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APPLICATION OF ABAQUS PROGRAM TO INVISTIGATE THE EFFECT OF VARIATION IN SUBGRADE LAYER PROPERTIES ON THE DAMAGE OF FLEXIBLE PAVEMENT STRUCTURE

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BSTRACT: The major purpose of the pavement structure is to reduce stresses in the subgrades so that there is little or no deformation in the subgrade. Therefore, the more the subgrade is resistant to deformation, the thinner the pavement will be, thus reduction in the construction cost of the road. Finite Element techniques can be effectively applied to simulate different pavement problems that could not be modeled using the simpler multi-layer elastic theory. Thus, finite element Abaqus 6.14-1 program is used in this study. The laboratory tests are carried out on both the natural and stabilized soil samples that used as subgrade layer to determine the properties of subgrade that will be used as inputs for the finite element Abaqus program. The natural samples tested with three percentages of moisture contents (11.5%, 13.5%, and 15.5%). Different types of stabilizers are used in this study in form of mixture of two types of stabilizers. So, mixture of lime-kaolin (3%, 4%), mixture of silica fume-Poly Vinyl Alcohol (2%, 2%), mixture of Rice Husk Ash-Poly Vinyl Alcohol (3%, 2%), and 2% of silica fume are used as stabilizers. The pavement application by Abaqus program indicating that, the characteristics of subgrade layer have a big influence on the vertical deformation of whole pavement. The combination of (3% of Rice Husk Ash and 2% of Poly Vinyl Alcohol) as a stabilizer to the subgrade layer reduces the deformation about (9.5 %). While the addition of (3% of Lime and 4% of Kaolin) led to regard the deformation about (7.8%).

Keywords: Subgrade, Strength, Deformation, Finite element method, Shear strength, Elastic modulus.

1. INTRODUCTION

Finite Element Method is the dominate discretization technique in the structural mechanics. The basic concept in the physical interpretation of finite element method is the subdivision of the mathematical model for disjoint components of simple geometry called finite element [1]. The non-linear modulus and deformation behavior of the fine grained soil were studied using the subgrade layer and the unbounded aggregate for the base/subbase layers with respect to repeated wheel loads by using Abaqus program [2]. Abaqus is a commercial finite element modeling program. This program is suite of engineering analysis software packages used around the world for the simulation of the physical response of structures and soil bodies for loads, impact, contact, temperature and the other environmental conditions [1]. The Abaqus software used to investigate the dynamic response of pavement in term of elastic behavior [3]. The results of this work indicating that, there is a reduction in the longitudinal strain in the asphalt layer. Also the comparison between the strains computed at the field and those of model is a suitable accommodation. [4] Suggested the using of linear elastic modeling to determine the expected fatigue and rutting damage in flexible pavements due to the traffic loads [5].

2. METHODOLOGY

Three dimensional finite element method is the best approach to analyze more accurately critical pavement response through the minimizing or eliminating the assumptions of the two dimensional analysis. The analysis in (3D) method is more complicated as compared with the axisymmetric because of the extra coupling that will occur in additional direction [6].

The responding of each element is expressed in terms of a finite number of degrees of freedom that characterized as the value of unknown function at a set of nodal points. For typical finite element analysis by any software, it's very important to provide the following information:

1. The geometry of the structure.
2. Elements connecting.
3. Materials properties.
4. The boundary conditions or the restraints.
5. Load or the details of forcing function.

The solution process in finite element method can be summarized in the following steps:

1. Dividing the structure into pieces (the meshing step).
2. Connecting the elements at the nodes form on approximate system of equations for the whole structure.

3. Solving the equations that involve the unknown quantities at the nodes.
4. Calculating the desired quantities such as stresses, strains at the selected element.

3. MATERIALS AND TESTS

The soil used in this research is brought from AL- Sader city at the east of Baghdad. The sample is taken from *(2-4m)* depth below the existing ground surface. The soil transferred in plastic bags to soil mechanics laboratory of the highway and transportation engineering department. Tests are carried out on the soil samples to determine the physical and chemical properties. The tests included particle size distribution, soil classification and description, specific gravity, Atterberg limits.
Table 1 and Tables 2 represent the physical properties and chemical composition of the soil sample used in this study.

Table 1 Physical Properties of Soil Samples

Index Property	Value
Liquid Limit (L.L.)	45
Plastic Limit (P.L.)	20
Plasticity Index (P.I.)	20
Specific gravity (G_s)	2.65
%Gravel	0
%Sand	20
%Silt	24
%Clay	56
AASHTO Classification	A-7-6
Unified Soil Classification System (U.S.C.S.)	CL

Table 2 Chemical Properties of Soil Samples

Index Property	Value
Total Soluble Salts (T.S.S.)	10.8
Organic Matter Content	2.4%
Total Sulphate Content	1.45%
PH Value	7.9
Gypseous Content	3.57

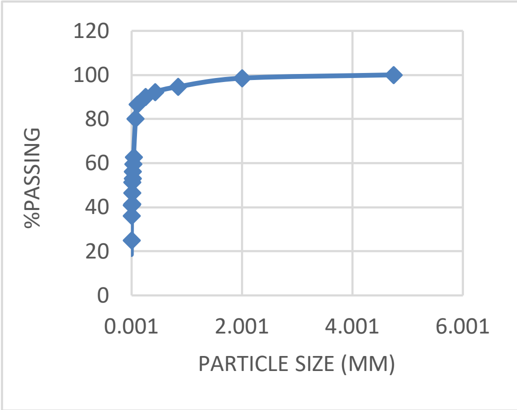

Fig.1 Grain Size Distribution of Soil Sample

3.1 Lime-Kaolin Mixture

Both of these materials are brought from the local market. In this study hydrated lime Ca $(OH)_2$ is used. in this work 3% of lime and 4% of kaolin are mixed and added to the natural soil. The additives and soil are mixed until obtaining homogeneous mixture in color. Physical and chemical properties for both lime and kaolin are shown in tables (3) & (4).

Table 3 Physical Properties of Hydrated

Properties	Lime
Form	Fine dry white powder
Color	White
Specific Gravity	2.3
PH (25^0 C)	12.93
Finess (m^2/Kg)	657

Table 4 Physical Properties Kaolin

Property	Index
Specific Gravity	2.58
Liquid Limit (L.L.)	57
Plastic Limit (P.L.)	27
Plasticity Index (P.I)	30
Soil Symbols (USCS)	CH

3.2 Silica-Fume

Silica-fume is brought from the local market. It's a highly effective material because of the high silica content and the extreme fineness. This stabilizer is available in two colors weight and dark grey. In this study 2% of silica-fume is used as a percent of the dry weight of the natural soil. Physical and Chemical properties of this stabilizer are shown in Table 5 and Table 6 respectively.

Table 5 Physical Properties of Silica-Fume According to (ASTM C1240-03).

Physical Property	S.F.
%Retaining on 45-μm (No. 325) sieve, Max.	7
Specific Surface, Min., m^2/g	21
Specific gravity	2.231

Table 6 Chemical Properties of Silica-Fume According to (ASTM C1240-03).

Oxide Composition	S.F.
Sio_2, Min. percent	90
Moisture Content, Max. percent	0.68
Loss of Ignition, Max. percent	2.86

3.3 Mixture of Rice Husk Ash (RHA) and Poly Velyin Alcohol (PVA)

RHA is obtained from the mailing of rice ash which is brought from Al-Meshkhab in Al-Najaf city. The rice ashes are burn at (600 C) for 2 hours. In controlled temperature then the by-product is mailed to obtain the RHA in powder form. Plate (3.1) shows the rice husk and rice husk ash. PVA is a white to yellow powder that obtained from the local market. In this research (3% of RHA) is mixed with (2% of PVA) the added to the natural soil to study the effective of this additive on the soil.

3. Silica-Fume and Poly Vinyl Alcohol (PVA)

In this study a mix of (2% Silica-Fume) and (2% PVA) is used. Before the using of this mixture, the three additives are mixed together and then added to the natural soil.

4. MATERIAL PROPERTIES

For understanding and investigating the distribution of stresses, strains and displacement in the pavement layers with the variation in subgrade layer properties, 3D models are created by finite element Abaqus program. The simulation of subgrade layer in this case included the using of drucker prager to produce the elasto-plastic behavior. The angles of friction (ø) and cohesion stress (C) were determined through the direct shear test while the values of modulus of elasticity (E) are obtained from the results of U.C.S as shown in Table 7.

Table 7 Material Properties

Layer		Density (Kg/cm^3)	E (Mpa)	Ø(Deg.)	Poisson's ratio	C (Mpa)
6		2310	1200	-	0.3	-
Subbase		2200	110	-	0.3	-
Stabilized Subgrade	Lime and	1640	18.9	38	0.4	0.08
	S.F	1692	10.5	42	0.4	0.07
	(RHA and	1680	21.5	46	0.4	0.05
	(S.F. and PVA)	1660	12.9	40	0.4	0.03

5. SIMULATION OF MOVING LOAD

The application of layered theory for the design of flexible pavement included the assumption of circular contact area for each tire. This assumption is not correct but the error is very small. So, for simplification the analysis of flexible pavement, a single circular with same contact area as the duals is used to simulate a set of dual tires instead of using two circular areas. The contact pressure on the pavement is equal to the tire pressure. In this study the load of one tire is considered equal to (96 Kg) and it distributed uniformly over the total contact area. The pressure used in this research to (550 Mpa).The simulation of moving load on the pavement structure included division the pavement into (12) Steps to simulate the path of tire on the asphalt surface layer, each step consist of number of cycles through the using of time-amplitude tabular. Step by step loading is used to simulate the motion of wheel in a determined speed. The loading place must be moved in a gradual form in order to have a complete wheel turn. Fig. 2 represents the steps of loading used in finite element Abaqus program. The simulation of repeated load by using time-amplitude tabular is shown in Fig. 3.

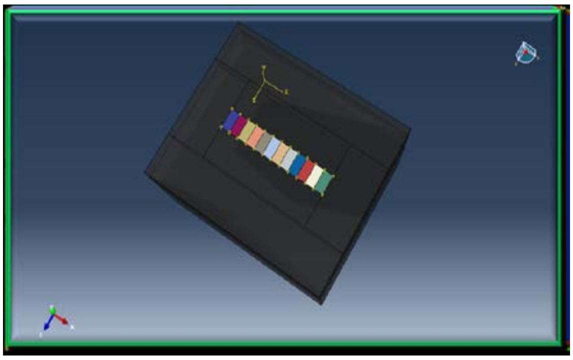

Fig.2 Steps Used to Simulate Moving Load in Finite Element Abaqus Program.

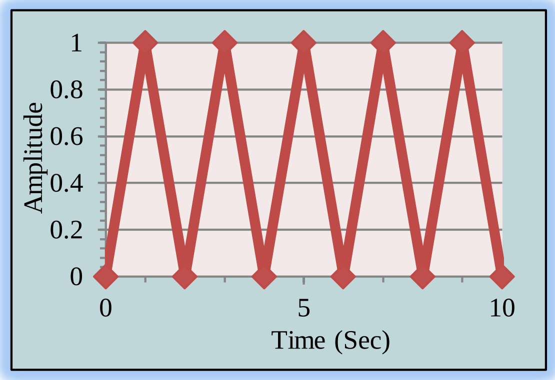

Fig.3 Simulation of Moving Load by Using Time-Amplitude Tabular

6. BOUNDARY CONDITIONS

The boundary conditions of the model have important effect in the prediction of response of the model. Steel box is assumed to be used, so the bottom of subgrade and the sides of each layer is assumed to be fixed. In other word, there is no horizontal or edges of pavement are assumed free to move vertically but forced in the horizontal direction. Fig. 4 represents the boundary conditions of the model.

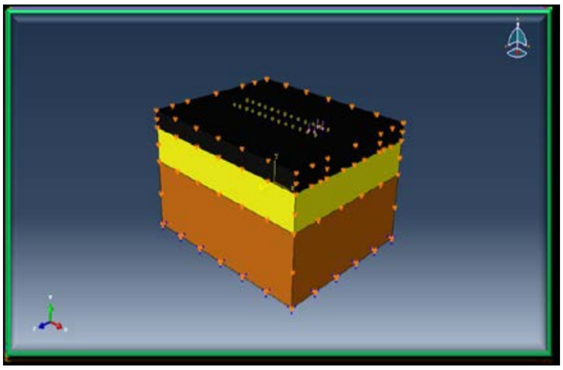

Fig.4 Boundary Conditions of the Model Simulated by Finite Element Abaqus Program.

7. FINITE ELEMENT TYPE

All the parts of the model that created by finite element *Abaqus 6.14-1* are modeled using *(8)* nodes continuum three dimensional brick element *(C3D8R)* with reduced order numerical integration available in Abaqus program [5]. This element has the ability to represent large deformation, geometric and material nonlinearities. Solid element *(C3D8R)* has three degrees of freedom at each node, translations in the nodal *X*, *Y* and *Z* directions. The pavement layers are simulated with same shape to reserve the continuity of the nodes between the sequential layers [6].

7.1 Meshing Size

The mesh of model is considered in way to provide best and more accurate results. So, (8) nodes linear brick reduced integration elements (C3D8R) meshing is used to improve convergence rate. (C3D8R) elements are of quadratic type. Quadratic elements have better results than the linear interpolation element (Hadi and Bodhinayake, 2013). Fine mesh size is used around the loading area, along the wheel path and at the interface between layers where the gradients of stresses and strains are higher. Fig. 5 shows the mesh size for all layers of the model.

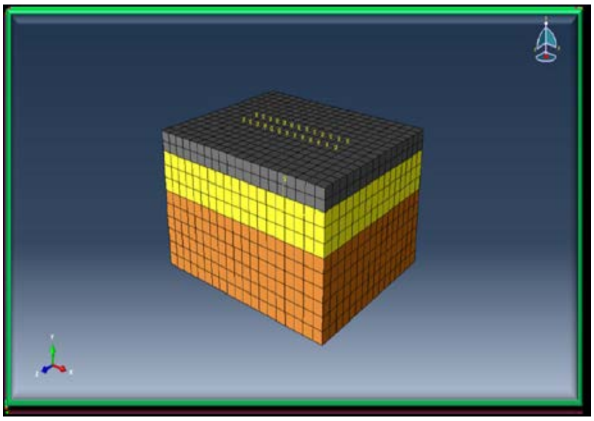

Fig. 5 Meshing of all Parts of the Model.

8. INTERACTION MODELLING TECHNIQUES

To contact the parts of model together by using Abaqus program, it's very important to define the surfaces of interaction between two layers. There is several formulation of contact in Abaqus program. Each formulation is depending on the choice of contact discretization, tracking approach and assignment of (master) and (slave) roles for the contact surfaces[7]. The interaction technique permits merging two regions together. In this study, (Surface to Surface) contact with small sliding is used for all the contact interactions in the model which assumed a comparatively small sliding but could submit to an arbitrary rotation of the bodies. The formulation of interaction between the layers of model is shown in Fig. 6.[8]

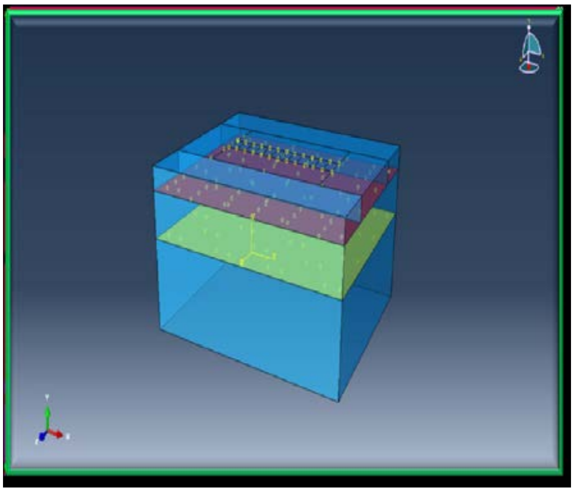

Fig.6 Formulation of Interaction between the Layers of the Model.

9. RESULTS AND DISCUSSIONS

To study the influence of variation in subgrade layer properties on the permanent deformation of the flexible pavement structure, seven models are built by using finite element Abaqus program[9][10]. In this research, the comparison between these models based premilary on the permanent deformation. Fig. 7& Fig 8 show the vertical permanent deformation for the natural and stabilized models at Dry side & O.M.C. [11]

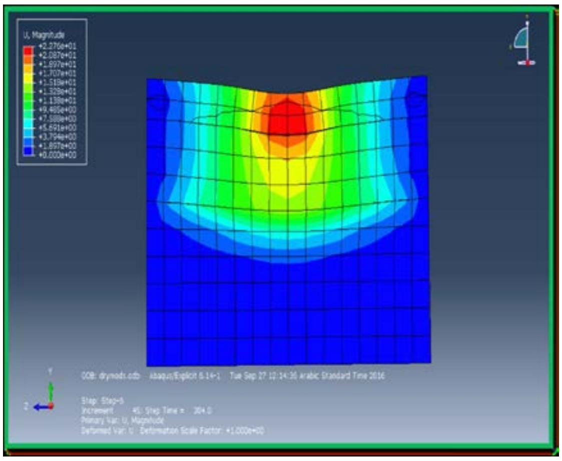

Fig. 7 Vertical Deformation for Natural Model Compacted at Dry Side.

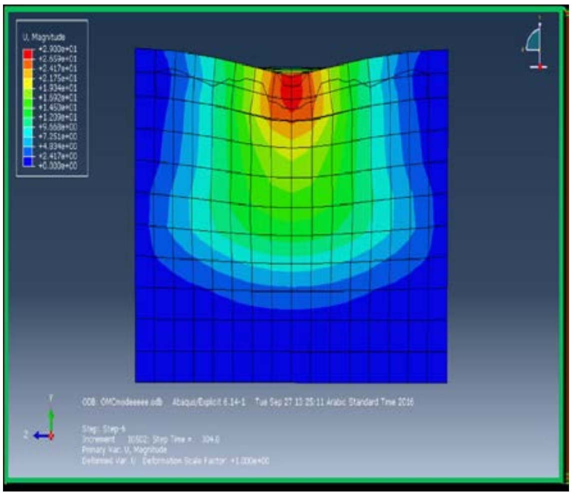

Fig. 8 Vertical Deformation for Natural Model Compacted at O.M.C.

For the models with untreated subgrade layer it's noted that, the vertical deformation reduced about (5.3%) due to the increasing of moisture from (11.5%) to (13.5%). The increasing in moisture to (15.5%) results in increasing the surface deformation about (7.8%).

The using of (3% of RHA and 2% of PVA) as stabilizers for the subgrade layer led to improving the deformation to (9.5%) as compared with untreated model. The other stabilizers improved the deformation with different percentages. Fig. 9 and 10 illustrated the values of vertical deformation for the natural and stabilized models respectively.

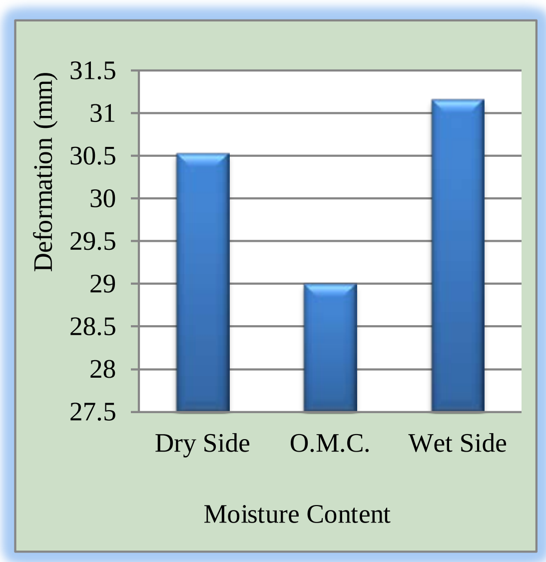

Fig.9 Vertical Deformation for Elasto-Plastic Models with Natural Subgrade Compacted at Different Moisture Contents.

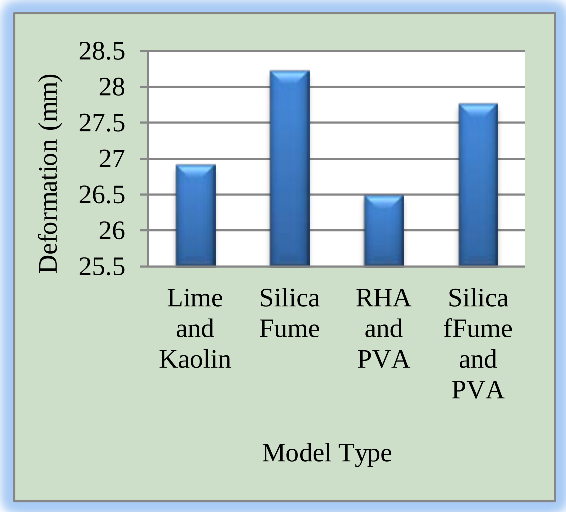

Fig. 10 Vertical Deformation for Elasto-Plastic Models with Stabilized Subgrade Compacted at Optimum Moisture Contents.

The percentage of improvement in vertical deformation due to using stabilized subgrade layer with different stabilizers is shown in Fig. 11 below.

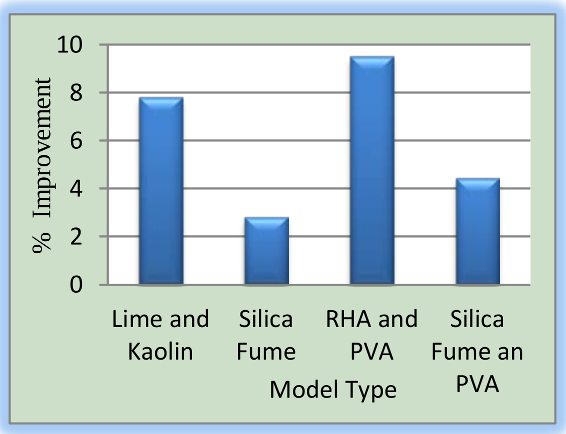

Fig. 11 Percentages of Improvement in Vertical Deformation Due to Using Stabilized Subgrade Layers

SUMMARY AND CONCLUSSIONS

The untreated subgrade layer that compacted at the wet side resulting in high vertical deformation due to the applied traffic loading as compared to the subgrade layers compacted at dry or O.M.C.

All types of stabilizers used in this research improved the deformation but the addition of combination of (RHA and PVA) gives a less deformation as compared to the other types of stabilizers.

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