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EFFECT OF REINFORCEMENT ON IMPROVE SURFACE PAVEMENT FOR WEAK SUBGRADE CONDITIONS

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ABSTRACT: A pavement structure consists of several layers for the primary purpose of transmitting and distributing traffic loads to the subgrade. Rutting is one form of pavement distresses that may influence the performance of road pavements. Soft subgrade soils are distinguished by their low undrianed shear strength and high compressibility. The effect of geogrid and steel mesh to improve the performance pavement is experimentally investigated and evaluated. To compare the experimental and analytical outputs, three dimensions finite element throughout models using ABAQUS ver.6.12.3 software are developed to simulate and analyze the relations between the cycling load and deformation of the suggested pavement modes. Based on the results and the limitation of this study it is concluded that, using geogrid and steel mesh in pavement layers leads to increases in load carrying capacity and decrease the permanent deformation in surface pavement for (1000) cycles load by (27.3%) and (18.3%) respectively, as compared with unreinforced model. The results of ABAQUS program are very close to results of laboratory tests.

Keywords: Soft subgrade, Geogrid, Steel mesh, Abaqus models

1. INTRODUCTION

In recent years, the reinforcement of road pavements has increased quickly for improvement construction and performance. In pavement systems, the term reinforcement refers to the ability of an interlayer to better distribute the applied load over a larger area and to compensate for the lack of tensile strength within structural materials. As with any reinforcement applications, the interlayer should be stiffer than the material to be strengthened [1], [5-7]. In such pavement applications, reinforcements involving either (1) subgrade and granular layers or (2) HMA layers and overlays have achieved particular success. Fig. 1 illustrates a number of potential geosynthetic applications in a layered pavement system to improve its performance [2]. Subgrade stabilization refers to situations where geosynthetics are placed on weak subgrade prior to the placement of an aggregate layer. Reinforcement placed within asphalt layers are used to reduce fatigue, thermal and reflective cracking, control rutting.

2. STUDY OBJECTIVE

1. Investigating, evaluating experimentally the effect of geosynthetics to improve the performance of pavement.

2. Developing a three dimensions finite element throughout using ABAQUS ver.6.12.3 software to simulate and analyze the relations between the cycling load and deformation of the proposed pavement modes; raw material model, geosynthetics model.

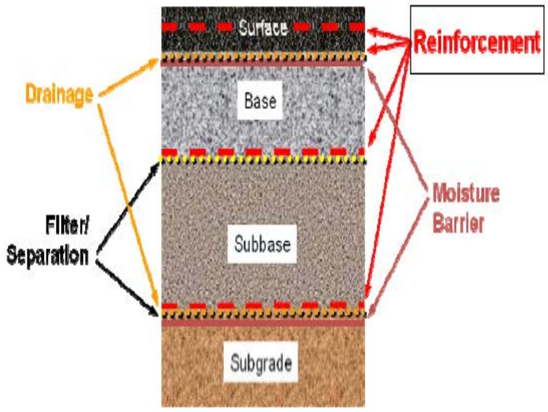

Fig. 1 Potential applications of geosynthetics in a layered pavement system.

2. EXPERIMENTAL WORK

3.1 Materials Properties

3.1.1 Soil

A brown lean clayey soil is brought from a depth of 5m from the site of abridge in the sport city within Al-Basrah city. Standard tests are performed to determine the physical and chemical properties of the soil, details are given in Table 1.

Table 1 Physical and Chemical Properties of Natural Clayey Soil Used

Property	Value	Standard
Liquid limit %(LL)	47	ASTM D4318
Plastic limit %(PL)	23	ASTM D4318
Plasticity index %(PI)	24	
Liquidity index %(LI)	0.48	
Specific gravity (Gs)	2.7	ASTM D854
Total soluble salt%	6.13	
SO3 content%	0.6	B.S.1377:1990
Organic matter O.M%	1.09	
Gypsum content%	1.17	
pH	8.34	
Classification (USCS)	CL	

3.1.2 Subbase

The subbase is brought from Al_Nibaee/ quarry, north of Baghdad, this type of subbase is commonly used as a granular layer in flexible pavement section.

3.1.3.Base

Base layer consists of weighting aggregate and filler according to the State Corporation for Roads & Bridges in Iraq [3].

3.1.4 Asphalt cement

The asphalt cement used in this study is of (40-50) penetration grade, and brought from Daurah Refinery. Table 2 shows the physical properties of Asphalt Cement.

3.1.5. Geogrid reinforcement

The geogrid material used in this study is Pars Mesh Polymer (PMP) Type SQ12 manufactured by the Iranian company Pars Mesh Polymer.

3.1.6 Steel wire netting

Steel wire reinforcement consists of a double twist, hexagonal shape, galvanized wire netting.

Table 2 Physical Properties of Asphalt Cement

Test	Result	Unit	SCRB Specifications
Penetration (25°C,100g,5sec) ASTM D 5	48	1/10mm	40 – 50
Ductility (25°C, 5 cm/min). ASTM D 113	166	Cm	≥ 100
Flash point (cleave land open cup) ASTM D 92	252	°C	≥ 232
Ductility of residue	151	Cm	> 25

Aggregate

The (crushed) aggregate used in this work is brought from Al-Nibaee quarry. The physical properties of the aggregate (coarse and fine) are shown in Table 3.

Table 3 Physical Properties of Nibaee Aggregates

Property	Coarse Aggregate	Fine aggregate
Bulk Specific Gravity (ASTM C127 and C128)	2.672	2.633
Apparent specific Gravity (ASTM C127 and C128).	2.601	2.431
Percent water absorption (ASTM C127 and C128)	0.45	0.531
Percent wear (Los- Angeles Abrasion) (ASTM C131)	20.10	-

3.2 Preparation of Model Test

Natural subgrade soil is mixed with quantity of water to get the desired consistency. After that, the soil is placed in a steel container (600*600*700) mm in five layer. After that, the geogrid layer is placed on the surface of the subgrade soft soil (in case of the subbase reinforced model) and folded in 90̊ against the long side of the steel container to obtain necessary anchorage and slight pre-tensioning, as well as to prevent shifting of the geogrids out of position, [4]. Then, the construction of the subbase and base layers begins.

Preparation of asphalt layer consists of mixing aggregate, filler and asphalt according to the gradation of [3]. To prepare the slab reinforcement asphalt pavement, the same procedure to prepare of the ordinary slab asphalt pavement is followed and the reinforcement is embedded at the bottom of the binder layer which matches what was recommended by [8].

3.3 Experimental Setup

To study and investigate the optimal way to improve the strength of pavement layers over weak subgrade; an experimental setup is designed and assembled to achieve this goal as shown in Fig. 2.

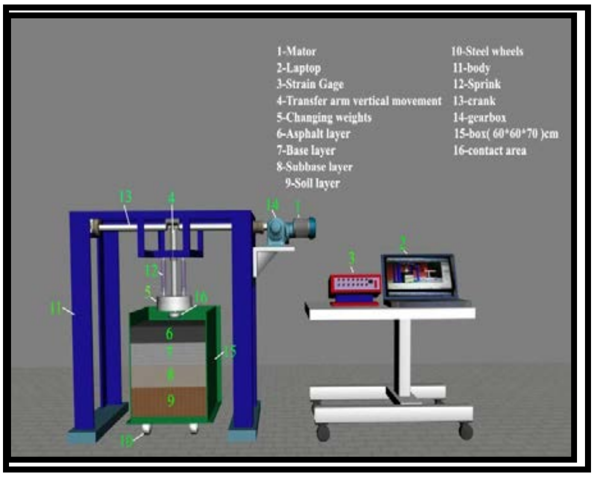

Fig. 2 Experimental Test Container and Loading System

3.4 Results of Experimental Work

The data obtained from the experimental work is permanent deformation as shown in following figures.

Fig. 3 show the relation between permanent deformation and loading cycles for the asphalt surface layer. It is clearly noticed that, the permanent deformation increases with the increase in the number of cycle load.

The permanent deformation is recorded at 1600 cycle load and compared with the raw material model. The geogrid and steel mesh decreases the permanent deformation in surface pavement for (1000) cycles load by (27.3%) and (18.3%) respectively.

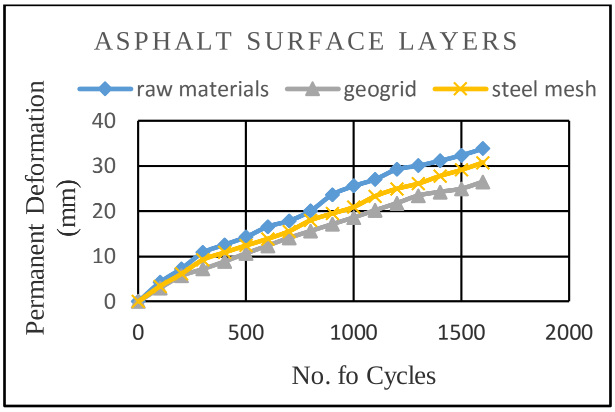

Fig. 3 Permanent Deformations versus the Number of Cycle for Asphalt Concrete Layers

4. FINITE ELEMENT MODELING

4.1 Pavement Layers Modeling based on ABAQUS

4.1.1 Model geometry

Three-dimensional continuum solid elements are often selected to simulate the problem in consideration. The model consists of a 130 mm of asphalt surface layer (wearing and binder) placed on 150 mm of subbase and 150 mm base over 200 mm of sub-grade soil.

4.1.2 Material Characteristics

The most important aspect of Finite Element Analyses is the simulation of the material characteristics. The material properties for pavement layers are summarized in Table 4.

Table 4 Material Properties (Input Data)

Layer	Density (Kg/m³)	Young's Modulus (MPa)	Poisson's Ratio (ν)
Wearing layer	1922	2413	0.35
Binder layer	1734	2375	0.35
Base layer	2141	241	0.4
Subbase layer	2200	110	0.4
Subgrade layer	982	8	0.45

4.1.3 Element type and mesh size

The pavement structure is meshed using an 8-node continuum linear brick reduced integration element (C3D8R element). The total number of element is 12096 and the mesh convergence study is executed to find this optimum number of element. All layers are simulated with the same shape to preserve the continuity of nodes between consecutive layers. Fig. 4 shows meshing of total model.

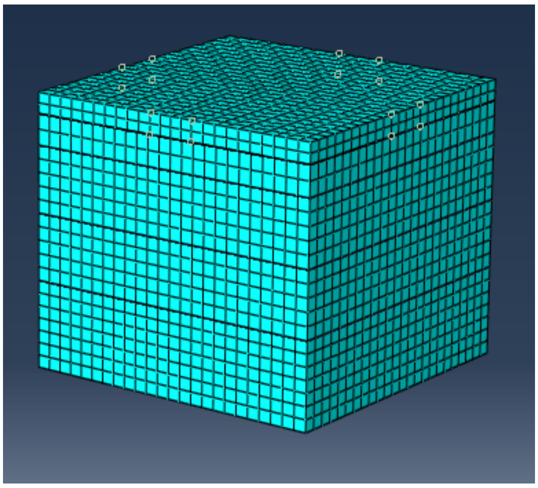

Fig. 4 3D Finite Element Mesh Model

4.1.4 Loading and boundary condition

The F.E is then run simulating a dynamic load, modeled as a pressure load applying at the same location of the pavement, as shown in Fig. 5 . The load applied in the ABAQUS is 280 Kg (2.8 KN).

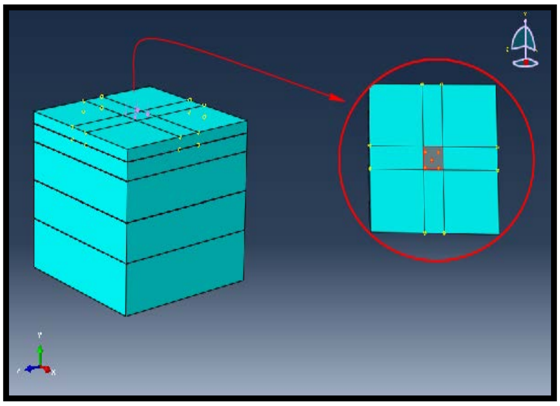

Fig. 5 Loading Applied in ABAQUS Program

The boundary conditions have a significant influence in predicting the response of the model, the bottom surface of the subgrade and sides of layers is assumed to be fixed, Fig. 6 shows the boundary conditions used in the analysis

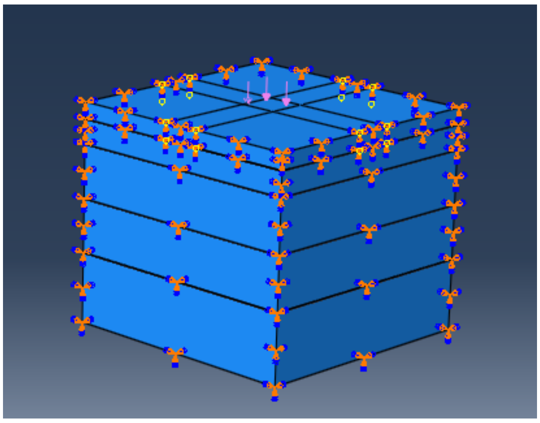

Fig. 6 Boundary Conditions for Model

ABAQUS Program's Output

Rutting is simulated as a vertical displacement in the ABAQUS model analysis. The magnitude of the displacement U beneath the center of the load at 1000 cycles load is shown in Fig. 7, 8 and 9.

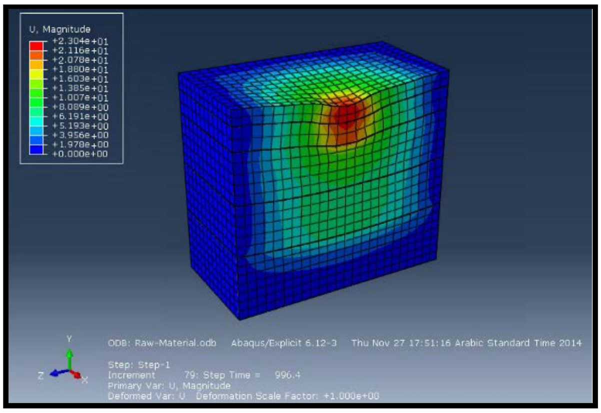

Fig. 7 Vertical Displacement for the Model with Raw Materials

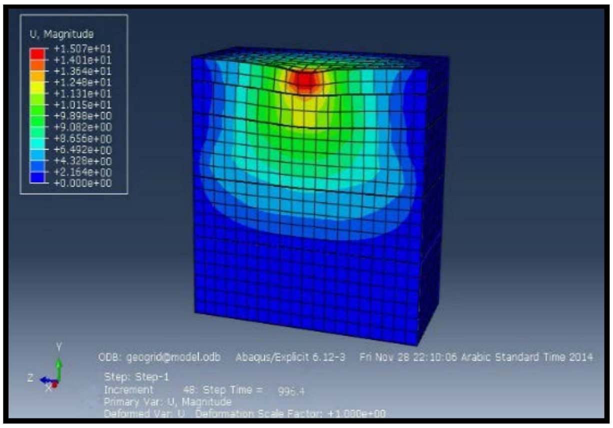

Fig. 8 Vertical Displacement for the Model with Geogrid

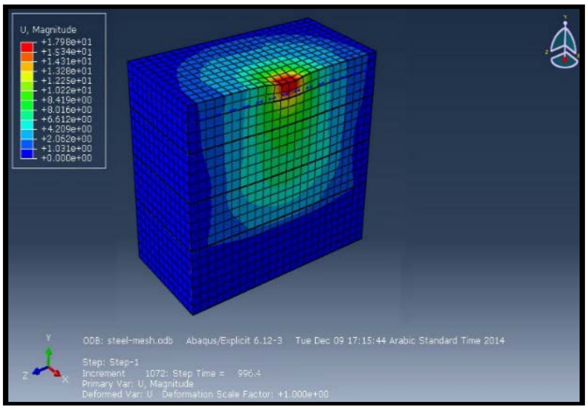

Fig. 9 Vertical Displacement for the Model with Steel Mesh

Fig. 10, 11 and 12 show the comparison between vertical displacements (rutting) obtained by experimental work and ABAQUS results at different number of cycle load. It can be seen that there is no significant difference appears between experimental and ABAQUS results.

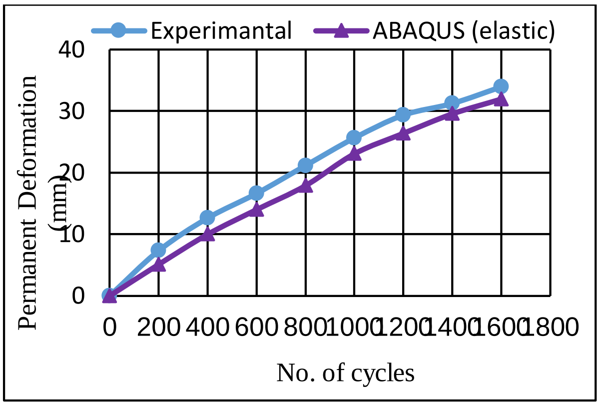

Fig. 10 Comparison between Experimental Result and ABAQUS for Raw Materials Model

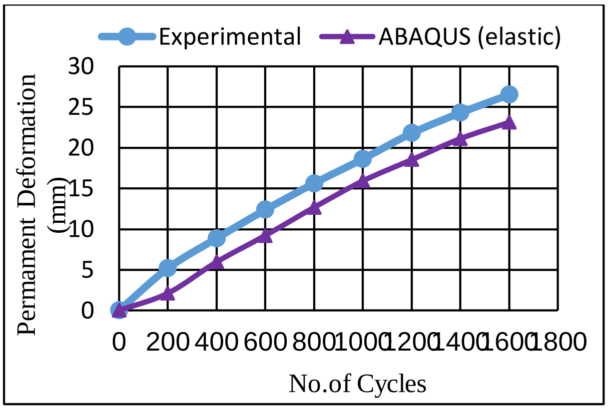

Fig. 11 Comparison between Experimental Results and ABAQUS for Geogrid Model

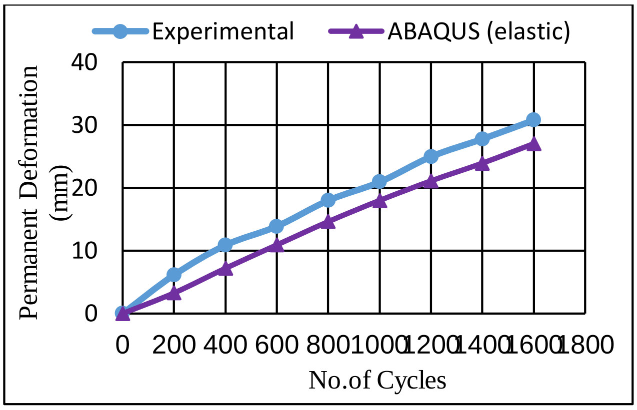

Fig. 12 Comparison between Experimental Results and ABAQUS for Steel Mesh Model

5. CONCLUSIONS

1. It is found that, using geogrid, is more practical and suitable to improve weak subgrade against permanent deformation as compare with steel mesh mode. It shows a typical increase in the ability to support repeated and dynamic loads transmitted from the pavement structure.
2. ABAQUSE program was successful in simulation pavement structure models, so ABAQUS program can use in analysis of paved road.

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