THE IMPLEMENTATION OF MECHANISTIC-EMPIRICAL PAVEMENT DESIGN METHOD TO EVALUATE ASPHALT PAVEMENT DESIGN IN QATAR

Husam Sadek [1], Eyad Masad [2], Okan Sirin [3], Hussain Al-Khalid [4], and Dallas Little [5]

[1] Department of Civil&Architectural Engineering, College of Eng., Qatar University, Qatar E-mail hsadek@qu.edu.qa

[2] Mechanical Engineering Program, Texas A&M University at Qatar, Qatar, E-mail: eyad.masad@qatar.tamu.edu

[3] Department of Civil&Architectural Engineering, College of Eng., Qatar University, Qatar
E-mail: okansirin@qu.edu.qa

[4] Centre for Engineering Sustainability, School of Engineering, University of Liverpool, Liverpool, UK
E-mail:H.Al-Khalid@liverpool.ac.uk

[5] Zachry Department of Civil Engineering, Texas A&M University, Texas, USA, E-mail:d-little@tamu.edu

ABSTRACT

The State of Qatar is currently investing billions of dollars in building its road network. The objective is to build a sustainable road network that is designed according to the State-of-the-practice standards and methods. Several field studies have shown that the current and projected traffic loads (axle weights and design traffic) are unprecedented in the State of Qatar. Therefore, there is a need to evaluate whether the current designs are suitable for these projected loads. This paper has focused on mechanistic-empirical analysis of asphalt pavements designed according to the current Qatar Highway Design Manual (QHDM). The analysis was carried out using the Mechanistic-Empirical Pavement Design Guide (M-E PDG) software with environmental conditions, traffic loading, and material properties selected to represent those in the State of Qatar. Pavements performance was assessed in terms of resistance to longitudinal cracking, alligator cracking, total rutting depth, and International Roughness Index (IRI). The input parameters used in the M-E PDG analysis were selected based on the review of the authors of material specifications used in Qatar and data from various projects' reports. The results demonstrated the benefits of using modified PG 76-10 asphalt bitumen instead of unmodified Pen 60-70 bitumen currently used in Qatar. In addition, the results lead to recommendations in terms of various structural designs that can be adopted under different conditions and with the use of improved material properties. The outcomes of this study will be very useful to promote the use of calibrated mechanistic-empirical design approaches and also to design more durable and long-lasting pavements in the State of Qatar.

Keywords: Mechanistic-Empirical Pavement Design, Sustainability, Modified Bitumen, Rutting, Cracking

1. INTRODUCTION

The population in Qatar has been increasing rapidly due to the tremendous economic growth over the past five years. As a result, traffic loading has also increased rapidly, which affected the performance of existing roads and highways. Figure 1 illustrates the expected growth in residents and employees in Qatar. In order to accommodate this increase, the government decided to invest about $3.72 billion in improving the road network by the year 2019. This investment should be accompanied with the adoption of state-of-the-art methods in the design of asphalt pavements that can sustain the increase in traffic loading.

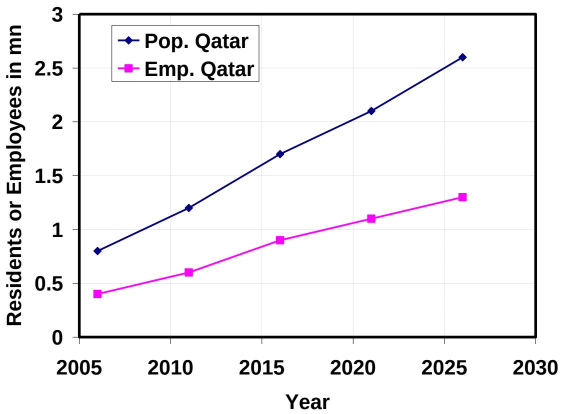

Figure 1: Growth of population and number of employees in Qatar [1]

The Qatar Highway Design Manual (QHDM) [2] is the current major reference that is being used for pavement design in Qatar. It was issued in 1997 replacing the old manual that was produced in 1989 by the Civil Engineering Department of the Ministry of Public Works in Qatar. The QHDM provides the designs for various types of pavement construction in a series of charts. Based on the subgrade and traffic classes, the thicknesses of the construction layers can be easily assigned for each pavement type. This study has focused on the evaluation and analysis of asphalt pavement designs provided in details in the QHDM using the Mechanistic-Empirical Pavement Design Guide (M-E PDG version. 1.1). The M-E PDG software was used at “level 3”, which provides some default and typical values for the traffic volume adjustment factors, axle load distribution factors and axle configuration.

The M-E PDG is being implemented in many developed countries, while some countries like Korea have recently developed a domestic pavement design guide (KPDG) based on the M-E PDG principles [3]. Ceylan *et al.* [4] stated that many benefits would accrue when the M-E PDG is implemented such as: more appropriate designs will be provided to meet expected performances; better performance prediction; better material-related research since the M-E PDG method is based on actual material properties; and use of a powerful forensic tool to analyse failed pavements and identify the factors responsible for the failure.

2. OBJECTIVES OF THE STUDY

The main objectives of this study are to:

- carry out preliminary evaluation of the suitability of asphalt pavement designs provided in QHDM in withstanding various levels of traffic loading.
- evaluate the effect of using different bitumen grades on the performance of pavement designs.
- evaluate the effect of increase in traffic loading above the design levels on the performance of asphalt pavements.

In order to achieve the above objectives, pavement designs used for different traffic classes in the QHDM [2, 5] were evaluated using the M-E PDG software. The input parameters were selected by the authors to represent the properties of typical mixtures and materials used in the State of Qatar. Future work will focus on measuring the properties of various materials and also on the calibration of the models used in the M-E PDG for the prevailing conditions in Qatar.

3. GENERAL ASSUMPTIONS

3.1 Traffic Data Inputs

The following assumptions are used for all of the subsequent sections:

- Design life (years): 20
- Number of lanes in design direction: 2
- Percent of trucks in design direction: 50%
- Percent of trucks in design lane: 95%
- Operational speed (km/h): 96
- Traffic growth: 4%

The other traffic values such as traffic volume adjustment factors, axle load distribution factors, and axle configuration are default values specified in "level 3" of the M-E PDG software. The values of Annual Average Daily Truck Traffic (AADTT) determined in Table 1 correspond to different levels of design traffic in terms of equivalent single axle load (ESALs).

Table 1: The AADTT for the required ESALs and Traffic Classes

QHDM Traffic Class	ESALs (million)	2-way AADTT (M-E PDG input)
T4	10	1,594
T5	20	3,188
T6	50	7,970

3.2 Climatic Data Inputs

In order to carry out the performance analysis using the M-E PDG software, it is necessary to use the climate database available in the software. The temperature is generally very high with almost no precipitation in Qatar. The best location available in the software, which has a climatic data with temperature and precipitation similar to those of Qatar, was Needles Airport Station, California. The latitude of this station is 34.46 and the longitude is 114.37. The climatic data, mean high air temperature and precipitation values for both Qatar and Needles Airport are given in Table 2. A comparison of the yearly mean high air temperature profiles between both locations is shown in Figure 2. It can be seen form the figure that the yearly mean high air temperatures for both locations are very close to each other. Therefore, the use of the climatic data from Needles Airport Station, California to represent the condition in Qatar is deemed acceptable.

Table 2: Climatic Data for Needles Airport, CA, US and Doha, Qatar

Month	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean High Air Temp. (°C)	*Needles, CA*	16.0	17.9	23.6	28.5	35.2	40.4	43.5	41.4	37.2	29.1	19.7	14.3
	Qatar	18.2	22.8	22.8	29.1	35.4	40.0	41.7	40.0	35.4	29.1	22.8	18.2
Precipitation (mm)	*Needles, CA*	37.6	6.9	7.9	0.0	0.0	51.1	7.9	2.8	9.4	15.0	28.2	-
	Qatar	13.0	17.0	16.0	9.0	4.0	0.0	0.0	0.0	0.0	1.0	3.0	12.0

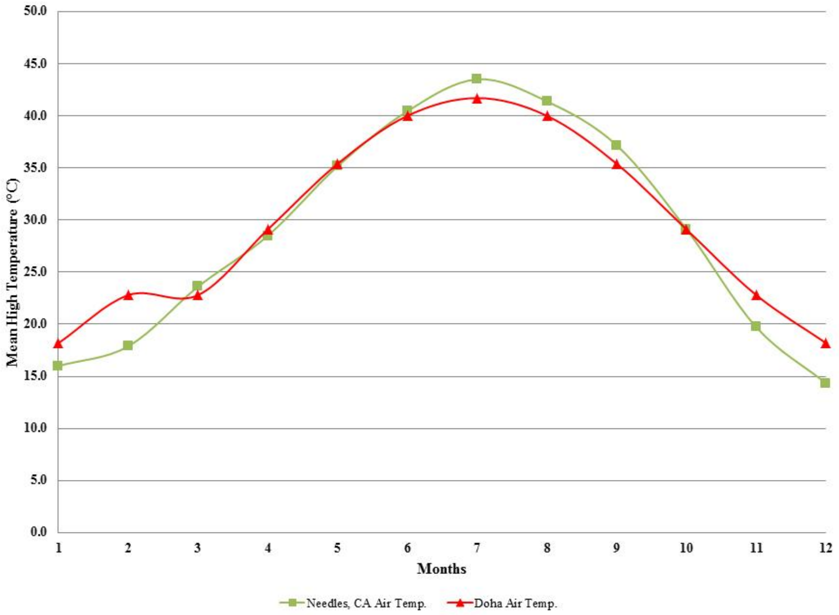

Figure 2: Yearly Mean High Air Temperatures for Qatar and Needles Airport Station in US

4. PAVEMENT LAYERS AND MATERIALS

4.1 Typical Pavement Layers

Typical pavement layers are described in the QHDM as shown in Figure 3. It can be seen from the figure that there are four different layers namely Wearing Course, Roadbase, Sub-base and Subgrade. Details for each one of these layers are described in the following sections.

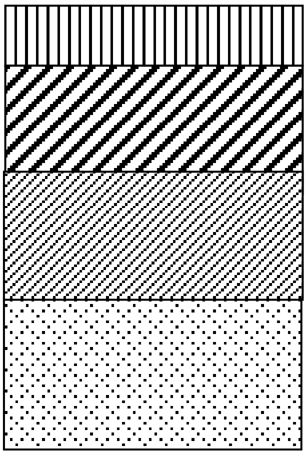

Figure 3: Typical Pavement Layers as in the QHDM.

4.2 Pavement Materials

The properties of the materials used in the various pavement layers were determined based on the guidance provided in Section 9 of the QHDM manual.

4.2.1 Subgrade

Qatar generally has high strength natural soils consisting of weathered limestone or sands. Therefore, "A-2-4" and "A-1-b" soil classifications, based on the AASHTO Soil Classification System, were used for the subgrade layer in this study [6, 7]. The present pavement design designs in QHDM include three classes of subgrade defined by CBR values as given below:

S1: $25\% > CBR \geq 15\%$
S2: $50\% > CBR \geq 25\%$
S3: $CBR \geq 50\%$

These CBR values were measured using the BS 1377 method, on soaked subgrade samples compacted to 95% of maximum dry density (MDD) which must be the same in situ. The subgrade modulus values which are required to be used for "level 3" design in the M-E PDG software are given in Table 3. The Poisson's ratio of 0.45 is used for all subgrade classes.

Table 3: Subgrade Modulus required for Subgrade Classes

Subgrade Class	AASHTO Classification	CBR value	Modulus (M-E PDG input)
S1	A-2-4	20%	120 MPa
S2	A-2-4	40%	187 MPa
S3	A-1-b	60%	242 MPa

4.2.2 Granular Sub-base

Based on the QHDM, the granular material may consist of either crushed stone or gravel with CBR value not less than 60% when compacted to 100% of MDD using the BS 1377 4.5 kg rammer method. In this study, crushed stone was selected for the Sub-base layer due to its common use in Qatar. The CBR value for the crushed stone material is 60%, which corresponds to a modulus value of 242 MPa using M_r (psi) $\approx 2555 (CBR)^{0.64}$. A Poisson's ratio of 0.35 was used for the crushed stone.

4.2.3 Asphalt Concrete Roadbase

According to the QHDM, the thickness of the asphalt concrete for the roadbase layer varies between 100 and 250 mm. This material must comply with a given grading envelope (maximum particle size 37.5 mm) and is proportioned using the Marshall design method to meet a minimum stability of 8 kN, maximum flow of 4 mm, air voids of 3 to 6% and voids filled with bitumen of 60 to 75%. This layer is analysed with the use of unmodified bitumen Pen 60-70, which is currently being used in Qatar according to the Manual, and also with the use of modified bitumen PG 76-10 which was selected based on Qatar climatic conditions.

4.2.4 Cement Bound Roadbase

The cement bound material is used as alternative roadbase in a flexible-composite pavement given in QHDM. This material consists of sand, gravel or crushed rock that are mixed with cement either in-place or in an off-road mixer. In the QHDM, the strength of this material is given as 7.5 MPa at 7 days but this is inaccurate. It is only 2 MPa at 7 days based on some previous experimental work. This is what is considered in this study to reflect the real case of Qatar and evaluate the Manual precisely. The elastic/resilient modulus value for this material is 2,400 MPa, while the Poisson's ratio is 0.2.

4.2.5 Wearing Course

A standard surfacing of asphalt concrete, laid as a 40 mm course, is used on all asphalt concrete pavement designs according to QHDM. The Manual specifies Pen 60-70, just like the roadbase layer, to be assigned for the wearing course with bitumen content typically between 4 and 5%. As mentioned earlier, the analysis and comparison was carried out for two bitumen types: Pen 60-70 and PG 76-10.

4.3 Asphalt Pavement Sections

The designs for the types of pavement designs are provided as a series of charts in the QHDM manual. In this study, the evaluation was conducted for the pavements shown in Tables 4 and 5.

Table 4: Asphalt Pavement Designs with Full Asphalt Concrete Roadbase

QHDM Traffic Class	Subgrade Class	Wearing Course Thickness, mm	Upper Roadbase Thickness, mm	Lower Roadbase Thickness, mm	Granular Subgrade Thickness, mm
T4	S1	40	95	95	200
T5	S1	40	105	105	200
T6	S1	40	125	125	200
T4	S2	40	95	95	150
T5	S2	40	105	105	150
T6	S2	40	125	125	150
T4	S3	40	95	95	100
T5	S3	40	105	105	100
T6	S3	40	125	125	100

Table 5: Asphalt Pavement Designs with Asphalt Concrete Upper Roadbase and Cement Bound Lower Roadbase

QHDM Traffic Class	Subgrade Class	Wearing Course Thickness, mm	Upper Roadbase Thickness, mm	Lower Roadbase Thickness, mm	Granular Subgrade Thickness, mm
T5	S1	40	100	270	200
T6	S1	40	150	270	200
T5	S2	40	100	270	100
T6	S2	40	150	270	100
T5	S3	40	100	270	0
T6	S3	40	150	270	0

5. M-E PDG ANALYSIS RESULTS AND DISCUSSION

All data shown in this section are all the result of the M-E PDG software. Because of the lack of measurements of the properties of materials in Qatar that can used as inputs for the M-E PDG, all input parameters were selected by the authors based on review of specifications and numerous reports. Future work will focus on calibration of mechanistic-empirical models based on actual measurements of materials in Qatar.

The nine pavement designs described in Table 4, and the six sections in Table 5 were analyzed using the M-E PDG software. Performance evaluation of pavement designs was conducted based on the longitudinal cracking, alligator cracking, total rutting depth and International Roughness Index (IRI) [5,8]. The analysis was carried out using the maximum design traffic for each section and also using twice this design traffic. The design limits for each of the pavement distresses are shown in Table 6.

Table 6: Design Limits for The Performance Criteria of Pavement Designs

Performance Criteria	Design Limit
Longitudinal Cracking	2000 ft/ml (378 m/km)
Alligator Cracking	25%
Total Rutting Depth	0.75 in (19 mm)
International Roughness Index (IRI)	172 /ml (2.717 m/km)

5.1 Asphalt Concrete Roadbase Designs' Analysis Results

Analysis results for both bitumen types for Subgrade Class 1, Class 2 and Class 3 are given in Tables 7, 8 and 9, respectively. It can be seen from these tables that the use of modified bitumen PG 76-10 improved the performance of the pavement designs design for all subgrade classes. Results for Subgrade Class 1 have shown that the amount of longitudinal cracking was decreased by 45%, 54% and 73% for traffic classes T4, T5 and T6, respectively. The average performance improvement for alligator cracking, total rutting depth and the IRI was 23%, 16% and 4%, respectively. The use of PG 76-10 instead of Pen 60-70 improved the performance of pavement designs.

Table 7: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S1

Traffic Classes	T4			T5			T6		
Performance After 20 Years	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**
Longitudinal Cracking, m/km	764.2	417.7	45%	641	292.6	54%	172	46	73%
Alligator Cracking, %	4.43	3.38	24%	5.34	4.12	23%	5.52	4.28	22%
Rutting, mm	16.2	13.8	15%	20.4	17.2	16%	23.3	19.6	16%
IRI, m/km	1.75	1.68	4%	1.86	1.78	4%	1.94	1.84	5%

Table 8: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S2

Traffic Classes	T4			T5			T6		
Performance After 20 Years	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**
Longitudinal Cracking, m/km	1115	752.7	32%	1080	664.1	39%	535.2	209.8	61%
Alligator Cracking, %	3.66	2.74	25%	4.39	3.32	24%	4.37	3.32	24%
Rutting, mm	15.2	12.9	15%	19.4	16.2	17%	22.4	18.7	17%
IRI, m/km	1.72	1.66	3%	1.83	1.75	4%	1.91	1.81	5%

Table 9: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S3

Traffic Classes	T4			T5			T6		
Performance After 20 Years	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**
Longitudinal Cracking, m/km	1168.5	849	27%	1058.8	693	35%	608.3	273.4	55%
Alligator Cracking, %	3.18	2.37	25%	3.63	2.73	25%	3.54	2.67	25%
Rutting, mm	14.7	12.4	16%	18.8	15.7	16%	21.8	18.2	17%
IRI, m/km	1.68	1.62	4%	1.79	1.71	4%	1.86	1.77	5%

The results for longitudinal cracking, alligator cracking, total rutting depth and IRI using Subgrade S1, Traffic Class T4 for both bitumen types are shown in Figures 4, 5, 6 and 7, respectively. It can be seen from Figure 4 that the pavement design using pen 60-70 bitumen has experienced high longitudinal cracking at very early ages in comparison with PG 76-10. It is also observed that the performance of PG 76-10 against alligator cracking, total rutting depth and IRI was better than that of Pen 60-70 as seen in Figures 5, 6 and 7.

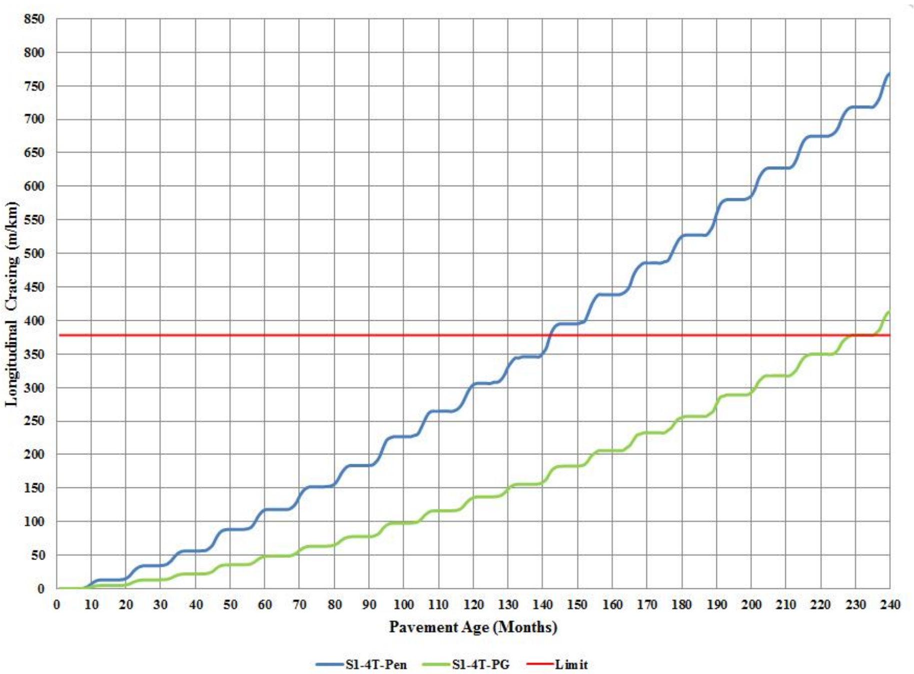

Figure 4: Longitudinal Cracking vs. Pavement age for S1-T4 (Pen 60-70) and (PG 76-10)

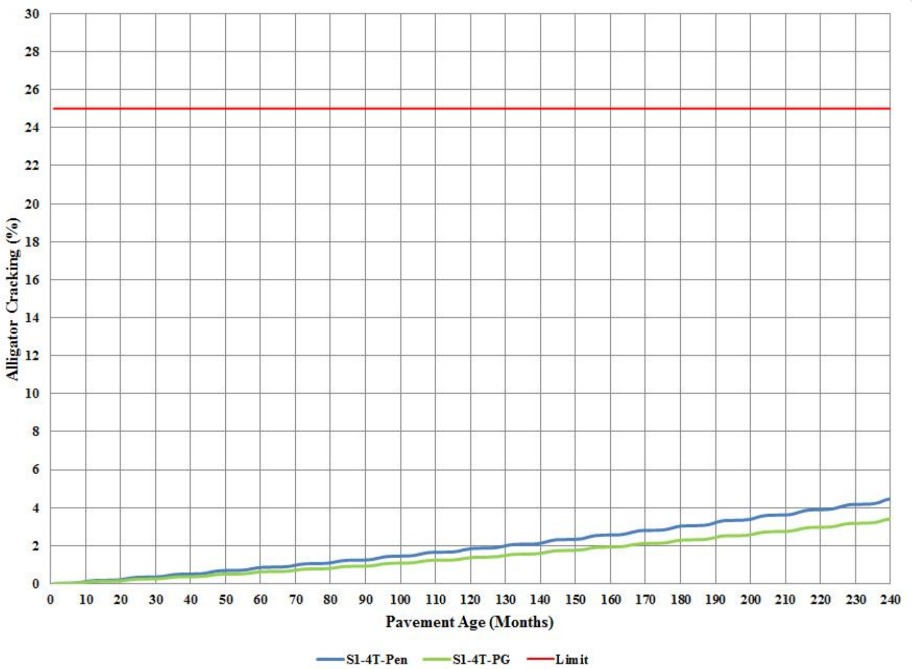

Figure 5: Alligator Cracking vs. Pavement age for S1-T4 (Pen 60-70) and (PG 76-10)

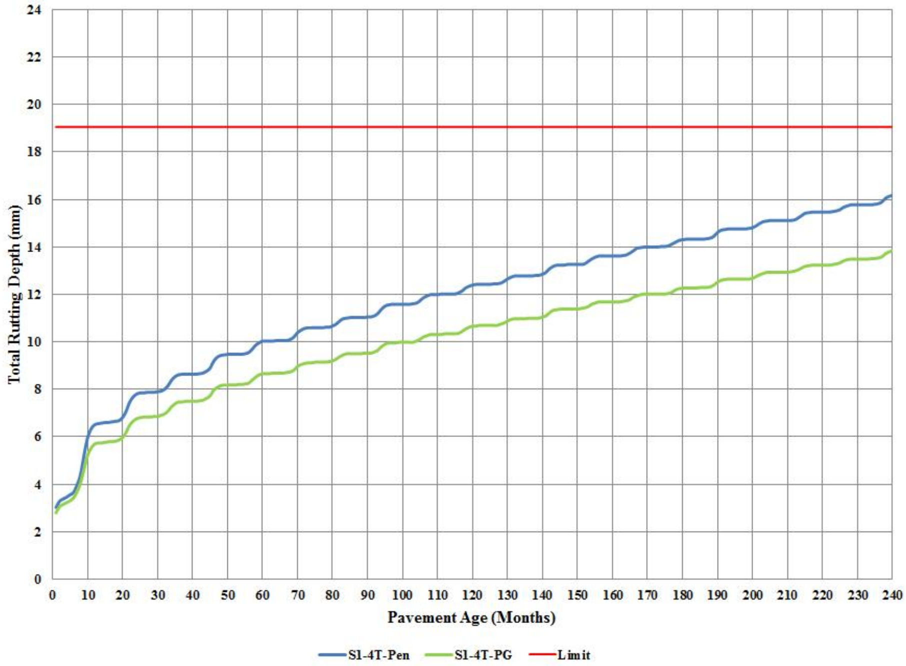

Figure 6: Total Rutting Depth vs. Pavement age for S1-T4 (Pen 60-70) and (PG 76-10)

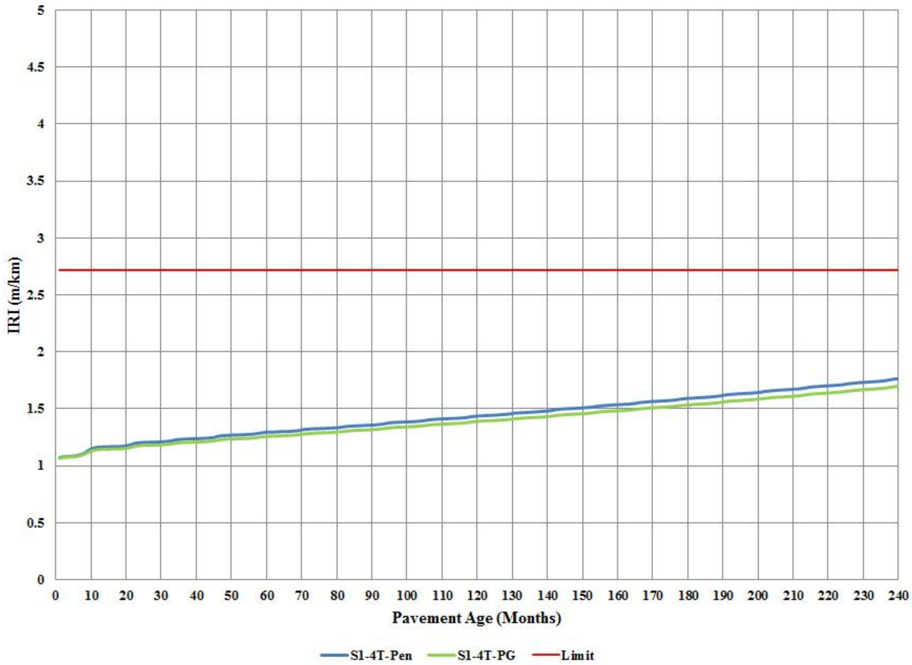

Figure 7: IRI vs. Pavement age for S1-T4 (Pen 60-70) and (PG 76-10)

The performance of pavement designs using Pen 60-70 and PG 76-10 are also investigated with traffic loads that are twice the design values. Analysis results for both bitumen types for Subgrade Class 1, Class 2 and Class 3 are given in Tables 10, 11 and 12, respectively. It can be seen from tables that the use of modified bitumen PG 76-10 improved the performance of the pavement designs design for all subgrade classes. Results for Subgrade Class 1 have shown that the amount of longitudinal cracking was decreased by 34%, 52% and 70% for traffic classes T4, T5 and T6, respectively. The average performance improvement for alligator cracking, total rutting depth and the IRI was 22%, 16% and 5%, respectively. The use of PG 76-10 instead of Pen 60-70 also improved the performance characteristics of pavement designs when subgrade classes of S2 and S3 are used in the M-E PDG software. The % improvements in the performance can be seen in Tables 11 and 12 for Subgrade Classes S2 and S3, respectively.

Table 10: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S1 after Doubling the Traffic Loading

Traffic Classes	2×T4	2×T5	2×T6

Performance After 20 Years	Pen	PG	% Improved	Pen	PG	% Improved	Pen	PG	% Improved
Longitudinal Cracking, m/km	1301	864	34%	1157	660.3	52%	425.4	126.5	70%
Alligator Cracking, %	8.87	6.85	23%	10.6	8.26	22%	10.9	8.53	22%
Rutting, mm	20.6	17.4	16%	26.3	22.0	16%	30.4	25.3	17%
IRI, m/km	1.90	1.80	5%	2.05	1.93	5%	2.16	2.01	7%

Table 11: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S2 after Doubling the Traffic Loading

Traffic Classes	2×T4			2×T5			2×T6		
Performance After 20 Years	Pen	PG	% Improved	Pen	PG	% Improved	Pen	PG	% Improved
Longitudinal Cracking, m/km	1579	1276	19%	1553	1170	25%	1030	504	51%
Alligator Cracking, %	7.39	5.59	24%	8.77	6.71	23%	8.70	6.69	23%
Rutting, mm	19.6	16.4	16%	25.3	21.0	17%	29.5	24.5	17%
IRI, m/km	1.86	1.77	5%	2.01	1.89	6%	2.12	1.98	7%

Table 12: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S3 after Doubling the Traffic Loading

Traffic Classes	2×T4			2×T5			2×T6		
Performance After 20 Years	Pen	PG	% Improved	Pen	PG	% Improved	Pen	PG	% Improved
Longitudinal Cracking, m/km	1607	1357	16%	1540	1201	22%	1118	628	44%
Alligator Cracking, %	6.45	4.85	25%	7.31	5.54	24%	7.10	5.41	24%
Rutting, mm	19.1	15.9	17%	24.8	20.5	17%	28.9	23.9	17%
IRI, m/km	1.82	1.73	5%	1.97	1.84	7%	2.06	1.93	6%

5.2 Flexible-Composite Roadbase Designs' Analysis Results

In the case of flexible-composite roadbase design, a total of six different pavement designs as shown in Table 5 were analyzed by using traffic classes of T5 and T6 and two bitumen types of Pen 60-70 and PG76-10. Performance of these designs is compared between two bitumen types using the criteria given in Table 6.

Analysis results for both bitumen types for Subgrade Class 1, Class 2 and Class 3 are given in Tables 13, 14 and 15, respectively. It can be seen from tables that the use of modified bitumen PG 76-10 improved the performance of the pavement designs for all subgrade classes. Results for Subgrade Class 1 have shown that the amount of longitudinal cracking was decreased by 83% and 92% for traffic classes T5 and T6, respectively. The average performance improvement for total rutting depth and the IRI was 17% and 6%, respectively. The use of PG 76-10 instead of Pen 60-70 also improved the performance characteristics of pavement designs when subgrade classes of S2 and S3 are used in the M-E PDG software. The % improvements in the performance can be clearly seen in Tables 14 and 15 for Subgrade S2 and S3, respectively.

Table 13: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S1

Traffic Classes	T5			T6		
Performance After 20 Years	Pen	PG	% Improved	Pen	PG	% Improved
Longitudinal Cracking, m/km	1.17	0.20	83%	51.0	4.1	92%
Alligator Cracking, %	0.0	0.0	0%	0.0	0.0	0%
Rutting, mm	23.9	19.9	17%	32.5	26.8	18%
IRI, m/km	1.91	1.81	5%	2.12	1.98	7%

Table 14: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S2

Traffic Classes	T5			T6		
Performance After 20 Years	Pen	PG	% Improved	Pen	PG	% Improved
Longitudinal Cracking, m/km	6.4	2.1	67%	129.4	15.6	88%

Alligator Cracking, %	0.0	0.0	0%	0.0	0.0	0%
Rutting, mm	23.0	19.1	17%	31.6	25.9	18%
IRI, m/km	1.88	1.79	5%	2.1	1.96	7%

Table 15: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S3

Traffic Classes	T5			T6		
Performance After 20 Years	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**
Longitudinal Cracking, m/km	18.1	6.8	62%	224.5	39.3	82%
Alligator Cracking, %	0.0	0.0	0%	0.0	0.0	0%
Rutting, mm	22.4	18.6	17%	30.9	25.3	18%
IRI, mm/km	1.85	1.75	5%	2.06	1.92	7%

The results for longitudinal cracking, total rutting depth and IRI using Subgrade Class 1, Traffic Class T6 for two bitumen types are shown in Figures 8, 9 and 10, respectively. It can be seen from Figure 8 that the pavement design using Pen 60-70 bitumen has experienced high longitudinal cracking at very early ages compared to PG 76-10. It was also observed that the performance of PG76-10 against total rutting depth and IRI was better than that of Pen 60-70 as seen in Figures 9 and 10.

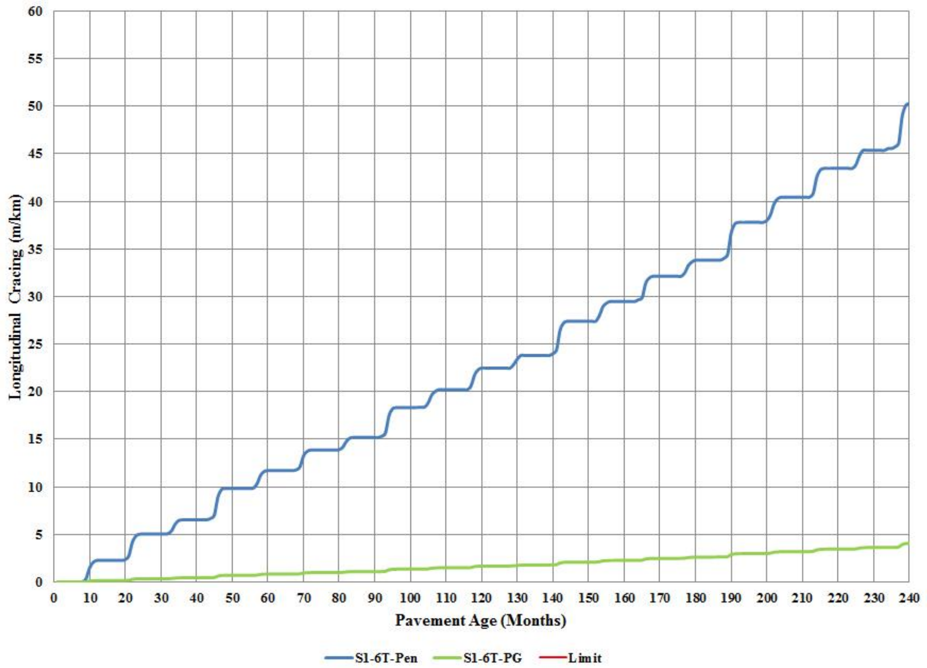

Figure 8: Longitudinal Cracking vs. Pavement age for S1-T6 (Pen 60-70) and (PG 76-10)

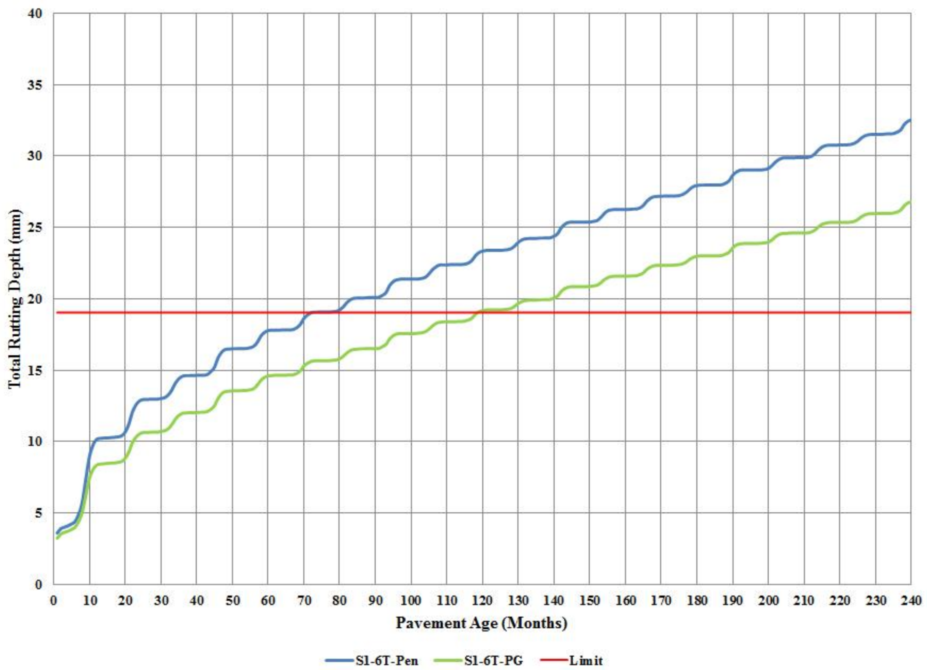

Figure 9: Total Rutting Depth vs. Pavement age for S1-T6 (Pen 60-70) and (PG 76-10)

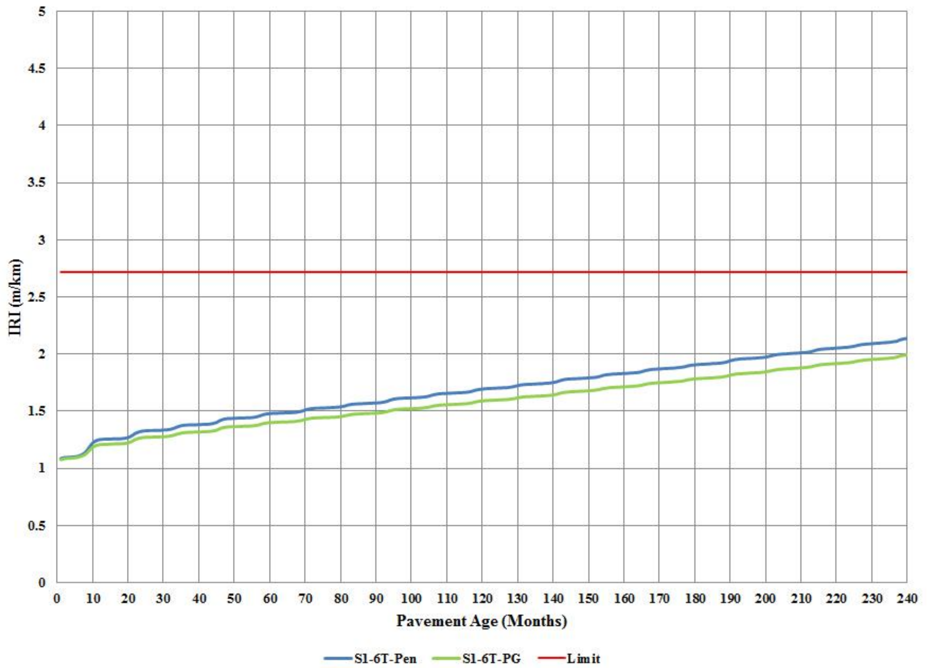

Figure 10: IRI vs. Pavement age for S1-T6 (Pen 60-70) and (PG 76-10)

The performance of Flexible-Roadbase pavement designs using Pen 60-70 and PG 76-10 are also investigated after doubling the traffic loading due to rapid increase in traffic over the past 5 years in Qatar. Analysis results for both bitumen types for Subgrade Class 1, Class 2 and Class 3 are given in Tables 16, 17 and 18, respectively. It can be seen from tables that the use of modified bitumen PG 76-10 improved the performance of the pavement designs design for all subgrade classes especially against longitudinal cracking. Results for Subgrade Class 1 have shown that the amount of longitudinal cracking was decreased by 83% and 92% for traffic classes T5 and T6, respectively. The average performance improvement for total rutting depth and the IRI was 18% and 7%, respectively. The use of PG 76-10 instead of Pen 60-70 also improved the performance characteristics of pavement designs when subgrade classes of S2 and S3 are used in the M-E PDG software. The percent improvements in the performance can be seen in Tables 17 and 18 for Subgrade Classes S2 and S3, respectively.

Table 16: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S1 after Doubling the Traffic Loading

Traffic Classes	2×T5			2×T6		
Performance After 20 Years	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**
Longitudinal Cracking, m/km	3.37	0.56	83%	140	11.8	92%
Alligator Cracking, %	0.0	0.0	0%	0.0	0.0	0%
Rutting, mm	31.8	26.2	18%	43.8	35.8	18%
IRI, m/km	2.11	1.97	7%	2.40	2.20	8%

Table 17: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S2 after Doubling the Traffic Loading

Traffic Classes	2×T5			2×T6		
Performance After 20 Years	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**
Longitudinal Cracking, m/km	18.3	5.9	68%	331	44.1	87%
Alligator Cracking, %	0.0	0.0	0%	0.0	0.0	0%
Rutting, mm	30.8	25.4	18%	42.7	34.8	19%
IRI, m/km	2.08	1.95	6%	2.38	2.18	8%

Table 18: Analysis Results of Using Pen 60-70 and PG 76-10 for Subgrade S3 after Doubling the Traffic Loading

Traffic Classes	2×T5			2×T6		
Performance After 20 Years	**Pen**	**PG**	**% Improved**	**Pen**	**PG**	**% Improved**
Longitudinal Cracking, m/km	51.0	19.4	62%	571.7	108.6	81%
Alligator Cracking, %	0.0	0.0	0%	0.0	0.0	0%
Rutting, mm	30.1	24.7	18%	42.0	34.1	19%
IRI, m/km	2.04	1.91	6%	2.34	2.14	9%

6. CONCLUSIONS

This study has focused on the evaluation and analysis of current asphalt pavement designs used for major highways in the State of Qatar. The analysis was carried out using the M-E PDG software. The analysis considered the use of both unmodified bitumen Pen 60-70 and the modified bitumen PG 76-10. The analysis also investigated the influence of the increase in traffic loading on performance.

According to the results, the analysis evidences how effective is to replace the unmodified bitumen Pen 60-70 with the modified bitumen PG 76-10 for the highway pavement designs in Qatar. The performance of the pavement designs is improved for Subgrade Classes S1, S2 and S3 especially for the longitudinal cracking. The pavement life increased for all designs because of the use of PG 76-10 bitumen. The results showed that the pavement design can withstand significant increase in the traffic loading higher that the design traffic when PG 76-10 is used. This paper presented preliminary evaluation of the M-E PDG and comparative analysis of the influence of traffic and different materials. Future work will focus on the calibration of M-E design for the State of Qatar based on actual measurements of materials properties and monitoring of pavement performance.

ACKNOWLEDGEMENTS

This publication was made possible by a grant from the Qatar National Research Fund under its National Priorities Research Program award number NPRP 08-310-2-110. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the Qatar National Research Fund

REFERENCES

[1] Transportation Master Plan, Urban Planning Authority, Qatar.
[2] Qatar Highway Design Manual, Qatar 1997.
[3] Development of Korean Pavement Design Guide for Asphalt Pavements Based on the Mechanistic-Empirical Design Principle, Anh, T.L., Hyun, J.L., Hee, M.P. and Tae, W.K. 2011.
[4] Design of Rigid Pavements in Iowa using the Mechanistic-Empirical Pavement Design Guide, Ceylan, H., Coree, B. and Gopalakrishnan, K. 2008.
[5] Permanent deformation analysis of asphalt mixtures using soft computing techniques, M. R. Mirzahosseini, A. Aghaeifar, A. H. Alavi, A. H. Gandomi and R. Seyednour, 2010.
[6] Mechanistic-empirical mixture design for hot mix asphalt pavement recycling, I. Widyatmoko, 2008.
[7] Pavement Design and Materials, A. T. Papagiannakis and E. A. Masad, 2008.
[8] Development of mechanistic–empirical design method for an asphalt pavement rutting model using APT, Y. Suh, N. Cho and S. Munb, Nov. 2010.