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Structural evaluation of perpetual flexible pavements for various climatic conditions

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Original scientific paper

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Properties of perpetual flexible pavements on heavily-trafficked rural roadways in different climatic conditions are analysed in the paper. In order to evaluate performance of such pavements, their behaviour is compared in several towns in Iran (Rasht, Tehran, and Ahvaz). It was established that the use of perpetual pavements is appropriate, especially for high-traffic-volume roadways. Perpetual flexible pavements exhibit much better resistance to fatigue cracking when compared to conventional pavements.

Key words:
perpetual flexible pavement, asphalt concrete pavement, rural roads, climatic conditions

Izvorni znanstveni rad

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Ocjena ponašanja trajnih savitljivih kolnika u raznim klimatskim uvjetima

U radu je prikazano istraživanje svojstava trajnih savitljivih kolnika na vrlo prometnim izvangradskim cestama koje se nalaze u različitim klimatskim uvjetima. Kako bi se procijenilo ponašanje takvih konstrukcija, uspoređena su njihova ponašanja u nekoliko gradova u Iranu (Rašt, Teheran i Ahvaz). Dobiveno je da je primjena trajnih savitljivih kolnika dobra osobito za ceste s velikim prometnim opterećenjem. Ovi kolnici imaju znatno bolju otpornost na pukotine koje nastaju uslijed zamora u usporedbi s uobičajenim kolnicima.

Ključne riječi:
trajni savitljivi kolnik, asfaltbetonski kolnik, izvangradske ceste, klimatski uvjeti

Wissenschaftlicher Originalbeitrag

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Strukturelle Bewertung dauerhafter flexibler Fahrbahnen bei verschiedenen Klimabedingungen

In dieser Arbeit sind Untersuchungen der Eigenschaften dauerhafter flexibler Fahrbahnen auf verkehrsbelasteten Landstraßen unter verschiedenen klimatischen Bedingungen dargestellt. Um die Antwort solcher Konstruktionen einzuschätzen, wird ihr Verhalten in mehreren Städten Irans (Rašt, Teheran und Ahvaz) verglichen. Die Resultate zeigen, dass die Anwendung dauerhafter flexibler Fahrbahnen insbesondere für Straßen mit starker Verkehrsbelastung geeignet ist. Im Vergleich zu herkömmlichen Fahrbahnen sind dauerhafte flexible Fahrbahnen beständiger gegen Risse, die aufgrund von Müdigkeit auftreten.

Schlüsselwörter:
dauerhafte flexible Fahrbahn, Asphaltbetonbelag, Landstraßen, klimatische Bedingungen

1. Introduction

Perpetual pavement (PP) is a long life pavement constructed to last for more than 50 years. It does not require major structural rehabilitation or reconstruction during its service life, and it only needs periodic surface layer renewal. Perpetual pavements can be either flexible or rigid pavements overlaid with asphalt concrete. The concept of perpetual flexible pavement (considered in this study) is not new, and so full-depth and deep-strength asphalt pavement structures have been constructed since the 1960s [1]. The Main advantage of perpetual pavement application is that the overall cross-section of the pavement is thinner than in case of pavements employing thick granular base courses. Also, perpetual pavements are suitable for high-traffic-volume roadways and airport runways, where it is undesirable to fully or partially close the facility for maintenance activities [2]. A perpetual flexible pavement system typically involves the following three hot mix asphalt (HMA) layers: surface layer, intermediate layer, and HMA base layer. Characteristics of these layers are explained below.

The Renewable surface layer must resist rutting and surface cracking and should also reduce the hydroplaning and tire noise. For these reasons, the most effective material to be used for this layer is the Stone Mastic Asphalt (SMA). It is also appropriate to apply a thin open-graded asphalt concrete layer on the SMA [3]. Nevertheless, some functional requirements, such as skid resistance, point to the need to conduct surface inspections and repairs at regular intervals. This layer ranges from 40 to 75 mm in thickness, and its design life varies between 8 and 14 years [1].

The stability and durability of this layer must enable proper rutting and fatigue resistance. The high-temperature grade of the asphalt should be the same as that on the surface to resist rutting. However, the low-temperature grade could probably be relaxed by one grade, since the temperature gradient in the pavement is relatively steep and the low temperature in this layer would not be as severe as in the surface layer. The thickness of this layer varies between 100 and 175 mm [3].

The fatigue resistance and bottom-up cracking prevention are the main requirements to be addressed by this layer. To increase the resistance of this layer to fatigue cracking, the percentage of asphalt binder in asphalt concrete mixture can be increased by 1 % [3]. In addition, the increase in the total pavement thickness plays a vital role in decreasing the tensile strain at the bottom of asphalt layers, and therefore ensures an appropriate fatigue life of asphalt concrete used for the HMA base layer [4].

2. Structural design of perpetual pavements

The purpose of structural design of perpetual pavements is to reduce stresses, strains, or displacements due to a vast majority of loads lower than those that would cause structural damage [5]. In other words, the design theory behind perpetual pavement is that distresses are limited to top-down cracking in the top asphalt lift, and the lower HMA layers are designed to resist fatigue cracking and permanent deformation according to the criteria presented below [6, 7].

2.1. Criteria for rutting

According to these criteria, the aim is to limit vertical compressive strain at the top of the subgrade. The maximum amount of this strain is considered to be equal to 200 με [5].

2.2. Criteria for alligator fatigue cracking

The tensile strain at the bottom of the asphalt concrete layer must be reduced to increase the pavement strength against fatigue cracking, and to extend the flexible pavement life. Based on the Schapery's fundamental law of fracture mechanics, a cohesive fracture hypothesis was developed for the cyclic fatigue loading, to obtain the rate of crack growth per load cycle. This relationship can be presented by equation (1):

$$\frac{dc}{dN} = A\left[\frac{\partial W_R/\partial N}{\partial csa/\partial N}\right]^n - \frac{dh}{dN} \tag{1}$$

where [8]:

$\frac{dc}{dN}$ - rate of crack growth per load cycle

W_R - rate of energy dissipation due to damage

$\frac{dh}{dN}$ - crack healing per load cycle

N - load cycle
A, n - constant coefficients
csa - crack surface area.

In this equation, the rate of energy dissipation during various loading cycles is a new parameter for determining the amount of damage to asphalt concrete [9]. The effect of healing on the crack propagation in asphalt concrete (AC) is also considered. For conventional and intermediate strain levels, the amount of healing energy is negligible in comparison to damage energy. However, the amount of healing energy and damage energy are equal for low strain levels and, therefore, the fatigue life or the number of load repetitions to reach stiffness of asphalt concrete mixture to 50 % of its initial value, increases remarkably [10]. According to this concept, the fatigue endurance limit has been defined for asphalt concrete mixtures, and some researches have shown that, if the endurance limit is taken to be 70 με, this would extend the fatigue life considerably [10]. However, Japanese researchers have suggested that the tensile strain limit at the bottom of the asphalt concrete layer could be increased to 150 με [11]. In perpetual pavement, because of thick AC layers, the amount of strains created at the bottom of the asphalt concrete layer is low, and so the flexible pavement life extends remarkably with regard to fatigue cracking.

2.3. Effects of top-down fatigue cracking on perpetual pavement performance

As already indicated, the rutting and the bottom up fatigue cracking are used to design perpetual pavements. However, the damage due to the top-down fatigue cracking has been given more attention in recent years, especially with regard to thick flexible pavements [12]. According to the viscoelastoplastic continuum damage (VEPCD) model developed by Kim and Underwood [13], the cracks created in the total thickness of the asphalt concrete layer can affect performance of perpetual pavements. It is therefore not sufficient to consider the tensile strain at the bottom of the asphalt concrete layer as a means to determine the fatigue life of perpetual pavements. Consequently, the top-down fatigue cracking is considered here for evaluating performance of perpetual pavements.

The evaluation of perpetual pavements and their comparison with conventional pavements is presented in earlier papers. For example, Amini et al. [14] compare the life cycle cost (LCC) of rural highways with conventional and perpetual pavements in various traffic and climatic conditions for Iranian highways. The results of the study show that the perpetual pavement construction could reduce the LCC of pavements by 4-20 %. In addition, the evaluation of perpetual pavements on a portion of the Interstate Highway 287 in New Jersey shows that when the pavement is structurally sound, the placement of a thin overlay using a polymer modified binder in the HMA could keep the pavement in an excellent service condition [15].

According to the above explanations, perpetual flexible pavements can be an appropriate type of pavement, especially for high-traffic-volume roadways. Thus, this research aims to investigate the effects of perpetual flexible pavement application on the extension of the pavement service life and reduction in pavement distresses for rural roads with high traffic volume, by considering various climatic conditions. High-traffic-volume rural highways are considered in this study to evaluate perpetual pavements structurally, because axle loads are greater in rural highways and it is less desirable to fully or partially close the high-traffic-volume roadways for maintenance activities.

3. Methodology

Three cities in Iran with various mean annual air temperatures and rainfall levels are considered to evaluate performance of perpetual pavements for high-traffic-volume rural roadways. These cities are Tehran, Ahvaz and Rasht. For this purpose, the mechanistic empirical pavement design guide (MEPDG) software is used to evaluate distresses created in the perpetual and conventional pavements during the design life, taking into account climatic and traffic conditions. The MEPDG software, developed under the National Cooperative Highway Research Projects 1-37A and 1-40D, employs a layered elastic model and integrates it with the coming AASHTO pavement design guide to predict distresses created in pavements [16]. The Version 1.1 of the software is used in this study (release date: August 2009). The main criteria for comparing perpetual pavements with conventional flexible ones are fatigue cracks, the international roughness index (IRI), and the rutting, all of which can be calculated using the MEPDG software. The results obtained through the use of this software are compared with the results obtained using the KENLAYER software developed by Huang [17]. The KENLAYER computer program can be applied to layered systems under single, dual, dual-tandem, or dual-tridem wheels with each layer behaving differently, i.e. presenting the linear elastic, nonlinear elastic, or viscoelastic behaviour.

Appropriate perpetual pavement and conventional pavement cross-sections are first selected using the MEPDG software, for adequate traffic and roadbed soil conditions. In the next step, perpetual pavement and conventional flexible pavement distresses are obtained during the pavement design life under passing traffic, and this by modelling properties of pavement sections. Finally, the KENLAYER software is used to evaluate more accurately the structural performance of perpetual pavement.

4. Properties of pavement layers

Properties of the asphalt concrete mixture used in intermediate layer of the perpetual pavement and surface layer of the conventional pavement are listed in Tables 1 using the results presented by Rodezno and Kaloush [18]. As shown in this table, the binder grade used in the considered mixture is PG 58-22, and the penetration level of this bitumen is 60. Also, the air void content in the selected HMA is 6 %. The properties of this asphalt mixture are the same as those of the conventional asphalt mixture used in Iran. Thus the mentioned HMA has been employed in this study. Characteristics of the mixture used for the HMA base layer are considered to be the same as those given in Table 1, except that the amount of an optimum asphalt content has been increased by 1 %. Furthermore, the mix design properties of the stone matrix asphalt used for surface layer of perpetual pavement according to Lane et al. is shown in Table 2 [19]. In addition, A-2-4 soil type with CBR of 20, and A-6 soil type with CBR of 5, are considered for roadbed soil in this study [20].

The gradation of base and subbase layer materials according to the ASTM D1241-07 [21] is presented in Table 3. The type I and gradation B are selected for base and subbase layers. CBR values considered for base and subbase layers are equal to 80 and 30, respectively, which is in compliance with minimum requirements [22].

Table 1. Mix design properties of dense graded asphalt mixture [18]

Characteristic	Value
Level of input	Level 1
Type of asphalt binder	PG 58-22
Specific gravity of asphalt binder	1.04
Penetration level of asphalt at 25 °C [0,1 mm]	60
Absolute viscosity [Poise (Pa s)]	6000
Optimum asphalt binder content [%]	5.1
Effective asphalt binder content [%]	4.6
Asphalt mixture air voids content [%]	6

Table 2. Mix design properties of stone matrix asphalt [19]

Characteristic	Value
Level of input	Level 3
Type of asphalt binder	PG 58-22
Effective asphalt binder content [%]	6
Asphalt mixture air voids content [%]	4
Cumulative amount retained at 9.5 mm sieve [%]	26
Cumulative amount retained at #4 sieve [%]	74
Passing #200 sieve [%]	9

The analysis of the ADT classification criteria for rural and urban high-traffic-volume roads resulted in the following definition of rural high-traffic-volume routes: the minimum average annual daily traffic (AADT) is equal to 5000 vehicles per day for rural roadways with heavy traffic [23]. Because high-traffic-volume roadways are considered in this paper, the AADT is taken to be10000, while an average annual daily truck traffic (AADTT) is taken to be 1000 AADTT for the design lane. Here it is assumed that 10 % of traffic consists of truck traffic, while the traffic growth rate is assumed to be 4 %. In addition, the truck traffic group 1, presented in Table 4, is used [24]. This table shows the AADTT distribution by vehicle class for this group. The climatic situation of the cities studied in this research (Ahvaz, Tehran and Rasht) is imported to MEPDG using the integrated climatic model (ICM) files. Hourly climatic data about the temperature, precipitation, wind speed, percentage of sunshine and relative humidity, are essential for the creation of ICM files [25]. Thus, the meteorological data for twenty consecutive years (1982–2002), presented by the Iranian meteorological organization (IMO), are utilized [26, 27]. Climatic conditions in the studied cities are presented in Table 5. As shown in this table, Tehran and Ahvaz are quite similar in terms of the mean annual rainfall. Also, Tehran and Rasht present minor differences in terms of the mean annual temperature.

Table 3. Gradations used for granular base and subbase layers [21]

Sieve size [mm]	Percentage passing	
	Base – Type I (Gradation B)	Subbase – Type I (Gradation B)
50	100	100
37,5	---	---
25	85	85
19	---	---
9,5	57.5	57.5
4,75	45	45
2	32.5	32.5
0,425	22.5	22.5
0,075	5	8.5

Table 4. AADTT distribution by vehicle class for truck traffic group 1 [24]

Vehicle name	Bus	2 axle SU$_1$	3 axle SU	4 or more axle SU	4 or less axle ST$_2$	5 axle ST	6 or more axle ST	5 or less axl MT$_3$	6 axle MT	7 or more axle MT
AADTT distribution [%]	1.3	8.5	2.8	0.3	7.6	74	1.2	3.4	0.6	0.3
SU - single unit; ST - single trailer; MT - multi trailer AADTT - average annual daily traffic of trucks										

Table 5. Climatic conditions in studied regions [27]

Climatic properties	Teheran	Ahvaz	Rašt
Scanned period [godina]	1982.-2005.	1982.-2005.	1982.-2005.
Mean annual air temperature [°C]	17.9	25.8	16.3
Mean annual rainfall [mm]	246.4	241.8	1378.2
Freezing index [°C/dan]	10	0	0.5
Average annual number of freeze-thaw cycles	2	0	0

5. Results

5.1 Selection of appropriate structural cross-sections for perpetual and conventional pavements

When making a comparison between the two pavement models (perpetual and conventional), the first step is to find appropriate cross-sections for perpetual and conventional pavements taking into account appropriate traffic and roadbed soil conditions. Initial thicknesses considered for perpetual pavement layers are based on Nunn and Ferne (2001), but thicknesses considered for conventional flexible pavement are based on MEPDG analyses and there is no need for structural overlay during 10 years after construction. Table 6 presents the final thicknesses obtained from MEPDG analyses for the conventional asphalt concrete pavement and perpetual pavement. In this table, thinner sections are considered when the type of roadbed soil is A-2-4, while thicker sections are applied when the type of roadbed soil is A-6.

To examine whether the considered sections act as perpetual pavement, results from MEPDG are compared in Table 7. As can be seen, after 50 years, less than 1 % of the bottom-up fatigue cracking has been observed at these sections. Also, the permanent deformation of all HMA layers, except for the surface layer that is subject to overlaying, is less than 10 mm.

According to the considered pavement-layer properties and considering the output obtained by the MEPDG software, the cross-sections selected for perpetual pavements and conventional pavements are appropriate for the assumed climatic and traffic conditions.

5.2. Comparison of performance of perpetual pavement and conventional pavement

The results obtained by the MEPDG software can be used to compare performance of perpetual pavements and conventional flexible pavements. The MEPDG results for comparison between perpetual pavements and conventional flexible pavements are shown in Figure 1 with regard to

Table 6. Sections considered for conventional and perpetual flexible pavements

Perpetual pavement						
No.	**Thickness of each layer** [mm]				**Abbreviated designation for each section**	**Initial two-way AADTT**
	Renewal surface layer	**Intermediate layer**	**HMA base layer**	**Base layer**		
1	75	150	150	200	PP-7.5-15-15-20	2000
2	75	200	150	300	PP-7.5-20-15-30	2000
Conventional flexible pavement						
No.	**Asphalt concrete layer**	**Granular base layer**	**Granular subbase layer**		**Abbreviated designation for each section**	**Initial two-way AADTT**
3	200	250	350		CP-20-25-35	2000
4	200	300	400		CP-20-30-40	2000

Table 7. Results of MEPDG analysis for perpetual pavement in Tehran

Characteristic	**Roadbed soil: A-2-4**		**Roadbed soil: A-6**	
	PP-7.5-15-15-20		**PP-7.5-20-15-30**	
	10 years	**50 years**	**10 years**	**50 years**
Terminal IRI [m/km]	1.45	2.87	1.49	3.14
Fatigue AC bottom-up cracking [%]	0.0135	0.186	0.0055	0.0748
Permanent deformation (Total pavement) [mm]	5.87	12.57	6.73	14.15
Permanent deformation (AC only) [mm]	2.72	8.43	2.84	8.79
Permanent deformation (Total pavement except surface layer) [mm]	3.35	4.80	4.09	6.06
Permanent deformation (AC only except surface layer) [mm]	0.20	0.66	0.21	0.71

rutting for all pavement layers and for the roadbed A-2-4. According to this figure, the rutting depth for all pavement layers is bigger for climatic conditions of Ahvaz, compared to Tehran and Rasht. Because of higher rainfall in Rasht, a greater permanent deformation can be expected in granular layers. It should however be noted that due to greater thickness of asphalt layers, the effects of the mean annual air temperature (MAAT) are greater than the effects of rainfall. Also, the rutting in the total perpetual pavement (with the exception of the surface layer) amounts to about one half of the total rutting depth for conventional pavement ten years after initial construction. The percentage of total pavement rutting occurring in asphalt concrete and granular layers of perpetual and conventional pavements is shown in Figure 2 for the roadbed A-6. As illustrated in this figure, the amount of rutting in asphalt layers of the perpetual pavement is higher than that in the conventional pavement because the thickness of asphalt layers in perpetual pavement is greater when compared to that of the conventional pavement. In addition, for climatic conditions in Ahvaz, more than 50 % of permanent deformations occur in AC layers of perpetual pavement. However, rutting in asphalt concrete layers of perpetual pavement can be reduced using an appropriate asphalt concrete mixture for warm weather conditions. Figure 2 also shows that the percentage of total pavement rutting occurring in granular layers in Rasht is greater compared to Tehran and Ahvaz. The greater rutting depth in granular layers for climatic conditions pertaining to Rasht is due to the following main reasons: the assumed section lies on a weaker subgrade, i.e. A-6, and the mean annual rainfall in Rasht is higher.

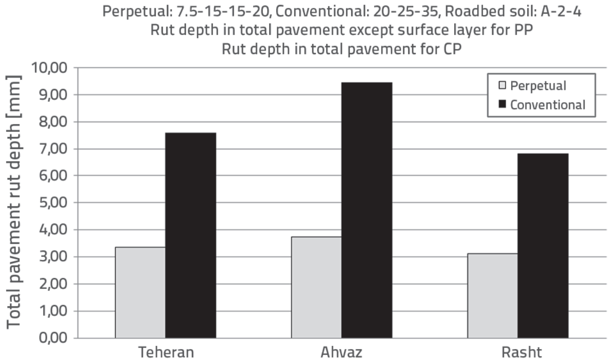

Figure 1. Comparison of rutting depth in total pavement 10 years after initial construction, for perpetual and conventional pavements (climatic conditions for a particular city are given in Table 5)

The rutting performance of perpetual and conventional pavements constructed on the low strength soil (A-6) is shown in Figure 3 for both short and long design life. This figure shows the level of rutting in the perpetual pavement (not including the surface layer) and the total rutting in the conventional pavement ten and fifty years after initial construction. According to this figure, the level of rutting in the conventional pavement is remarkably higher (by about 3 times) compared to perpetual pavement fifty years after pavement construction. On the other hand, the perpetual pavement rutting after fifty years is less than 10 mm, but it can be seen that for climatic conditions in Ahvaz, the conventional pavement rutting depth increases from 11.58 after 10 years in service to 23.39 mm after 50 years in service. It should also be noted that the effects of climatic conditions shown in this figure are the same as those presented in Figure 1.

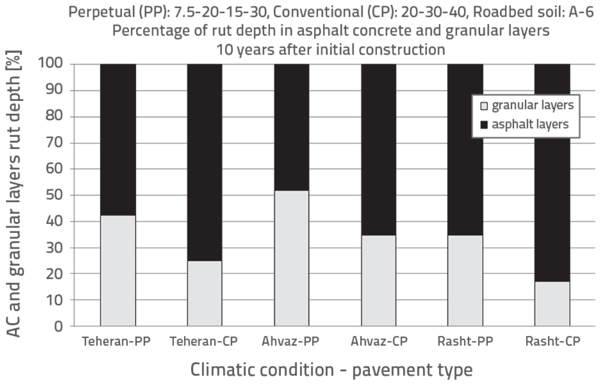

Figure 2. Comparison of rutting depth percentage in asphalt concrete and Granular layers ten years after initial construction, for perpetual and conventional pavements

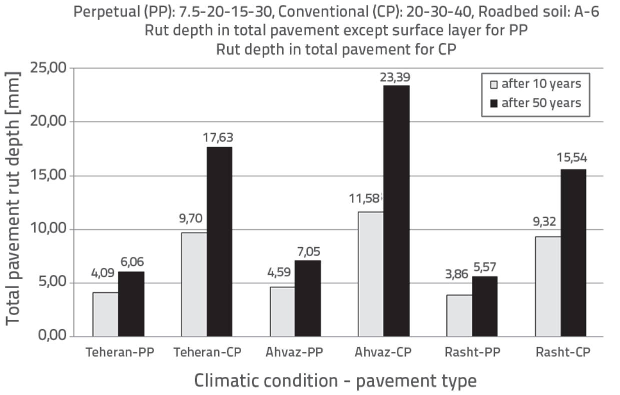

Figure 3. Comparison of rutting depth in total pavement ten and fifty years after initial construction, for perpetual and conventional pavements

The amount of IRI on the pavement surface ten years after initial construction, for both perpetual and conventional pavements, is compared in Figure 4. For the same thicknesses of pavement layers, the amount of IRI ten years after initial construction is higher for conventional pavement compared to perpetual pavement. In addition, the IRI is higher in Ahvaz than in Tehran because of the higher MAAT in this city, and the IRI is greater in Tehran than in Rasht because of climatic conditions, although th mean annual rainfall is higher in Rasht. The main reason is that thicknesses obtained for perpetual and conventional pavement layers are remarkable and therefore, the effect of high rainfall values on the decreasing of granular layers modulus is insignificant.

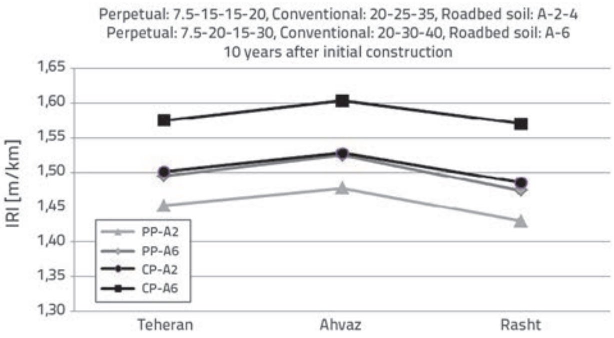

Figure 4. **Comparison of IRI values on pavement surface ten years after initial construction, for perpetual and conventional pavements (climatic conditions for a particular city are given in Table 5)**

In addition, the HMA layer thickness in perpetual pavement is 375mm, and the asphalt concrete thickness in conventional pavement is 200mm. Thus, both pavements have thick AC layers and the effects of temperature are higher than those of the rainfall. It should be noted that the IRI calculated by means of MEPDG contains all types of distresses, as shown by equation (2):

$$IRI = IRI_0 + \alpha SF + \beta\left(FC_{Total}\right) + \eta\left(TC\right) + \gamma\left(RD\right) \qquad (2)$$

where [28]:

IRI_0 - initial IRI measured within six months after pavement construction

SF - site factor related to pavement life, average annual rainfall and freezing index

FC_{Total} - total area of fatigue cracking, percent of wheel path area, [%]

TC - total length of transverse cracks, [m/km]

RD - average rutting depth, [mm]

$\alpha, \beta, \mu, \gamma$ - constant coefficients.

Therefore, IRI is an appropriate parameter that can be used to compare performance of perpetual and conventional pavement for various climatic conditions.

Fatigue cracks occurring ten and fifty years after initial construction of perpetual and conventional pavements are compared in Table 8 for climatic conditions prevailing in Tehran, Ahvaz, and Rasht, in order to evaluate resistance of these two pavement types to fatigue cracking. The total fatigue cracking, including the bottom-up (alligator) cracking, and the top-down (longitudinal) cracking in the asphalt concrete layers, is presented in Table 8. As shown in this table, the fatigue cracking performance of perpetual pavement is better than that of the conventional pavement, and this for various climatic conditions. According to this table, the conventional pavement will need structural overlay after ten years since the amount of fatigue cracking will exceed 1 %. On the other hand, the amount of fatigue cracking in perpetual pavement will be negligible. Von Quintus [29] indicates that pavement failure occurs when fatigue cracking affects 20 % of the road surface. So, without the maintenance and rehabilitation of conventional pavements, the functional pavement failure would occur before the pavement reaches fifty years of service life.

5.3. Comparison of MEPDG and KENLAYER results

The perpetual pavement damage predicted according to the KENLAYER software is shown in Table 9 to enable comparison with the MEPDG results. In KENLAYER, the damage analysis is based on two criteria: the fatigue cracking based on the tensile strain at the bottom of the asphalt layer, and the permanent deformation based on the compressive strain at the subgrade surface. Therefore, each year is divided into 4 periods, and the modulus computed by MEPDG for each period and each perpetual pavement layer is considered as input to KENLAYER for various periods and layers. To model the effects of various loading conditions, eleven load groups are considered in KENLAYER so as to evaluate the effects of single, tandem, and tridem axles. According to Table 9, this type of pavement could be designed to last more than 50 years without any structural damage. As shown in this table, the results obtained by KENLAYER are the same as the results obtained by MEPDG, i.e., the best performance of perpetual pavements is for climatic conditions in Rasht, and the worst performance is for Ahvaz. However, using the asphalt binder that is more consistent with warm climatic conditions can improve performance of perpetual pavements under such climatic conditions.

Table 8. Amount of fatigue cracking (alligator and longitudinal) in asphalt concrete layers ten and fifty years after initial construction, for conventional and perpetual pavements

Type of pavement	**Teheran**		**Ahvaz**		**Rašt**	
	Amount of fatigue cracking [%] – Roadbed soil: A-2-4 Perpetual pavement designation: 7.5-15-15-20. Conventional pavement designation: 20 -25-35					
	10 years	**50 years**	**10 years**	**50 years**	**10 years**	**50 years**
Conventional Pavement	1.66	45.27	3.65	85.98	1.24	30.41
Perpetual Pavement	0.014	0.186	0.021	0.293	0.011	0.148

Table 9. Predicted damage in perpetual pavement by KENLAYER software

Type of distress (damage)	Teheran		Ahvaz		Rašt	
	Damage ratio	**Design life** [year]	**Damage ratio**	**Design life** [year]	**Damage ratio**	**Design life** [year]
Tensile strain at the bottom of the rich bottom layer	0.0172	58.1	0.0265	37.6	0.0138	72.1
Compressive strain at the top of the subgrade layer	0.0056		0.0124		0.0029	

6. Conclusions

The main aim of this research was to evaluate and compare perpetual pavements with conventional flexible pavements and to study the possibility of their use instead of conventional flexible pavements for high-traffic-volume rural routes and various climatic conditions prevailing in some cities in Iran. The MEPDG software was used for this analysis. Also, the results obtained using this software were compared with the results obtained by KENLAYER for some cases. Based upon this study, the following conclusions can be made:

- The levels of rutting in pavement layers (not including the surface layer) and fatigue cracking are negligible for perpetual pavements as compared to conventional thick pavements.
- Because of greater asphalt layer thickness in perpetual pavements, the mean annual air temperature can affect their performance more than the mean annual rainfall for each region under study.
- When a perpetual pavement rests on a weaker subgrade, its performance can be more affected by the mean annual rainfall.

In summary, perpetual pavements can last for a long period of time without any remarkable structural damage and in various climatic conditions.

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