Applying the Mechanistic Empirical Pavement Design Guide Under The Egyptian Conditions

تطبيق الطريقة الميكانيكية التجريبية في تصميم الرصف علي الظروف المصرية

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الخلاصة: ان التصميم الانشائي للرصف ليس بالأمر البسيط فالأحمال المرورية و مواصفات المواد المستخدمة في الانشاء والعوامل الجوية جميعها عوامل يجب اخذها في الاعتبار اثناء التصميم كما يجب ان يكون هناك دراية بتأثير كل عنصر من هذه العناصر علي أداء الرصف . في السنوات الأخيرة تعددت طرق التصميم الانشائي للرصف بداية بالطريقة التقريبية ومرورا بطريقة خفض الترخيم ونهاية بطريقة ASHTOO في عام وغيرها١٩٩٣ و لكن أي من هذه الطرق لم تأخذ في الاعتبار حساب الشروخ والتشوهات المتوقعه في الرصف علي مدار العمر التصميمي للطريق كما لم تأخذ معظمها في الاعتبار تأثير العوامل الجوية وتطور المواد المستخدمة في الانشاء ولكن في عام ٢٠٠٢ ظهرت الطريقة الميكانيكية التجريبية في التصميم و التي تمكن المهندسين من التحكم في الأداء المتوقع للرصف علي مدار العمر التصميمي وكذلك تاخذ في الاعتبار العوامل التي اغفلتها الطرق الاخري مثل الاحمال المرورية والعوامل الجوية و خصائص مواد الرصف المستخدمة وتم صياغة هذة الطريقة الحديثة عن طريق برنامج يقوم المصمم بادخال المدخلات المتوفرة لديه عن الطريق الي البرنامج وادخال قطاع الرصف المقترح ويقوم البرنامج بدوره بحساب الاجهادت في طبقات الرصف المختلفة بطريقة ميكانيكية ومن ثم يقوم بتحويل الاجهادات المحسوبة بالطريقة الميكانيكية الي التشوهات والشروخ المتوقع حدوثها للرصف علي مدار العمر التصميمي وتركز هذه الرسالة علي امكانية تطبيق الطريقة الميكانيكية التجريبية في جمهورية مصر العربية والتعديلات المطلوب ادخالها عليها ومقارنتها بطرق التصميم في مصر وتم التوصل الي انه من الممكن تعديل الظروف المناخية للبرنامج و امكانية استخدامه علي الظروف المصرية وكذلك حساب التشوهات المتوقعه علي الطرق المصرية المختارة.

1-Abstract:-

Pavement structural design is a complicated task; traffic loads, characterizations of pavement materials and climatic conditions all are factors must be taken into consideration during the design process and it is important to understand how each factor affects the overall performance of the pavement structural design. For many years, extensive research has been performed on the refinement and development of pavement structural design procedures such as, (Empirical Methods, Limiting Deflection Failure Methods, Stone Matrix Asphalt and AASHTO 1993). All mentioned methods does not take into consideration the pavement performance or it does not take all important factors which affect the pavement performance like (Traffic loads, Climatic conditions and Material characterizations) [1], But now the Mechanistic-Empirical Pavement Design Guide (MEPDG) which was created by the AASHTO organization in 2002 can be used. This design method allows engineers to design pavement structural layers to sustain predefined limits of distress levels due to traffic loads and environmental conditions based on mechanistic empirical locally or nationally calibrated performance models. The user is required to input variables related to traffic, environment, HMA, base/sub-base and sub-grade characteristics. This paper is focused upon the ability of using the MEPDG under the Egyptian conditions and the modifications needed to use it in Egypt comparing it with other used methods in Egypt and it was found that it is possible to use the MEPDG in Egypt and replace the American climatic data by the Egyptian one also the distresses on the chosen Egyptian roads were predicted

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2-Introduction:-

The MEPDG includes the following improvements that make it superior to the existing AASHTO Pavement Design Guide: (a) the use of mechanistic-empirical pavement design procedures, (b) the implementation of performance prediction of transverse cracking, faulting, and smoothness for jointed plain concrete pavements, (c) the addition of climatic inputs, (d) better characterization of traffic loading inputs, (e) more sophisticated structural modeling capabilities, and (f) the ability to model real-world changes in material properties. But it should be kept in mind that the program will not compute a thickness for any pavement layer, A trial cross section with initial thickness for every layer will be assumed then all required data will be inputted (traffic loads, characterizations of pavement materials and climatic conditions) and establish acceptable pavement performance criteria (acceptable values for rutting, cracking and the international roughness index IRI) then select a desired level of reliability of these performance indicators then the program will compute the stresses and strains using multilayer elastic theory or finite element models for each damage calculation increment through the design period, calculate accumulative distresses at the end of the design life, predict key distresses (rutting, fatigue cracking and thermal cracks) [2].

The input data needed to run the MEPDG software is very extensive and detailed. The amount of data required is much bigger than with traditional design methods or with previous versions of AASHTO design methods. In order to use the software and to take advantage of its full power, the local input data needs to be available at the level of detail required by the program. This paper included the available data about some roads network in Egypt the resulted distresses by using the MEPDG.

Inputs required by the MEPDG software can be classified in four categories: general, traffic, weather and structural. The program gives the designer the flexibility to use site specific or general input data for the traffic and structural inputs. Site specific information will provide for the most reliable design, but since the level detail required is high, the data is not always available for the designer. General default input parameters should be used with caution, since they should represent the input data of the project.

Depending on the quality of the input data used, the design is categorized into three input levels, level 1 from actual laboratory and field testing, like dynamic modulus testing of HMAs, site specific axle load spectra and vehicle class distributions. Level 2 designers use an intermediate level of input that could be obtained from an agency database, derived from a limited testing program or estimated through correlations. Level 3 design uses default values or typical averages for the region [3].

So the program will not make a design or suggest a pavement section but it will analyze an existing section then make a distress prediction.

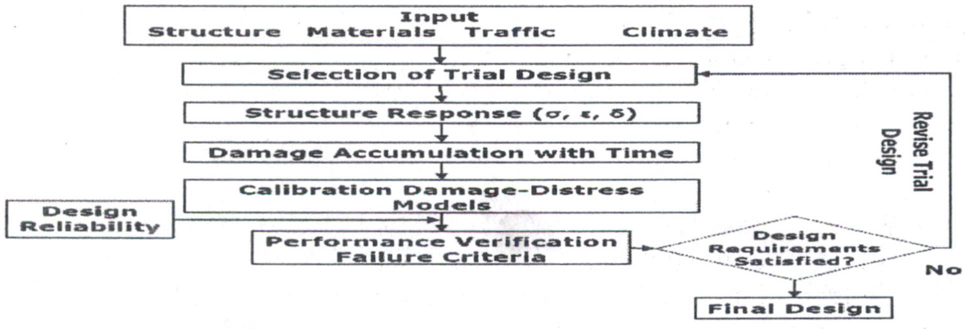


Fig.1 The flow chart of the new design guide system [4]

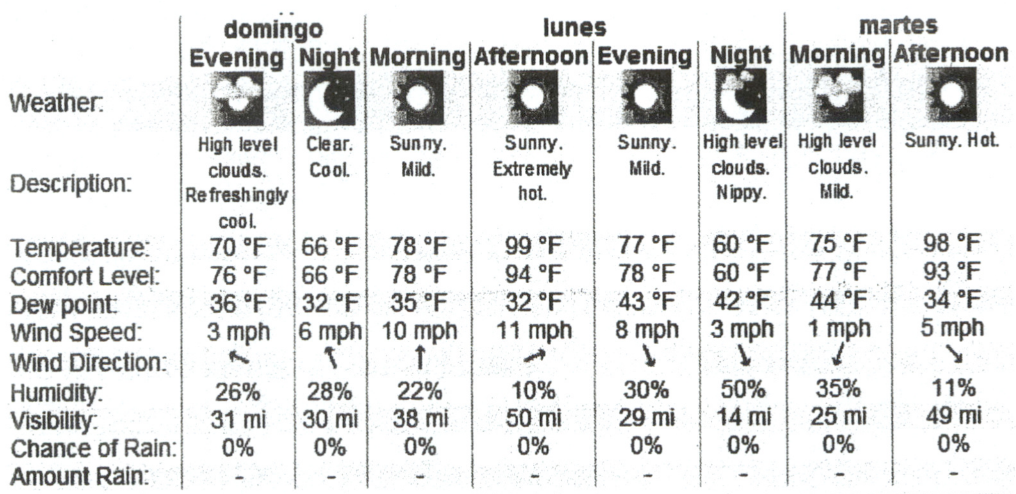
3-Objectives:-

This research work aims to study the possibility of using the MEPDG method in the design of Egyptian roads and determine the required data for this purpose (weather data, Traffic, Materials) two roads were selected to compare the pre-designed sections with the resulted distresses calculated by using the MEPDG Cairo Alex New Desert Road, Cairo Ismailia Road as cases of study.

4- Design required data under the Egyptian conditions:

4-1Weather information:-

The weather information in Egypt is not included in the program. The United states data is the only available data so the program was modified to accept the Egyptian weather data. The data was collected from the Hong Kong observatory web site [5] , Weatheronline.UK web site and www.timeanddate.com web site[6]. Cairo was chosen to represent the climatic condition for Egypt.



	domingo		lunes				martes	
	Evening	Night	Morning	Afternoon	Evening	Night	Morning	Afternoon
Weather:								
Description:	High level clouds. Refreshingly cool.	Clear. Cool.	Sunny. Mild.	Sunny. Extremely hot.	Sunny. Mild.	High level clouds. Nippy.	High level clouds. Mild.	Sunny. Hot.
Temperature:	70 °F	66 °F	78 °F	99 °F	77 °F	60 °F	75 °F	98 °F
Comfort Level:	76 °F	66 °F	78 °F	94 °F	78 °F	60 °F	77 °F	93 °F
Dew point:	36 °F	32 °F	35 °F	32 °F	43 °F	42 °F	44 °F	34 °F
Wind Speed:	3 mph	6 mph	10 mph	11 mph	8 mph	3 mph	1 mph	5 mph
Wind Direction:	↖	↖	↑	↗	↘	↘	↙	↘
Humidity:	26%	28%	22%	10%	30%	50%	35%	11%
Visibility:	31 mi	30 mi	38 mi	50 mi	29 mi	14 mi	25 mi	49 mi
Chance of Rain:	0%	0%	0%	0%	0%	0%	0%	0%
Amount Rain:	-	-	-	-	-	-	-	-

Fig.2Egyptian weather data

4-2Structural Data:-

The structural data for the chosen roads was determined from the Information Department of the General Authority of Roads, Bridges and Transportation (GARBT)in the Egyptian Transportation Ministry and it was as following [7].

Table 1 pavement thicknesses

Road name	Wearing surface(cm)	Binder Corse (cm)	Macadam (cm)	Base Corse(cm)	Sub-base (cm)
Cairo-Alex Desert	5	6	7	15	25
Cairo-Ismailia	5	6	-	25	-

4-3Traffic Data:-

The traffic data for the chosen roads was also determined from the Information Department of the (GARBT) and it was as following.

Table 2 Traffic data for Cairo Alex road
And Ismailia road year 2009 [7]

Road name	Cairo Alex	Ismailia
A.A.D.T	32772	66081
Bikes%	1.36	.95
Cars and Trlrs%	55.18	72.33
2 Axle long%	13.62	10.98
Buses %	11.03	9.89
2 Axle 6 tires%	5.91	3.85
3 Axle single %	3.91	0.59
4 Axle single%	1.89	0.02
□5 Axle double%	3.21	0.45
5 Axle double%	2.52	0.51
□ 6 Axle double%	0.78	0.22
□ 6 Axle multi	0.44	0.13
6 Axle multi%	0.140	0.08
□ 6 Axle multi%	0.01	0.00
PCU	46346	40042

4-4Material properties:-

From several Contractors companies laboratories the materials data was collected such as the mix design and the soil properties. As an example, the data of the new Cairo Alex Deseret toad and Ismailia road was as following:-

Table 3 material properties

Road	Alex	Ismailia	Alex	Ismailia	Alex	Ismailia
Layer properties	Wearing surface		Binder Corse		Macadam	
Specific gravity	2.32	2.35	2.4		2.4	___
Binder content %	5.1	5.0	4.8		4	___
Air voids %	5	4.8	8		13	___
Ret % # 3/4 in	1.3	1	13		25	___
Ret % # 3/8 in	21	24	45		25	___
Ret % # no 4 in	52	49.5	62		50	___
Passing % # no 200	4.5	5	1		0	___
Dynamic modulus psi	268000	265000	207000	200000	166000psi	___
Binder grade	Pen (60-70)					
Granular base	CBR = 80 % (A-1-a) soil					
Sub-base	CBR = 30 % (A-1-b) soil					
Subgrade	CBR = 10 % (A-3) soil					

5-Applying the MEPDG:-

For the New Cairo Alex Desert road and Ismailia road the distresses prediction was as following:-

Fatigue cracking and rutting was assumed to be the most important distresses'

Table 4 Cairo Alex desert road distresses

Road	Alex		Ismailia	
Time in year	Max fatigue cracking%	Total rutting cm	Max fatigue cracking%	Total rutting in
2	4.05	1.2	2.3	1.09
4	8.17	1.33	5.11	1.29
6	12.3	1.53	8.21	1.43
8	16.5	1.65	11.5	1.56
10	20.6	1.75	15	1.67
12	24.7	1.84	18.6	1.78
14	28.7	1.92	22.3	1.88
16	32.7	2.01	26.1	1.98
18	36.5	2.09	29.9	2.08
20	40.3	2.17	33.6	2.15

6- The Design reliability:

The reliability of the pavement design performance process is the probability that a pavement section designed using the process will perform satisfactorily over the traffic and environmental conditions for the design period. [8]"

How the design reliability could be measured:-

After running the MEPDG program and predicting the distresses such as (rutting, thermal cracks, fatigue, IRI) then the actual distresses are measured in the field then a relation between the actual and the predicted distress is plotted [8].

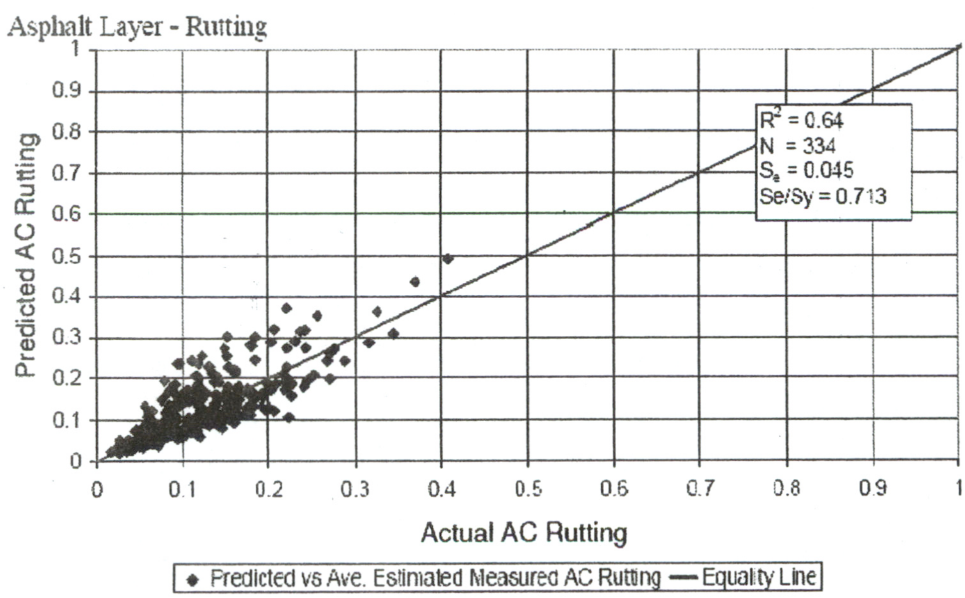


Fig.3 Reliability Calculation

7- Discussion:

Figure 6 and 10 show that the rutting deformation will reach and overreach the allowable value before the end of the design life for the two chosen roads about 30% of the predicted permanent rutting occurs at the first year of the design life then it increases in a semi linear behavior at that is familiar to the and this is conformity to the usual.

Figures 8 and 12 show that the chosen roads have no problem with the longitudinal cracks at all and that is reasonable to the fact because in Egypt it is rare to see a longitudinal crack.

Both roads have high alligator damage percent and that is reasonable because of the very high traffic loads.

Figures 7 shows that Cairo Alex desert road will reach very high level of fatigue damage and high level of fatigue cracking, however it is consisted of three asphalt layers base layer and sub-base layer and that is reasonable since alligator damage occurs due to tensile strain from the bottom to top, the three used asphalt layers used in the roads (wearing surface, binder course and macadam layer) are arranged as shown in figure 4

5cm Wearing surface

6cmBinder course

7cm Macadam

Fig.4 Cairo Alex desert road pavement section

since the less ductile layer was placed at the bottom of the pavement section (at the maximum tensile strain) so it is predicted that it will not have the ability to resist the tensile strain which means that the alligator cracks must happen and it will begin at the bottom of the macadam layer the upper layer of the macadam is the binder course one which has less air voids than the macadam layer so it will be easy for the alligator cracks at the macadam layers to be reflected on the binder course layer and then to the wearing surface layer but if macadam and binder course layers are exchanged in place, there will be no problem with the alligator cracks .

The predicted values of rutting were also high values and that is also expected because rutting reaches it is maximum value at 2 in (5.08cm) depth of the pavement section as shown in figure 5 that means that the maximum rutting will occur on the surface the binder course layer which has higher bituminous content than the macadam layer so it has less rutting resistance but if the macadam layer and the binder course on exchanged the maximum rutting will occur on the macadam layer which has low bituminous content and high resistance to the rutting.

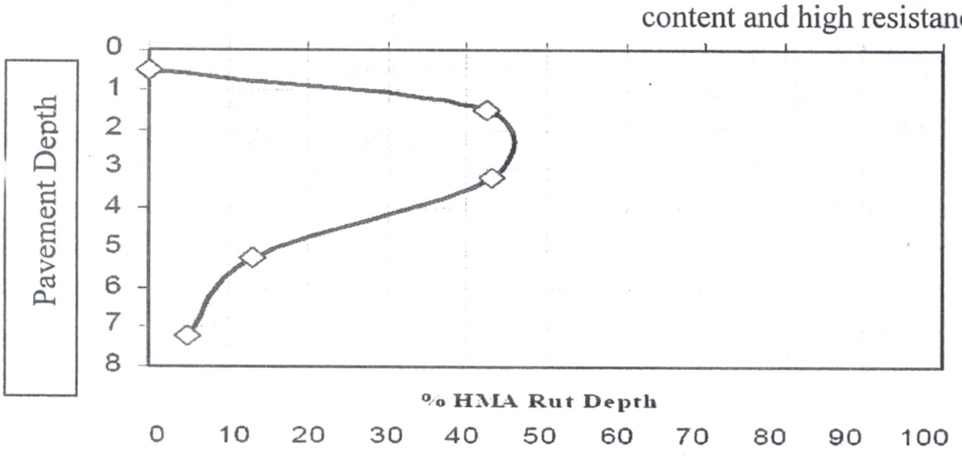


Fig 5 rut depth via pavement depth [9]

8-Conclusions:

The analysis showed that the following conclusions are:

1-MEPDG could be used in Egypt. The local input data required can be obtained and the distress can be predicted.
2-The distress models of the MEPDG are Flexible and can be calibrated to fit the pavement performance observed in Egypt.
3- Some updates for the MEPDG software that would make it easier to use in regions outside North America are including the possibility of adding new stations with all the weather data, to avoid the need to modify an existing station.
4- Level 2 data input binders is ready to be used in Egypt. Traditional binder testing at different temperatures provides the required information to characterize the binders .
5- For HMA mixtures it is suitable to use level 2 of design. The required mixture and binder properties needed for the material characterization can be easily obtained for the local materials.
6- Level 1 design input for material characterization would require investments in testing equipment, which are not widely spread in Egypt.

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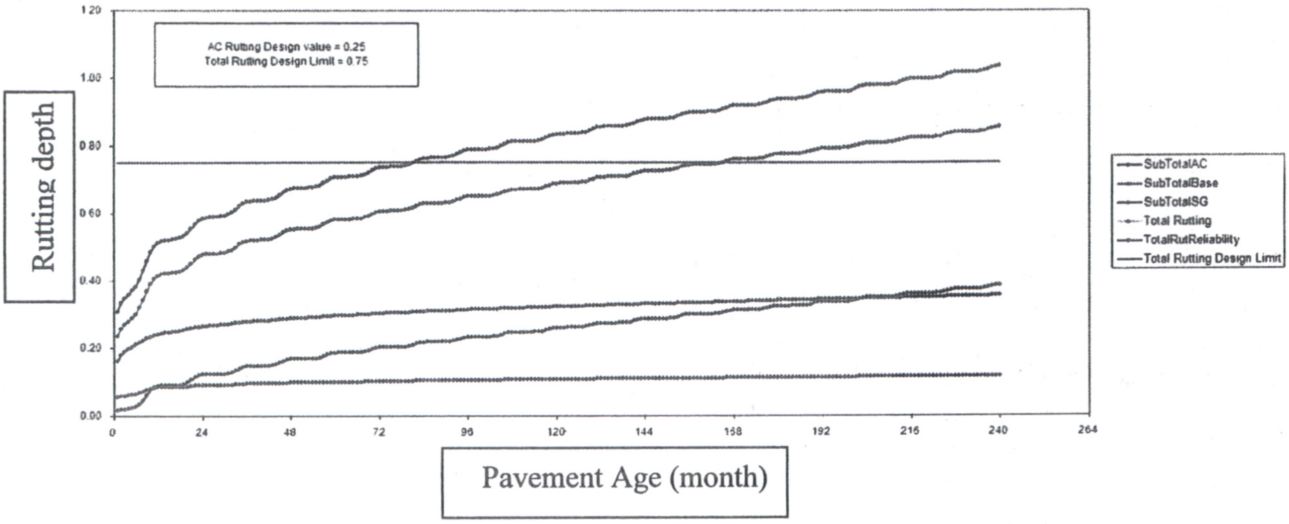

Fig.6Total rutting in Cairo Alex desert road

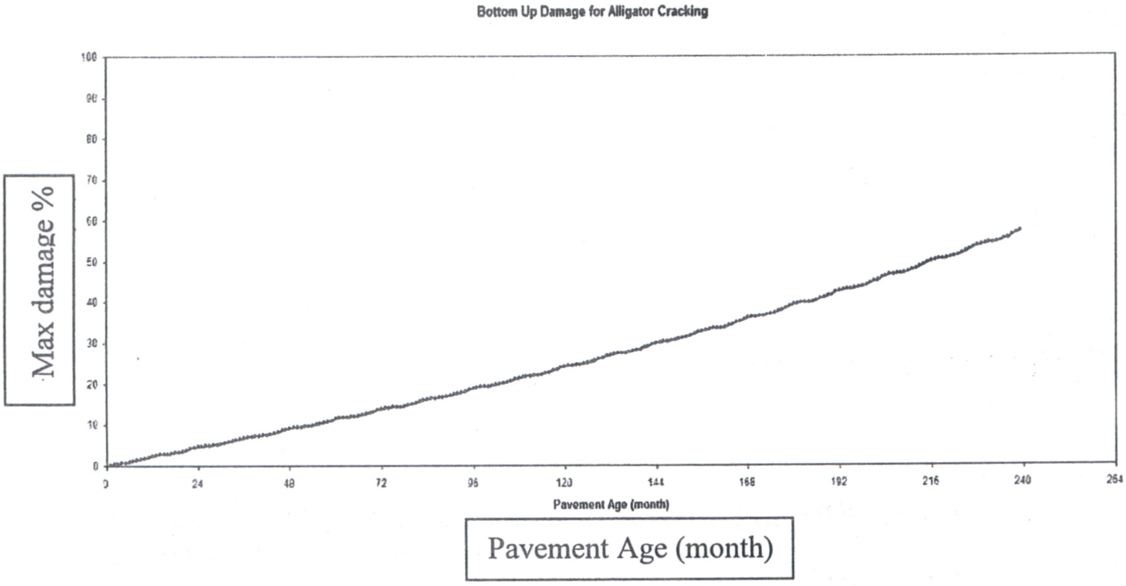

Fig.7 Cairo Alex Desert Road Alligator Crack

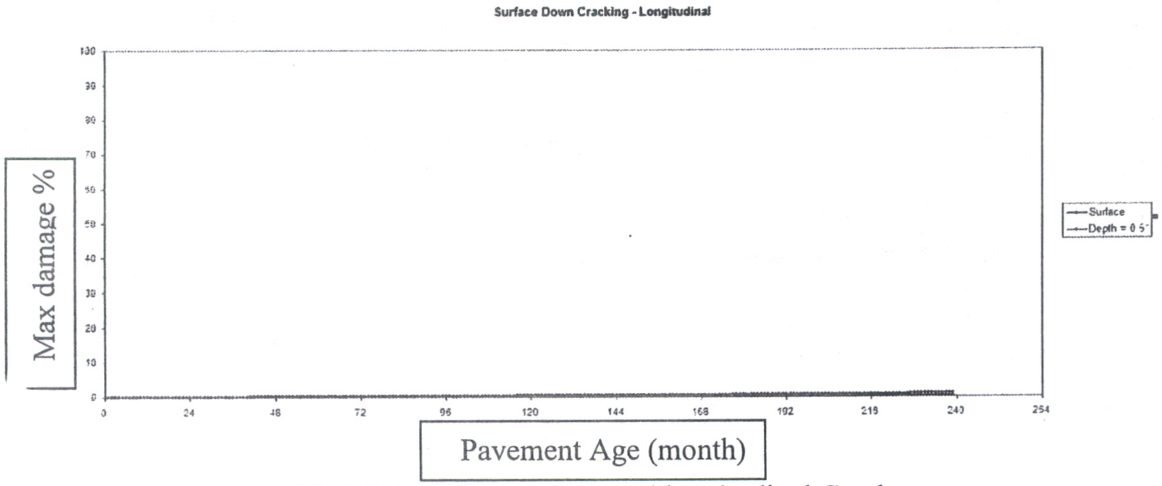

Fig.8Cairo Alex Desert Road longitudinal Crack

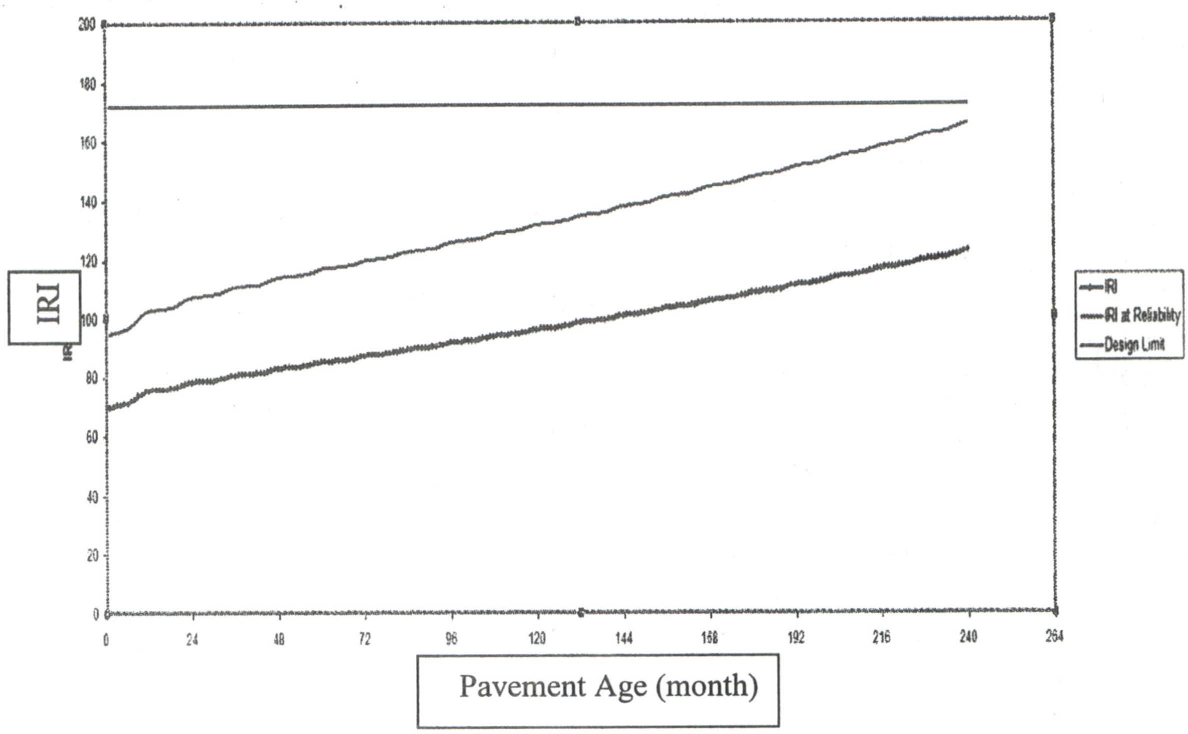

Fig.9 Cairo Alex Desert Road IRI

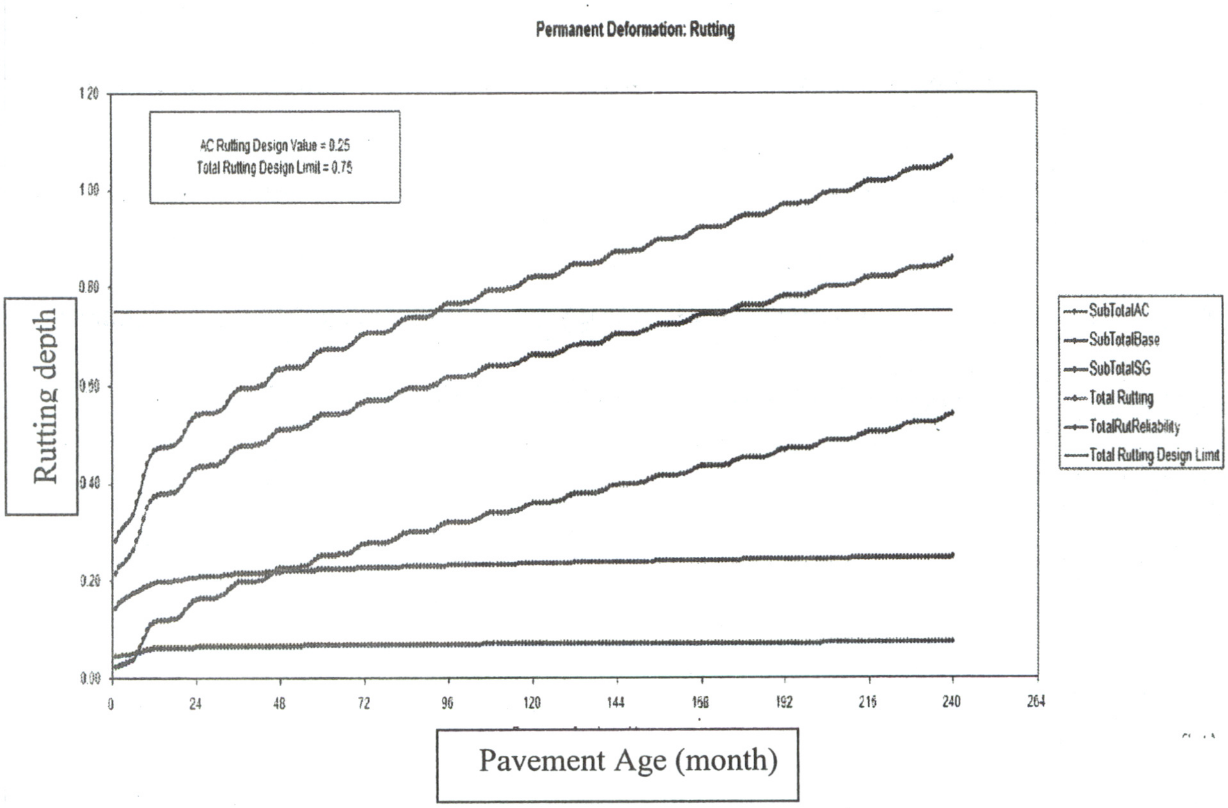

Fig.10Rutting in Ismailia road

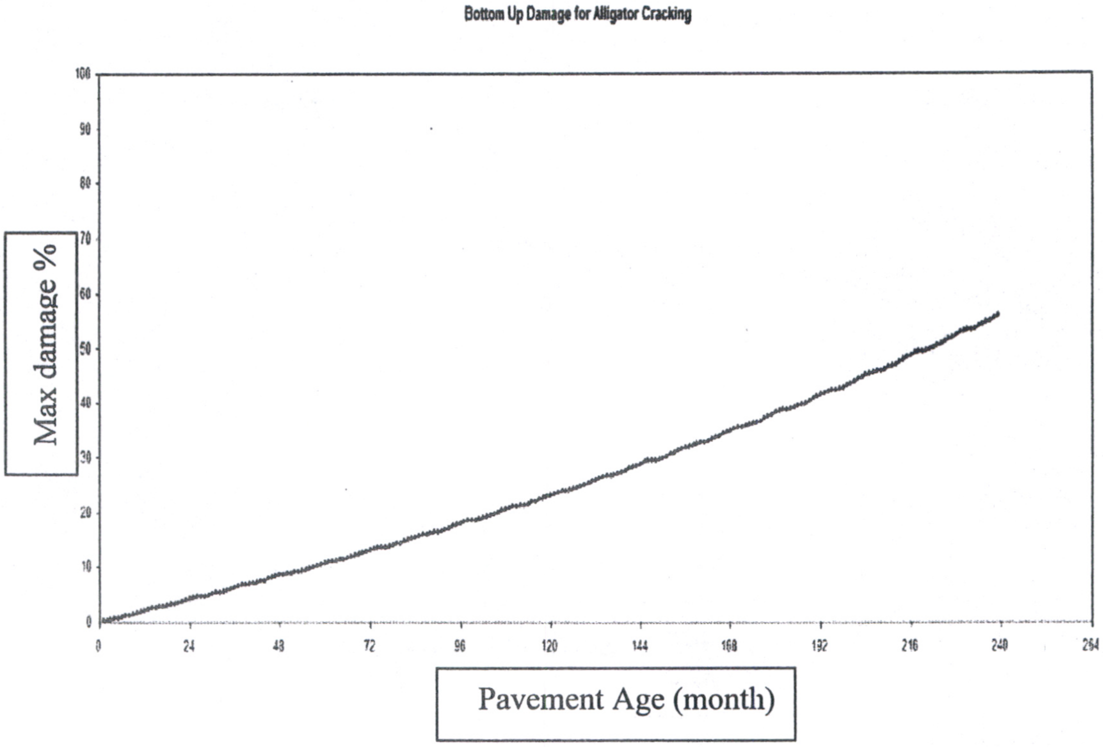

Fig.11 Ismailia Road Alligator Crack

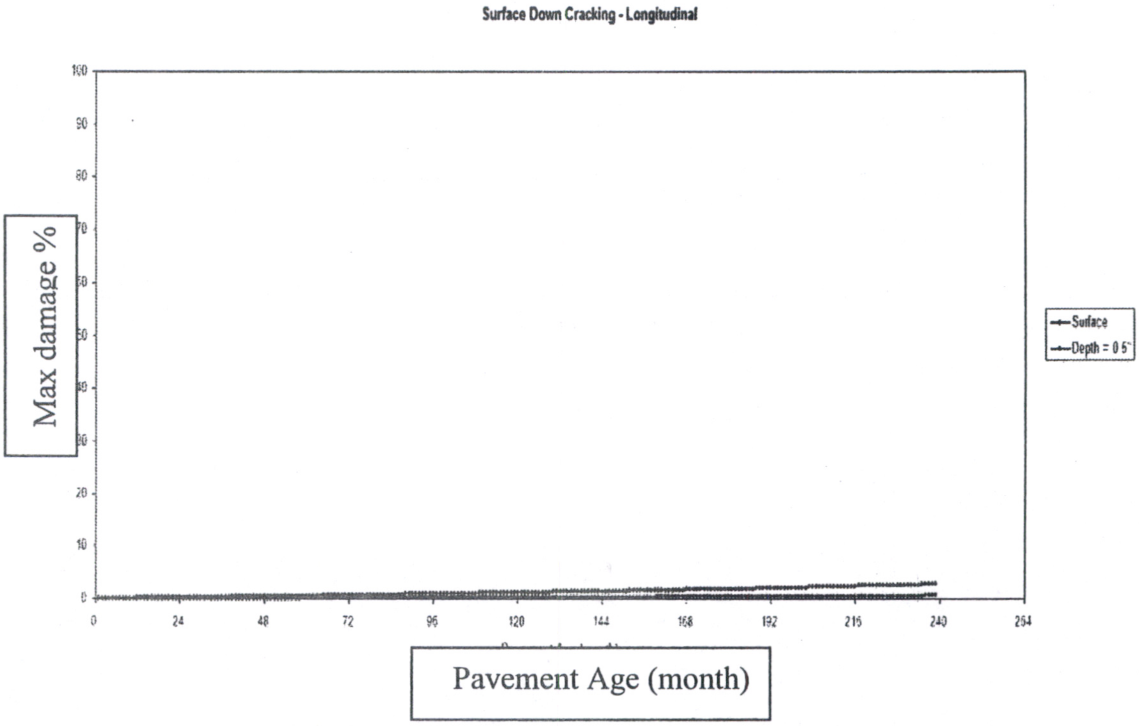

Fig.12Ismailia Road Longitudinal Crack

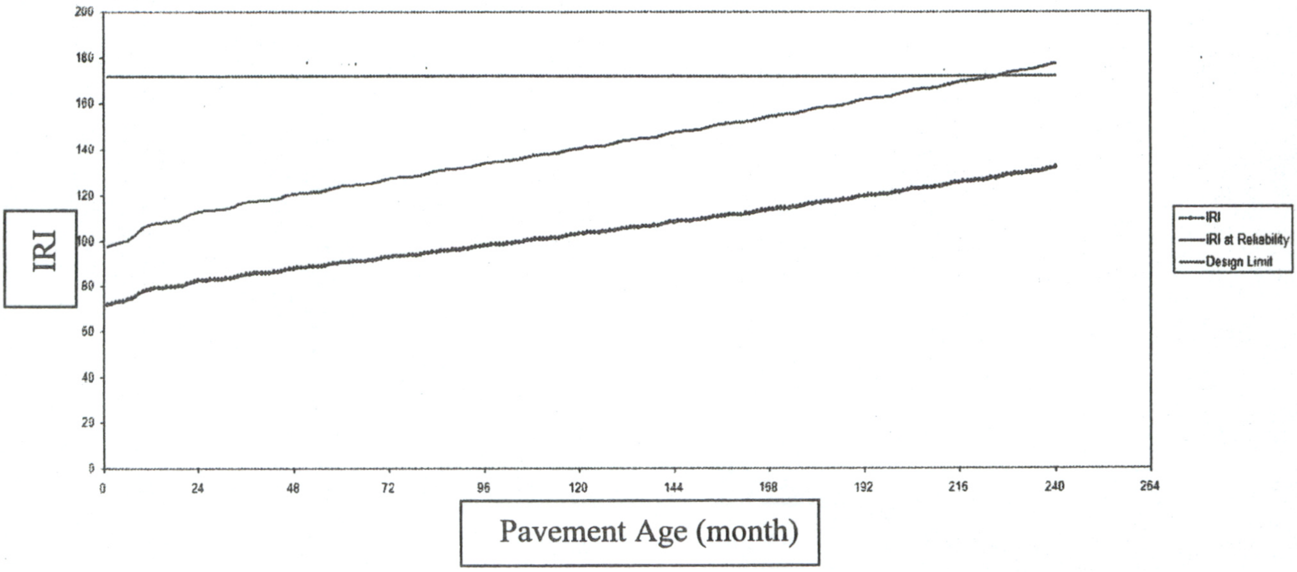

Fig.13 International roughness index in Ismailia Road