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USING GEOSYNTHETICS MATERIALS TO IMPROVE SUBGRADE LAYER FOR HIGHWAYS

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الملخص العربي

تهدف هذه الدراسة إلي اقتراح قطاع تصميمي قادر علي تحمل الأحمال المرورية المتوقعة تحت مختلف الظروف وذلك من خلال عمل نموذج ديناميكي يحاكي منظومة المركبات مع الطرق مضاف الي هذا النموذج ماده بوليمريه تساعد علي تحمل الأحمال المختلفه وإجراء إختبارات معمليه عليها ويتم إستخدامها مع نوعين مختلفين من التربه وعلي أعماق مختلفه وذلك للحصول علي افضل استخدام لهذه المواد لاعطاء افضل قطاع للطريق أمن وموفر الي اقصي درجه ممكنه ثم بعد ذلك تحليل ذلك النموذج عن طريق الحاسب الآلي باستخدام نظرية العناصر المحدده.

ABSTRACT

Establishing a pavement section with a weak subgrade soil causes many problems such as rutting, sags, cracks and so on. These problems cause a permanent deformation in pavement sections that give rise to serviceability problems on the roads and structural damage in pavement sections.

In this study a two kind of weak subgrade soils (Clay lumped soil and Sandy friable soil) were used to construct a pavement sections. Those pavement sections conducted to plate loading test before and after reinforced their layers with geo-synthetic sheets in different ways.

To evaluate the resistance to static load deformation of each kind of subgrade soils and find out the best way to reinforce the base and subgrade layers of the pavement sections, a four model of pavement section would constructed of each subgrade. The first model was the control without any reinforcement and the other three models present the different ways of the reinforcing with geo-synthetic sheets.

Keywords: Geosynthetic, Static deformation, Soil reinforcement, Mechanical properties.

1. Introduction

Soils with high fines contents are not desirable to be used in the basement layers due to their moisture-sensitive nature and the consequent loss of subgrade strength particularly in rainy seasons. All of these may cause pavement deformations. The deformation may be noticed as a pavement distresses. The most popular distresses are rutting, sags, corrugations, cracking, etc.

The designers concluded three methods to avert the previous problems. The first one was by increasing the thicknesses of the pavement layers (both unbound and asphalt concrete). The second method was by removing the top layer of the subgrade and backfilling it with a soil of higher bearing capacity and better properties. The third method was by stabilizing the subgrade through different techniques such as adding lime or cement. While these methods of stabilizing subgrade soils were usually provide an adequate load bearing capacity for the pavement founding, the costly expenses associated with excavation, transportation, and construction materials can be a drawback due to budgetary constraints.

Recently geo-synthetics were considered a simple and an economic treatment to reinforce the weak soils. Modern geo-synthetics frequently offered solutions, which gave engineering practice and very economic when compared to older methods of construction.

After a review of previous studies and researches reinforcing or stabilizing the base layers of asphaltic pavement sections, we observed that there was a great difference in opinions about the techniques of the bedding layers reinforcing. Tang et al. [1] stated that butting the geo-synthetic sheets above subgrade layer is the best technique, while M.R.Abdi [2] stated that butting the geo-synthetic sheets into asphaltic thin layer through the bedding layers is the best technique, however its cost were get that technique out of the comparison. According to Palmeira et al [3] the geo-synthetic materials are used in stabilization of weak soil with cavities. Palmeira [3] also used the geo-grids to avoid reflective cracking in pavements. G.N.America [4] compared between using of geo-synthetic materials and lime in stabilization of soil. The comparison result indicated that using of geo-synthetic material is better than using lime because geo-synthetic are delivered to the site in ready to use rolls and can be installed quickly and easily. Once the geo-synthetic are installed, construction can continue immediately. There is no waiting during a mellowing or curing period, nor is there uncertainty as to whether the material has been mixed sufficiently. Ferrotti et al. [5] studied the performance investigation of geo-grids in flexible pavements. This study focused on the validation of a laboratory approach for the behavior of reinforced flexible pavement systems. Two different types of bitumen emulsions were applied at the interface of the double-layered slabs: a conventional cationic emulsion and polymer-modified emulsion.

Therefore, the objectives of this study were to investigate the effect of reinforcing a pavement section of such weak subgrade soils by using geo-synthetics and comparing the different techniques of reinforcing. In addition to economic evaluation will be conducted.

2. Experimental work

2.1. Basic materials

2.1.1. Aggregates and filler

In this study, natural aggregates used were obtained from Attaqa stone-pit. The classified crushed materials were mixed and graded to meet the gradation limits of a binder layer grade (3C) according to ECP 104-2008 [6]. As shown in table (1) the natural aggregates properties were evaluated according to EN standards and specification of ECP 104-2008 [6].

2.1.2. Asphalt binder (Bitumen) and bitumen emulsion

AC 60/70 bitumen from oil refineries labs in Suez governorate was used as asphalt binder in this study. Its properties are shown in table (2).

2.2. Testing program

To evaluate the stabilizing of a pavement section of weak subgrade soil by reinforcing its bedding layers by using geo-synthetic sheets and the reinforcing methods, two groups of pavement sections models will be constructed. The first group is about weak clay subgrade soil, and the other is about weak sandy subgrade soil. Every group contains four models, first model is about pavement section without geo-synthetic reinforcement, second model is about pavement section with single reinforcement above subgrade soil, third model is about single reinforcement through the base layer, and the fourth is about double reinforcement as a combination of model 2 and model 3. The constructed eight models will conducted to a plate-loading test to compare the resistance to static load deformation that indicates the effect of geo-synthetic reinforcement and the reinforcing technique.

2.2.1. Optimum asphalt content (OAC)

After the first stage that was about the gradation of aggregates blend and the properties of the used materials, the second stage role came to obtain the OAC for the asphalt mixture. A four mixes were prepared at 4.0%, 5.0%, 6.0%, and 7.0% asphalt content. We chose Marshall Method, to obtain the OAC. A four asphalt mixtures with the materials selected in the first stage and different asphalt contents had been prepared and conducted to Marshall design mix method (AASHTO T245) [7]. To determinate mixtures properties according to (AASHTO T166) [8] and tested them by Marshall Apparatus to obtain stability and flow, then a result comparison was made to found the optimum asphalt content (O.A.C) that was 5.0%. It is worth mentioning that the OAC is the asphalt content that provides maximum stability and reasonable flow, bulk specific gravity and percentages of air voids. Table (3) shows the properties of the asphalt mix, and ECP 104-2008 [6] requirements for binder layer grade (3C).

2.2.2. Models formation

The asphalt mixture designed at the pervious stage would be used in 5 cm thickness above a 30 cm base layer and a 110 cm subgrade soil as shown in figure (1). The models Prepared by paving the layers in a mold of 1m length, 1m width and 1.5m in thickness. The all three layers were compacted manually to a compaction degree of 95% for asphalt layer (5% air voids), 80% compaction degree for base layer, and 10% compaction degree for subgrade as shown in figures (2:5). For the first model (control model), there were no reinforcement to bedding layers. However, the other three models had a reinforcement of geo-synthetic sheets that were geo-grid sheet and geo-textile sheet.

The all eight models would be conducted to the plate-loading test and the results of load verses displacement would be recorded as shown in figure (6).

3. Test results and discussion

3.1. Plate-loading test

A plate of 30×30 cm was loaded at the center of the asphalt layer surface and the deformation was recorded every 5 ton load until 50 ton. Table (4) shows the deformation verses load for the eight models. Figure (7) shows the results of group 1 (clay subgrade), and figure (8) shows the results of group 2 (sandy soil).

Table 1

Properties of aggregates

Property	Standards	Natural aggregates	*ECP104[3] specifications
Bulk density (g/cm^3)	EN 1097-6	2.65	-
Water absorption (%)	EN 1097-6	0.7	-
LA abrasion (%)	EN 1097-2	23.8	≤40%
Shape index (%)	EN 933-4	8.5	≤25%
Flakiness index (%)	EN 933-3	12.5	≤25%

Table 2

Properties of asphalt binder

Property	Standards	AC 60/70	*ECP104[3] specifications
Penetration (0.01mm)	AASHTO T49	66	60 – 70
Softening point (°C)	AASHTO T53	52	45 – 55
Ductility (cm)	AASHTO T51	110	At least 90

Table 3

HMA properties for the control mix and RADW mixes

Property	Standards	Control Mix	*ECP104[3] specifications
Stability (kg)	AASHTO T275	1200	≥ 900
Flow (mm)	AASHTO T275	2.5	2 – 4
Marshall stiffness (kg/mm)	AASHTO T275	480	-
Air voids (%)	AASHTO T166	8.5	≤15%
Bulk density (g/cm^3)	AASHTO T166	2.38	-
No. of Marshall blows	-	75	75

***** ECP 104-2008 specifications for bonding heavy traffic asphalt layer.

Table 4

Plate-loading test results for each model

Load (ton)	Model 1		Model 2		Model 3		Model 4	
	Clay	Sand	Clay	Sand	Clay	Sand	Clay	Sand
	Disp. (mm)	Disp. (mm)	Disp. (mm)	Disp. (mm)	Disp. (mm)	Disp. (mm)	Disp. (mm)	Disp. (mm)
0	0	0	0	0	0	0	0	0
5	0	1	0	0	0	0	0	0
10	4	2	2	1.5	1	1	1	0
15	8	3	4	2	2.5	1.5	1.5	1
20	12	5	7	2.5	4	2	2	1.5
25	21	5	10	3	5	3	2.5	1.5
30	25	6	15	4	6	4	3.5	2.5
35	31	8	20	6	8	6	4	4
40	34	9	26	8	12	7	5	5
45	39	12	30	9.5	17	8	6.5	6.5
50	45	15	33	12	28	9	11	7

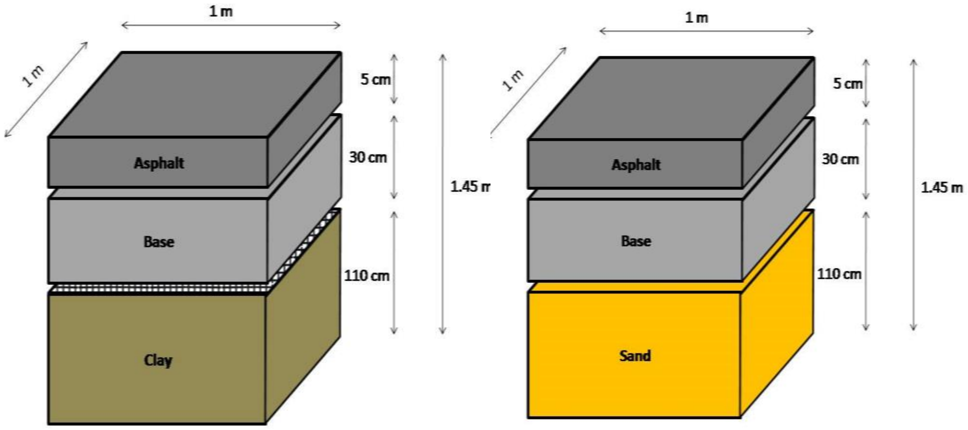

Fig.1. Preparation Mold

Fig.2. Subgrade forming

Fig.3. Geo-textile + Geo-grid sheets above subgrade

Fig.4. Base layer formation

Fig.5. Asphalt layer formation

Fig.6. Plate-loading test

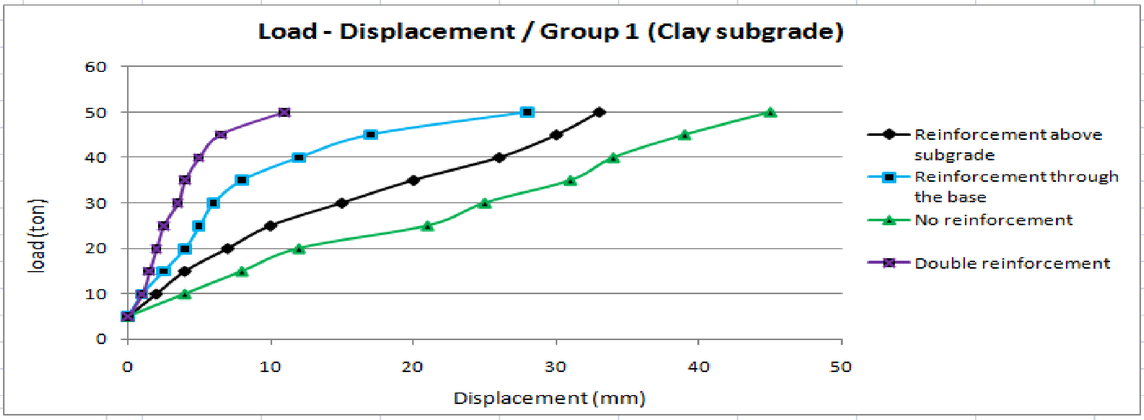

Fig.7. Effect of reinforcement and its technique on clay subgrade pavement section

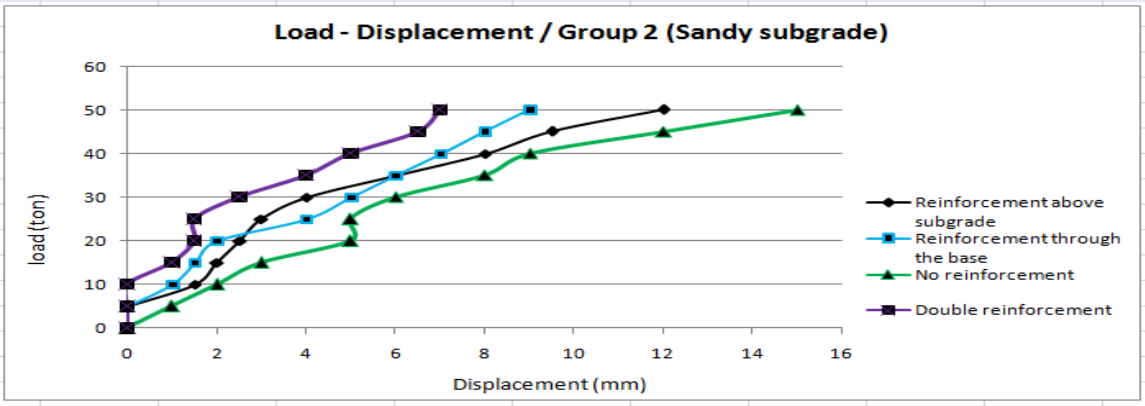

Fig.8. Effect of reinforcement and its technique on sandy subgrade pavement section

4. Conclusions

Based on the results of experimental work and review of literatures the following points can be concluded:

1- Weak sandy soil is better than clay soil as a subgrade soil for pavement section.

2- Reinforcing weak clay subgrade soil with single reinforcement above the subgrade, increase the resistance to static load deformation by 26%.

3- Reinforcing weak clay subgrade soil with single reinforcement through the base layer, increase the resistance to static load deformation by 38%.

4- Reinforcing weak clay subgrade soil with double reinforcement, increase the resistance to static load deformation by 75%, but it costing much more.

5- Reinforcing weak sandy subgrade soil with single reinforcement above the subgrade, increase the resistance to static load deformation by 20%.

6- Reinforcing weak sandy subgrade soil with single reinforcement through the base layer, increase the resistance to static load deformation by 40%.

7- Reinforcing weak sandy subgrade soil with double reinforcement, increase the resistance to static load deformation by 53%, but it costing much more.

8- At a subgrade of sandy soil, single reinforcement above the subgrade gave a resistance much more than single reinforcement through the base layer at the beginning of the operating and with load increasing the reinforcement through base layer gave a resistance better than it at the top of the subgrade.
9- Geo-synthetic reinforcement gave a performance with weak sandy soil better than weak clay soil.

5. References

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