

THE DEVELOPMENT IN THE USE OF ASPHALTIC CONCRETE IN HYDRAULIC STRUCTURES (FOR EXAMPLE AL SOURANI DAM IN SYRIA)

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INTRODUCTION

Nowadays, linings for dams are usually manufactured from asphalt. This type of sealing also proves to be advantageous in the case of large dams and for irrigation water, drinking water, and water for industrial uses. Asphaltic linings are also suitable for replacing or overlaying old sealings made of concrete or mineral materials, which have become less efficient for one reason or another.

Asphalt is a mixture of bitumen and mineral aggregates. With a suitable composition, if professionally placed, asphaltic concrete can be manufactured in such a way that it is waterproof.

The advantageous characteristics of an asphaltic lining in relation to its basic requirement, namely impermeability to water that: it can absorb pressure forces as well as bending and shearing forces, and up to a certain limit, it is compatible with regard to consolidation settlements.

To a certain extent, as a result of the visco-elastic characteristics of the bitumen, tensile stresses in the film of the bonding agent between the adjacent grains of mineral can be reduced without the development of cracks. This feature, exploited in the asphaltic linings with large areas, can be produced without seams.

Asphaltic mixes can be composed in such a way that in addition to the desired consistency and flexibility they also have sufficient suitability to be placed on slopes with an inclination of up to 1: 1.3.

The first use of the asphaltic concrete in Syria was the sealing of Al-Sourani Dam in Tartous by the use of asphalt facing with an inclination of 1: 2.25. The construction of the asphalt facing was finished in Nov. 2003.

In this paper, we shall explain the property of the construction materials, lining design, quality control, and thermal condition in such semi-arid area.

CONSTRUCTION MATERIALS

1- Bitumen

The usual classification of bitumen in grades is done according to penetration. In fact, this represents the viscosity at a certain temperature. It is the value in 1/10 mm, by which a needle loaded with 100 g penetrates the bitumen at 25 °C in 5 seconds. In hydraulic engineering, bitumen with a penetration range of 50 and 70, is usually designated as B65, and penetration of between 70 to 100, designated as B80.

The penetration of the bitumen used in Al-Sourani Dam was 71. It has also the following properties:

- Ductility 150 mm
- Ring and ball 65 °C

2- Mineral aggregates

The mineral aggregates should be from healthy rock, free of all swellable components and with a good affinity to bitumen. Impact shatter values and compression strength are not important as in road engineering.

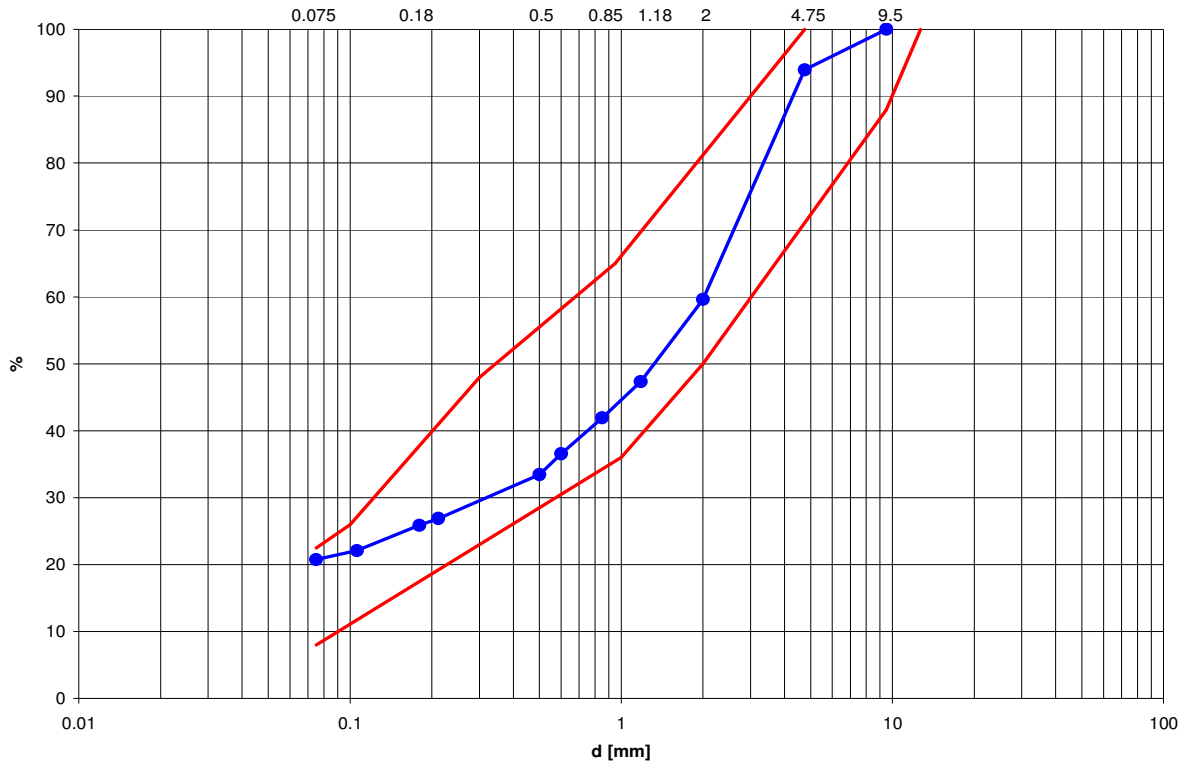
Fillers < 0.09 mm, manufactured sand, natural sand of 0.09 – 2 mm, crushed aggregates in sizes of 2/5 mm, 5/8 mm, 8/11 mm, 11/16 mm and if needed 16/32 mm for drainage layers, are used.

The aggregates used for Al-Sourani Dam was from healthy rock from area near Lattakia (Rassion). The grain-size distribution for the used aggregates is shown in Figure (1) for impervious layer.

3- Lining Design

The cross section of the asphalt facing used in Al-Sourani Dam is shown in Figure (2). It consists of:

- 1- Asphaltic mastic seal coat approx. 1-2 mm (70% filler + 30% bitumen)
- 2- Impervious asphaltic concrete course (2x5 cm)
- 3- Asphalt binder course (0-25 mm), thickness 10 cm
- 4- Bituminous emulsion 2 kg/m²
- 5- First transition layer (0 – 56) mm ;thickness 100cm
- 6- Second transition layer(0 – 32) mm ,thickness 100 cm



Figure(1) :The grain-size distribution for the used aggregates in AL-sourani dam (- - -)
 The grain-size distribution range for impervious asphaltic concrete (—)

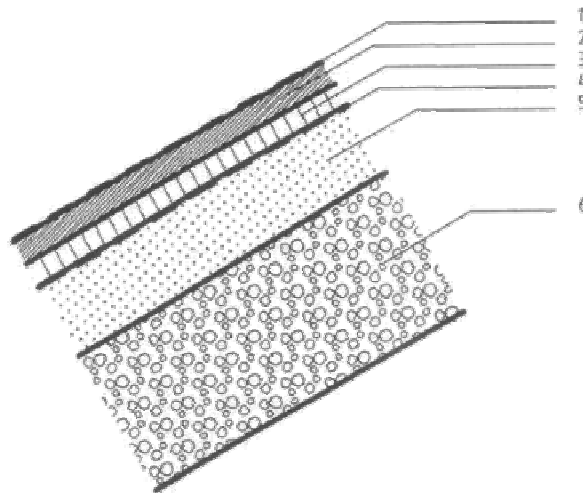


Figure (2)

QUALIFICATION TESTS

Qualification tests must demonstrate, on a Marshal specimen compacted with an effort comparable to that achievable on site, that a final void content in a range well below the maximum value of 3% vol. is attainable.

Final compaction by the rollers will vary according to mix temperature, slope and equipment used for the considered project, in the design of the mix, the number of Marshal blows on each side of the specimen must be adapted to the compaction that finally can be expected with the equipment. It is the responsibility of the contractor to select the right number of blows to represent the compaction effort achievable in practice on the slope.

From experience it is known that the number of blows can vary between 7 and 35. The number of blows should always be stated when the void content of a sample prepared in the laboratory mix is given.

The weight of the roller used in Al-Sourani Dam was about 5 ton and the Marshal blows were 30.

In the qualification tests, mix compositions of aggregate and bitumen was tested with:

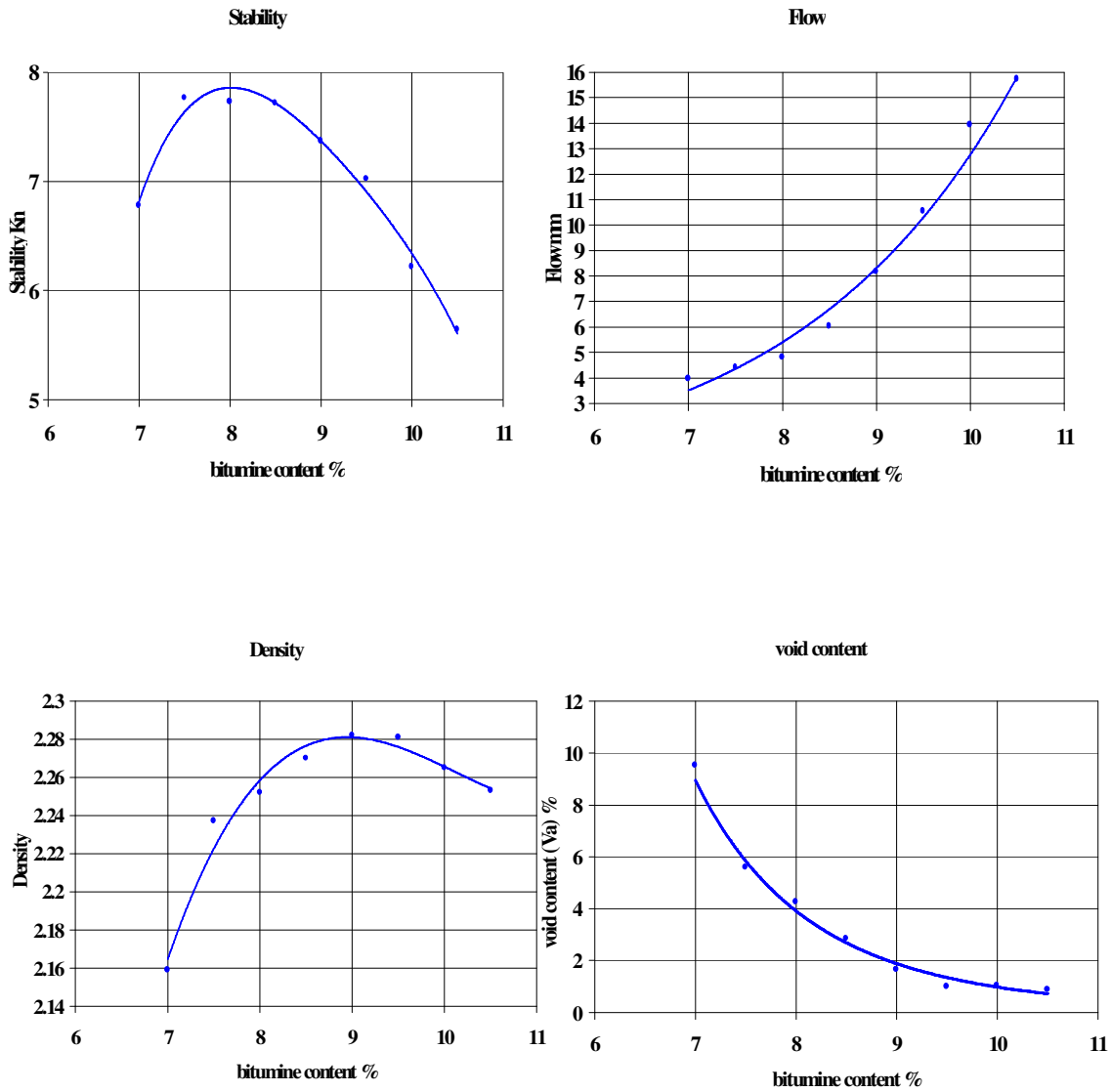
- 8 different amounts of bitumen, with increments of 0.5% (7%, 7.5%, 8%, 8.5%, 9%, 9.5%, 10%, 10.5%)
- 3 specimen was made for each bitumen content, and compaction was carried out with the standard Marshal hammer.
- The specimen was weighed in air and in water to determine the mass density of the compacted mix.
- At each bitumen content the following mix properties were determined (average of the three specimens):
 - Marshal stability and flow
 - Voids in the mineral aggregate in the compacted specimen $V(ma)$
 - Air voids of the compacted specimen (VA)

These properties were entered into Figure (3). The Vma for hydraulic mixes with a sufficient bitumen content will normally be positioned just beyond the minimum on the rising branch of the curve.

While the mass density ρ_A will be positioned just beyond the maximum on the falling branch. The bitumen content must be so-coordinated in such a way that, on the one hand there is a sufficient coating of the mineral particles, on the otherhand, the stability on slope is guaranteed.

The optimal bitumen content is a function of the type of aggregate employed, of the necessary workability of placing temperatures, of the layer thickness and required service life.

From Figure (3) the optimal content of bitumen is selected to be 9% and the air void was about 1.66%, Marshall stability = 7.37 KN, $V_{ma} = 21.6\%$, flow = 8.17 mm, density = 2.28 g/cm²



Figure(3): Qualification tests for the asphaltic concrete mix with varying amounts of bitumen.

OTHER MIX PROPERTIES**Table (1) Requirements for impervious layer [2]**

	Properties	Permissible values	Experimental values
A	Basic requirements		
1	Compression strength At temperature 20 °C – R 20 At temperature 50 °C – R 50 At temperature 0 °C – R 0	30 15 --	55 20.15 126.43
2	Coefficient of thermal stability Kt = R 20/R 50	2- 2.5	2.734
3	Coefficient of water resistance after test performed in vacuum	> 0.9	0.92
4	Coefficient of elasticity Ke = R0/R20	2 – 2.8	2.295
5	Coefficient of permeability –(cm/s)	<10E-7	6.8x10E-8
B	Supplementary requirements		
1	Water absorption in % of the volume	< 1.5	0.3
2	Swelling, % of the volume	< 0.5	0.038
3	Bond index of the asphalt with the surface of mineral aggregates	> 90%	0.95
4	Marshal stability	> 6 KN	7.37KN
5	Marshal stability after 14 days water laying down	5.4 KN	6.7KN
6	Flow according to Marshal	(4-8)mm	8 mm

SPECIAL TEST METHODS**1- Flexibility Tests**

To test the flexibility of asphaltic layers an apparatus was manufactured for this purpose described in [1] where the sample was exposed to water pressure equivalent to the water high upstream the dam ,the thickness of the sample was about 50 mm and the diameter 500 mm. The space below the test specimen was only partially filled with

sand, so there was free space left. The partial filling forms a saucer with depth (h) equal to one tenth of the diameter (s). The pressure was increased in the way described in [2] and consequently the sample remained quite impermeable.

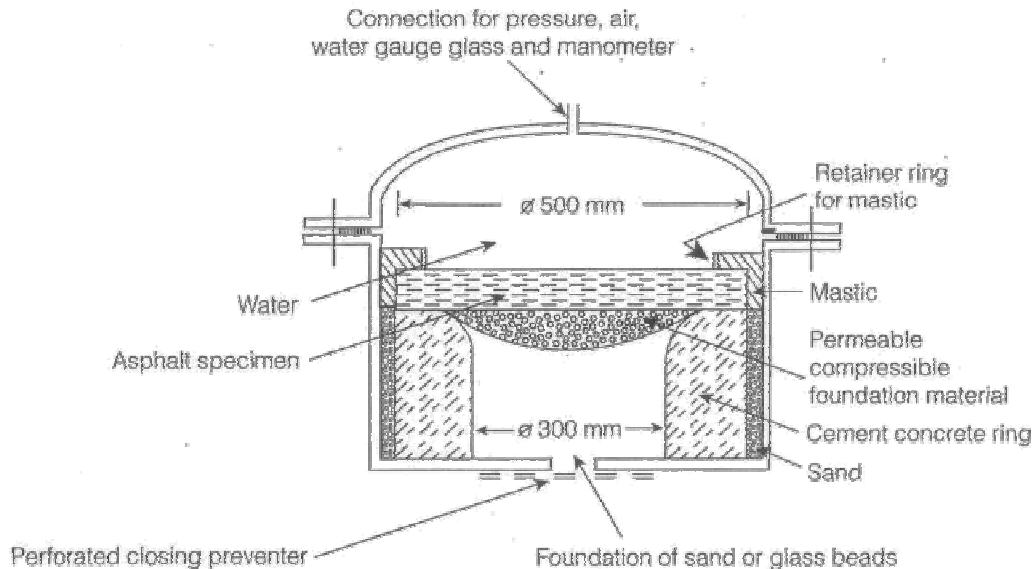


Figure (4) Used apparatus (manufactured according to [1])

2- Slope Stability Tests for Asphaltic Concrete Mixes

2-1- Determination of Maximum Temperature of the Asphalt Facing

Temperature has been measured in many depths in an experimental area that was built near the location of the dam site which has the same inclination (1:2.25), the measurements were taken for two consecutive years.

The maximum temperature on the surface was about 60°C during the measuring period. To obtain the maximum temperature which may occur, a mathematical-physical model was established through which the maximum expected temperature could be calculated on the surface of the asphaltic facing and at various depths. This model depends on the energy budget equation at the surface of the asphaltic facing [3]. The model requires climatic information such as (air temperature – atmospheric pressure, air turbidity etc...) as well as geographic information such as (latitude, height above sea level etc...) and information related to properties of heat transfer of asphaltic concrete.

The above mentioned model and the respective program with the actual measures performed in the experimental area were tested and results showed good conformity between the calculated values through the model and the measured values in the

experimental area. For determining the maximum temperature of the asphaltic concrete may be exposed, search was made for the highest air temperature in the dam area during fifty-year period and this temperature was 41°C.

Other accidental climatic conditions that lead to maximum temperature were also indicated.

By using the mathematical-physical model the maximum temperature that could be occur once every fifty-year period was calculated and it was about 73°C and temperature was also calculated on various depths of the asphaltic facing as illustrated in Figure (5).

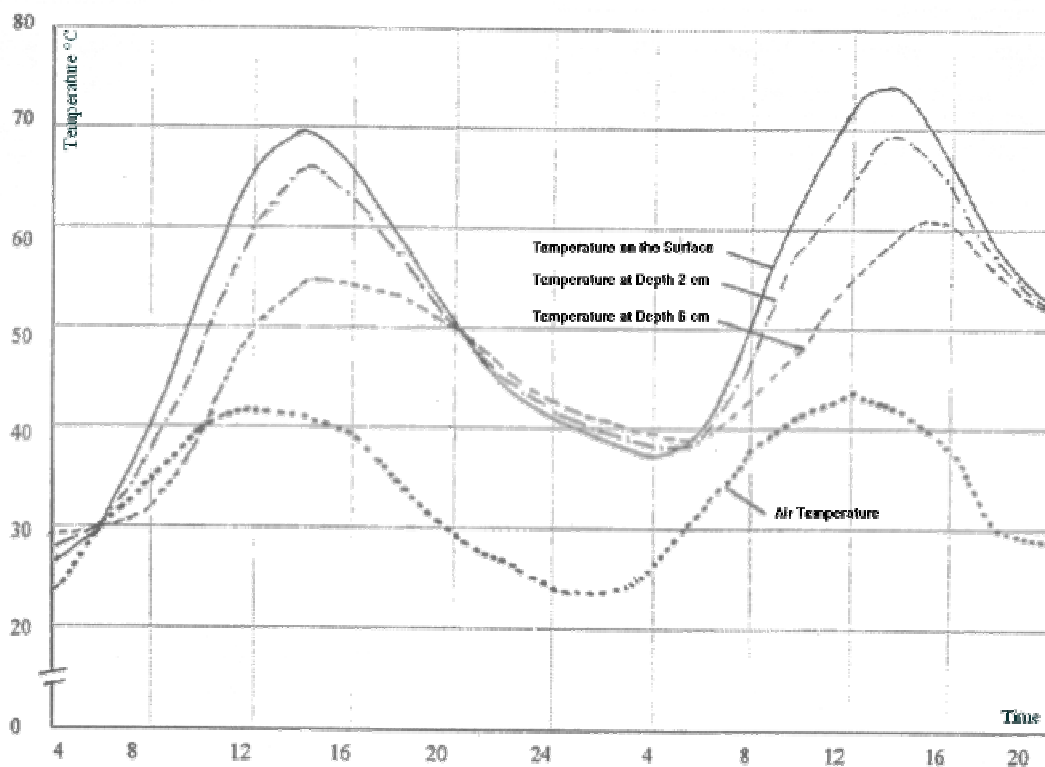


Figure (5) Temperature changes on the surface of the asphaltic concrete and in various depths of Al-Sourani Dam (Syria)

2-2- Stability Test

For testing slope stability (Schoenian, [1]) showed an apparatus. As a simpler method, it is recommended to take Marshall specimens, cut them in two half-cylinders and store them for 48 hours in an oven at the highest ambient temperature to be expected (For AL-Sourani Dam in Syria at 73°C), the specimens were taken from the executed layers and were placed on a tilted plate with the inclination of the projected structure

(1:2.25) and held by a metal strip about 1 mm high, the rest of the cylinder height of ca. 65 mm being free to deform .

Deformation of the specimen was small within the first 24 hours and not further increase substantially during the second 24 hours [1], so we can say the layer is stable on the slope.

SITE INSPECTION

During the execution period specimens were continuously taken from the asphaltic mix and from executed layers after compaction. The void content and the mass density were determined. Experiment results showed that the values of void content were less than 3% of the specimens taken from the executed layers and laboratory specimens prepared by using the hot mix. The average rate of compaction was more than 97%.

Permeability factor of specimens of the executed layer was also indicated and the average value of six specimens was 4.2×10^{-8} cm/s.

Grain-size distribution was also controlled many times per day and the abnormal mixes were refused.

CONCLUSION

Asphaltic concrete linings for dams are today classed as state of art. Many dams are sealed with asphaltic concrete world-wide. AL-Sourani dam (SYRIA) was the first dam sealed with asphaltic concrete.

However, certain prerequisites are absolutely necessary for the successful use of this sealing method. First, there must be careful selection and suitability testing of the construction materials and then the subsequent elaboration of the mix composition for the various layer .

Professional placement and careful compaction are of critical importance for the quality of the finished lining. Moreover, continuous control of the construction materials, mix and layers placed is imperative.

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