Al-Qadisiya Journal For Engineering Sciences, Vol. 5, No. 4, 466-476, Year 2012

EFFECT OF BINDER LAYER PROPERTIES ON FLEXIBLE PAVEMENT IN IRAQ

Assist. Lecture Salam Adil Mutlag/ Misan University
Email: salampave@yahoo.com

ABSTRACT

Premature failure of flexible pavements has a large problem in many Iraqi roads with drastic increase in truck axle loads. It is necessary to reduce this early collapse and make the best use of the pavement material in the design of economic. In this paper, the control on the properties of binder layer at the expense of wearing layer to achieve better balance between the damage ratio compared to the most design life are adopted. The methodology is based on the damage analysis concept which is performed for both fatigue cracking and rutting on different pavement sections using KENLAYER program.

The investigated pavement components are thickness and elasticity modulus for binder layer and thickness of wearing layer. The results of pavement analysis showed that the design life increases with increasing the thickness of wearing layer when the thickness of binder layer increases more than (3.94 in) and it decreases when the thickness of binder layer increase less than (3.94 in). The fatigue damage ratio decreases with increasing the thickness of wearing layer when increasing the thickness of binder layer more than (3.94 in) and it increases with increasing the thickness of wearing layer when increasing the thickness of binder layer less than (3.94 in). The rutting damage ratio increases with increasing the thickness of binder layer and with increasing the thickness of wearing layer. Finally, the design life increases with decrease binder moduli and fatigue damage ratio increases with increasing the binder moduli and also the rutting damage ratio decreases with binder moduli (330000 psi).

KEYWORDS: Binder layer, Wearing layer, Design life, Fatigue damage ratio, Rutting damage ratio, and KENLAYER program.

الموجز

مازال الانهيار المبكر للأرصفة المرنة مشكلة الطرق العراقية في ظل الزيادة المطردة في أحمال محاور الشاحنات. وكان لابد للحد من هذا الانهيار المبكر والاستفادة المثلي من مكونات الرصف في تصميم اقتصادي .لذلك تهدف هذه الدراسة إلى السيطرة على خصائص طبقة (binder) على

حساب طبقة (wearing) من أجل تحقيق أفضل توازن بين نسبة الضرر بالمقارنة مع العمر التصميمي. تعتمد هذه المنهجية علي مفهوم تحليل الضرر للرصف والذي تم إجراءه باستخدام برنامج KENLAYER لتحليل العديد من القطاعات الإنشائية للرصف بالنسبة لكل من للكلل و التخدد .وكانت عناصر الرصف محل الدراسة هي سمك ومعامل المرونة الطبقة (binder) وسمك طبقة (wearing.). وأظهرت نتائج التحليل الرصيف زيادة العمر التصميمي مع زيادة سمك طبقة(wearing) عند زيادة سمك طبقة (binder) أكثر من (3.94 انج) و نقصان العمر التصميمي مع زيادة سمك طبقة(wearing) عند زيادة سمك طبقة (binder) للاقل من (3.94 انـج). نسبة الضرر الكلل يتناقص مع زيادة سماكة طبقة (wearing) عند زيادة سماكة طبقة (binder) أكثر من (3.94 انج)، زيادة نسبة الضرر الكلل مع زيادة سماكة طبقة (wearing) عند زيادة سماكة طبقة (binder) للأقل من (3.94 انج). زيادة نسبة الضرر للتخدد مع زيادة سماكة طبقة(binder) وبزيادة سماكة طبقة (wearing) . وبزيادة معامل المرونة يقل العمر التصميمي وتزيادة نسبة الضرر للكلل، في حين أن نسبة الضرر للتخدد يتناقص مع معمل المرونة (330000 باون/ انج المربعة).

1-INTRODUCTION AND BACKGROUND

Rutting and fatigue cracking are considered the most important distresses surveyed due to high severity and density levels, and consequently their high effects on the pavement condition. Flexible pavements should be designed to provide a durable, skid resistance surface under in service conditions. Also, it is essential to minimize cracking and rutting in flexible pavement layers. It was necessary to reduce this early collapse and make the best use of the pavement material in the design of economic. The increased rutting or decreased fatigue life of the flexible pavements may be attributed to the shortcomings of the application of flexible pavement analysis and the absence of attention to identify the pavement components that achieve a balanced section which gives equal pavement lives with respect to rutting and fatigue (**Barksdal, 1978**).

The variations in the modulus of elasticity of material affect the design life, even though not as significant as the traffic loading (**Balai Nasional.2011**). There are various modes in which the pavement fails. Cracking of the surface layer and permanent deformation of the pavement system which manifests as rutting on the pavement surface (**El-Hamrawy, 2000**). Larger and more concentrated loads produce larger stresses and strains, with thicker layer carrying higher flexural stresses than thinner layers (**Machemehl, 2005**). In pavement analysis, loads on the surface of the pavement produce two strains which are believed to be critical for design purposes. These are the horizontal tensile strain; εt at the bottom of the asphalt layer and the vertical compressive strain; εc at the top of the subgrade layer. If the horizontal tensile strain; εt is excessive, cracking of the surface layer will occur, and the pavement distresses due to fatigue. If the vertical compressive strain; εc is excessive, permanent deformation occurs at the surface of the pavement structure from overloading the subgrade, and the pavement distresses due to rutting ((**Mulungye, 2006**), (**Dessouky, 2007**) and ((**MS-1), 1982**))

The main objective of this study is to investigate the effects of binder layer components, thickness and elasticity modulus on pavement life with respect to fatigue and rutting.

2-PAVEMENT RESPONSE ANALYSIS METHODOLOGY

The KENLAYER computer program (**Huang, 2004**) was used to calculate the tensile strain (εt) at the bottom of the asphalt layer and the compressive strain (εc) at the top of the sub-grade soil. These computed strains are incorporated in the fatigue cracking and rutting models to estimate the pavement life.

2-1 Fatigue Criteria

The relationship between fatigue failure of asphalt concrete and tensile strain (εt) at the bottom of asphalt layer is represented by the number of repetitions as suggested by Asphalt Institute (**(MS-1), 1982**) in the following form equation (1):

$$Nf = 0.0796\ (1/\varepsilon t)\ 3.291\ (1/E1)\ 0.854 \tag{1}$$

Where:
Nf: number of load repetitions to prevent fatigue cracking.
εt: tensile strain at the bottom of asphalt layer.
E1: elastic modulus of asphalt layer.

2-2 Rutting Criteria

The relationship between rutting failure and compressive strain (εc) at the top of subgrade is represented by the number of load applications as suggested by Asphalt Institute (**(MS-1), 1982**) in the following form equation (2):

$$Nr = 1.365 * 10\text{-}9\ (1/\ \varepsilon c)\ 4.477 \tag{2}$$

Where:
Nr: number of load applications to limit rutting.
εc: vertical compressive strain, at the top of sub-grade

2-3-INVESTIGATED PAVEMENT CROSS SECTIONS

A typical cross section consists of wearing layer thickness (1.58-in) with elasticity modulus (380,000 psi), binder layer thickness (3.15-in) with elasticity modulus (330,000 psi), base layer thickness (7.09-in) with elasticity modulus (230,000 psi), and sub base layer thickness (15.75-in) with elasticity modulus (16,000 psi), resting on sub grade with elasticity modulus (7,000 psi) is considered a section with reference components. Different probable cross sections that may be used in Iraqi roads for binder layer are considered for analysis through varying the reference components by ± 25 % and ± 50 % are (1.58, 2.36, 3.15, 3.94, and 4.72) in. Four values of thickness are considered plus the reference one , ± 25 % are (247500,330000,412500) psi Two values of elasticity modulus are considered plus the reference one and ± 25 % are (0.79, 1.18, 1.58)in Two values of thickness of wearing layer are considered plus the reference one. Varying these components with each other give various cross sections for analysis.

2-4 Pavement Analysis

Flexible pavement is typically taken as a multi-layered elastic system in the analysis of pavement response. Materials in each layer are characterized by a modulus of elasticity (E) and a Poisson's ratio (μ). Poisson's ratio; μ is considered as 0.3, 0.35, 0.40, 0.40 and 0.45 for wearing layer, binder layer ,base course, sub-base layer and sub-grade, respectively. Traffic is expressed in terms of repetitions of single axle load 18-Kip applied to the pavement on two sets of dual tires. The investigated contact pressure is 140 psi. The dual tire is approximated by two circular plates with radius 3.86-in. and spaced at 13.60-in. center to center.

2-5 Damage Prediction

The prediction of pavement life is based on the cumulative damage concept in which a damage factor is defined as the damage per pass caused to a specific pavement system by the load in question. The damage (Di) caused by each application of a single axle load at any season can be given by equation (3):

$$D_i = \frac{1}{N_i} \tag{3}$$

where Ni is the minimum number of load repetitions required to cause either fatigue or rutting failure, as given by Equations (1) and (2). The total number of load repetitions (Nf) that are allowed over the pavement lifetime can be determined when total cumulative damage (Dt) reaches one. Therefore, Equations (1) and (2) can then be solved for the total allowable number of load applications required to cause either fatigue or rutting failures over the pavement lifetime.

The design life is computed through Equation 4 and calculated for fatigue cracking and for permanent deformation, and the one with a shorter life controls the design in period *i*.

$$Design\ life = \frac{i}{D} \tag{4}$$

3- ANALYSIS OF RESULTS

Multilayer elastic analysis is performed using the KENLAYER software. The different variables discussed in the previous section are considered. The resulting pavement strains, damage and design life showed below sections.

3-1 Effect of Thickness Layer on Pavement Strains and Damage Ratios

Figures 1, 2 and 3 show the relationship between tensile strain at the bottom of the binder layer versus thickness for different binder moduli and thickness` of wearing. The figures show that the tensile strain first decrease with increasing thickness of binder then with (3.94 in) increasing thickness. Notes that with increase thickness of wearing layer increase tensile strain and increase modulus of binder layer increase tensile strain.

On the other hand, **Figures 4, 5 and 6** show the relationship between the compressive strain at the top of subgrade soil versus thickness for different binder moduli. the compressive strain increases in a linear function with increasing the thickness of binder layer. It also shows that the rate of increase (slope of the line) is greater with binder layer having modulus (330000 psi)

3-2 Effect of Thickness of Binder on Damage Ratios

The estimated fatigue and rutting damage ratios versus thickness are presented in **Figures 7, 8 and 9** for different binder layer moduli and thickness of wearing layer . The figures show that the fatigue damage with first increases in a linear function with increasing the thickness for greater binder moduli then decrease for thickness (3.94 in). Notes that with increase thickness of wearing layer increase fatigue damage and increase modulus of binder layer increase fatigue damage. **Figures 10, 11 and 12)** show that the rutting damage increases in a linear function with increasing the thickness for greater binder moduli. Notes that with increase thickness of wearing layer increase fatigue damage and It also shows that the rate of increase (slope of the line) is greater with binder layer having modulus (330000 psi).

3-3 Effect of Axle Load on the Pavement Design Life

The pavement design life is the minimum number of load repetitions required to cause either fatigue or rutting failure, as given by Equations 1 and 2. **Figures 13, 14 and 15** show that the Design life with first decreases in a linear function with increasing the thickness then increase with increasing the thickness, while increases with decrease binder moduli.

4- CONCLUSIONS

Based on this study the following can be concluded:

1- The Design life increases with increasing the thickness of wearing layer when increasing the thickness of binder layer more than (3.94 in).

2- Design life decreases with increasing the thickness of wearing layer when increasing the thickness of binder layer Less than (3.94 in).

3- Design life increases with decrease binder moduli.

4- the fatigue damage ratio decreases with increasing the thickness of wearing layer when increasing the thickness of binder layer more than (3.94 in).

5- Fatigue damage ratio increases with increasing the thickness of wearing layer when increasing the thickness of binder layer Less than (3.94 in).

6- Rutting damage ratio increases with increasing the thickness of binder layer and with increasing the thickness of wearing layer.

7- Fatigue damage ratio increases with increasing binder moduli while the rutting damage ratio decreases with binder moduli (330000 psi).

6-REFERENCES

Asphalt Institute, “Research and Development of the Asphalt Institute’s Thickness Design Manual", 9th Edition, Research Report 82-2, the Asphalt Institute, (MS-1) 1982.

Barksdal, R. D., “Practical Application of Fatigue and Rutting Tests on Bituminous Base Mixes”, Proceedings, AAPT, Vol. 47, 1978.

Dessouky, S. H., Al-Qadi, I. L., and Yoo, P. J., “Full-Depth Flexible Pavement Response to Different Truck Tire Loadings”, Transportation Research Board, 86th Annual Meeting, Jan., 2007.

Balai Nasional, Ditjen Marga, Kementerian Umum “SENSITIVITY ANALYSIS IN FLEXIBLE PAVEMENT PERFORMANCE
USING MECHANISTIC EMPIRICAL METHOD” Jl. Pattimura No.20, Kebayoran Baru - Jakarta Selatan,2011

El-Hamrawy, S., “Effect of Wheel Load, Tire Pressure and Subgrade Stiffness on Flexible Pavements Responses)”, Al-Azhar Engineering 6th International Conference, Sept. 2000.

Huang, Yang H., "Pavement Analysis and Design," Englewood Cliffs, New Jersey, 2004.

Machemehl, R. B., Wang, F., and Prozzi, J. A., “Analytical Study of Effects of Truck Tire Pressure on Pavements with Measured Tire- Pavement Contact Stress Data”, Transportation Research Board 2005.

Mulungye, R.M., Owende, P.M.O., and Mellon, K., “Determining The Effect of Tyre Pressure, Axle Load and Wheel Configuration on Flexible Pavements Fatigue Life Using Finite Element Method” Proceeding 522, Applied Simulation and Modelling, 2006.

Table 1 The structural properties of the investigated pavement cross sections.

Layer	Thick. (in)	Modulus of elasticity (psi)	Poisson’s ratio
wearing layer	1.58	380,000	0.3
binder layer	3.15	330,000	0.35
base	7.09	230,000	0.4
subbase	15.75	16,000	0.4
subgrade	-------	7,000	0.45

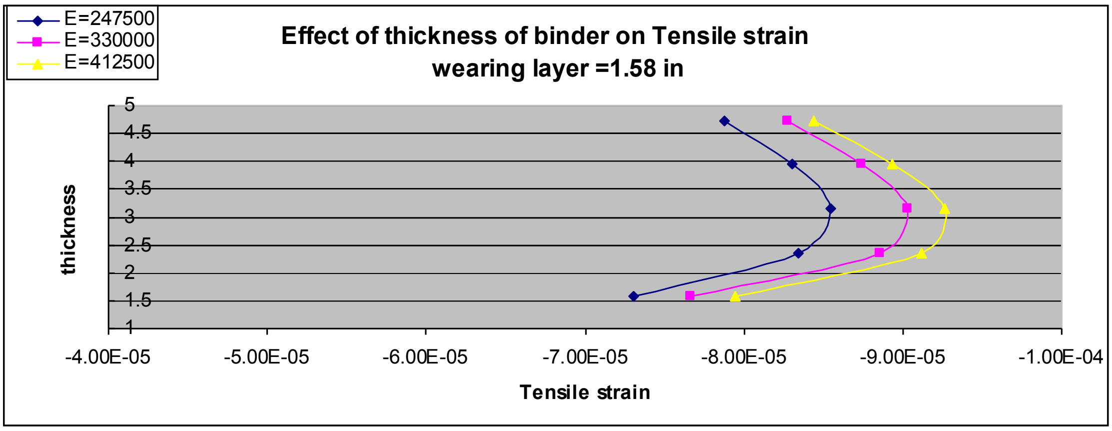


Figure 1 Effect of thickness of binder on Tensile strain wearing layer =1.58 in

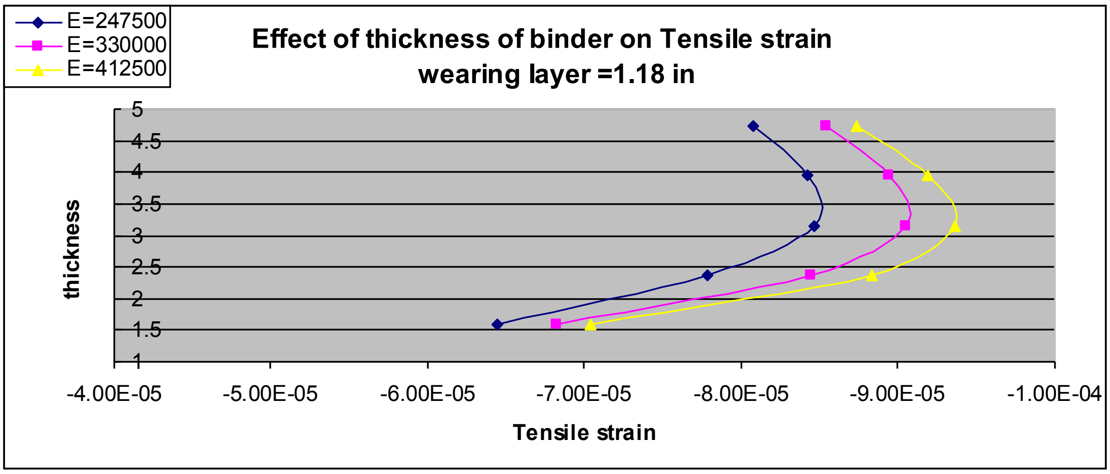


Figure 2 Effect of thickness of binder on Tensile strain wearing layer =1.18 in

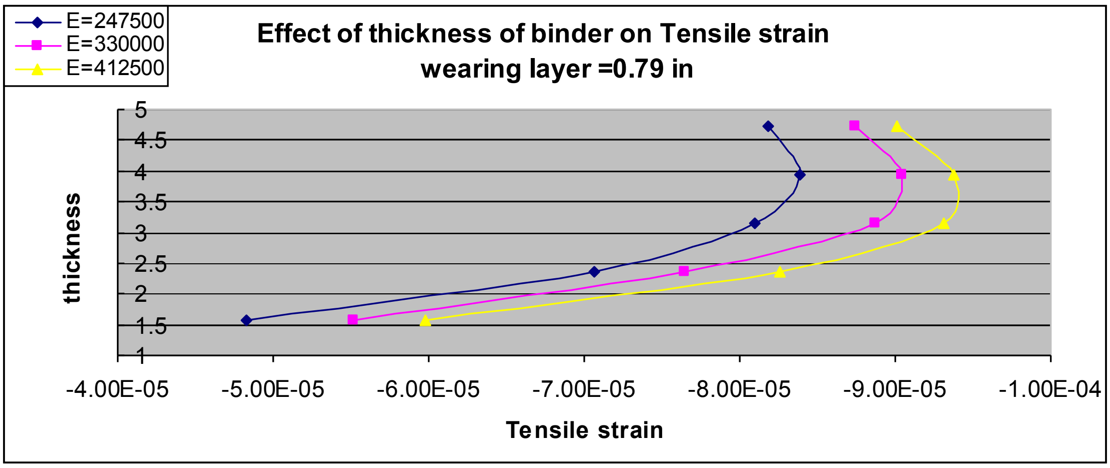


Figure 3 Effect of thickness of binder on Tensile strain wearing layer =0.79 in

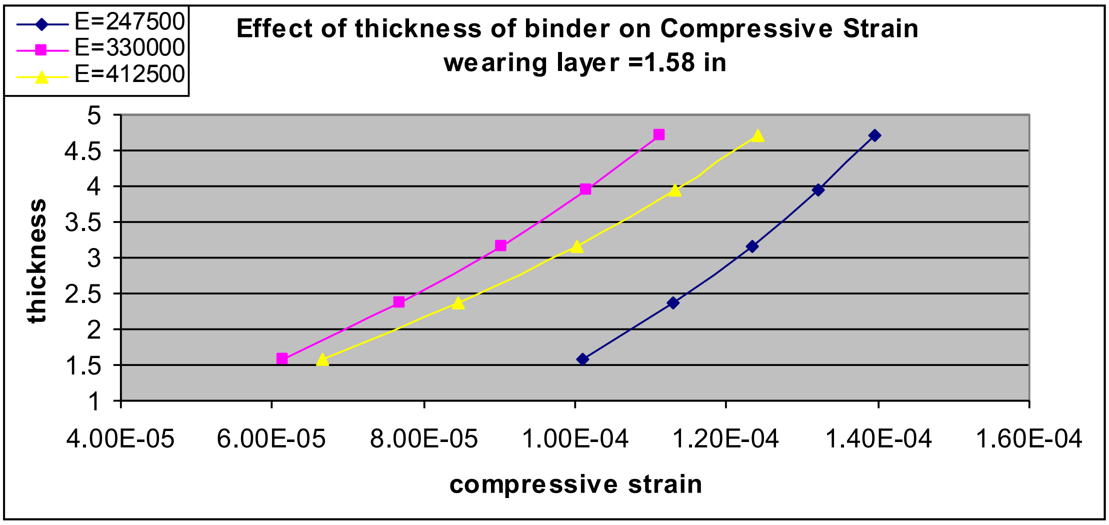


Figure 4 Effect of thickness of binder on Compressive Strain wearing layer =1.58 in

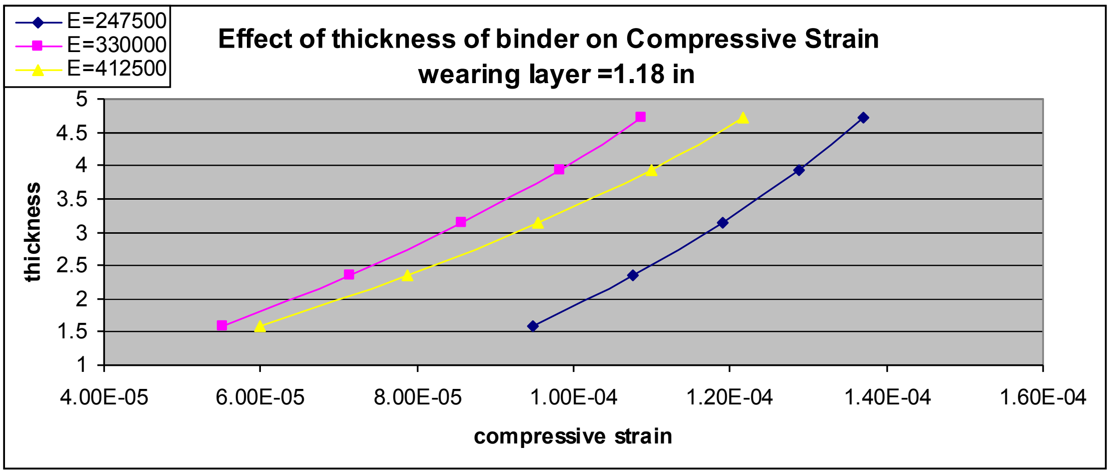


Figure 5 Effect of thickness of binder on Compressive Strain wearing layer =1.18 in

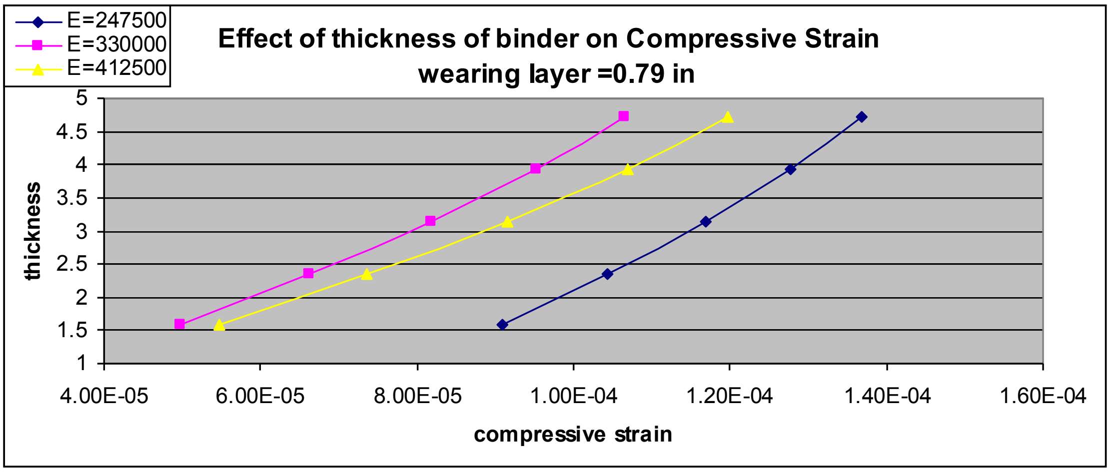


Figure 6 Effect of thickness of binder on Compressive Strain wearing layer =0.79 in

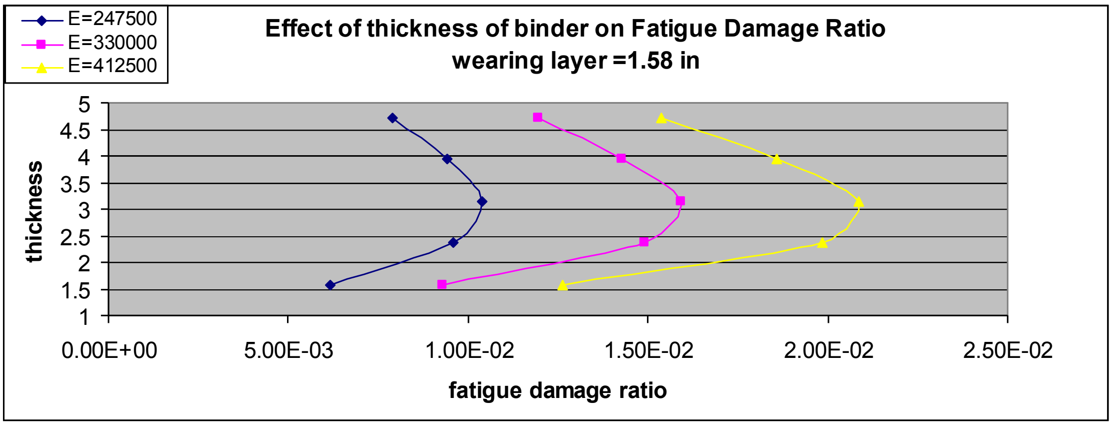


Figure 7 Effect of thickness of binder on Fatigue Damage Ratio wearing layer =1.58 in

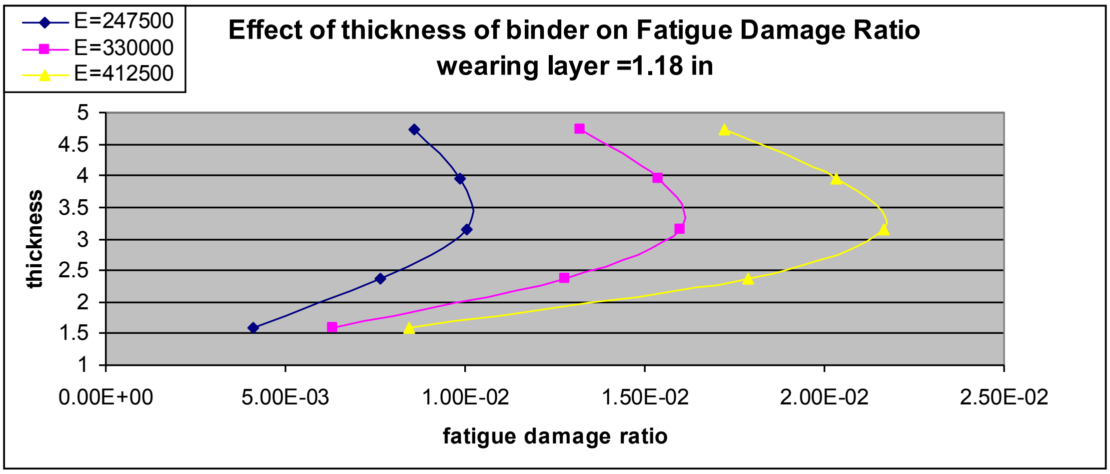


Figure 8 Effect of thickness of binder on Fatigue Damage Ratio wearing layer =1.18 in

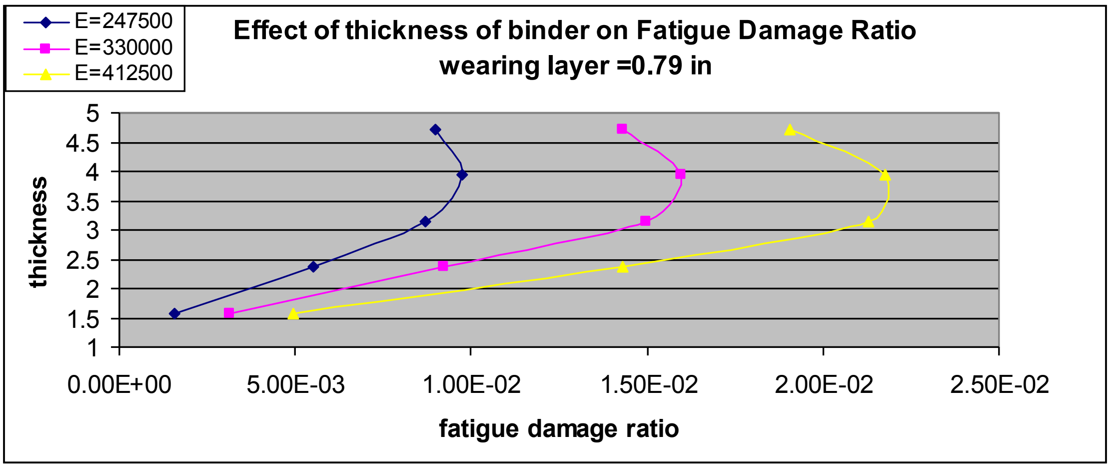


Figure 9 Effect of thickness of binder on Fatigue Damage Ratio wearing layer =0.79 in

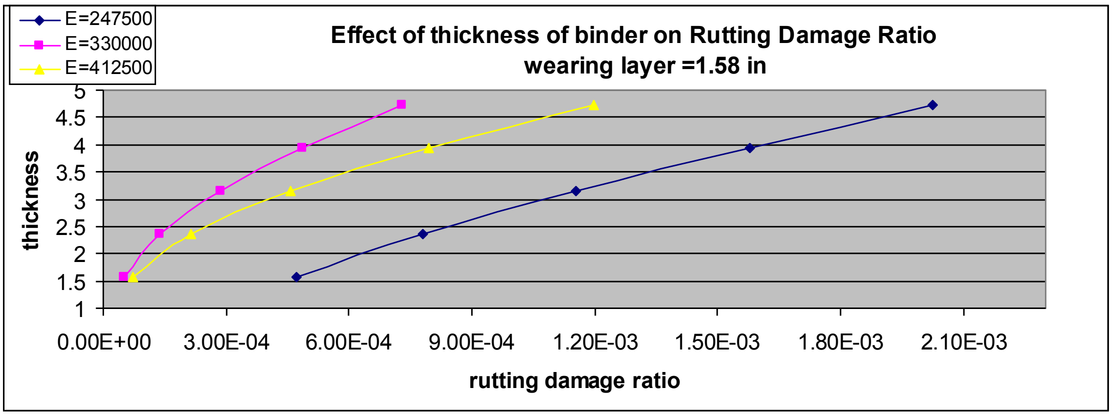


Figure 10 Effect of thickness of binder on Rutting Damage Ratio wearing layer =1.58 in

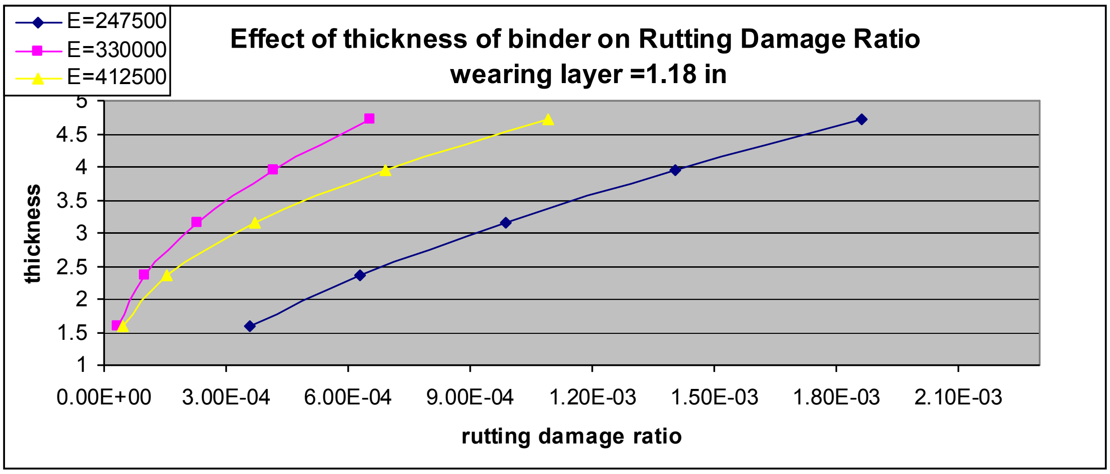


Figure 11 Effect of thickness of binder on Rutting Damage Ratio wearing layer =1.18 in

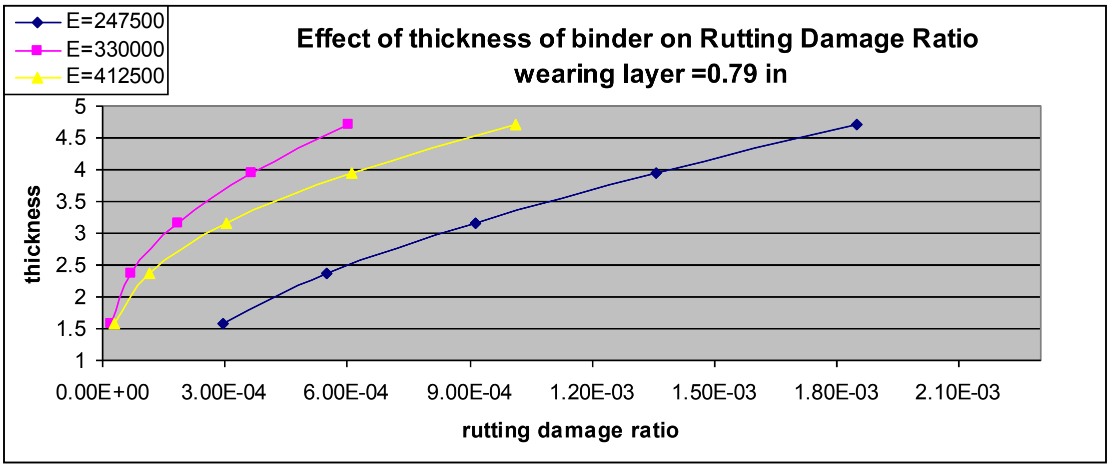


Figure 12 Effect of thickness of binder on Rutting Damage Ratio wearing layer =0.79 in

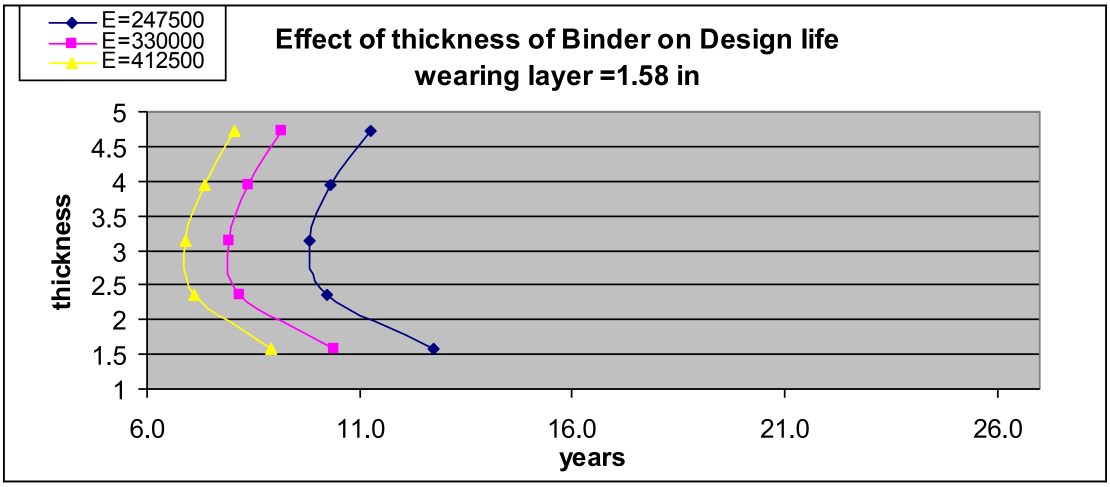


Figure 13 Effect of thickness of Binder on Design life wearing layer =1.58 in

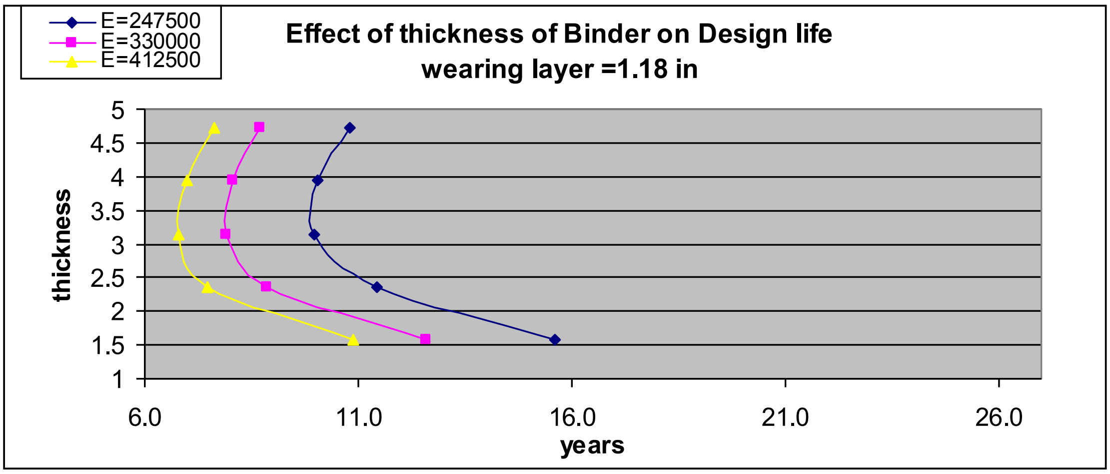
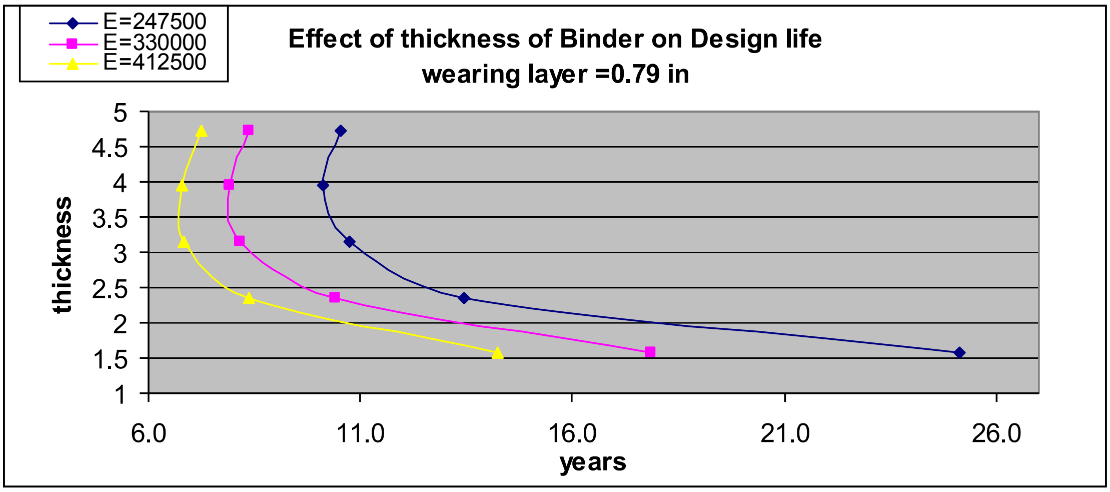


Figure 14 Effect of thickness of Binder on Design life wearing layer =1.18 in



Figuer 15 Effect of thickness of Binder on Design life wearing layer =0.79 in