

An Approach in Evaluating of Flexible Pavement In Permanent Deformation OF Paved AND Unpaved Roads Over Sand Dunes Subgrade Under Repeated Loads

Dr. Saad F.Ibrahim[1*] Dr. Gandhi G. Sofia [2*] Zaman T. Teama[3]
1* B.Sc., M.Sc., PhD (C.E.).MISSMGE.M.I.ASCE, College of Engineering.,Al-Mustansiria University, Iraq, drsaadfarhan@yahoo.com
2* B.Sc., M.Sc., PhD (C.E.), College of Engineering.,Al-Mustansiria University,Baghdad, Iraq, gandhisofia@gmail.com
3* B.Sc., M.Sc.(C.E.).College of Engineering.,Al-Mustansiria University, Iraq
alitalaz@yahoo.com

Abstract
Thickness of flexible pavement play very important factor in cost of construction of road ,in this study effect of change thickness of pavement on rutting of road is investigated . Two approaches are adopted; the first is the laboratory tests through simulation of three layers of paved road and two layers for unpaved road, using a steel box with dimensions of 600mm length 500mm width and 400mm depth. Sand dunes are used as a subgrade layer to investigate its behavior by using it as a part of flexible pavement structure under repeated load at relative density 55.7%. The effect of change in thickness of asphalt layer in permanent deformation is also investigated, through using three models at three different thicknesses, starting from zero (unpaved), 50mm and 100 mm. The second approach is the development of a three-dimensional finite element model for flexible pavements using ABAQUS (6.12-3) to simulate the laboratory test The results indicate that increase in the thickness of flexible pavement to 50mm from zero (unpaved), increases the number of passes about 971.42%, while the increase of thickness from 50mm to 100 mm, increases the number of passes by 517.33%. The results of ABAQUS program are very close to results of laboratory tests.
Keywords: Sand Dunes subgrade, Thickness of Flexible Pavement, ABAQUS Models

INTRODUCTIO

Flexible pavement layer in construction of roads consider as highest cost and more strength than other layers in paved road, asphalt layer carry the major part of the traffic loads and reduce the stress which progressive to subgrade to reduce the distress in pavement body .so it's necessary to study the effect of existing asphalt layer in ability of road to carry traffic load over sand dunes subgrade. Sand dunes cover large area of Iraq so it's necessary to investigate the behavior of paved and unpaved road over sand dunes subgrade. During construction and operation of roads or highways on sand dunes bed may encounter several problems. Some of the associated problems are mentioned ;A)The real problem of sand dunes is their crawl that affects development of projects.Sand Dunes cause a decrease in the efficiency and an increase in the maintenance costs for these projects. The delay of work in a highway between Diwaniyah and Nasriyia is a good example for that (Salem, 2011), B) the formation of depressions and settlement of road (Aiban,1994), C) Shallowness of the ground-water in some parts (Fookes and H igginbottom,1975) which alters the compressibility of the soil and can lead to fines migration , D)Variability in strength and compressibility leading to differential settlement (Abu-Taleb and Egeli, 1981; Al-Amoudi et al., 1991) E)Sand movement causes abrasion to the existing structures and blockage of some streets and highways. This presents an unacceptable risk in normal practice and calls for the improvement of the geotechnical properties of such soils prior to any construction (Aiban et al., 1996).

2. RESEARCH METHODOLOGY

2.1 Subgrade

Laboratory experimentation is done to investigate effect of change relative density of sand dunes subgrade

2.2 *Subbase Course*

The sub base is brought from Al_ Nibaee quarry, north of Baghdad, this type of sub base is commonly used as a layer in flexible pavement construction.

2.3 Surface course

50-60-penetration grade bitumen is considered for experimentation and aggregates Confirming midpoint gradation of grade II specifications as per Iraq specification have been used.

2.4 Laboratory pavement setup

Laboratory based pavement sections with conventional materials and that with one value of subgrades relative density is prepared , subbase layer and surface course is prepared in a prefabricated box type arrangement made of mild steel of size 600mm length X 500 mm width X 400 mm depth.

Three Laboratory based multi-layer sample pavement sections were formed, one of them pavement section with sand dunes subgrade at relative density 55.7% ,subbase and thickness of flexible pavement Zero (unpaved) mm symbol , other one of one of them pavement section with sand dunes subgrade at relative density 55.7,subbase and thickenss of flexible pavement 50 mm and last one same models but with flexible pavement thickness 100mm.

3 DATA ANALYSIS

3.1 Material Properties

Table 1 show properties of sand dunes which used, table 2 show properties of subbase layer and table 3 show properties of asphalt layer which used

Table 1: Properties of sand dune

Property	Type properties	Index	Standards
GS	Specific	2.67	ASTM: D -854 -
L.L	Liquid Limit	25	ASTM: D -4318-
P.L	Plastic Limit	NP	ASTM: D -4318-
PI	Plasticity Index (PI %)	NP	
γ max	Modify Compaction	18.7 kn/m3	ASTM 698-00
γ min	minimum dry density	12KN/m3	
	Soil Symbols(USCS)	SP-SM	(USCS).

Table 2: Properties of Subbase

Chemical Element	Result %
So3	2.26
gypsum	4.87
Tss	2.12
Om	1.69
Maximum density	2200
Soil classification	GP

Table (3) Properties of asphalt cement

Property	ASTM Designation Number [16]	Asphalt Cement Daurah (40-50)
Penetration (25°C, 100 gm., 5sec), (1/10 mm)	D-5	43
Softening Point (Ring and Ball), °C	D-36	51.5
Ductility, cm	D-113	> 100
Flash Point (Cleave land open-cup)	D-92	335
Specific Gravity , 25 °C	D-70	1.048
Loss on heat (5 hrs, 163 °C, 1/8"), %	D-1754	0.18

3.2 Laboratory based multi-layer pavement

The thickness of the pavement layers have been designed to ensure that the stresses reach the subgrade level. It was proposed to form the multi-layer sample pavement section with the 0,50mm and 100mm thick bituminous concrete, 100mm thick subbase layer and 200 mm thick as show in figure 1and Figure 2 depict the laboratory pavement.

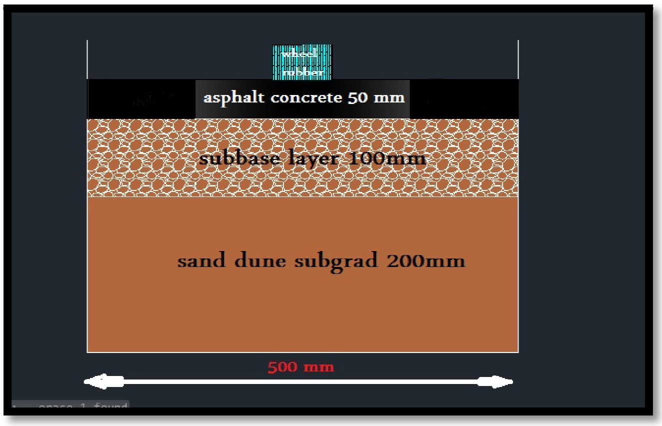

Figure 1 Cross section multi-layer pavement section

4-FINITE ELEMENT MODELING

4.1 Model geometry

FEA has been proven suitable for application to complex pavement problems. 3D mode was built by using the finite elements program ABAQUS (6.12-3), to understand, with more precision, the distribution of the displacements in the entire pavement layers when different densities of subgrade layer, (3D-DFEM) program that has the capacity to simulate actual vehicle loading conditions and estimate the structural response for flexible pavements are used to simulate laboratory models. The thickness of layers are same thickness of laboratory are 200mm sand dunes subgrade , 100 subbase and 50 mm and 100mm asphalt ,as shown in Figure (3). Elastic properties (modulus of elasticity and Poisson's ratio) are shown in Table (4)

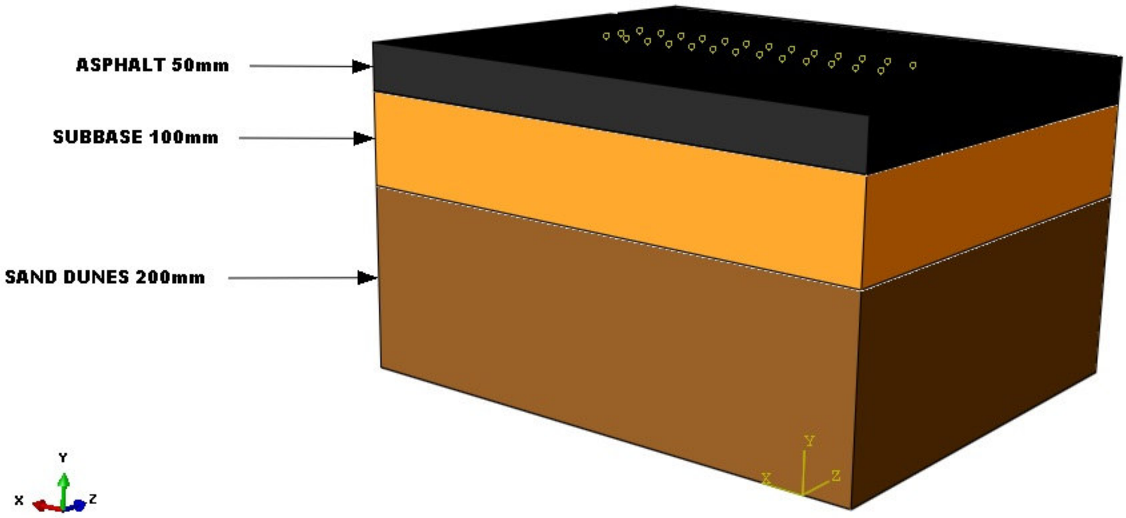

Figure (3): General Geometry of the Pavement Layers by ABAQUS Program

Table (4) material properties

Layers	Modulus of Elasticity (MPa)	Poisson's ratio(ν)*
Asphalt layer	1200	0.35
Subbase layer	110	0.35
Subgrade very loose layer	2	0.3
Subgrade loose layer	2.5	0.3
Subgrade medium layer	2.7	0.3

Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.14, 2014

4.2 Finite Element Types and Mesh Size

All the parts of the model are modeled using the 8-node continuum three dimensional brick element (C3D8R) with reduced order numerical integration available in ABAQUS (6.12-3). This element has the capability of representing large deformation, geometric and material nonlinear Solid element (C3D8R) has three degrees of freedom at each node. . All layers are simulated with the same shape to preserve the continuity of nodes between consecutive layers (Massod, 2013). Figure (4) shows total model

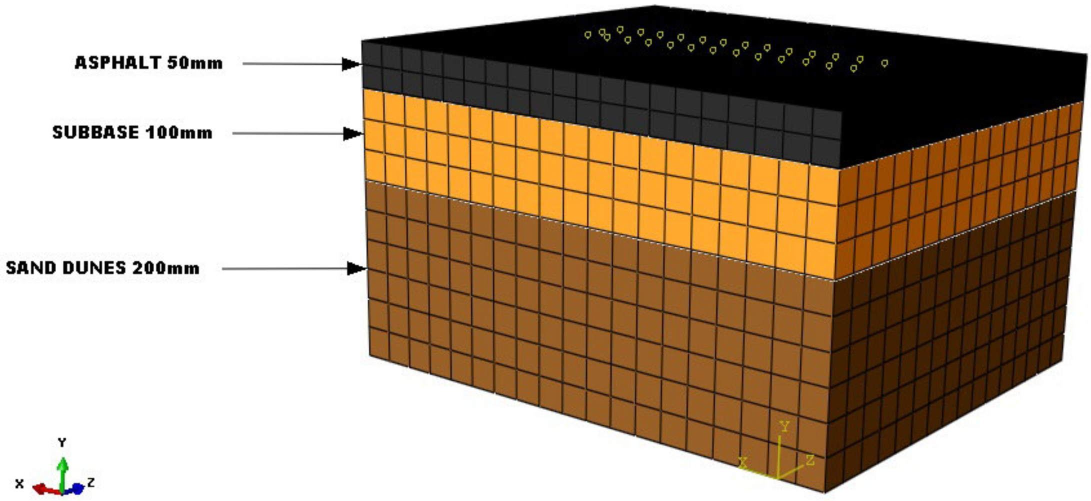

Figure (4)Mesh of All Layers

Boundary Condition

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, that means that nodes at the bottom of the subgrade and sides of layer cannot move horizontally or vertically. This represents the bottom and sides of steel box. Figure (5) shows the boundary conditions used in the analysis

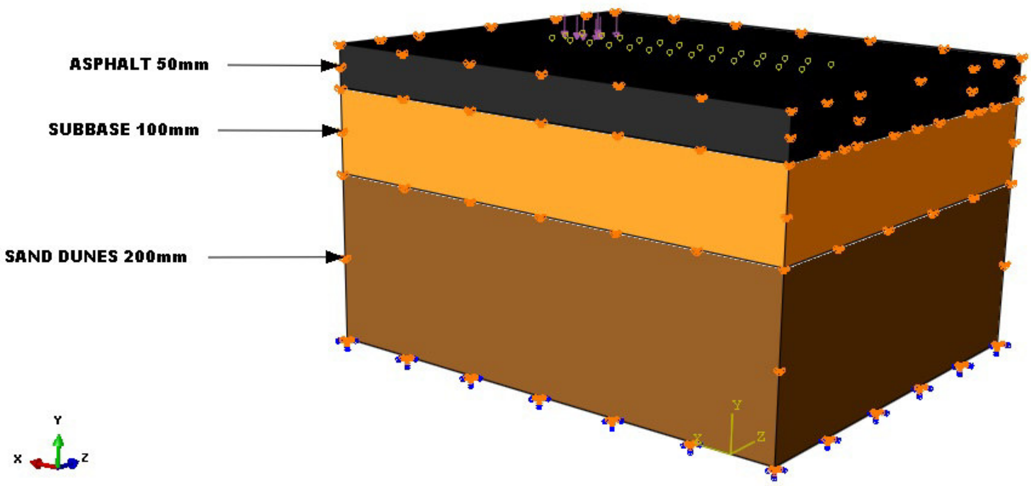

Figure (5) the Boundary Condition

4.3 Moving Load

The wheel load applied in the ABAQUS is 96 kg (0.96 KN) and is distributed uniformly over the total contact area. The resulting uniform contact pressure is 550 MPa which is equal to the pressure of tire which used two parameters, longitudinal and transverse distribution of vertical pressure on loaded area (Al-Qadi and Wang Hao 2009). Loading is applied to simulate wheel horizontal motion in a pre-determined speed. In this method, loading position should be moved in a gradual form in order to have a complete wheel rolling as shown in Figure (6).Figure (7) show wheel path in model

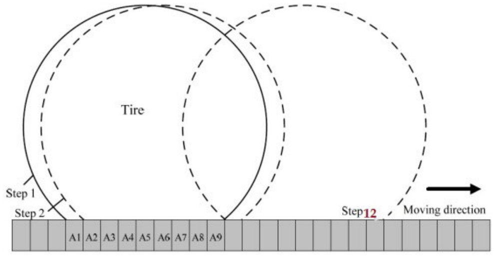

Figure (6) Schematic Illustration of Tire Moving along Pavement Surface

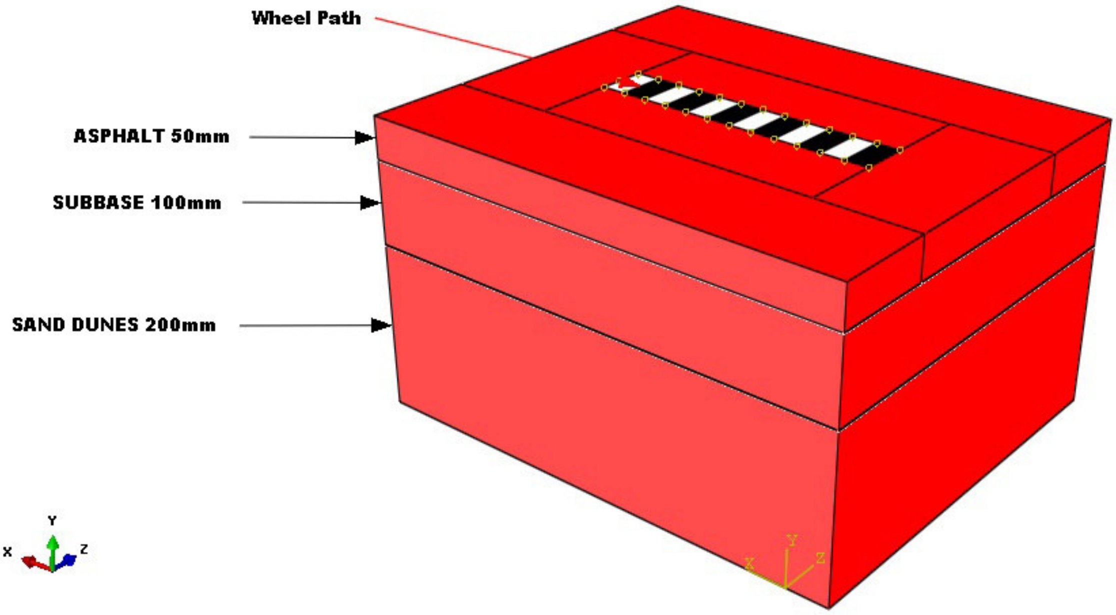

Figure (7) show wheel path

5 RESULTS

Wheel tracking device was used to evaluate the rut depth. These laboratory based pavement were subjected to wheel tracking on the wheel-tracking device under a contact pressure of 550 MPa and temperature 50 c^{o} result indicate when thickness of pavement change from zero to 50 mm the ability of pavement structure to carry traffic loads increase by about 971.42% this value show the effect of flexible pavement in increase capacity of pavement structure to carry traffic loads while the increase thickness of flexible pavement from 50mm to 100 mm increase ability of pavement to carry traffic loads by about 517.33% Figure (8) and (9) show pavement surface profile for subbase and subbase/subgrade interface for unpaved model. Figure (10 to 12) show flexible pavement surface profiles, flexible pavement/subbase interface and subase /subgrade interface respectively for model with asphalt thickness 50mm .Figure (13 to 15) show flexible pavement surface profiles, flexible pavement/subbase interface and subase/subgrade interface respectively for model with 50mm thickness for model with asphalt thickness 100 mm.

Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.14, 2014

The results of ABAQUS program are very close to results of laboratory tests, Figure 16 and 18 shows the ABAQUS out displacement (rutting) .figure 17 and 19 show shows the Result of Lab and ABAQUS for 50mm and 100mm asphalt thickness respectively. Figure 20 and 21 show the statistical analysis of two models to find the effectiveness of ABAQUS program in simulation laboratory models using Graphical Technique, histograms Technique. Figure 22 show the relation between rut depth and number of passes at different flexible pavement thickness. When thickness of flexible pavement increase traffic benefit ratio increase as shown in Table (5).TBR is defined as the ratio of the number of passes necessary to reach a given rut depth for model with specific pavement thickness , divided by the number of passes necessary to reach this same rut depth for control model with the same subgrade properties. Figure (23) shows the relationship between thickness of flexible pavement and number of passes at 6 mm rut depth. Figure (24) shows the relationship between rut depth and thickness of flexible pavement at constant number of passes, the number of passes 55 which represent the max number of passes in unpaved model.

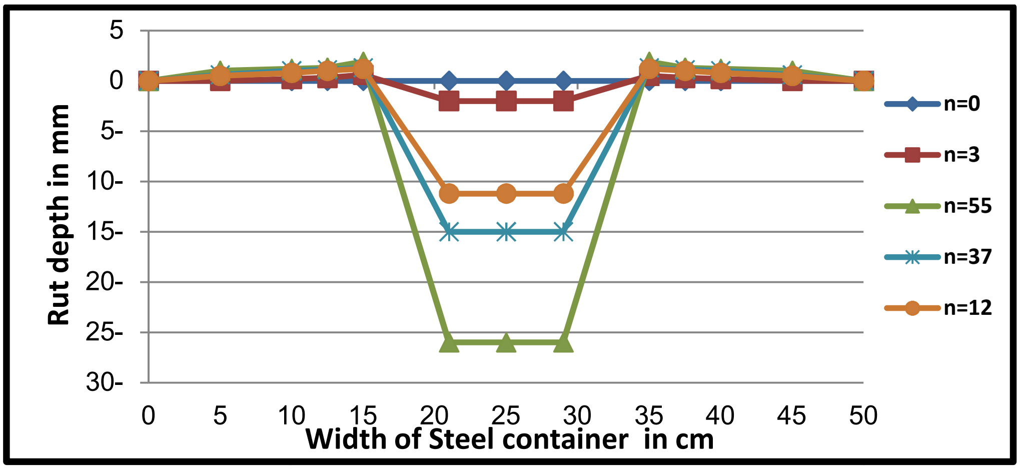

Figure (8) Surface Profile of Subbase

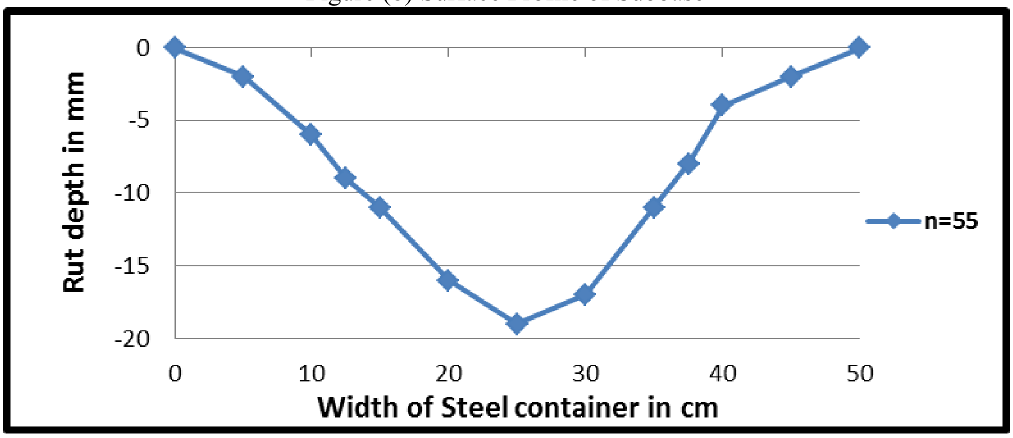

Figure (9) Surface Profile of Subbase /Interface

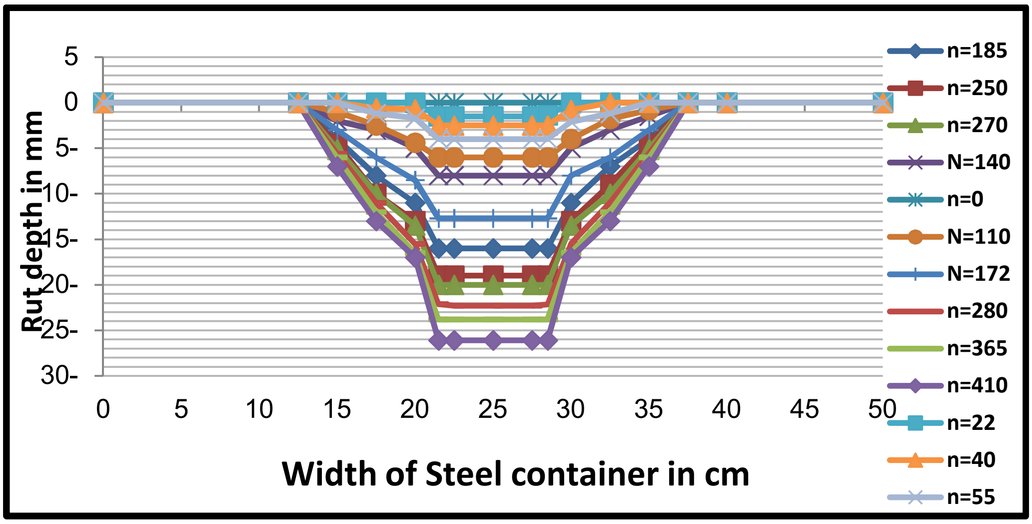

Figure (10) Flexible Pavement Surface Profile for 50mm Asphalt Thickness

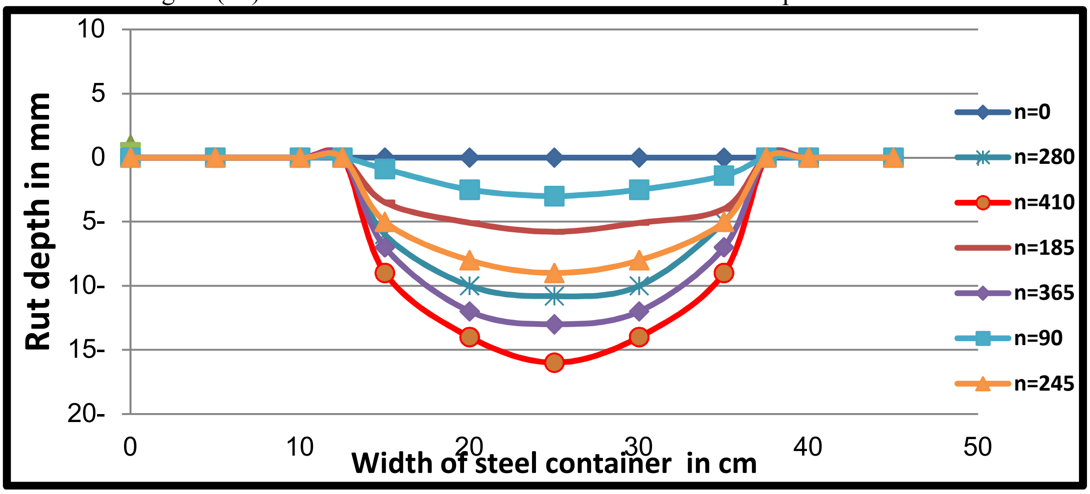

Figure (11) Asphalt /Subbase Interface Profile for 50mm Asphalt Thickness

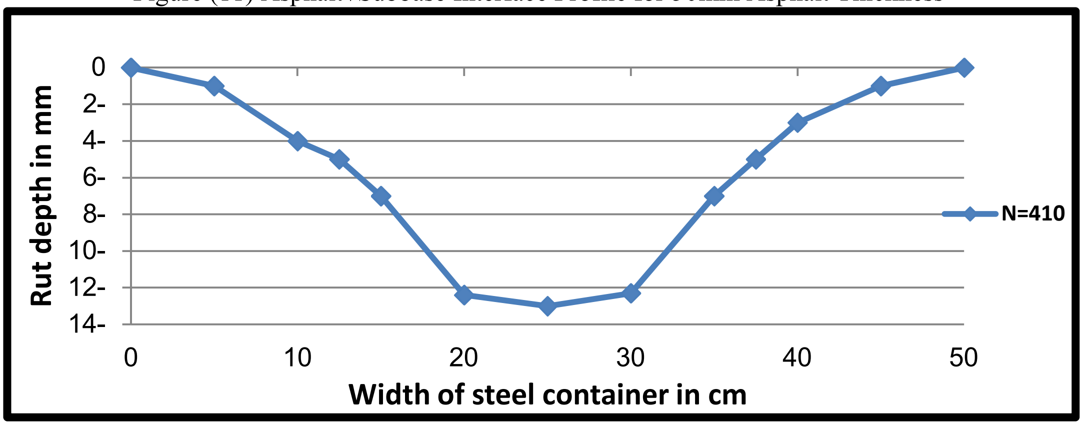

Figure (12) Subbase/Subgrade Interface Profile for 50mm Asphalt Thickness

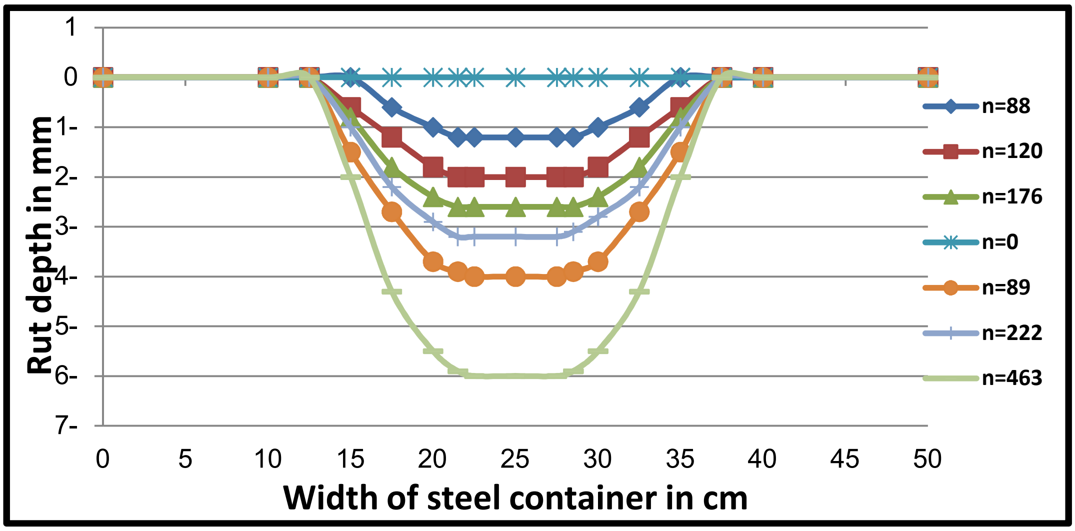

Figure (13) Flexible Pavement Surface Profile for 100mm Asphalt Thickness

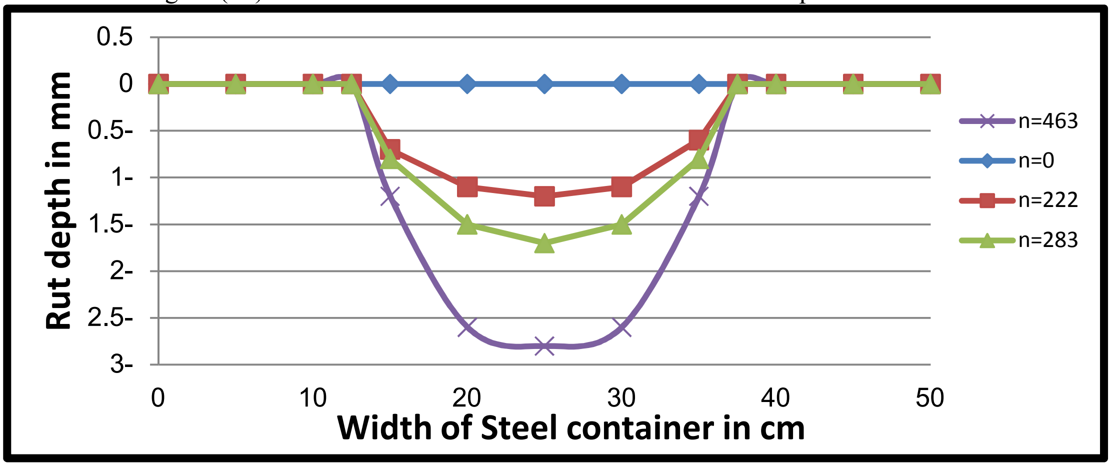

Figure (14) Asphalt /Subbase Interface Profile for 100mm Asphalt Thickness

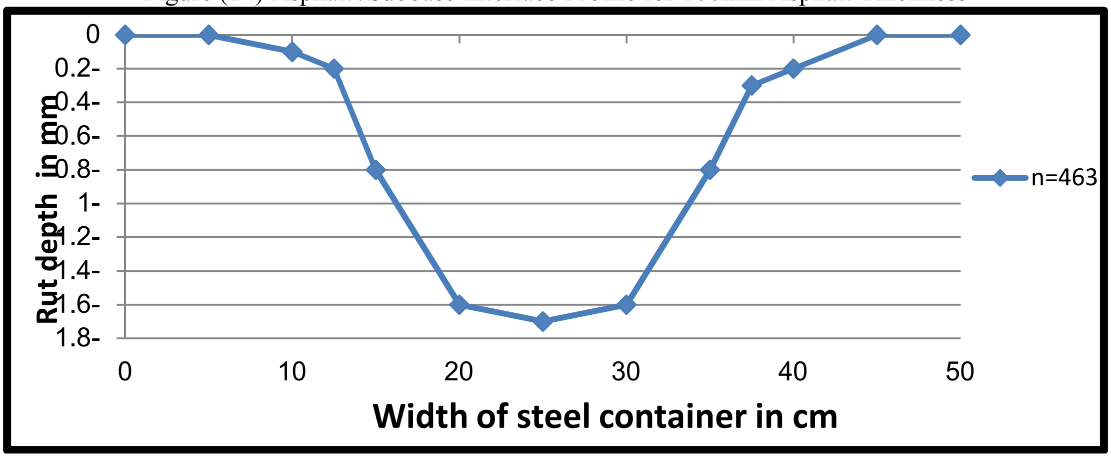

Figure (15) Subbase/Subgrade Interface Profile for 100mm Asphalt Thickness

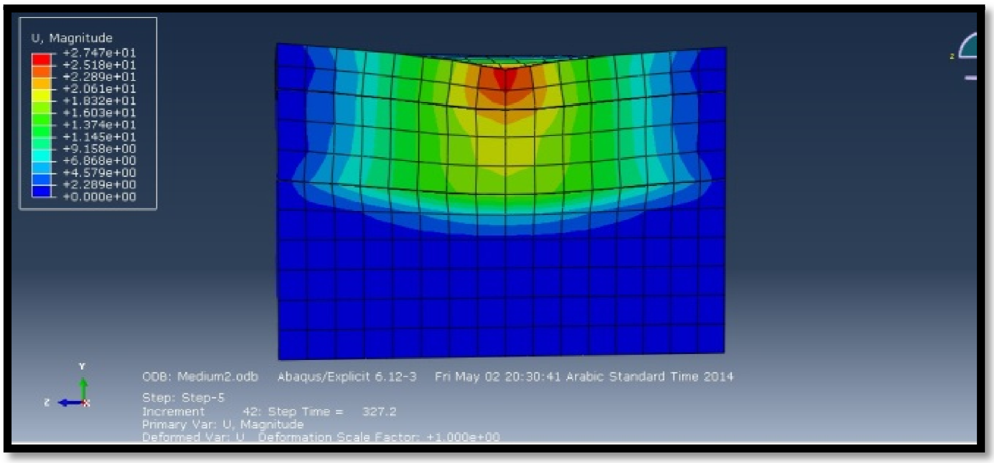

Figure (16): ABAQUS output of displacement side for 50mm asphalt thickness

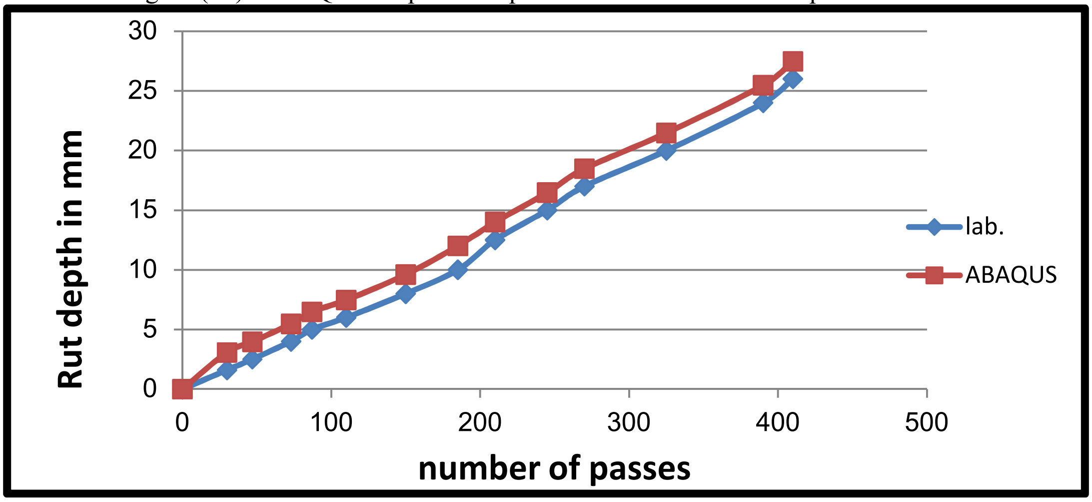

Figure (5.17): The Result of Lab and ABAQUS for 50mm asphalt thickness

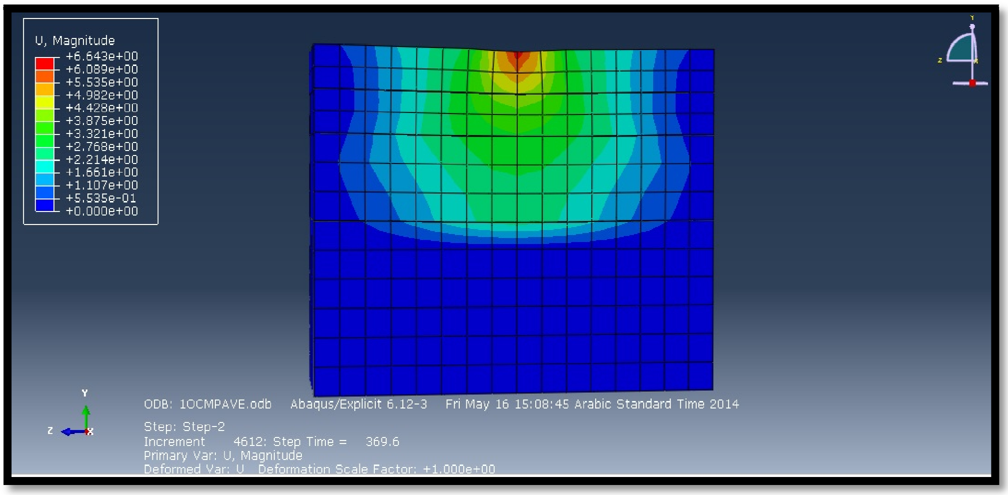

Figure (18): ABAQUS output of Displacement for 100mm asphalt thickness

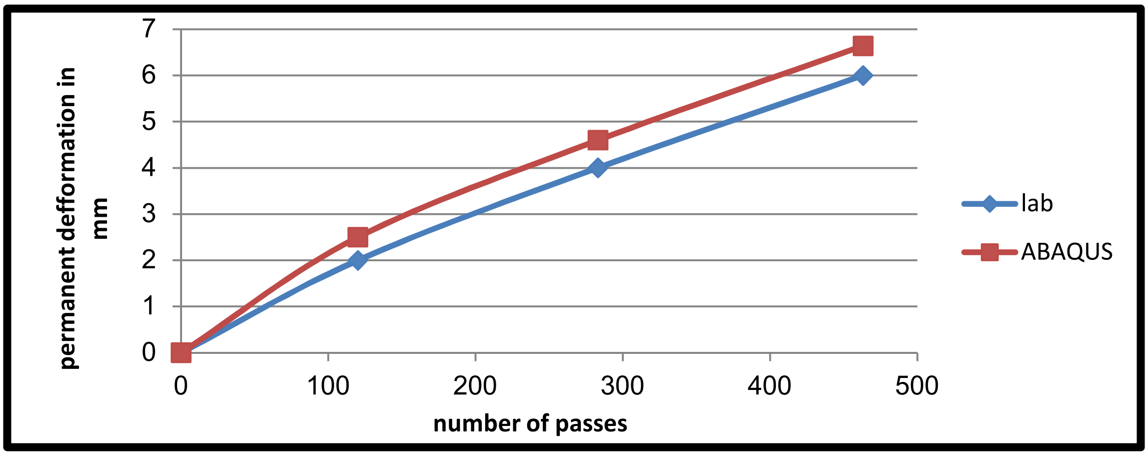

Figure (19): The Result of Lab and ABAQUS for 100 mm Asphalt Thickness

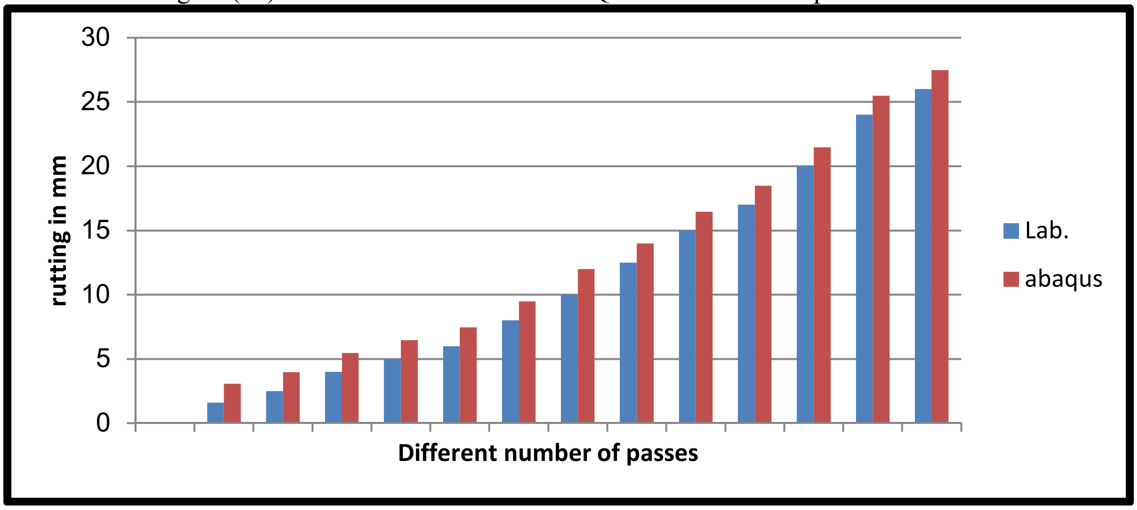

Figure (20) Histogram of Rutting in Lab. vs. Rutting in ABAQUS for 50mm asphalt thickness

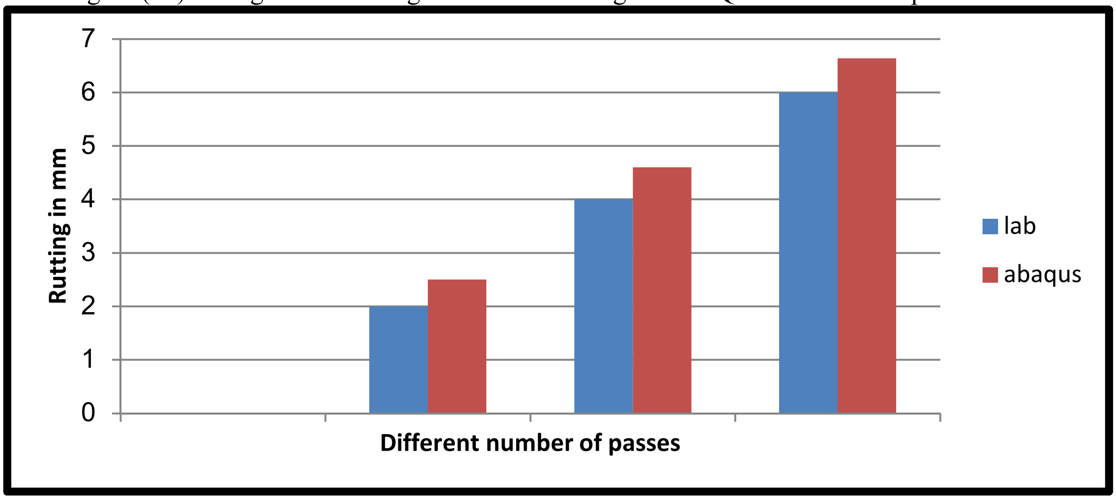

Figure (21) Histogram of Rutting in Lab. vs. Rutting in ABAQUS for 100mm asphalt thickness

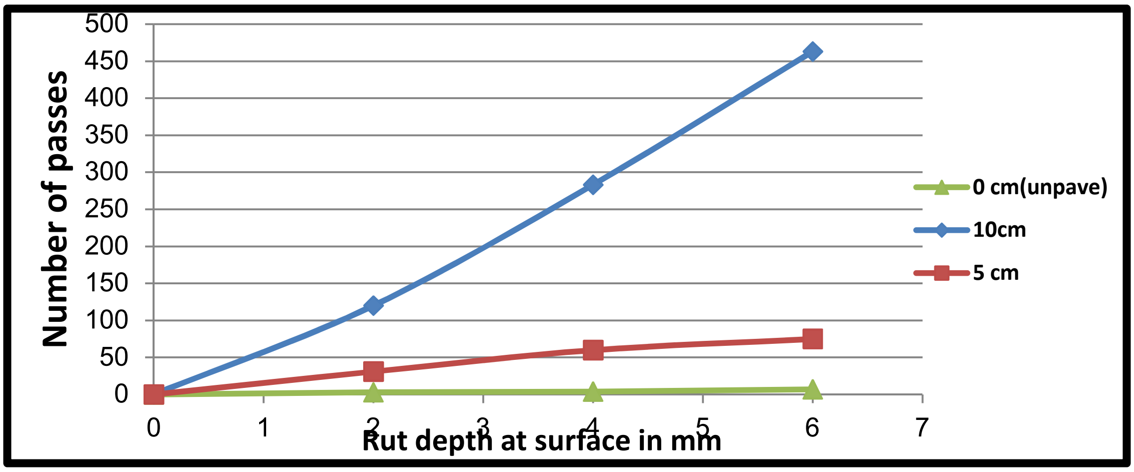

Figure (22) the Relation between Rut Depth and Number of Passes at Different Flexible Pavement Thickness

Table (5) Traffic Benefit Ratio TRB

Model type	TBR
S3-0-M	CONTROL
S3-50-M	7.45
S3-100-M	66.14

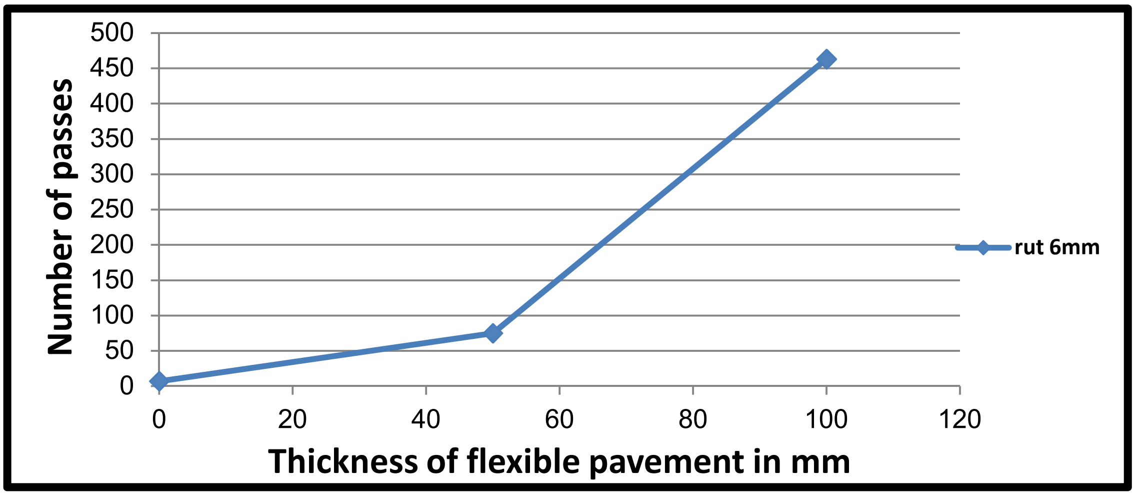

Figure (23) the Relationship between Thickness of Flexible Pavement and Number of Passes

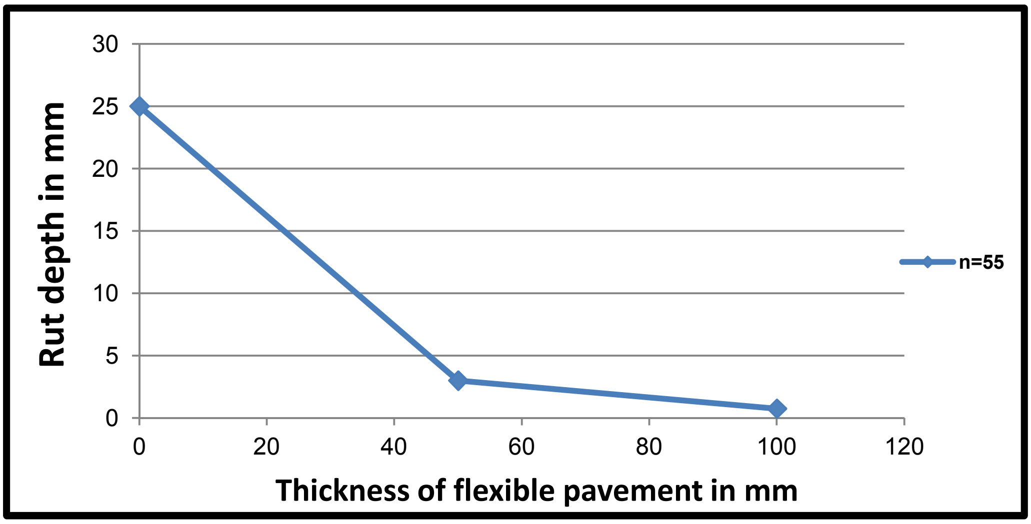

Figure (24) the Relationship between Thickness of Flexible Pavement and Number of Passes

5 CONCLUSIONS

Increase in the thickness of flexible pavement increases the number of passes which reaches the same value of rutting (value of failure) and leads to decrease the displacement in subgrade and subbase layers. ABAQUSE program was successful in simulation pavement structure models, so ABAQUS program can use in analysis of paved road.

REFRENCES

- Abu-Taleb, M.G. and Egeli, I. (1981): "Some Geotechnical Problems in the Eastern Province of Saudi Arabia." Proc., Symp. Geotechnical Problems in Saudi Arabia, King Saudi Arabia, Vol. I, 799-811
- Aiban, A. S. (1994): "A Study of Sand Stabilization in Eastern Saudi" Department of Civil Engineering, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia Received 24 March 1993; revised version accepted 5 July 1994
- Aiban, S., Al-Amoudi, O., Asi, I.M. and Zahrani, A. (1996):"Chemical Stabilization of Ras AL-Ghar Sabkha Soil", Twelfth Southeast Asian Geotechnical Conference, Kuala
- Al-Amoudi, O.S. and Abduljauwad, S.N (1991): " Geotechnical Considerations on Field and Laboratory Testing of Sabkha." Proc., Symp Recet Advances in Geotechnical Engineering III, Singapore, Vol. 1, 1-6.
- Al-Qadi and Wang H:" Pavement Damage Due to Different Tire and Loading Configurations on Secondary Roads" USDOT.(2009).
- ASTM D854-00: "Standard Test Method for Specific Gravity of Soil Solids by PycnometerLumpur, Malaysia, Vol. May, pp. 265-270
- Fookes, P. C. and Higginbottom, I. E. (1975): "The Classification and Description of Nearshore Carbonate Sediments for Engineering Purposes. " Geotechnique, 2, 406-414
- Masood , G.G. "Experimental and Numerical Investigation of stabilized unbound Granular Pavement Materials" AL-Mustansiriya University College of Engineering Highway and Transportation Engineering Department Ms. Thesis(2013):
- Salem L. A. (2011): " An Approach in Evaluating The Behavior of Dune sand Under Shallow Footing" Ms Thesis University of Baghdad, College of Engineering
- STM D698-00a: "Standard Test Methods for Laboratory Compaction Characteristics of Using Standard Effort (600 kN-m/m).