EVALUATION OF THE LIFE SHORTENING OF FLEXIBLE PAVEMENTS

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ABSTRACT

One of the reasons of life shortening of pavements operation is designing regardless of their administrative facts. The amount of transferred load between the layers depends on various factors such as the degree of adhesion and internal friction between the layers. If these layers limit by using proper bonding and sufficient density between the layers, they act integrated. In this study we evaluate the various pavement failures due to the possibility of friction under various loadings. Flexible pavement failure criteria are intended the vertical strain on the subsoil and analytically calculate the strain tolerance and pavement life of this strain were compared. According to these studies, shortening the life of pavements with limited layers and without internal friction has been determined compared to the pavement with internal friction.

Keywords: Internal friction, Tack-coat and Prime coat seals: Shortening the life of pavement, Vertical strain on the subsoil

INTRODUCTION

Flexible pavement layers usually are made from different materials in different thicknesses due to economic considerations. The contact method of two different layers in multi-layer pavement defines their "interfacial conditions". Interfacial conditions are effective in reactions at the level of under load. Pavements crashes which are observed early, is largely due to structural design regardless of what happens in implementation.

Now in the method of "mechanistic thickens plot "which is based on the structural response of the body is done through the design process, knowing interfacial conditions have found a more important role. Using "tack coat" and "prime coat" between two layers of asphalt or a layer of asphalt and a layer aggregate creates adhesion between the layers. The friction between layers in addition to the above seal of density depends on the material and the quality of layer materials, when density of the upper layers is high, the depression of interfacial components will be more and internal friction will reduce. The rate of rock materials resistance between the layers against abrasion will increases the resistance frictional layers.

2. The effect of horizontal loads and interlayer's friction between on pavements life

The absence of unlimited interfacial conditions in horizontal loading lead to wave deformation in slopes, turning points and starting points in heavy vehicles. Study on interfacial conditions and horizontal loads was conducted using finite elements software (ABAQUS) which in these studies, the geometric pavement model with different elements and interfacial conditions also define the types of existed nodes. Interfacial friction measured in other studies with laboratory experiments, including Shear Test Guillotine Type and Direct Test. Together, these studies show that horizontal loads extremely increases high tensile strains and upper and lower surface of the lining layer, which is causing premature failure of pavement. Cumulative conditions and poor interfacial effects of horizontal forces on the pavement is too big, the reduction in pavement life up to 300 times for semi-rigid pavement and 15 times more flexible for pavement.

Table 1 has compared between different states according to two criteria for assessing the quality of pavement interfacial conditions, including fatigue life and service life. Since the pavement management system failure occurs gradually, it should be able to know the proper implementation and controlling executive conditions in distribution, planning and density layer pavements as effective factors in interfacial condition for estimating the lifespan of the pavement and its management. In the present study the role of vertical loading on the existing pavement of country is imported in terms of different layers and it is desirable.

3. Theoretical analysis of the effect of interfacial conditions

Two different layers over one another is a simple model of pavement layer, when these two layers are subjected to vertical loading, it caused distortions, which causes deformation between the layers, different types of strain and stresses. Equations (1) and (2) and (3) are related into the stresses and strain into each other. [4]

$$v_x = \frac{1}{E}(\dagger_x - [(\dagger_r - \dagger_t)) \qquad (1)$$

$$v_r = \frac{1}{E}(\dagger_r - [(\dagger_1 + \dagger_2)) \qquad (2)$$

$$v_t = \frac{1}{E}(\dagger_t - [(\dagger_1 + \dagger_2)) \qquad (3)$$

In which:

ε_z, σ_z : Stress and strain of vertical pressure

ε_r , σ_r : Stress and strain of radial pressure

ε_t, σ_t : Stress and strain of tangential pressure

The direction of this strain can be seen in Figure 1. When it is possible to move the two layers on each other, the distance between the two layers, radial and tangential strains are zero and according to above equation the vertical strain can be achieved by equation (4).

$$4\text{-} v_{z1} = \frac{1}{E}\dagger_{z1}$$

When there is no possibility of movement of the two layers on each other, radial σ_r and tangential $\dagger_t$ stresses are zero and the ε_{z2} value decreases.

$$(5) \qquad \varepsilon_{z2} = \frac{1}{E}(\sigma_{z1} - 9)(\sigma_{t1} + \sigma_{rh}))$$

With regard to two equations, the vertical strain ε_{z2} in second case is less than vertical strain ε_{z1} In the first case, i.e.: $\varepsilon_{z1} > \varepsilon_{z2}$ (6)
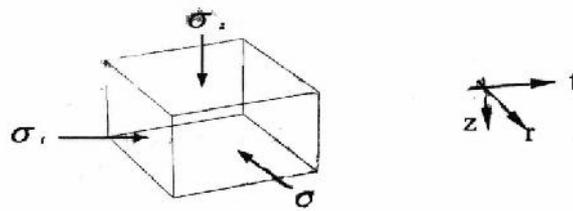

Fig.1. Simple model to characterize pavement layer devices

Table 1. Comparison between pavements lives due to different states of interfacial condition under horizontal loading

Analysis mode	Interfacial condition	Fatigue life	Service Life
A = stabilize subsoil with cement	Binder and linen are fully adherent, the binder and basis are fully adherent	766×10^2	953×10^6
B= subsoil of coarse aggregate	Binder and linen are fully adherent, the binder and basis are fully adherent	277×10^6	331×10^6
C = subsoil of aggregate coarse-grained	Binder and linen are moving over each other, the binder and basis are fully adherent	$0/21 \times 10^6$	176×10^6
D = stabilize subsoil with cement	Binder and linen are fully adherent, the binder and basis are moving over each other	0465×10^6	$13/8 \times 10^6$

According to the above observed, the theoretical relations emphasize that when the adhesion between the layers are more, stress and strain diminish and if the vertical layers slide over each other the strain increases.

4. The model selection and analysis method

In examining the impact of the agreement on the layer of pavement performance models are used that contain different pavement, so the effect of the lack of proper implementation of interfacial conditions on pavement performance calculated for comparison. Also the loading conditions are selected in such a way that considersthe maximum permissible heavy loads that caused the most damage on the tracks. The lifespan of the pavement on the number of

standard axes passing along the pavement useful life is calculated using the theoretical relationship.

4.1 Geometric pavement model

Pavement is modeled in three different modes, that is a strong or weak body with a thickness number (SN) is considered respectively 4 or 6 on the weakor strong bed with the resistance (CBR) 3.5 or 35. Pavement models along with details of used materials are shown in Figure 2.

A) Weak bed (CBR=3.5) weak pavement (SN=4)

P	5cm		$V = 0/35$	$E = 20000 kg\ cm^2$
Linen	5cm		$V = 0/35$	$E = 15000 kg\ cm^2$
Basis	20cm		$V = 0/3$	$E = 3500 kg\ cm^2$
Basis	20cm		$V = 0/4$	$E = 2000 kg\ cm^2$
	V=0/4			$E = 3500 kg\ cm^2$

B) Strong bed (CBR=35) weak pavement (SN=4)

P	5cm		$V = 0/35$	$E = 20000\ kg\ cm^2$
Linen	10cm		$V = 0/35$	$E = 15000 kg\ cm^2$
Basis	20cm		$V = 0/3$	$E = 3500 kg\ cm^2$
P	20cm		$V = 0/4$	$E = 2000 kg\ cm^2$
	V=0/4			$E = 3500 kg\ cm^2$

C) Strong bed (CBR=35), string pavement (SN=6)

P	5cm		$V = 0/35$	$E = 30000 kg\ cm^2$
Linen	10cm		$V = 0/35$	$E = 25000 kg\ cm^2$
Basis	20cm		$V = 0/3$	$E = 5000 kg\ cm^2$
	V=Sub-basis0/4			$E = 3500 kg\ cm^2$

Fig.2. Geometric pavement model, along with information on materials

KENLAYER software is used to analyze the stress and strain. Interfacial conditions in the software which is specific to flexible pavement, considered in both finite and infinite cases [1]. Analysis of stress and strain are defined due to interfacial load in two limited circumstances, without internal friction (1) or unlimited internal friction (0) and the various scenarios that may occur in the implementation, is used in the analysis, Table 2 presents the different states.

4-2 Loading

The maximum strain and deformations occur when the axial load which is placed on the pavement maximum permissible load which is capable of crossing paths. The selected loading is based on a "Iran code of permitted pavement loads "[5]. Axial load of 2.8, 13 and 21 tons and constant pressure of surface area for the loading is considered 5.5 kg per square centimeter and only the radius of the wheel used in this analysis have been modified.

Table 2. Different states interfacial conditions in implementing and analysis

Implementing Conditions	Restrictions of interfacial conditions of the lining and basis	Restrictions of interfacial conditions of the lining and pavement	Analysis mode
High performance: tack coat seals and prime coat have to form proper adhesion.	1	1	1
Poor performance: tack coat seals are not used and prime coat have to form proper adhesion.	1	0	2
Poor performance: tack coat seals formed proper adhesion and prime coat is not used.	0	1	3
Inappropriate performance: tack coat seals and prime coat were not used or have bad performance	0	0	4

4.3 A model to determine the lifespan of the pavement

Pavement life is an expression of the number of virtual axes, which pass the path in expected time, number of axles may pass at different time intervals over the life of the pavement, an expression of the life of the pavement, is the number of standard axes that passes the pavement. Determining the standard axe is based on the amount of compression strain based on the subsoil and stretching strains of asphalt layer is possible. Various institutions in this field have presented equations which in current study we use Shell equation:

7) $$N_d = 1/05 \times 10^{-7} (v_c) - 4/5$$

Equation (7) shows the passes of standard axis to create a sunken track wheel on asphalt layers that:

N_d : The number of allowed duplicates of standard axles (2.8 tons)

ε_c : The compression strain on subsoil

5. Analysis of different interfacial conditions on the performance of pavement life

In studies of different scenarios with the ideal number of iterations allowed for each mode has been implemented correctly and tack coat seals and prime coat with the proper functioning are compared.

5.1 Effect of weak implementation of tack coat seal (operating mode)

In the case of lining layer and pavement are not attached and they can move on each other, reducing pavement occurs life due to tensile strain and pressure. Table 3 presents various pavements and pavement age for different axes in the case of service life (related to the entrenchment of passing trucks) and Fig. 3 performs a comparison between decreases in life time.

Table 3. Calculation the service life of the pavement under various vertical loads and number of axles per million) Mode 2

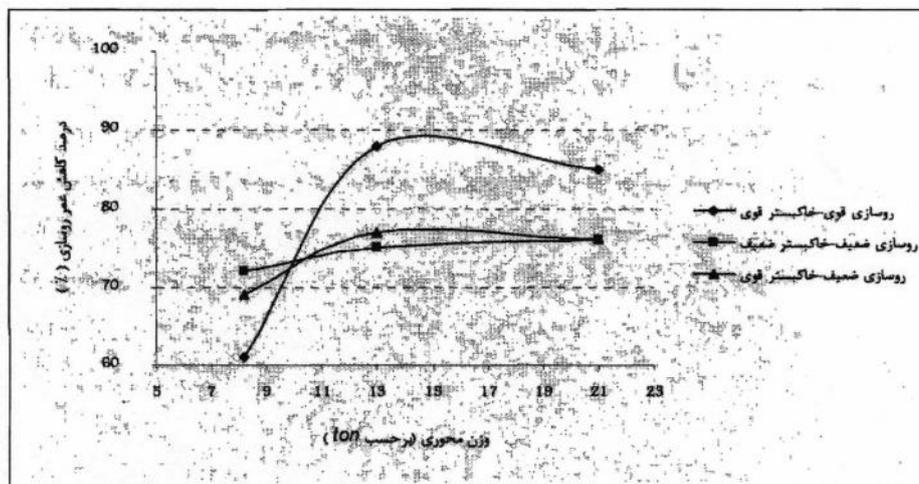| Pavement mode	Axis weight (Ton)	Mode 1	Mode 2	Pavement Life shortening percent
Strong Pavement- Strong bed		12/89	31/9	61/4
Weak Pavement- weak bed	8/2	0/467	1/67	72/04
Weak Pavement- strong bed		0/424	1/380	69/3
Strong Pavement- Strong bed		3/92	11/90	88/2
Weak Pavement- weak bed	13	0/180	0/684	73/68
Weak Pavement- strong bed		0/183	0/792	76/89
Strong Pavement- Strong bed		3/56	24/80	85/65
Weak Pavement- weak bed	21	0/298	1/25	76/16
Weak Pavement- strong bed		0/265	1/10	75/91

Fig.3. Diagram of shortening the life of pavements in terms of axle load in mode 2

5.2 Effect of weak implementation of prime coat seal (operating mode 3)

In cases where there is no sufficient adhesion between the primer and base layers there is possibility between these layers and as shown in Table (4) a reduction in pavement life happens, the average of reduction in pavement life is in this case is 87% of the average executive Mode 2 is higher the amount of 74%.

Table 4. Calculation of fatigue life of the pavement under different vertical loads (the number of axles per million) executive mode 3

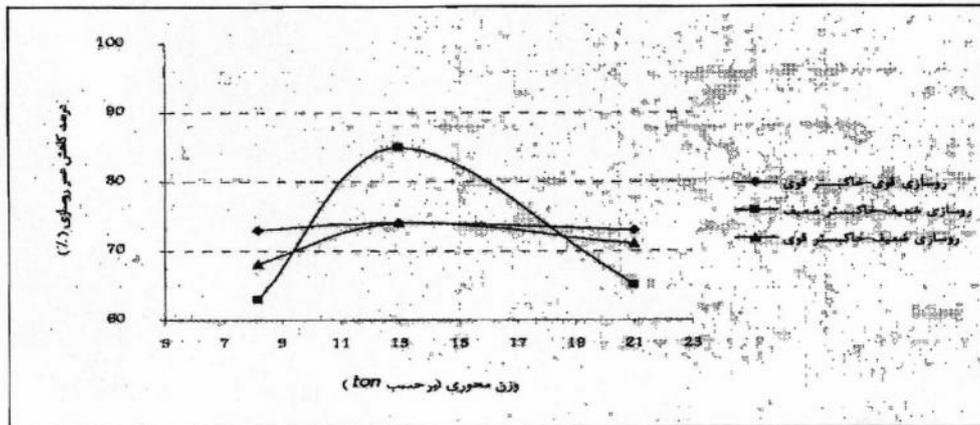| Pavement mode	Axis weight (Ton)	Mode 1	Mode 2	Pavement Life shortening percent
Strong Pavement- Strong bed		12/89	47	72/57
Weak Pavement- weak bed	8/2	0/467	1/26	62./94
Weak Pavement- strong bed		0/424	1/34	68/35
Strong Pavement- Strong bed		3/92	15/2	74/21
Weak Pavement- weak bed	13	0/180	0/212	85/1
Weak Pavement- strong bed		0/183	0/665	74/15
Strong Pavement- Strong bed		3/56	24/7	71/59
Weak Pavement- weak bed	21	0/298	0/493	65/56
Weak Pavement- strong bed		0/265	0/892	70/29

Fig.4. Diagram of shortening the life of pavements in terms of axle load in mode 3

5.3 Effect of improper implementation of between layers seals (operating mode 4)

When there is not a proper adhesion between pavement layers and liners and lining layer and there is not a movement possibility between layers are unstable due to rising tensions reduced pavement life. If we make a comparison between percent reductions in pavement life in this case, it will be seen that the average reduction in pavement life is 65%. Table 5 and Figure 5 present the reductions of pavement life for a variety of different loads.

Table 5. Calculation of fatigue life for different pavement under various vertical loads (the number of axles per million) executive mode 4

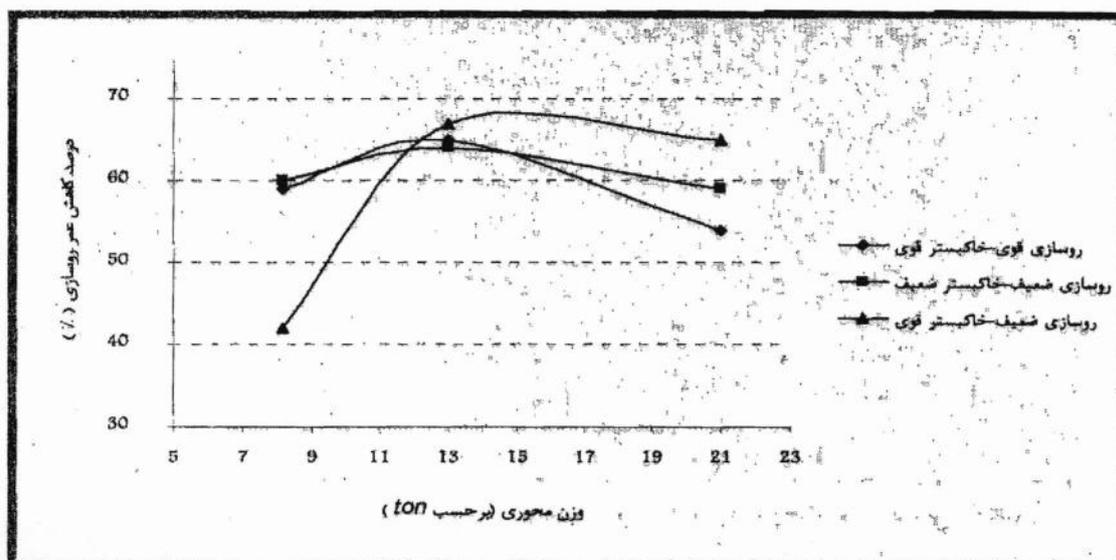| Pavement mode	Axis weight (Ton)	Mode 1	Mode 4	Pavement Life shortening percent
Strong Pavement- Strong bed		12/89	26/03	59/51
Weak Pavement- weak bed	8/2	0/467	1/87	60/25
Weak Pavement- strong bed		0/424	0/728	41/75
Strong Pavement- Strong bed		3/92	7/034	65/13
Weak Pavement- weak bed	13	0/180	0/313	65/45
Weak Pavement- strong bed		0/183	0/268	6/30
Strong Pavement- Strong bed		3/56	0/416	55/40
Weak Pavement- weak bed	21	0/298	0/725	59/55
Weak Pavement- strong bed		0/265	1/24	65/55

Fig.5. Diagram of shortening the life of pavements in terms of axle load in mode 4

6- CONCLUSION

This study investigated the effect of the lack of proper implementation of tack coat and prime coat seals which are causing internal friction under vertical loads for the pavements of the country. The results of these studies are divided into the following points:

- Due to slip in between layers in case of reduced internal friction between layers of pavement lifeand shortening the life of the pavement depends on pavement type and interfacial a condition which there is internal friction. Table (6) shows a decrease in pavement life under vertical loads.

Table 6. Comparison between different types of comparison due to the number of times the pavement life will decrease.

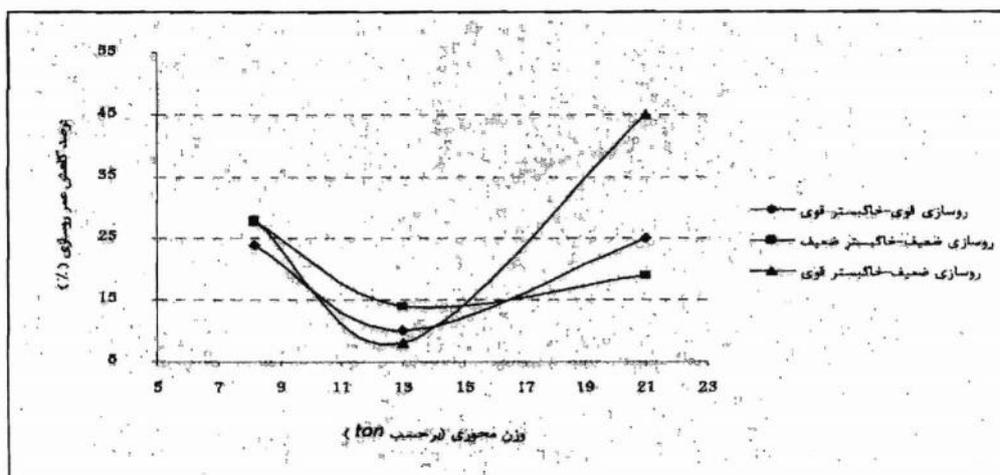| Pavement mode	Executive Mode 2	Executive Mode 3	Executive Mode 4
Strong Pavement- Strong bed	24	28	28
Weak Pavement- weak bed	10	14	8
Weak Pavement- strong bed	25	19	45

Fig.5. Diagram of comparing average shortening the life of pavements in terms improper executive mode

- When the subsoil of pavement is weak, the shortening the life of pavements will increase and the reason is that pavement life is based on the deformation of subsoil.

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