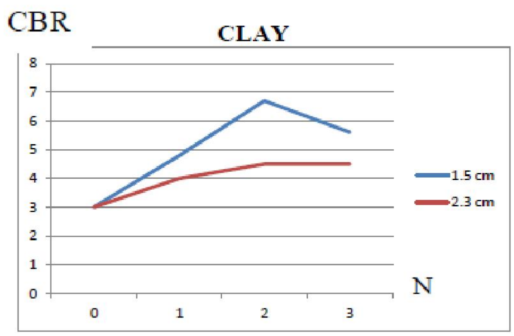

Figure (8): Effect of GEO1 at depths 1.5 cm, 2.3cm and their multiples on (CBR) clay test.

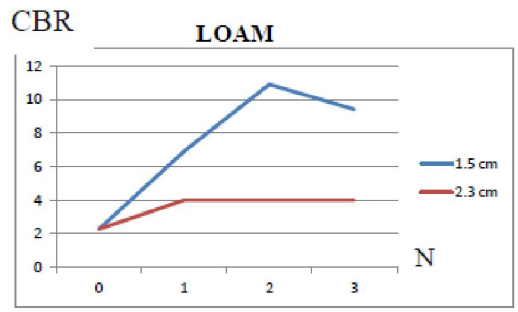

Figure (9): Effect of GEO1 at depths 1.5 cm, 2.3cm and their multiples on (CBR) loam test.

Table (4): Results of (CBR) test after adding GEO1 at depths of (1.5- 3- 4.5) cm in modified sand, clay and loam with a suitable percentage of permazyme.

Sample	Sand		Clay		Loam	
	Original	Mod.,	Original	Mod.,	Original	Mod.,
Original	28	28	3	3	2.26	2.26
One layer	30	24	4.8	9.6	6.9	8
Two layers	37	33	6.7	5.6	9.8	10.9
Three layers	43	35	5.5	5.5	8.6	9.4

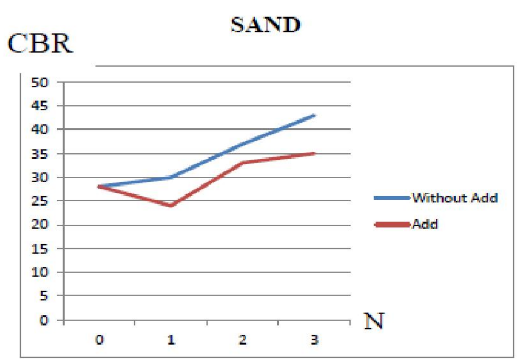

Figure (10): Effect of GEO1 at depths (1.5- 3- 4.5) cm in original and permazymemodified sand on (CBR) test.

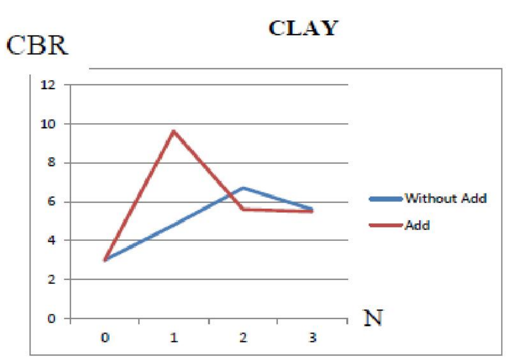

Figure (11): Effect of GEO1 at depths (1.5- 3- 4.5) cm in original andpermazyme modified clay on (CBR) test.

Figure (10): that the first layer of GEO1at depth 1.5cmin permazyme modified sand decreased (CBR) value ofsand from 28% to 24%. Two layers of GEO1 depths 1.5, 3cm increased (CBR) value from 28% to 33%. Three layers of GEO1 in modified sand at depths 1.5, 3 and 4.5cm increased (CBR) value from 28% to 35%.

Figure (11): fluctuation in modified clay performance. The first layer of GEO1at depth 1.5cmin permazyme modified clay increased (CBR) value of clay from 3% to 9.6%. Two layers of GEO1 depths 1.5, 3cm increased (CBR) value from 3% to 5.6%. Three layers of GEO1 in modified clay at depths 1.5, 3 and 4.5cm increased (CBR) value from 3% to 5.5%.

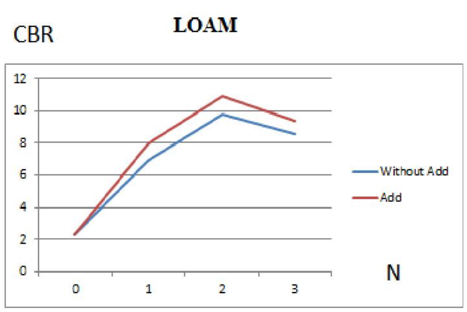

Figure (12): Effect of GEO1 at depths (1.5- 3- 4.5) cm in original and permazyme modified loam on (CBR) test.

Figure (12): fluctuation in modified loam performance. The first layer of GEO1at depth 1.5cmin permazyme modified loam increased (CBR) value ofloam from 2.26% to 8%. Two layers of GEO1 depths 1.5, 3cm increased (CBR) value from 2.26% to 10.9%. Three layers of GEO1 in modified loam at depths 1.5, 3 and 4.5cm increased (CBR) value from 2.26% to 9.4%.

2- Results of field tests:

Testing the settlement of original and modified soil in fieldresultsthe following values; table (5) shows the results of plate loading test in field:

Stress (kg\cm^2)	Original soil Δ (mm)	Soil+Geogrid Δ (mm)	Soil +Permazyme Δ (mm)	Soil+Geogrid+Permazyme Δ (mm)
0	0	0	0	0
0.25	0.1	0.107	0.09	0.090
0.5	0.183	0.210	0.147	0.177
0.75	0.297	0.310	0.237	0.243
1	0.383	0.407	0.317	0.320
1.5	0.530	0.570	0.443	0.420
2.5	0.830	0.827	0.553	0.603
3.5	1.120	1.117	0.720	0.890
4.5	1.560	1.370	0.970	1.113

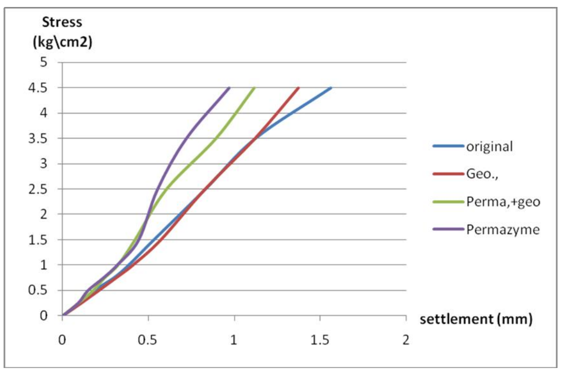

Figure (13): Effect of GEO1 and Permazyme *on soil settlement*

Figure (13): the results show that settlement of pure soil has been increased by increasing stress on soil. Geogrid didn't improve the soil in the beginning till stress of 3.5 kg\cm2, but at stress 4.5 kg\cm2 the geogrid decreased settlement in small rate. Permazyme Geogrid modified soil was better than original or Geo., reinforced soil, because soil settlement became less than the previous values under low and high stress. Permazyme modified soil wasn't better than Permazyme Geogrid modified soil under low stresses till 2kg\cm2, the condition reversed under high stressesas the settlement of Perma., modified soil has been decreased at 2.5kg\cm2 more than Perm., Geo., modified soil.

So, using Permazye as a soil modifier shows the least settlement of soil in field.

Conclusion:

In CBR laboratory test:

1- Geogrid (1) is better than Geogrid (2) as a modifier for sand, clay and loam.

2- Three layers of Geogrid (1) at depths (1.5- 3- 4.5) cm are better than depths (2.3- 4.6- 6.9) cm in sand.

3- Two layers of Geogrid (1) at depths (1.5- 3) cm are better than three layers at depths (1.5- 3- 4.5) cm in clay and loam.

4- Two layers of Geogrid at depths (1.5- 3) cm are better than three layers at depths (2.3- 4.6- 6.9) cm in clay and loam.

5- Using Permazyme in Geogrid reinforced sand weakens the sand soil.

6- Using Permazyme in Geogrid reinforced clay or loam strengthen them.

In settlement field test:

1- Adding Geogrid as a soil modifier to the soil didn't affect soil settlement except under high stress.

2- Adding Permazyme to Geogrid reinforced soil improve the soil performance.

3- Permazyme modifier has the best effect on soil, as it shows clear decreasing in soil settlement.

About The Author

Dr. Abdullah Abou Khadra is assistance professor (Lecturer) at Faculty of Engineering, Beni-Suef University and is head of the Road Research Laboratory. He is currently collaborating with Dr.

Ahmed Zidan, Associate professor, Faculty of Engineering, BSU and Dr. Yasser Gaber, Associate professor, Microbiology Department, Faculty of Pharmacy, BSU. The collaboration is funded by ASRT, Egypt, research project entitled “Low Cost Technology for Roads Construction”, PI Dr. Yasser Gaber. The project aims to develop, cheap, effective and green materials to be used in roads construction. Investigation of biologically derived material is considered such as enzymes, bacteria and biopolymers.

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