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Falah Hussein
Baghdad University

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ASPHALT CEMENT MODIFICATION TECHNOLOGY

Falah Hussein*
B. Sc. in Civil Engineering, Baghdad University.
Senior civil engineer, Head of Contracts Department, Holy Abbasiya Organization, Kerbala Centre, Iraq, falahhussein@yahoo.com (Corresponding Author)

ABSTRACT

As part of a study team working on the rehabilitation of Ghat Airport, located in the desert in south-west Libya, a study was undertaken by the Italian company CONICOS to apply a new asphalt cement modification technology. This study aimed to enhance asphalt quality and improve asphalt-concrete mechanical characteristics, in particular, thermal resistance. The proposed modification was achieved by adding special products and agents. These additives included polymers and anti-stripping agents. By using this new technology, we were able to enhance the characteristics of asphalt to make it able to withstand the stresses of fatigue. The asphalt was also able to sustain thermal stress resulting from the large margin of difference between maximum and minimum seasonal temperature in that area. The new technology also resulted in the reduction of the permanent deformation and rutting of the asphalt. After many laboratory tests, we decided to use a combination of two different additives at certain percentages. With this new Job Mix Formula, we were able to obtain loss in heating of 0.3%, a softening point of 53 ℃, loss in penetration of 39% of the original, and a ductility of more than 100 cm. The results have been implemented at other similar projects and have proved to be effective, economical, and applicable in the region.

KEYWORDS

Thermal cracks, rutting, ageing fatigue, bitumen, AASHTO, Laboratory Job Mix Formula, bulk density, air void, stability, flow, voids filled with bitumen, sand-bitumen, chemical additives.

INTRODUCTION

In the deserted areas where I have worked for more than ten years, the failure of the roadway has been a concern for the authorities and road companies who worked there. We studied in detail the stress and resistance of pavement layers. These studies focused on resistance to thermal cracking, rutting, and ageing fatigue. We discovered that those three problems are defects to the existing roads need a new asphalt mixture to make it more resistive.

GENERAL

Following are some definitions of common technical terms used in this paper:
Thermal cracks: Cracks that develop when the difference of temperature between upper and lower bounds is more than fifty degrees Centigrade and the cracks are usually limited to the area of repeated traffic loading. The cracks appear initially as a series of parallel longitudinal cracks within the wheel path. The cracks will increase with time and loads. On narrow, two-lane roads, thermal cracks may form along the centre line rather than in the customary wheel paths. Potholes and other occurrences of destroyed or missing pavement accumulate as high severity cracks.

Figure 1. Thermal cracks and fatigue on the Ubari - Ghat Roadway.

Figure 2. Thermal cracks and fatigue at Ghat International Airport.

The above “Figures 1 and 2” show types of failure in that area. Those figures also show transversal cracks which run perpendicular to the roadway centre line, and are caused by surface shrinkage due to the low temperature and/or hardening of the asphalt. The cracking shown can be classified into three types: low, medium and high.

Rutting: Surface depression within the wheel path is a second effect on the roads in that area. Rutting is permanent deformation in any of the pavement layers. Rutting is usually caused by consolidation or lateral movement of materials due to traffic load. Since there is no control on heavy traffic in that area, truck operators do not follow the limitations of loads on their vehicles. Consequently, when the upper layers are severely rutted, the pavement along the edges of the rutted area may be raised. These kinds of damage are shown clearly in road-ways, especially after flood season's heavy rains when the water flows over the roads and the ruts become visible.

Ageing: Pavement surface deterioration that occurs when aggregate particles are dislodged or oxidation causes loss of the aged asphalt. The severity of ageing is rated by the degree of aggregate and bitumen loss. This effect can also be characterized into three types: low, medium and high.

In 2004, we discovered sand-bitumen mixture to deal with the previous problems especially thermal cracks. Commercially sand-bitumen is better than its rivals like chemical additive, please check “Annex 1” for more details. We used this mixture as a binder layer over modified base course layer by milling the existing damaged base-course and asphalt layers then remixed, laid and compacted to create a new highly resistant layer of base course. Later we replaced the sand-bitumen with standard asphalt mixture as a binder course, please check “Annex 2” for more details, and then covered by polymer-modified asphalt as a wearing course. Using this approach we achieved economic high quality asphalt layers.

This paper show the methodology that we applied using two chemical additives called SUPERPLAST and ITERLENE IN/400S produced by the Iterchimica Company of Italy added to the wearing course at Ghat International Airport.

METHODOLOGY

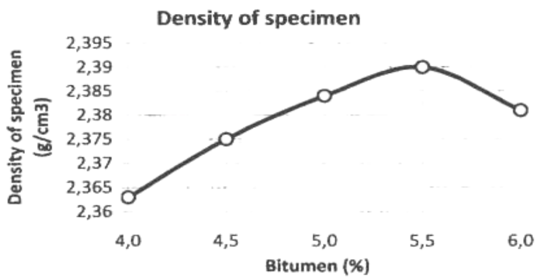
Laboratory Job Mix Formula (LJMF) of Wearing Course without Chemical Additives

Typically we use standard JMF for binder and wearing course designs without any additives. “Table 1” shows the results of the standard wearing course LJMF:

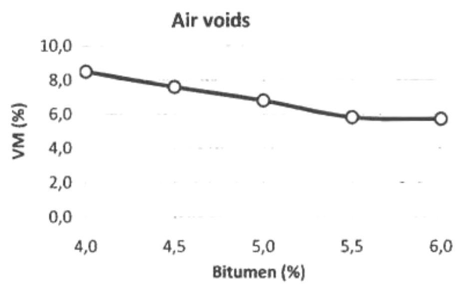
Table 1. Wearing Course Laboratory Job Mix Formula – Summary Results

ITEMS	RESULTS	SPECIFICATION
Gradation	OK	AASHTO – M6
Los Angeles Class (B)	28	40
Los Angeles Class (C)	30	40
Clay Lumps and F.P. Coarser N. 16	4.5	5
Soundness Test	1	12
Flakiness and elongation (3/4”)	F=8.2 E=9.4	35
Flakiness and elongation (3/8”)	F=6.2 E=7.8	35
Average Bitumen Content %	5.3 (+/-) 0.3	5.0 to 7.0
Bulk Density	2.39	N/S
Stability	1937.46 Kgf	900 Kg
Flow	3 mm	2 to 4 mm
Air voids %	6 mm	3 to 8 mm
Voids filled %	77	80

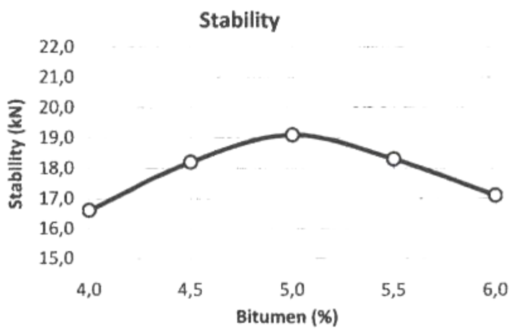
In below “Figure 3”, you can see some relationships which are estimating the optimal bitumen content:



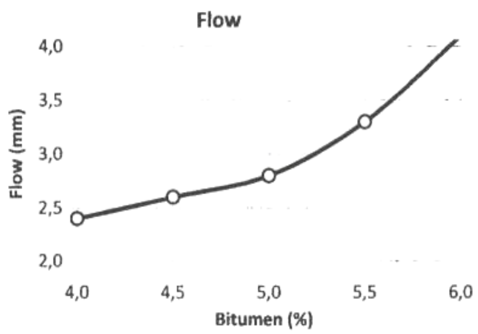
a) Density of specimen



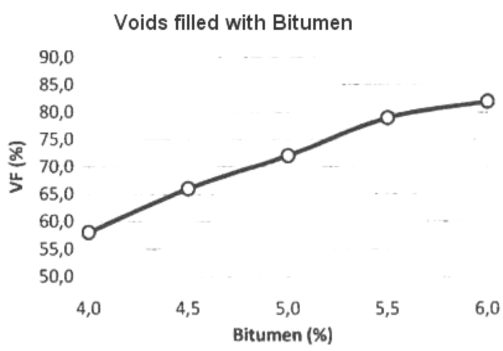
b) Air Void



c) Stability



d) Flow



e) Voids Filled with Bitumen (VFB)

Percent of bitumen content by aggregate weight:

1. % of bitumen at max bulk density = 5.5%
2. % of bitumen at max. stability = 5.0%
3. % of bitumen at max. air void = 5.5%
4. % of bitumen at VFB = 5.3%

Therefore, the average bitumen content = 5.3%

Result at optimal bitumen content:
Bulk Density (G_{mb}) = 2.390
Air Void = 4.5%
Stability = 1937.46 Kgf
Flow = 3.00 mm

f) Results

Figure 3. The relationships between bitumen contents and mix properties

We used the above-mentioned JMF in the execution of roadways and airports in the southern region of Libya. This JMF was successful for our previous projects and you can see more details in “Annex 3”. With asphalt ageing problems appearing our engineering team started a study to find a solution to the problem. The aim was to search for a suitable mixture and a way of increasing the life of the pavement and decreasing the maintenance requirements.

Laboratory Job Mix Formula of Wearing Course with Chemical Additives

The Laboratory Job Mix Formula was produced at the Iterchimica Laboratory in Italy, using our raw materials of aggregate produced from our crushing plant at Aweinat (130 km north of Ghat City) with bitumen produced by the Brega Oil Company at AlZawia (50 km north of Tripoli). “Table 2 and 3” show the results of the LJMF after adding the combination of SUPERPLAST and the anti-stripping agent ITERLENE IN/400-S, properties of aggregates, percent of bitumen and additives, see "Annex 4".

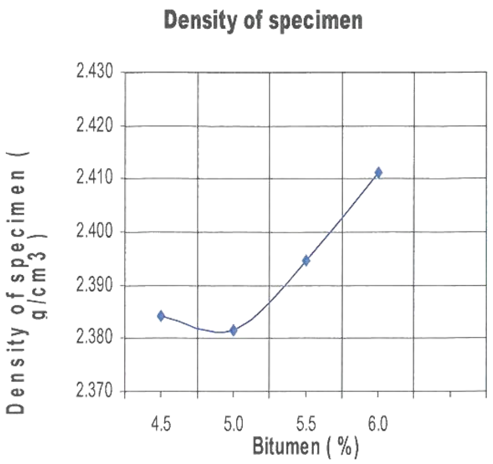
Table 2. Properties of Wearing Course Mixture at Optimum Asphalt Content

ITEMS	RESULTS	SPECIFICATION
Bulk Specific Gravity (G_{mb})	~ 2.381 g/cm3	-
Maximum Specific Gravity (G_{mm})	~ 2.474 g/cm3	-
Air Void (V_a)	4.5%	3 – 8
Voids in mineral aggregate	16.7%	-
Voids Filled with Asphalt (VFA)	69.4%	80 max.
Mechanical Test:		
Marshall Stability at 60 ℃ (MS)	1598.10 Kgf	900 min.
Marshall Flow at 60 ℃ (MF)	2.53 mm	2 – 4
Marshall Stiffness at 60 ℃ (S)	-	-
Resilient Modulus at 21 ℃ (MR)	-	-
Dust Ratio (Dp)	-	-

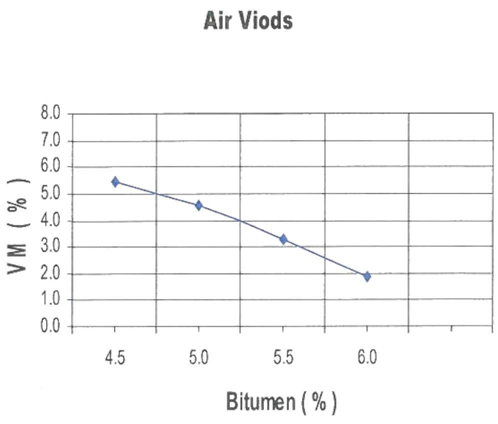
Table 3. Proportion of Aggregates, Percent of Bitumen and Additives

Aggregate Proportion		Bitumen and additives Percent	
Filler	-	Optimum asphalt content	5.0% by Agg. Weight
0 – 5 mm	50	Additive SUPERPLAST	4.5% by Agg. Weight
Desert Sand	10	Additive ITERLENE	0.4% by Agg. Weight
5 – 10 mm	20		
10 – 19 mm	20		

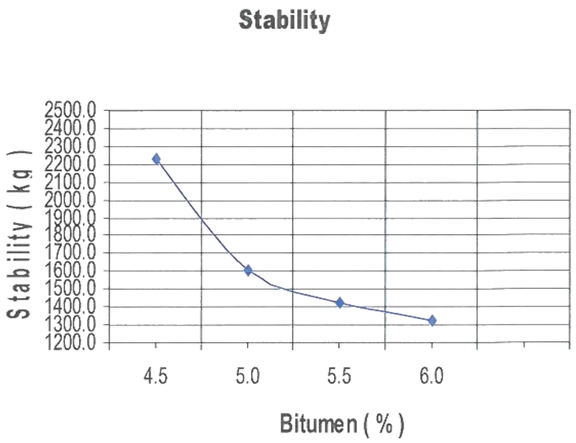
In below “Figure 4”, you can see some relationships which are estimating the optimal bitumen content:



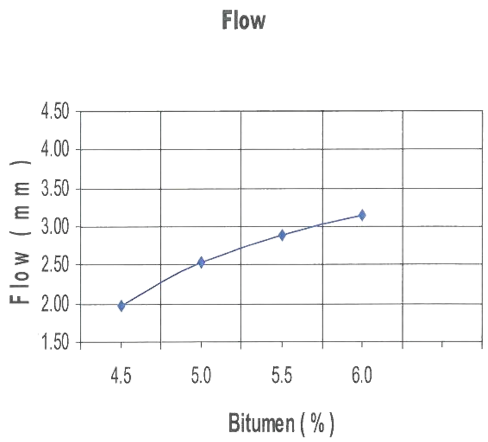
a) Density of specimen



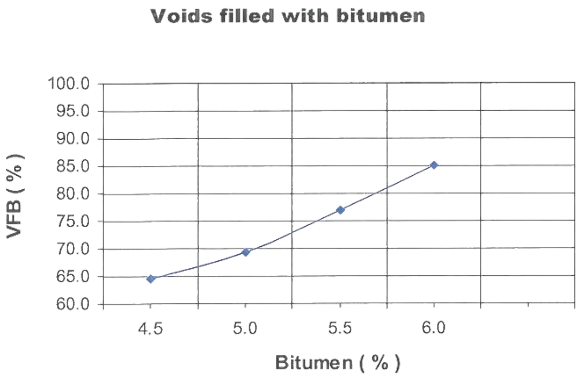
b) Air Void



c) Stability



d) Flow



e) Voids filled with bitumen (VFB)

Percentages of bitumen content by aggregate weight:

1. % of bitumen at max bulk density = 6.0%
2. % of bitumen at max. stability = 4.5%
3. % of bitumen at max. air void = 4.5%
4. % of bitumen at VFB = 5.5%

Therefore, the average bitumen content = 5.0%

Result at optimal bitumen content:
Bulk density (G_{mb}) = 2.381
Air void = 4.5%
Stability = 1598.10 Kgf
Flow = 2.53 mm

f) Results

Figure 4. The relationships between bitumen contents and mix properties

PROPERTIES OF MATERIALS USED:

Bitumen

“Table 4” shows typical results from the source and after the Rolling Thin Film Oven Test (RTFOT)

Table 4. Properties of Original Asphalt Bitumen

CHARACTERISTICS	UNITS	TEST RESULTS
Specific Gravity	g/cm3	1.025
Penetration at 25 C, 5 sec, 100 gm	mm^{-1}	63.0
Softening Point, (R&B) method	C	45.8
Ductility at 25 C, 5 cm/min	Cm	> 150`
Flash point Cleveland Open Cup	C	305
Fire point Cleveland Open Cup		351
Solubility	%	99.7
Absolute viscosity at 60 ℃	Pa. S	-
Kinematics viscosity at 135 ℃	m2/s	-
Fraas Breaking Point	C	-
Paraffin Content	%	-
TEST ON RESIDUAL FROM RTFOT		
Loss in heating after RTOFT	%	0.3
Softening Point, (R&B) method	C	53
Loss Penetration at 25 ℃, 5 sec, 100 gm	% of original	39
Ductility after Thin Film Over Test	Cm	> 100

Additive Polymer SUPERPLAST:

SIPERPLAST is a special polymer compound formed of flexible semi-soft granules. When SUPERPLAST is used, it improves the mechanical resistance and resilience of the mix. SUPERPLAST mast be added directly to the plant's mixer, avoiding the requirement of a modified bitumen tank. The physical properties of SUPERPLAST are as follows:

Aspect:	black/gray granules.	Softening point:	150 C
Fusion point:	160 C	Melt index:	1÷5

Additive Anti-Stripping Agent ITERLENE IN/400-S

ITERLENE IN/400-S GREEN is a very high efficiency liquid anti-stripping agent of new generation: It is free of aromatic oils hazardous to human health.
Physical properties of ITERLENE IN/400-S GREEN:

Colour:	yellow dark/brown.	Aspect:	liquid.
Density at 20 C:	0.90 – 0.96 g/cm3	Viscosity at 20 C:	400 ±50 cP.
Flash point:	> 160 C.	pH:	basic

RESULTS AND DISCUSSION

The tests confirmed that the application of the above-mentioned polymer to the mixture improves stability and brings the adhesion strength of bitumen to the aggregate. It develops improved stability in the mixture against rutting. The results shown in previous sections clearly show that the polymer does not change the Marshall Stability, most likely due to the fact that this material itself already has high Marshall Stability. The new mixture produces elastic performance in the asphalt mixture, and a high modulus between asphalt layers, thereby achieving greater load distribution and bearing capacity, high frictional wearing coarse layers with greater durability, rutting and fatigue resistance in both high temperature and warm weather. It also increases the stiffness of the mixture, which prevents the bitumen flowing when the outside temperature is high. At the same time, there is an increase of the air voids in the mixture, which might confer higher flexibility.

CONCLUSIONS

The modified LJMF was successfully applied in the execution of the wearing course at Ghat International Airport. The results proved the mixture to be successful, both technically and economically. The author and the CONICOS team in Libya are currently adopting the results of the research and are in the process of studying a modification to the research to develop a robust way to rehabilitate 360 km of the Ubari-Ghat roadway (figure 1) by using cold recycling system. The results will be published when the research is completed.

ACKNOWLEDGMENTS

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SUPERPLAST and ITERLENE IN/400-S Technical Data Sheets (TDS) of Iterchimica Co.
SUPERPLAST Specification and Application. January 2013 of Iterchimica Co.

ANNEXES

Annex 1. LJMF of sand-bitumen mixture.
Annex 2. LJMF of standard binder course.
Annex 3. LJMF of wearing withour additives.
Annex 4. LJMF of wearing with additives.