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The Algerian Experience in the Waterproofness of the Bituminous Concrete Masks Advantages and Inconveniences

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Bounaadja Zoulikha [α], Dr. Lakhdar Djemili [σ] & Pr. Houichi larbi [ρ]

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I. Introduction

A bituminous concrete face has been historically a real alternative solution as a water barrier for embankment dam and for other hydraulic works.

Baron Van Asbeck reported the oldest known dam with a sort of primitive bituminous concrete facing to be ASSURE, constructed circa 1300 years BC in Mesopotamia. That is most significant, because it gives testimony to the antiquity of the design concept. Modern construction using bituminous concrete facings starts with CENTRAL dam built in the United States in 1910. In the last sixty years more than 300 dams of height of 30 m and reservoirs of height more 15m; their water barrier were assured by the bituminous concrete. [1]

The continuous progress in conceptions about the construction of masks of this type led us to proceed a study about its characteristics. And to do this, we took the Bouhanifia dam as a model for this study.

The bituminous concrete mask was the water barrier system of Bouhnifia dam "Algeria". It was applied on the upstream slope [2-3]. The mask risked to be unstable because of the effect of sunlight temperatures which can reach (65°C). So, it was covered with a thermal protection, this last is also constituted by a layer of cement concrete of 10 cm thick, armed with a fencing wire of galvanized steel, This layer must be continuously renovated because of cracking. So, the necessity of the renovation of the protective layer influenced on the total cost of the project.

The present work, on the one hand exposes a presentation of the aroused dams, and it is also an analyzed study including an approved results to avoid the setting up of two layers (sealing layer and thermal protective layer) and to minimize the costs of realization. So we studied the mechanical and physical behavior of a reduced sample of the mask seal of the Bouhnifia dam under a temperature of (+ 65 °C) without thermal protection.

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II. General Presentation of Dams

a) Ghrib Dam

The Ghrib dam is situated on the upper course of Oued Chélif. It accumulates waters of the upper pond with the aim of the irrigation of plains situated in downstream and additionally of the production of the electrical energy. The work is constituted by a dike of fastened rockfill.

Built between 1926 and 1938; the dam of Ghrib was the first work in rockfill realized with an upstream mask in bituminous concrete. This mask performed suitably its role of supple water barrier, in spite of the disappearance of its thermal protection of porous concrete in 1952.

i. *Features of the dam*

- Length in crest: 270 m,
- Width of the base: 148 m,
- Maximum Height: 72 m,
- Slopes upstream bank: vary from 2/3 à 1 / 1,
- Slope bank downstream : 5/4,
- Capacity of the restraint: 300.106 m3.

b) Sarno Dam

The dam of Sarno is built between 1947 and 1954 on the Oued of the same name, streaming of Mekerra which takes its source in the mounts of Daia and ends in the swamps of the Macta. The dam of Sarno, is a dike in homogeneous ground with upstream mask in bituminous concrete. The mask gives complete satisfaction because in full restraint, the flights are unimportant. The paint reflection which constitutes the thermal protection of the mask must be redone.

i. *Features of the dam*

- Height above the twig: 28 m,
- Length in crest: 310 m,
- Fruit of the upstream bank: 1/2 in 1/2,5,
- Fruit of the bank downstream: 1/2 in 2/3,
- Width of the massif of the base: 150 m,
- Capacity of the basin: 21.106 m^3.

c) Ighil Emda dam

The dam of Ighil Emda is built on the confluence of adding two Oueds, the Oued Beard and the Oued Embarek which form the Oued Agrioun in 2 km in the South of Kherrata, It is a fixed dam creating a restraint of 160.106 m3 intended to produce some electrical energy.

i. *Features of the dam*

- Length in crest: 710 m,
- Maximum height: 75 m,
- Width of the massif of the base: 265 m,
- Fruit of the upstream bank: 1/1,6,
- Fruit of the bank downstream: 1/1,5,
- Capacity of the basin: 155.106 m^3.

d) Bouhnifia dam

The dam Bouhanifia is built between 1930 and 1941 on Oued Elmmam which takes its source in the mounts of Daia and ends in the swamps of Macta. It is about a work in rockfills with upstream mask in bituminous concrete, widely inspired by the dam of Ghrib. The mask assures without failure its role of the water barrier. [3-4] (Figure 1)

The watershed of the dam has a surface of 7,850 km2 and the annual average flow of the Oued reaches 110.106 m^3.

i. *Features of the dam*

The main features of the dam and the structure of the bituminous concrete facing are given respectively in (Figure 2 and 3).

III. Study of the Mechanical and Physical Behavior of Impervious Facing System of Bouhnifia Dam in Absence of the Thermal Protection

The study of the composition of a bituminous concrete mask consists of choosing among the economically available materials: aggregates with big elements, thin elements, filler as well as a quantity of bitumen to constitute a steady and impervious material after compaction (Table 1). For that to make, it is necessary to determine a correct grading composition in order to reduce to the minimum the percentage of the voids in the compacted mixture to dry Figure 4. The voids must be filled of bitumen to achieve the imposed limits of practical considerations, a specific weight as high as possible [5].

a) Formulation of the bituminous concrete

i. *Features of the used materials*

- *Coarse Aggregations:* We call big aggregations all aggregates retained on the sieve N 10. These aggregates are constituted by rolled gravel, stones or milkmen ground.
- *Fine Aggregates:* We call by fine aggregates all the aggregates passing in the sieve n°10 and retained to the sieve N 200. These aggregates are constituted by natural sand or crushing or by a mixture of these two materials.
- *Filler:* We call filler all materials passing in the sieve °200 and constituted by dry chalky fine grains, or cement, or by all other fine and inert material.
- The aggregations must not be dismayed by the bad weather, to be not frost-susceptible, clean and exempt of dusts in excessive quantity, of homogeneous quality and must not include more than 5% of elementary flat; they must possess a good affinity for the bitumen [1]. The physical characteristics of the aggregates are given in Table 2
- *Bitumen:* The bitumen is gotten by refinement of oils. They must be of homogeneous composition, exempt of water, and must be in conformity with some specifications. The used bitumen is characterized by: The penetration index and Softening point (Table 2)

In view of the previous study of searching the best composition to adopt for the confection of the recommended spoiled, One determines:

The apparent density; the percentage of the voids occupied by the air; the percentage of the voids of the aggregations and the percentage of the voids occupied by the bitumen [6].

a) Mixing and preparation of the samples

- We weigh successively the fixed quantities of different composing aggregates, these quantities must be calculated for a spoiled from 1000 to 1200 g, (binder not included).
- We carry the container and its content in an oven adjusted in 140° C during one hour. In another container, we put the quantity of the binder; we heat it to a temperature between 140 °C and 160 °C during 30 to 45 minutes in order to confer it to the

necessary fluidity of the coating without attending the temperature where the spraying of oils would become excessive.

- Immediately retired from the oven, the aggregations are poured in the binder's container. We add the filler, which doesn't need to be heated, but it must be dry. The mixture is introduced in a normalized mixer and it is homogenized during 30 minutes.
- We fill the molds, while packing every time with the spoon; we adjust the full cylinder and we carry it all between the trays of press. The samples are compacted by 50 strokes. For the aim of letting the samples cool, it is kept during 24 hours in the ambient temperature.
- We measure to the slide gauge, to the 1/10 of mm meadows the diameters and the heights of the samples and we weigh them at 0.5g meadows. (Figure 4)

b) *Determinations of the properties of the bituminous Mixing "samples"*

After verification of the features of the formulated bituminous concrete, we undertook the following tests: The compression resistance; the percentage of imbibition; the percentage of inflation; the stability following Marshall after immersion during 14 days; the permeability and the stability on the slope. [5-7]

i. *The Compression Resistance*

After confection of the samples, these are immersed in baths under temperatures 0°C, 20°C and 50°C during 3 hours. The samples are withdrawn from the baths and are immediately placed between the trays of the press. The compressive test has been driven on cylindrical samples with a press of capacity 1500 KN.

ii. *Percentage of Imbibition*

Two samples in view of calculation of the imbibition. The percentage of imbibition calculates from the following formula:

$$\left(\frac{P_h - P_o}{P_o}\right).100 \qquad (1)$$

In which:

Ph: Weight of the sample moistened after 14 days,

Po: Weight of the sample before the immersion.

iii. *Percentage of Inflation*

$$\left(\frac{V_h - V_o}{V_o}\right).100 \qquad (2)$$

In which:

V_O and *Vh*: are respectively the volumes of the samples before and after the immersion during 28 days.

iv. *Stability following Marshall after immersion during 14 days*

The stability of the samples is determined after 14 days of conservation under water to the ambient temperature with the Marshall device (Figure 5).

v. *Permeability*

The seal is the fundamental quality of a mask; all samples have been tested under a water pressure of 6 kg. They are all stayed sealed after 24 hours of contact. The value of the favorite permeability must be lower to the recommended value of 5.10^{-8} cm/s [2-5].

The coefficient of permeability is calculated with the following relation:

$$K(cm/s) = \frac{q \times l}{h \times f} \qquad (3)$$

In which :

q: debit of flight of (cm^3/s),

l: the thickness of the plate of (cm),

h: pressure of (cm) of water, measured since the lower face of the plate,,

f: surface of the sample of (cm^2).

vi. *Verification of the stability on the slope*

To verify the stability of the bituminous coatings put on slope, some samples put on an inclined support of 1/1 (slope of the Bouhanifia dam) (Figure 6), and placed in an oven during 48 hours under a temperature of 70°C, the samples must distort during the test [5-7].

The results of the tests are presented in Table 3.

IV. Results and Discussion

According to the (figure 4) we noticed that the grading curve of the mixture was registered in the recommended spindle which gave us a correct composition and allowed to reduce the percentage of the voids in the mixture, this last was the most important characteristic in the bituminous concrete, because it assured its permeability and durability. It also protected the bituminous concrete from the outside effects, that's why we gave a lot of importance for that characteristic (one tried to reduce to the maximum the percentage of the voids occupied by air). The advisable value was between (1, 5% and 2, 3%). For our case one found 1.75 which is in the norms.

For the percentage of the voids between the grains, the advisable value must be superior to (16-19) % and lower to 22%. According to the Table 3, we noticed that the percentage 21.68% respected the advisable norms. Following the found results, one noticed that all securities levels were in the norms and in the limits of the advisable securities.

Finally, concerning the verification of the stability of the samples on the tilted slope, which is the purpose of this research we found that, After the 48 hours of conservation, the samples kept their initial shapes which allowed us to determine that the bituminous concrete facing resisted indeed the elevated temperatures without risking of deforming. (Figure 6).

V. Conclusion

The gotten results and observations during the exploitation of the four Algerians dams with bituminous concrete masks are:

- Excellent holding of the upstream mask, which followed the massif deformations without losing its qualities, in spite of the slope equals 1/1 and temperatures reach 60-70 ° C.
- Competitive cost price: the mask of Ghrib cost only 1/100th of the cost of the work, that of the Ighil Emda 5/100th. These costs are lower than those of an impervious core or concrete face, taking into account local circumstances.

The bituminous concrete mask is certainly the easiest and the most economical solution that can be designed for perfect sealing of embenkement dams. The complete coating as it was executed in Bouhnifia dam doesn't present hundredth part of the cost of the work, however one takes into account the significant costs of developing the method and the high construction costs of special equipment.

The major problem of such type of masks is the surface temperature due to solar radiation, according to the conducted tests and the obtained results; we can say that the bituminous concrete mask of Bouhnifia dam resists one to one temperature (70 ° C) in spite of the absence of the thermal protection.

VI. Acknowledgments

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Table 1 : Features of bituminous concrete facing of Bouhanifia dam

Grain diameter	(mm)	percent (%)
Gravel	18/25	20.54
	12/18	14.65
	5/12	19.96
	2.5/5	6.75
Sand	0.63/2.50	10.17
	0.28/0.63	13.90
	0.1/0.28	4.28
Filler	Smaller than 0.1	9.75
Bitumen	Penetration 80/100	8% by weigh of dry materials

Table 2 : Physical features of aggregates "mixing" and bitumen

Number of samples	Specific gravity (t/m^3)	Sand Equivalent (%)
03	2.66	77.33
Number of samples	Index penetration	Softening point
03	84	51°

Table 3 : Results Table For Bouhnifia mask

Studied characteristics	Mean obtained values	Recommended values
Density (g/cm^3)	2.39	Maximal
Creep (mm)	2.72	≤ 8.0
Stability (KN)	8.00	≥ 6.0
% Air voids	1.75	(1.5-2.3)
% Aggregate voids	21.68	> (16-19) %
Compressive strength R20 (kg/cm2)	79.62	> 30
Compressive strength R50 (kg/cm2)	19.90	> 15
Coefficient of thermal stability K_t	4.00	> 2.5
Flexibility coefficient K_e	1.50	< 2.8
Imbibition percentage (%)	0,39	< 1.50
Percentage of swelling Percentage of swelling (%)	0.39	< 0.5
Marshall stability after immersion 28 days.	9.50	> 5.4
Permeability (cm/s)	$4.10.10^{-8}$	5.10^{-8}

Figure 1 : Bouhnifia dam

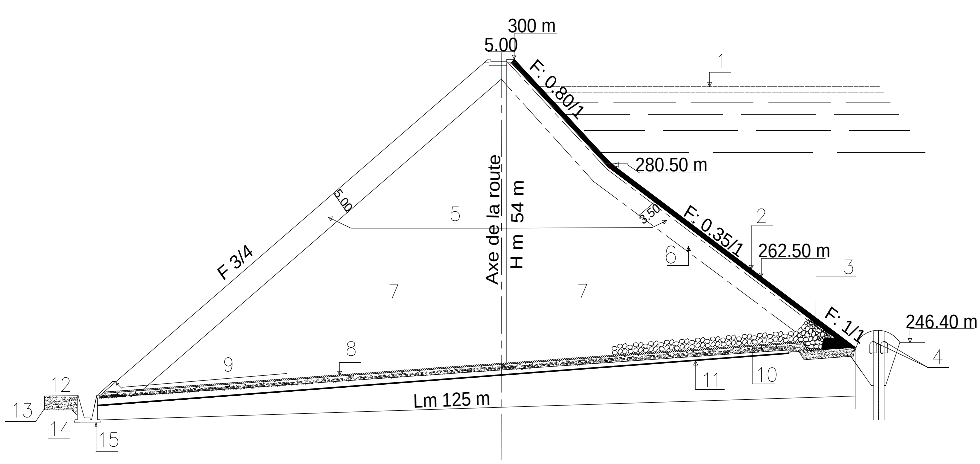

Figure 2 : Cross the mask Bouhnifia dam

Legends

1 - Hold Normal: 295.00 m.
2 - Mask tight.
3 - Masonry hourdée permeable gravel to concrete.
4 - Galleries and drainage work.
5 - Loose stones neatly arranged.
6 - Sitting slightly raised decrease the step.
7 - Rock boulders secured.
8 - Layer masonry.
9 - Berm for listing 248.00m.
10 - Filter.
11 - Drain Bonna.
12 - Pavement.
13 - Filter.
14 - Murette.
15 - Cambre colature of drainage.
16 - Layer Oliocène.

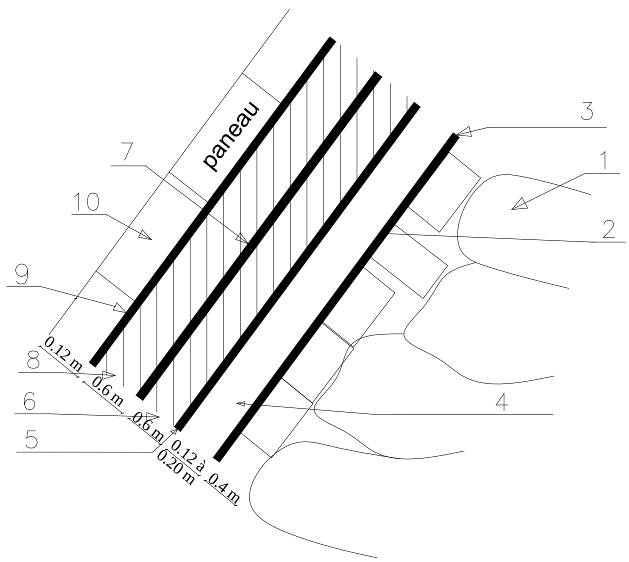

Figure 3 : Structure of the mask seal

Legends

1- Rock.
2 - Reinforcement.
3 - Coating mortar.
4 - Concrete Buidling the drainage layer.
5 - Hinge bitumen dissolved in gasoline.
6 - to 1st layer waterproof asphalt concrete.
7 - Filler bitumen fluxed with gasoline.
8 - 2nd sealed asphalt concrete layer.
9 - Paper interposed to prevent contact between the front mask and the barrier layer.
10 - Signs of the front protective mask made of reinforced concrete.

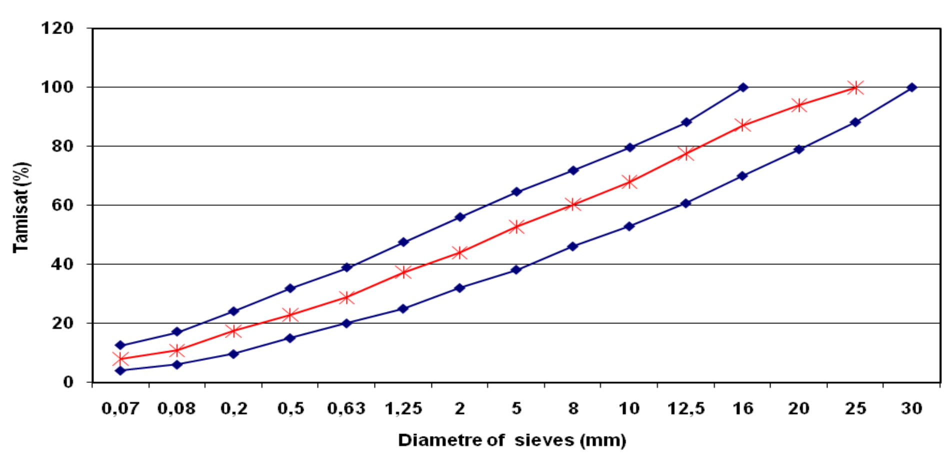

Figure 4 : Grading curve of the mixture (gravel, sand and filler)

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Legends

1 - From 0.01 mm to 30 mm diameter of sieve.

2 - 0 to 100%: percentage of underflow.

3 -: Time recommended size.

4 -: Grading curve of the mask seal of Bouhnifia dam.

Figure 4 : Sections of the samples

Figure 5 : Marshall Test

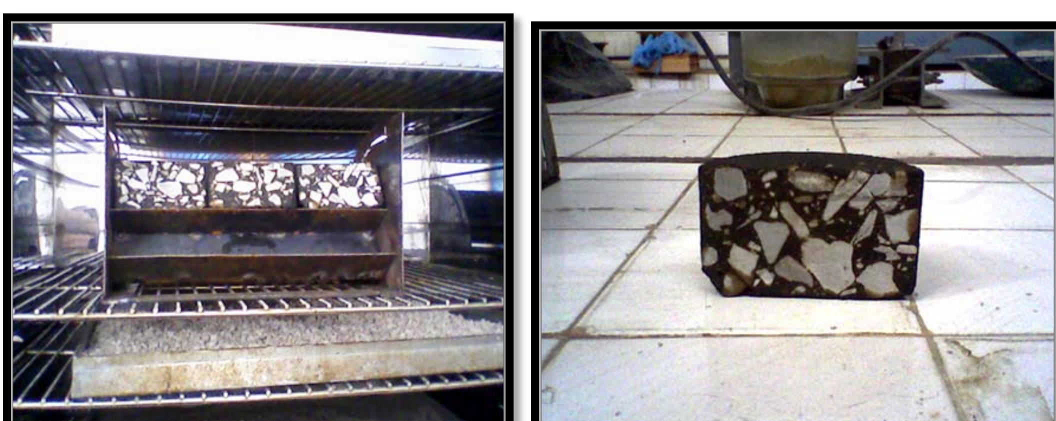

Figure 6 : Specimens after storage 48 h in the oven

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