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TEMPERATURE ZONING OF IRAQ FOR ASPHALT MIX DESIGN

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Abstract: currently asphalt grading in Iraq depend on two types; penetration grade and viscosity grade. These grades did not give impression on asphalt pavement performance because it is depend on fixed temperature test. In this paper Iraq map was developed by using superpave method to find performance grade. High and low pavement temperature was calculated. Contour maps for high and low pavement temperature developed by using geographic information system (GIS). A map presented the temperature zones in Iraq in terms of asphalt performance grade. The data of temperature was taken from 48 weather stations distributed to all region of Iraq. It has been found PG70-10 and PG76-10 covering more than 70% of the parts of Iraq.

Keywords*: Temperature Zone, Superpave, Performance Grade.*

درجه حراره المناطق في العراق لتصميم الخلطات الاسفلتيه

الخلاصة: المواصفات الحاليه للاسفلت بالعراق مبنيه على تدرج الاختراق. فحص الاختراق يؤدى بدرجه حراره 25 ^{0}س. ويعتبر فحص تجريبي للقوام ويستخدم تجريبيا كمؤشر لمعرفه حساسيه الاسفلت للتخدد والكلل للاسفلت السمنتي وليس له علاقه باداء التبليط. تم وضع منهاج في إطار برنامج بحوث (SHRP)سمي ب(SUPERPAVE) وهو النهج القائم على الأداء. ولتطبيق اول خطوه بمنهاج ال(SUPERPAVE) يجب تحديد درجه حراره التبليط العليا والصغرى. درجات الحراره هذه تحدد متطلبات الاداء للاسفلت السمنتي (PG). في هذا البحث تم تطوير خارطه تحت مستويات الثقه المحدده باستخدام برنامج (GIS) توضح المناطق المختلفه بالعراق وبدلاله حراره التبليط ومتطلبات الاداء للاسفلت السمنتي. وجرى تقسيم مناطق الحرارة في العراق من خلال استخدام بيانات درجات الحرارة التي تم الحصول عليها من 48 محطة من الهيئه العامه للانواء الجويه والرصد الزلزالي. تم استخدام موديلات SHRP للتنبؤ بدرجات حاراه التبليط على مستوى 98 ٪ من الموثوقية .وجد انه تصنيف اداء PG70-10وPG76-10 اكثر شيوعا ويضم 70% من مناطق العراق.

1. Introduction

SHRP aims of asphalt research viewing why asphalt pavement perform good, while others not well. Tests and materials specification that will excellence and perpetrate the asphalt pavement constructed today were developed and to work with industry and agency highway to give the new specifications put to use [1,2]. The SHRP asphalt research program give Superpave system "Superior Performing Asphalt". In Sudia Arabia asphalt cement stabile for only 40% of road[3]. SHRP had proven useful in most causes. A temperature map was developed for Jordan with three asphalt zones consist of PG64-10, PG64-16 and PG70-10 [4]. In Oman result in four high temperature grades PG52, 58, 64 and 70. While low pavement grades restricted to PG-10 and PG-16 [5].

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2. Binder Specifications

The asphalt testing development goes back to 1988 when invented the Bowen Penetration Machine [6]. By many modifications of penetration equipment, the penetration equipment became establishing for the standard of the asphalt consistency at 25 ^{0}C. In 1918 Public Road (USA) presented penetrated grading system then" American Association of State Highway and Transportation Officials" (AASHTO) published the specification on asphalt grade penetration. The next change came with the introduce of viscosity grading system in 1960. Both ASTM and AASHTO depend on this system and presented viscosity specification at 60^{0}C.The test of penetration is empirical. It fails to account the binder consistency.

The binder testing the performance at 25 ^{0}C only, which is near to the average pavement temperature, and not be applicable to the asphalt performance of the lower or higher temperatures.The "American Association of State and Highway Transportation Officials" (AASHTO), "American Society for Testing and Materials" (ASTM), and "Federal Highway Administration" (FHWA) sought to change the penetration grading system with viscosity tests. This system recommended measure the consistency at temperatures approximating the maximum pavement temperature. It is also referred to as AC viscosity grading system, which viscosity based on consistently at 60 ^{0}C. Asphalt viscosity and ductility are applies on thin-film oven aged asphalt samples The system AR aged residue from the rolling thin film oven, RTFO. Like the AC the low temperature performance of asphalt. In addition, the system not evaluated modified asphalt or considered of asphalt long-term aging [7]. ASTM present five binder grades based on penetration at 25 ^{0}C. softer binder is greater penetration .

Table 1 shows the standard penetration and viscosity grades [8]. Penetration and viscosity specifications can classify same grading with different asphalt types, but in reality these asphalts have a different performance and temperature. From October 1987 to March 1993, the Strategic Highway Research Program (SHRP) developed performance tests and specifications asphalt binders and hot asphalt mixtures. Which sign "Superior Performing Asphalt Pavements". The system of Superpave present an improved of asphalt mix design and analysis. Asphalt tests and specifications for Performance Graded (PG) were also developed by SHRP research. The new specification of asphalt binder were developed to eliminate the shortcomings of the previous asphalt grading system [9].

Table 1 Asphalt Cements Viscosity Graded [8]

Test	*Viscosity Grade*					
	AC-2.5	AC-5	AC-10	AC-20	AC-30	AC-40
Viscosity, 140^o F(60^o C), Pa.s	25$^{\pm}$50	50$^{\pm}$100	100$^{\pm}$200	200$^{\pm}$400	300$^{\pm}$6	400$^{\pm}$80
Viscosity, 275 ^{o}F(135 ^{o}C), min,cSt(mm^2/s)	80	110	150	210	250	300
Penetration,77 ^{o}F (25^{o}C),100g, 5s, min	200	120	70	40	30	20
Flash Point Cleveland open cp, min, ^{o}C, (^{o}F)	165(325)	175(350)	220(425)	230(450)	230(450)	230(450)
Solubility in Trichloroethylene, in%	99.0	99.0	99.0	99.0	99.0	99.0
Test on Residue from Thin Film Oven Test						
Viscosity, 140o F(60o C), Pa.s	125	250	500	1000	1500	2000
Ductility, 77 ^{o}F (25^{o}C), 5cm/min,cm	100	100	50	20	15	10

3. Temperature Grade

The selected performance grade of asphalt depend on climate of region that pavement will serve. The customize various asphalt grades is the specified high and low pavement temperatures to meet the requirements. Asphalt binder with PG70-10 means that asphalt will meet the required properties up to maximum pavement temperature of 70^0C and the low temperature down to -10 ^{0}C. Maximum and minimum temperature increments with six degree as presented in Table2. Superpave set the maximum and minimum temperature by seven day average maximum air and one day minimum air. For all the years, mean and standard deviation of the average seven day high air temperature have been calculated. One day low air temperature is the lowest temperature of air for the year recorded and means and standard deviation for all years calculated.

Table 2 Superpave Performance Grade Specifications[1]

	High Temperature Grade	*Low Temperature Grade*
PG	46	-34, -40, -46
PG	52	-10, -16, -22, -28, -34, -40, -46
PG	58	-16, -22, -28, -34, -40
PG	64	-10, -16, -22, -28, -34, -40
PG	70	-10, -16, -22, -28, -34, -40
PG	76	-10,-16,-22,-28,-34
PG	82	-10,-16,-22,-28,-34

4. Data Base of Air Temperature

In order to develop contour maps for performance grade of Iraq maximum and minimum temperature for pavement must be defined. Data of air temperature for 48 weather station that distributed for all region of Iraq are arrangement. These data were collected from the Iraqi Meteorological Organization. Each station has a global code registered in World Metrological Organization (WMO).The stations of weather used for the zones of pavement temperature summarize in Table 3. The table resents the weather station, its code, latitude, longitude, elevation, and number of years for the data. For each year seven day hottest air temperatures are specified and the average air for high and low air temperature based on the data collected for all years. Table 4 presents the average and standard deviation for the collected data and gives the maximum and minimum air temperature at 50% and 98% level of reliability. In the equation 1 and 2 below, used to present of asphalt binder maximum temperature at 98% reliability level.

$$T_{Max\ at\ 98\%} = T_{Max\ at\ 50\%} + 2.055 \times \sigma_{high\ Temp} \quad \ldots..(1)$$

$$T_{Min\ at\ 98\%} = T_{Min\ at\ 50\%} - 2.055 \times \sigma_{low\ Temp} \quad \ldots..(2)$$

Where:

$T_{Max\ at\ 98\%}$ = Maximum air temperature for 98% reliability level.

$T_{Max\ at\ 50\%}$ = Maximum air temperature for 50% reliability level.

$\sigma_{high\ Temp}$ = standard deviation of high air temperature.

$T_{Min\ at\ 98\%}$ = Minimum air temperature for 98% reliability level.

$T_{Min\ at\ 50\%}$ = Minimum air temperature for 50% reliability level.

$\sigma_{low\ Temp}$ = standard deviation of air low temperature.

Table 3 Summary of Weather Stations

No.	*Station code*	*Station Name*	*Latitude (degrees)*	*Longitude (degrees)*	*Elevation (m)*	*Data Availability (years)*
1	602	Rabia	36.8	42.1	382	1993-2012
2	603	Tallafar	36.22	42.92	0	1981-2012
3	604	Sinjar	36.37	41.83	476	1962-2012
4	605	Zakho	37.13	42.68	0	1977-1990
5	608	Mousl	36.32	43.15	223	1937-2012
6	609	tall abta	35.55	42.43	0	1993-2012
7	610	Al baiji	36.02	41.44	0	1992-2012
8	611	Salahadeen	36.38	44.2	1088	1967-1990
9	616	Irbil	36.09	44	0	1982-1991
10	619	Makhmoor	35.45	43.36	0	1989-2012
11	621	Kirkuk	35.47	44.4	0	1939-2012
12	623	Sulaimaniya	35.55	45.43	853	1971-1991
13	627	qaim	34.23	41.01	0	1989-2012
14	629	Ana	34.37	41.95	0	1968-2012
15	631	Buji	34.93	43.48	150	1979-2012
16	632	al tuz	34.53	44.39	0	1992-2012
17	633	tikrit	34.34	43.42	0	1989-2012
18	634	Haditha	34.07	42.37	140	1971-2012
19	635	Samraa	34.18	43.83	0	1981-2011
20	637	Khanaqin	34.3	45.3	202	1937-2012
21	638	Al khalis	33.5	44.32	0	1991-2012
22	640	Kelo-160	33.13	41.47	0	1979-2012
23	642	Rutba	33.03	40.28	615	1939-2012
24	643	Aukashat	33.48	40.08	0	1993-2012
25	644	H1	33.78	41.63	409	1979-1989
26	645	Al Ramadi	33.27	43.19	0	1981-2012
27	646	Hit	33.38	43.45	0	1995-2012
28	650	Baghdad	33.23	44.23	34	1937-2012
29	655	An altamor	32.33	44.43	0	1991-2006
30	656	Kerbala	32.59	44.03	29	1992-2012
31	657	Hillah	32.27	44.27	0	1979-2012
32	658	Nukiaib	32.03	42.25	305	1963-2011
33	660	Al Aziziyah	32.55	45.04	0	1994-2012
34	662	Badrah	33.06	45.57	0	1994-2012
35	664	Al Kut	32.3	45.49	0	1989-2012
36	665	AlHai	31.17	46.05	15	1940-2012
37	666	Ali algharbi	32.33	46.43	0	1994-2012
38	670	Najaf	31.98	44.32	32	1963-2012
39	672	Dawaniya	31.98	44.98	20	1939-2012
40	674	Samawa	31.32	45.27	6	1937-2012
41	675	al Rifai	31.43	46.06	0	2010-2012
42	676	Nasiriya	31.08	46.23	3	1940-2012
43	680	Amara	31.85	47.17	9	1971-2012
44	684	Alsalman	30.5	44.53	202	1977-2002
45	686	Bussaia	30.1	46.12	144	1976-1989
46	689	Basrah/ Hay alhssain	30.34	47.47	0	1937-2012
47	690	Basrah	30.57	47.78	0	1989-2012
48	691	Faw	29.59	48.3	0	1979-2012

Table 4 Maximum and Minimum Air Temperatures

No.	*Station Name*	*Max. air temperature, ˚C (50%) reliability*		*Min.. air temperature, ˚C (50%) reliability*		*Max. air temperature, ˚C (98%) reliability*	*Min.. air temperature, ˚C (98%) reliability*
		Mean	slandered deviation	Mean	slandered deviation		
1	Rabia	44.9	1.506	-6.4	2.72	48	-12
2	tallafar	44.9	1.523	-2.1	2.121	48	-6
3	Sinjar	42.9	1.518	-2.1	2.316	46	-7
4	Zakho	44.2	0.859	-2.3	2.341	46	-3
5	Mousl	46.1	1.213	-3.7	1.847	49	-7
6	tall abta	46.8	0.871	-3.6	2.293	49	-8
7	Al baiji	45.6	1.328	-3.8	1.921	48	-8
8	Salahadeen	39	0.719	-5.3	2.494	40	-10
9	Irbil	44.1	0.466	-3	2.297	45	-8
10	Makhmoor	47.2	1.326	-2.5	2.466	50	-8
11	Kirkuk	46.1	1.269	-2	2.384	49	-7
12	Sulaimaniya	42.7	0.928	-5.8	3.259	45	-12
13	qaim	44.3	1.589	-4.1	1.969	48	-8
14	Ana	45.3	1.587	-4.2	2.141	49	-10
15	Buji	47	1.135	-2.3	1.583	49	-6
16	al tuz	46.5	1.647	-2.4	2.023	50	-7
17	tikrit	47.1	1.088	-2.4	2.087	49	-7
18	Haditha	46.1	1.546	-3.6	1.917	49	-8
19	Samraa	46.9	2.061	-0.7	1.517	51	-4
20	Khanaqin	47.1	1.821	-2	2.722	51	-8
21	Al khalis	46.2	1.732	-3.6	2.053	50	-8
22	Kelo-160	44.6	1.594	-3.7	3.09	48	-10
23	Rutba	42.4	1.507	-4.8	3.064	46	-11
24	Aukashat	42.4	0.859	-4.6	2.16	44	-9
25	H1	44.6	1.539	-5.4	2.1	48	-10
26	Al Ramadi	45.4	1.876	-1.2	1.839	49	-5
27	Hit	47.3	1.596	-3.2	1.997	51	-7
28	Baghdad	46.9	1.35	-3.2	1.838	50	-7
29	An altamor	46.5	1.719	-1.8	2.584	50	-7
30	Kerbala	47.2	1.779	-0.7	1.89	51	-5
31	Hillah	46.8	1.27	-0.6	1.923	49	-5
32	Nukiaib	46.2	1.532	-2.9	2.798	49	-9
33	Al Aziziyah	48	1.537	-0.5	2.13	51	-5
34	Badrah	48.8	1.28	-2.2	1.861	51	-6
35	Al Kut	48.4	1.202	0.1	1.818	51	-4
36	AlHai	47.4	1.784	-0.5	2.271	51	-5
37	Ali algharbi	49.1	1.141	-0.3	1.688	51	-4
38	Najaf	47.7	1.267	-1.1	1.985	50	-5
39	Dawaniya	46.7	1.707	-1.8	2.806	50	-8
40	Samawa	47.8	1.467	-0.6	1.683	51	-4
41	al Rifai	49.4	0.157	0.5	2	50	-4
42	Nasiriya	47.5	1.709	-0.9	2.083	51	-5
43	Amara	48.5	1.139	-0.1	1.652	51	-3
44	Alsalman	47.7	1.955	-0.8	1.757	52	-4
45	Bussaia	47.9	1.65	-1.7	1.895	51	-6
46	Basrah/ Hay alhssain	46.7	2.624	0.4	1.557	52	-3
47	Basrah	49.7	1.226	0.2	5.151	52	-10
48	Faw	48.3	1.556	1	1.694	51	-2

The high temperature of SHRP designed at a depth 20mm below the surface of pavement as shown in the equation below [1].

$$T_{pave,h} = 0.9545 [T_{air} - 0.00618\ lat^2 + 0.2289\ lat + 42.2] - 17.78 \quad \ldots\ldots (3)$$

Where-:

Tpav,h = High Asphalt Cement pavement temperature at 20 mm in °C.

Tair = average seven day high air temperature, °C.

Lat = section geographic latitude in degrees.

The low temperature of pavement design simply can be assumed to be the same as the low air temperature. This method recommended by SHRP researchers. Table 5 summarizes the maximum and minimum pavement temperature with performance grade for the station regions under consideration in Iraq.

Table 5 Maximum and Minimum Pavement Temperatures with PG Grading

No.	*Station Name*	*Maximum Pavement Temperature ^0C*	*Minimum Pavement Temperature ^0C*	*Performance Grade (PG)*
1	Rabia	69	-12	PG70-16
2	tallafar	66	-6	PG70-10
3	Sinjar	67	-7	PG70-10
4	Zakho	64	-3	PG64-4
5	Mousl	70	-7	PG70-10
6	tall abta	70	-8	PG70-10
7	Al baiji	69	-8	PG70-10
8	Salahadeen	61	-10	PG64-10
9	Irbil	66	-8	PG70-10
10	Makhmoor	71	-8	PG76-10
11	Kirkuk	70	-7	PG70-10
12	Sulaimaniya	66	-12	PG70-16
13	qaim	69	-8	PG70-10
14	Ana	70	-10	PG70-10
15	Buji	70	-6	PG70-10
16	al tuz	71	-7	PG76-10
17	tikrit	70	-7	PG70-10
18	Haditha	56	-8	PG58-10
19	Samraa	56	-4	PG58-4
20	Khanaqin	72	-8	PG76-10
21	Al khalis	71	-8	PG76-10
22	Kelo-160	69	-10	PG70-10
23	Rutba	67	-11	PG70-16
24	Aukashat	66	-9	PG70-10
25	H1	69	-10	PG70-10
26	Al Ramadi	70	-5	PG70-10
27	Hit	72	-7	PG76-10
28	Baghdad	71	-7	PG76-10
29	An altamor	68	-7	PG70-10
30	Kerbala	72	-5	PG76-10
31	Hillah	71	-5	PG76-10
32	Nukiaib	75	-9	PG76-10
33	Al Aziziyah	72	-5	PG76-10
34	Badrah	73	-6	PG76-10
35	Al Kut	72	-4	PG76-4
36	AlHai	73	-5	PG76-10
37	Ali algharbi	72	-4	PG76-4
38	Najaf	72	-5	PG76-10

No.	Station Name	Maximum Pavement Temperature ^{0}C	Minimum Pavement Temperature 0C	Performance Grade (PG)
39	Dawaniya	72	-8	PG76-10
40	Samawa	73	-4	PG76-4
41	al Rifai	72	-4	PG76-4
42	Nasiriya	73	-5	PG76-10
43	Amara	73	-3	PG76-4
44	Alsalman	74	-4	PG76-4
45	Bussaia	73	-6	PG76-10
46	Basrah/ Hay alhssain	74	-3	PG76-4
47	Basrah	74	-10	PG76-10
48	Faw	73	-2	PG76-4

Table 6 present the comparison of minimum and maximum temperature of pavement for 98% reliability of 48% region in Iraq. It was shown that the northern part of Iraq much cooler than the southern part. -12^{0}C for the lowest temperature and 56^{0}C for the highest air temperature. Range of maximum pavement may be from –2^{0}C to 75^{0}C at 98% level of reliability.

Table 6: High and low Pavement Temperatures Comparison

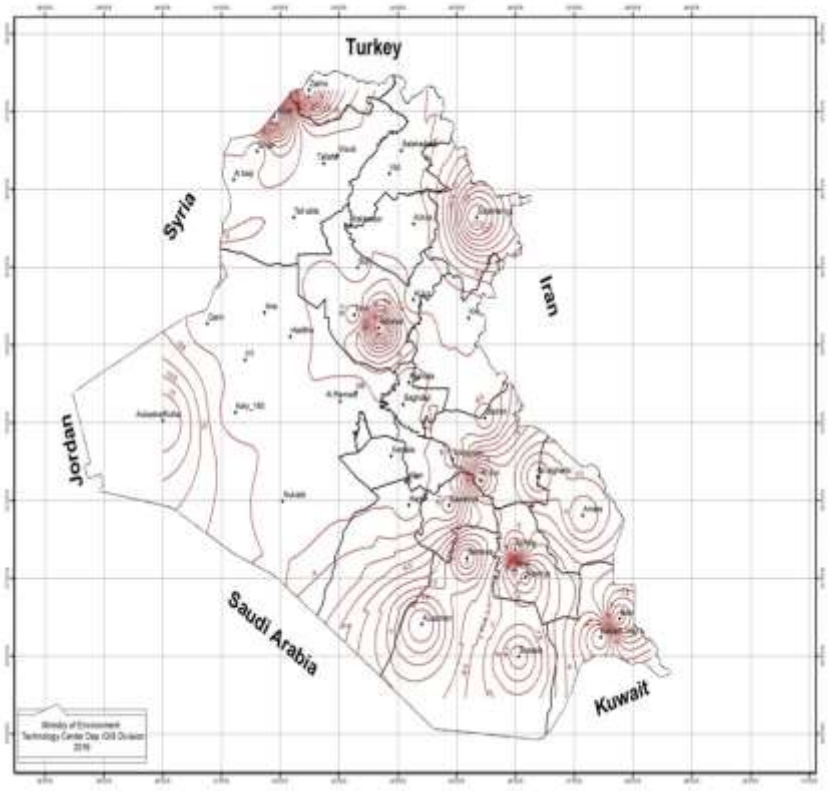
Statistical Parameter	*High Pavement Temperature*	*Low Pavement Temperature*
Minimum Temp. deg. C	56	-12
Maximum Temp. deg. C	75	-2
Average, deg. C	69.8	-6.8
Standard Deviation, deg. C	4.1	2.5

5. PG System and Temperature Zoning

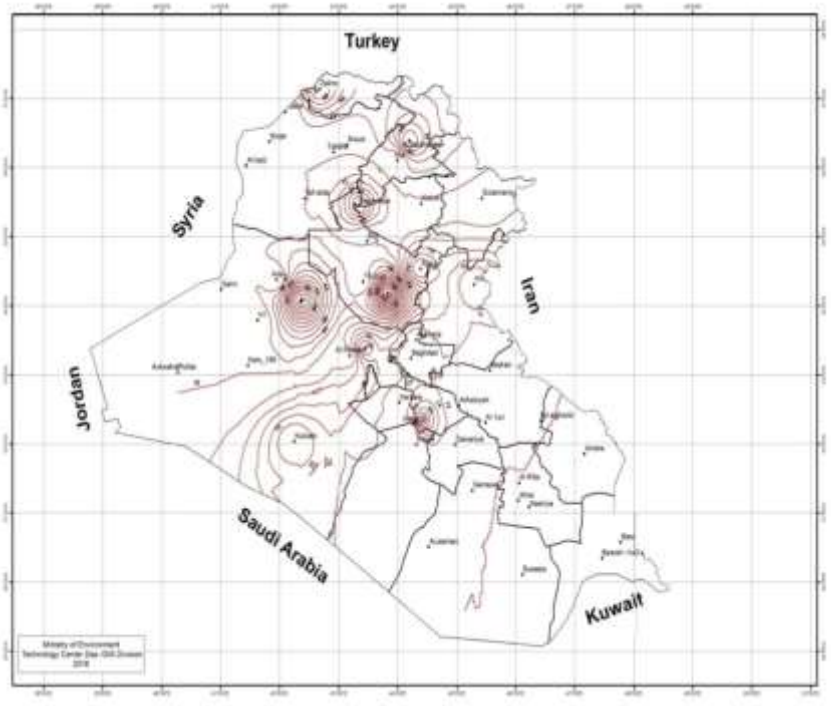
For all 48 weather station maximum and minimum air temperature converted to pavement temperature by using Superpave model and performance grade calculated as presented in Table5. This model estimate that the pavement subjected fast and transient loads. So to accommodate these situations SHRP requires that increase the grade for high pavement temperature by one or two grades for slower loading speed and standing load [10].

At specific confidence levels Maps inherently are developed. Geographic Information system (GIS) can supply maps which were generated using the computer program. According to PG binder grade by county these maps are color coded. Each color represents a different PG binder.

Contours for an entire dataset created From the ArcGIS Spatial Analyst toolbar. The base contour is the begin amount of generating contours. Painted contours below and above this amount as needed to cover all value range of the grid.Figure1 and 2 presents contour maps for the low and high pavement temperature for Iraq respectively. Depending on these figures Figure 3 zoning the Iraq into different performance grades.



Figurer 1 Minimum Pavement Temperature Contour for Iraq



Figurer 2 Maximum Pavement Temperature Contour for Iraq

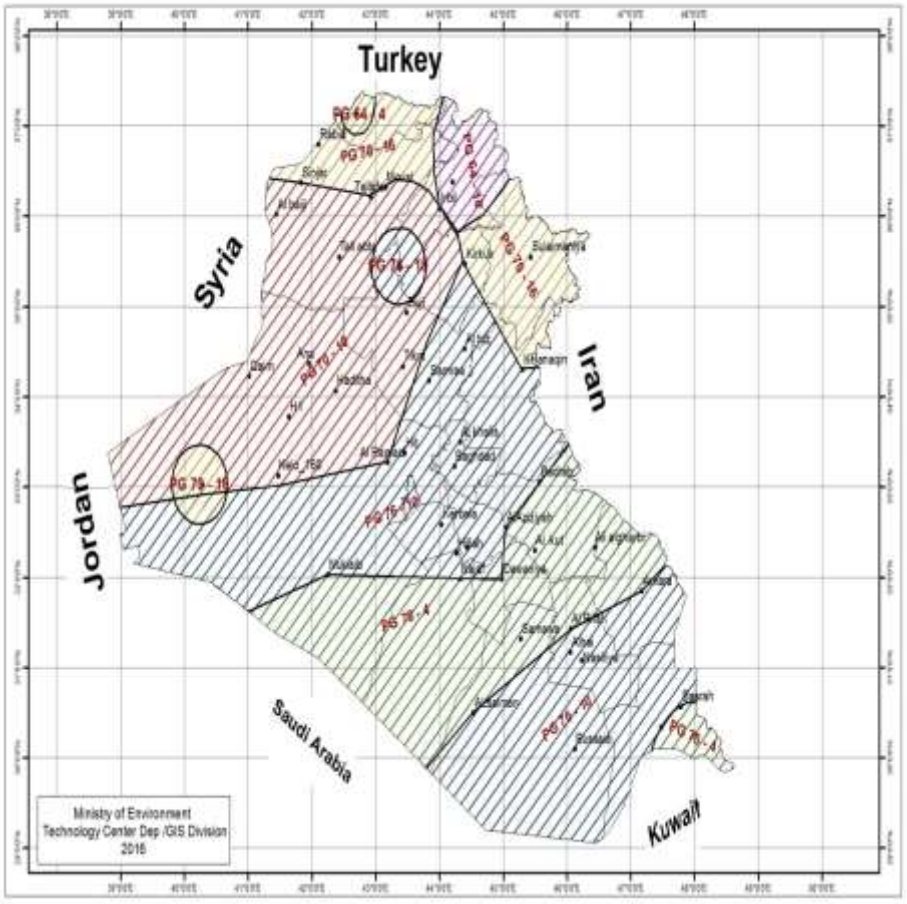


Figure 3 Temperatures Zoning for Asphalt Binder Specification for Iraq

6. Conclusions

1- At specific confidence levels Maps inherently are predicted. Geographic Information system (GIS) supply maps which were generated using the computer program. According to PG binder grade by county these maps are color coded. Each color represents a different PG binder.

2- Iraqi zoning map for temperature was developed. It consisted of eight grade zones, PG70-10, PG70-16, PG64-4, PG64-10, PG76-10, PG58-10, PG58-4, and PG76-4.

3- PG 76-10 covers more than 37 percent of the area, PG70-10 covers 33 percent of the area and other performance grade cover the other area in Iraq.

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