ADAPTATION OF SHRP PERFORMANCE BASED BINDER SPECIFICATIONS TO THE GULF COUNTRIES

H.I. Al-Abdul Wahhab, M.F. Ali, I.M. Asi and I.A. Al-Dubabe
King Fahd University of Petroleum and Minerals
Dhahran, Saudi Arabia

ABSTRACT. The rheological behavior of asphalt cement has a great influence on the behavior of the asphalt mixture. The asphalt binder plays a significant role in pavement ability to withstand thermal and fatigue cracking and contributes to permanent deformation behavior. The current binder specifications, as applied in the Gulf countries, are based primarily on penetration or viscosity testing which does not properly account for pavement performance. This research was undertaken to provide a rational scientific binder specification for the Gulf countries based on SHRP findings, considering the prevailing environmental and traffic conditions and type of locally produced asphalt. Results indicated that locally produced asphalt can be used in a limited area of the Gulf countries while bulk of the region requires modification of the asphalt binder prior to its use.

1. INTRODUCTION

The asphaltic constituents of petroleum are usually dark brown to black, sticky, and semi-solid to solid. They are obtained by various refining processes such as the residuum from vacuum distillation, or as the material precipitated by liquid propane-liquid butane mixtures during the deasphalting stage of petroleum refining. While most asphalts consist of straight distillation residue, some asphalts are made by other means. The behavior and properties of asphalts are dependent on their constitution (physical make-up). Most petroleum scientists support the model in which asphalt's physical properties are best described by the effectiveness with which the polar associating materials are dispersed by the solvent rather than by global chemical parameters such as elemental composition.

The rheological behavior of asphalt cement has a great influence on the behavior of asphalt mixture. The asphalt binder plays a significant role in pavement ability to withstand thermal and fatigue cracking, and contributes to permanent deformation behavior. The current binder specifications, as applied in the Arabian Gulf countries, are based primarily on the consistency of asphalt cements as measured by penetration or viscosity tests. Unfortunately, these measures do not relate well to pavement behavior and performance [1]. Fatani et al. [2] in a study about permanent deformation in the Kingdom have concluded that the asphalt cement is responsible for a major part of the Kingdom's rutting, and that the current asphalt cement specifications has failed to produce mixtures that can sustain the harsh environment of the region.

Studies on both the physical and chemical aspects of asphalt binder have recently been receiving greater attention, one of the major researches is the Strategic Highway Research

Program (SHRP). The principal goal of the SHRP asphalt research program was to develop performance-based specifications for asphalt binders and asphalt-aggregate mixtures. The binder specifications will allow the engineer to select an asphalt binder on the basis of the performance level required of the pavement under the present and predicted traffic and environmental conditions. The SHRP asphalt program and its experiment designs have further established that pavement performance is definitely affected by the physiochemical properties of the asphalt binder. However, these requirements must be based on the climatic regime prevailing at the specific location where the asphalt binder will be used.

In an effort to establish a sound binder specification which is based on prevalent environmental conditions in the Gulf countries, traffic loading and native asphalts, King Abdulaziz City for Science and Technology has funded a project entitled "Adaptation of SHRP Performance Based Asphalt Specifications to the Gulf Countries" for a period of 30 months. The project is undertaken with the following broad objectives:

1. Determine suitable temperature zoning for the Gulf countries (GC).

2. Study the chemical and physical characterization of Arab asphalts (GC-asphalts).

3. Evaluate the suitability of presently used regional asphalts on the basis of the SHRP performance-based specifications.

4. Study ways to improve asphalts to meet the proposed specifications.

This paper describes the findings of the study as related to results of the physical and performance based testing of Arab asphalts, temperature zoning and the suitability of currently used asphalt binder for the Gulf region.

2. PROJECT DESIGN

In order to achieve the stated objectives, the work is being carried out in six tasks and extends for 30 months. A schematic flow chart for the project design is shown in Fig. 1. Details of some of the planned tasks is as follows:

1. Temperature data collection and temperature zoning: Metrology and Environmental Protection Agencies, Directorate of Climatology and other similar agencies in the Gulf countries were approached to provide the research team with the available historical annual environmental data covering the Gulf countries (GC). These data were analysed and used to build temperature data base and to develop suitable temperature zoning for the GC.

2. Asphalt samples collection: Asphalt binder samples were collected from all asphalt cement producing refineries in the Gulf which include Ras Tanura and Riyadh (Saudi Arabia), Al-Ahmadi (Kuwait), and BAPCO (Bahrain) and an additional sample was collected from Awazel private company which modifies asphalt produced by Riyadh refinery.

3. Asphalt testing: Collected asphalt samples were subjected to comprehensive testing to determine their physical and chemical properties. Testing included:

   a. Consistency testing; viscosity at 25° (ASTM D 3570), 60° (AASHTO T-202-

80) and 135°C (AASHTO T-201-80), penetration at 25°C and 4°C (AASHTO T-49-80), softening point (AASHTO T-53-81) and ductility (AASHTO T-51-81). Testing was carried out on fresh asphalt and rolling thin film oven (RTFO) residue (AASHTO T-240-78).

b. Performance based testing which was performed on original binder, RTFO residue and pressure aging vessel (PAV) residue [3]. Tests included flash point, rotational viscosity, dynamic shear, mass loss after RTFO, flexural creep stiffness and direct tension failure strain [3].

c. Chemistry; chemical composition of collected samples were determined using Corbett's method, ion exchange chromatography and high pressure gel permeation chromatography.

6. Asphalt modification: Asphalt cement which has a performance grade that does not satisfy the binder specification as determined by temperature zoning on step 3, will be modified to improve its quality. Modified binder will be subjected to the same set of tests as in task No. 5. The potential output of this step is a modified asphalt that will satisfy the performance requirements of the Gulf countries.

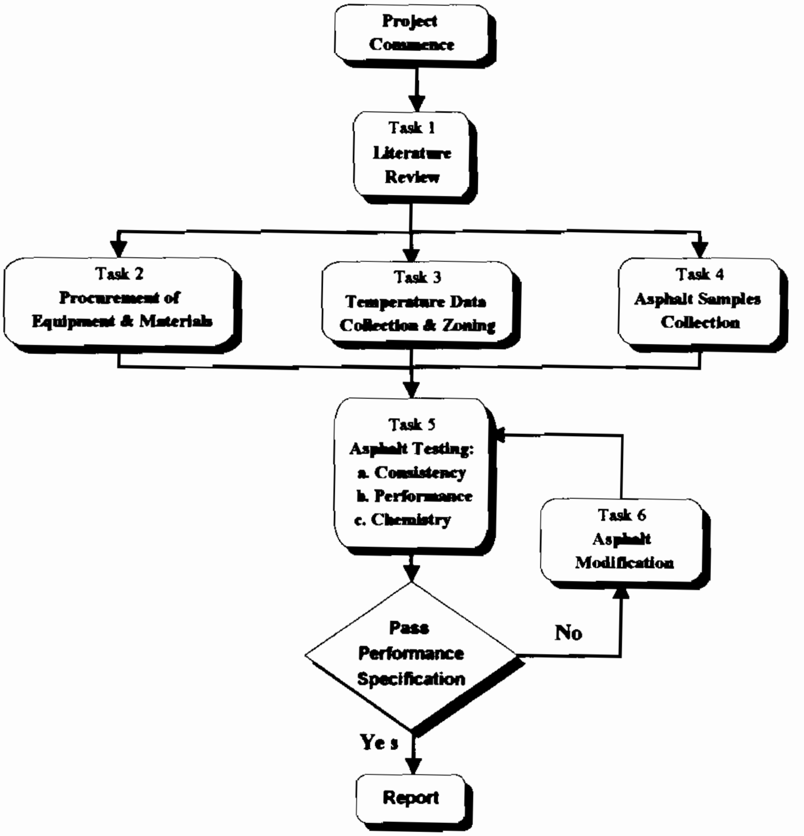

Figure 1: Schematic flow chart of the project design.

Five representative asphalt samples were collected, according to statistical sampling plan, at a rate of one sample every two weeks. In addition, one sample from Awazel Company was included in the testing program since it is the only source within the Kingdom of Saudi Arabia that produces a 40/50 penetration grade asphalt cement.

3. RESULTS AND DISCUSSION

3.1 Temperature Zoning

Metrology and Environmental Protection Agencies in the Gulf countries were approached through the Gulf Cooperation Council (GCC) to provide the research team with the available environmental data that has been collected up to the present time. Forty-four weather stations across the Gulf countries were included and data covering upto 26-year period were collected. Table 1 presents a list of weather stations in the Gulf countries with minimum air temperature and average maximum air temperature over seven consecutive days.

Table 1. Minimum and seven-day maximum air temperature for the different used weather stations.

Country	Station Location	Minimum Temp, C	Avg. Seven-day Maximum Temp, C
Saudi Arabia	Jeddah	8.2	43.6
Saudi Arabia	Makkah	10.2	45.9
Saudi Arabia	Taif	-1.2	37.6
Saudi Arabia	Al-Baha	0.6	37.5
Saudi Arabia	Sulayyil	0.6	46.2
Saudi Arabia	Bisha	-0.8	41.1
Saudi Arabia	Abha	0.0	32.5
Saudi Arabia	Khamis Mushayt	-3.1	34.0
Saudi Arabia	Najran	-0.5	41.0
Saudi Arabia	Sharurah	0.8	44.5
Saudi Arabia	Jizan	14.0	41.4
Saudi Arabia	Turaif	-8.0	43.4
Saudi Arabia	Arar	-5.6	46.9
Saudi Arabia	Gurait	-8.0	45.3
Saudi Arabia	Al-Jauf	-7.0	44.7
Saudi Arabia	Rafha	-6.6	48.3
Saudi Arabia	Qaisomah	-4.1	48.8
Saudi Arabia	Tabuk	-5.0	43.8
Saudi Arabia	Hail	-9.4	42.3
Saudi Arabia	Al-Wajh	5.0	39.4
Saudi Arabia	Qassim	-4.0	46.1
Saudi Arabia	Dhahran	1.6	46.3
Saudi Arabia	Riyadh	-0.5	47.3
Saudi Arabia	Yanbu	6.5	44.4
Saudi Arabia	Madinah	1.0	46.1
Saudi Arabia	Al-Hasa	-2.3	47.6
Saudi Arabia	Al-Dawadmi	5.7	34.1
U.A.E.	Abu Dhabi Int'l AP.	5.4	47.6
U.A.E.	Al Ain	0.6	48.5
U.A.E.	Bu Hasa	4.0	49.0
U.A.E.	Dibba	8.0	48.6
U.A.E.	Dubai Int'l AP.	7.4	47.3
U.A.E.	Kalba	8.4	49.6
U.A.E.	R.AL Khaimah Int'l AP.	4.4	48.2
U.A.E.	Sharjah Int'l AP.	2.5	49.2
Kuwait	Kuwait Airport	-1.6	49.9
Oman	Seeb Airport	10.0	49.2
Oman	Khasab	8.4	49.0
Oman	Buraimi	2.6	50.8
Oman	Sur	7.0	49.8
Oman	Salalah	10.0	47.2
Oman	Thumrait	1.6	46.0
Qatar	Doha Airport	3.8	49.0

Extensive research on temperature distribution in asphalt pavements has been carried out in many different climatic areas of the world. In the Gulf region, Fatani et al. [2], Al-Abdul

Wahhab and Balghunaim [4], Bissada [5] and Potocki [6] have carried out different researches to quantify temperature regimes in local pavements. It was observed that the single most important factor that affects pavement-temperature was air temperature which is directly affected by cloud cover and solar radiation and that the minimum pavement temperature is always recorded on the surface of the pavements which matches the lowest air temperature. The average maximum pavement design temperature over seven consecutive days is measured at a depth of 20 mm in pavement as recommended by the FHWA LTPP study [7]. Regression relationships were developed to correlate air temperature to the 20 mm depth pavement temperature with high accuracy. Contour maps for both the minimum temperature and/or the average maximum consecutive seven days pavement (at 20 mm depth) temperature were developed. Based on those contour maps and considering slow transient loads, four asphalt binder performance grades (PG) are recommended: PG 76-10, PG 70-10, PG 64-10 and PG 58-10 as shown in Fig. 2. For example, an asphalt with a performance grade of PG 76-10 designates an asphalt that will satisfy performance requirements for a temperature zone that has an average maximum seven consecutive days temperature of less than 76°C and a minimum pavement temperature greater than −10°C. Asphalt binder used in any of these zones must meet the performance requirements for these temperature extremes, namely, maximum seven consecutive days temperature and minimum pavement temperature.

3.2 Asphalt Testing

Collected asphalt samples were subjected to comprehensive testing to determine their physical and chemical properties. The measured physical properties were utilized to determine penetration, AASHTO and WASHO asphalt grading, and to calculate relevant temperature susceptibility indices such as: penetration index "PI", penetration viscosity number "PVN" and viscosity temperature susceptibility "VTS". Results are shown in Table 2. The following are observations that can be stated for asphalt produced in the Gulf:

* Bahrain Refinery (BH) samples met the 40/50 penetration grade, two Ras Tanura Refinery (RT) samples met the 60/70 penetration grade while the rest of the samples did not meet any penetration grade.

* Softening point of all samples ranged from 49°C to 51.50°C except the Awazel Company (AZ) sample which had a softening point of 54.75°C.

* Samples are graded as AC-40 according to the AASHTO asphalt grading method, except three "RY" samples which had a grade of AC-20 and the "AZ" sample which could not be defined.

* Samples are graded as AR-8000 according to the WASHO method, except one Ras Tanura Refinery (RT) sample, two "RY" samples and three "BH" samples, which had a grade of AR-4000.

* Samples have a penetration index (PI) ranging from -0.44 to -1.53. "RT" samples have the lowest temperature susceptibility while "BH" samples have the highest temperature susceptibility.

* The penetration viscosity number (PVN) of all samples ranged from -0.36 to -0.83.

* The viscosity temperature susceptibility (VTS) ranged from 3.37 to 3.71.

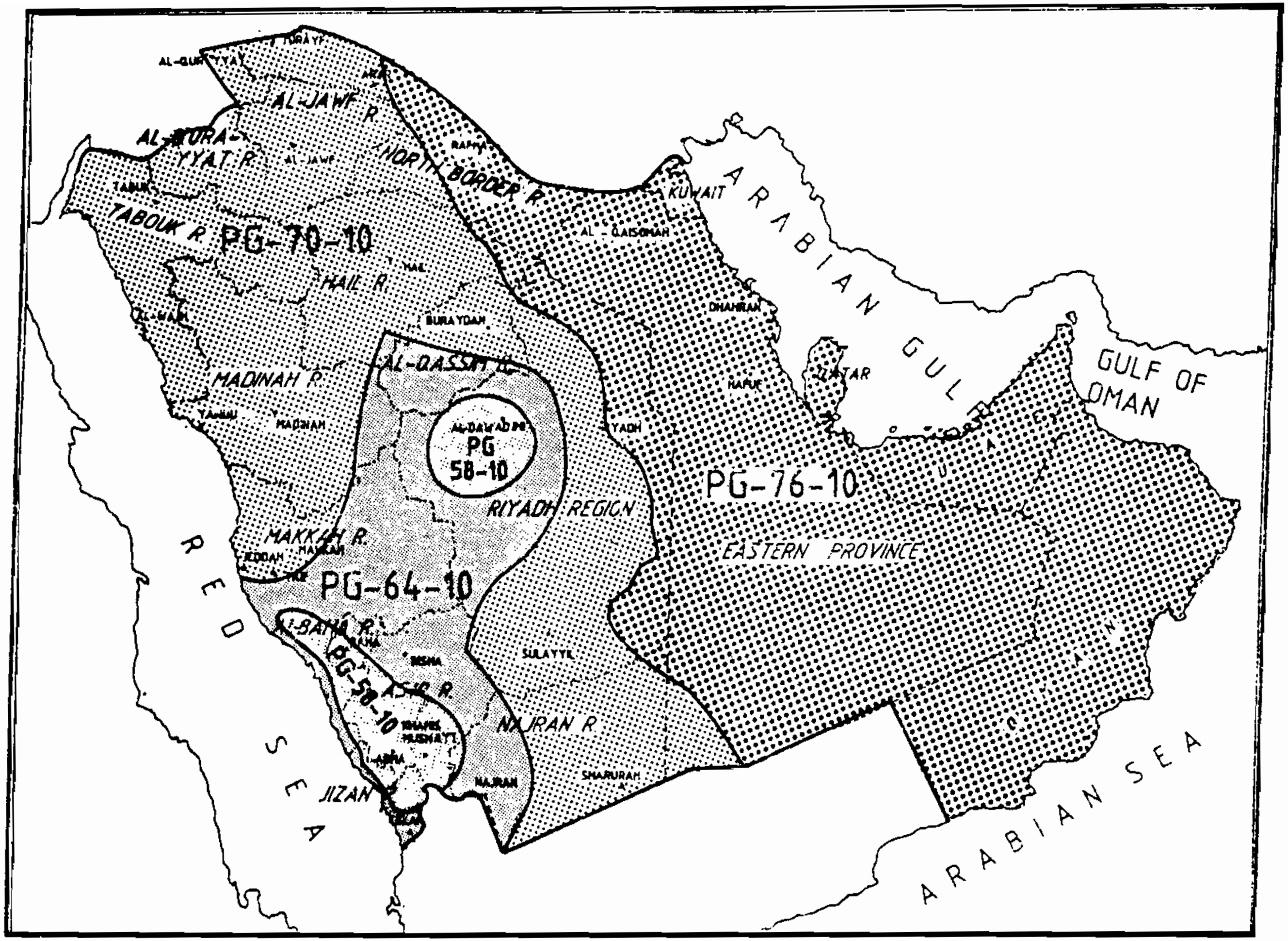

Figure 2: Recommended temperature zoning for asphalt binder specification for the Gulf region.

Table 2. Summary of grading and physical testing results.

Country of Origin	Sample ID	Softening Point, C	Penetration @ 25C	Penetration Index, PI	Penetration Viscosity Number, PVN	Viscosity Temperature Susceptability, VTS	Asphalt Grade (AASHTO Classification)	Asphalt Grade (WASHO Classification)	Asphalt Performance Grade (SHRP Classification)
Saudi Arabia	RT1	50.25	60	-0 72	-0.75	3 65	AC-40	AR-4000	PG-64-22
	RT2	50 75	63	-0.44	-0 42	3 50	AC-40	AR-8000	PG-64-22
	RT3	50.00	56	-0 95	-0.56	3 52	AC-40	AR-8000	PG-64-28
	RT4	50.75	51	-0.98	-0.66	3.55	AC-40	AR-8000	PG-64-28
	RT5	50 75	56	-0 73	-0.70	3.56	AC-40	AR-8000	PG-64-28
	RY1	49.25	54	-1 20	-0 83	3 56	AC-20	AR-4000	PG-64-22
	RY2	49.75	57	-0 98	-0.70	3.53	AC-20	AR-8000	PG-64-22
	RY3	49 75	50	-1 28	-0.74	3 53	AC-40	AR-8000	PG-64-22
	RY4	50 00	54	-1 01	-0 50	3 37	AC-20	AR-4000	PG-64-22
	RY5	51.25	51	-0 86	-0.48	3 37	AC-40	AR-8000	PG-64-22
	AZ1	54.75	38	-0 68	-0 83	3 71	NOT DEFINED	AR-16000	PG-70-22
Bahrain	BH1	50.00	45	-1 41	-0 79	3 54	AC-40	AR-8000	PG-64-22
	BH2	49.50	47	-1.45	-0.74	3.49	AC-40	AR-8000	PG-64-22
	BH3	49.00	48	-1.53	-0.82	3 53	AC-40	AR-4000	PG-64-22
	BH4	49.75	50	-1 25	-0 78	3.54	AC-40	AR-4000	PG-64-22
	BH5	50.00	48	-1 27	-0.83	3 54	AC-40	AR-4000	PG-64-22
Kuwait	KW1	50.25	53	-1 01	-0.51	3.43	AC-40	AR-8000	PG-64-22
	KW2	51.00	51	-0.93	-0 42	3 39	AC-40	AR-8000	PG-64-22
	KW3	51.50	54	-0.63	-0.48	3 50	AC-40	AR-8000	PG-64-22
	KW4	50.00	56	-0.93	-0 44	3.45	AC-40	AR-8000	PG-64-22
	KW5	50.50	55	-0.86	-0.36	3.42	AC-40	AR-8000	PG-64-22

The performance-based rheological properties of these samples are determined using the Dynamic Shear Rheometer (DSR), Bending Beam Rheometer (BBR) and a locally manufactured Direct Tension Tester (DTT) [3]. Performance testing is being performed for the purpose of grading the locally produced asphalts based on the SHRP recommended performance grading system. The performance grades of the tested samples are shown in Table 2.

Results indicate that asphalt cement produced in the Gulf satisfies the low temperature requirement but can only satisfy one average seven day consecutive maximum temperature zone, i.e. PG 64-10. Awazel air blown asphalt met the requirement of PG 70-10 while PG 58-10 and PG 76-10 zones have not been met. This indicates the necessity of modifying locally produced asphalts to meet the performance requirements of these temperature zones.

4. CONCLUSIONS

1. Asphalts, as produced by Gulf refineries, are variable.

2. Penetration and viscosity are not sound basis for local asphalt binder specifications.

3. Temperature zoning, a prerequisite for performance based specification for the Gulf countries, was developed. Temperature zones range between PG 58-10 to PG 76-10.

4. Locally produced asphalt cement needs modification to suit the different Gulf temperature zones.

ACKNOWLEDGEMENT

The authors would like to thank King Abdulaziz City for Science and Technology (KACST) for providing support for this research and to the King Fahd University of Petroleum and Minerals for providing the laboratory space and facility.

REFERENCES

[1] Bahia, H.U. and Anderson, D.A., "The New Rheological Properties of Asphalt Binders: Why are They Required and How They Compare to Conventional Properties." Physical Properties of Asphalt Cement Binders, ASTM STP 1241, John C. Harden, Ed., American Society for Testing and Materials, Philadelphia, 1994.

[2] Fatani, M.N., Al-Abdul Wahhab, H.I., Balghunaim, F.A., Bubshait, A., Al-Dubabe, I. and Noureldin, A.S., "Evaluation of Permanent Deformation of Asphalt Concrete Pavement in Saudi Arabia." Final Report, National Research Project, King Abdulaziz City for Science and Technology, Saudi Arabia, 1992.

[3] Strategic Highway Research Program, "The Superpave Mix Design System Manual of Specification, Test Methods, and Practices." Report No. SHRP-A-379, Washington, D.C., 1994.

[4] Al-Abdul Wahhab, H. and Balghunaim, F., "Asphalt Pavement Temperature Related to Arid Saudi Environment." Journal of Materials in Civil Engineering, ASCE, Vol. 6, No. 1, 1-15, 1994.

[5] Bissada, F., "Asphalt Pavement Temperatures Related to Kuwait Climate." Highway Research Record 404, Transportation Research Board, Washington, D.C., 71-85, 1972.

[6] Potocki, F.P., "Road Temperatures and Climatological Observations in the Emirate of Abu Dhabi." Unpublished Report, TRRL Technical Note TN 812, 1973.

[7] Federal Highway Administration, *Specific Pavement Studies Experimental Design and Research Plan for Experiment, SPS-9A SuperPAVE™ Asphalt Binder Study*. Turner-Fairbank Highway Research Center, Mclean, Virginia, 1994.