

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

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Abstract

The experience of the use of bituminous concrete upstream facing is presented in Algeria in the four big dams: Ghrib (1926-1938), Bouhnifia (1930-1941), Sarno (1947-1954) and Ighil Emda, The problem posed in the aroused dams is especially delicate because of the instability of the mask which could become precarious to the temperature. Therefore it was covered with a thermal protection, which demands a periodic renovation. This solution was very expensive. To avoid these costs, one tried to test the stability of the mask without the thermal protection. One prepared a reduced sample of the mask of bouhnifia dam. Then, one put this sample on an inclined facing of 1/1 (slope of the dam); and maintained it in an oven during more than 48 hours under a temperature of 70 C°. This experience permitted to determine that the sample kept its initial shape. The gotten results confirmed that the mask of the Bouhnifia dam can resist the action of the temperature without the necessity of the thermal protection.

Index terms— dam, water barrier, upstream mask, bitumen, bituminous concrete.

1 Introduction

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.

41 **2 II.**

42 **3 General Presentation of dams a) Ghrib Dam**

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

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

49 **4 d) Bouhnifia dam**

50 The dam Bouhanifia is built between 1930 and 1941 on Oued Elmmam which takes its source in the mounts
51 of Daia and ends in the swamps of Macta. It is about a work in rockfills with upstream mask in bituminous
52 concrete, widely inspired by the dam of Ghrib. The mask assures without failure its role of the water barrier.
53 [3][4] (Figure ??)

54 The watershed of the dam has a surface of 7,850 km² and the annual average flow of the Oued reaches 110.106
55 m³.

56 **5 i. Features of the dam**

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

59 **6 III.**

60 **7 Study of the Mechanical and Physical Behavior of Impervious Facing System of Bouhnifia Dam in**

61 Absence of the Thermal Protection

62 The study of the composition of a bituminous concrete mask consists of choosing among the economically
63 available materials: aggregates with big elements, thin elements, filler as well as a quantity of bitumen to
64 constitute a steady and impervious material after compaction (Table 1). For that to make, it is necessary to
65 determine a correct grading composition in order to reduce to the minimum the percentage of the voids in the
66 compacted mixture to dry Figure ?. The voids must be filled of bitumen to achieve the imposed limits of
67 practical considerations, a specific weight as high as possible [5]. a) Formulation of the bituminous concrete i.
68 Features of the used materials -Coarse Aggregations: We call big aggregations all aggregates retained on the
69 sieve N 10. These aggregates are constituted by rolled gravel, stones or milkmen ground.

70 -Fine Aggregates: We call by fine aggregates all the aggregates passing in the sieve n°10 and retained to the
71 sieve N 200. These aggregates are constituted by natural sand or crushing or by a mixture of these two materials.

72 -Filler: We call filler all materials passing in the sieve °200 and constituted by dry chalky fine grains, or cement,
73 or by all other fine and inert material.

74 -The aggregations must not be dismayed by the bad weather, to be not frost-susceptible, clean and exempt
75 of dusts in excessive quantity, of homogeneous quality and must not include more than 5% of elementary flat;
76 they must possess a good affinity for the bitumen [1]. The physical characteristics of the aggregates are given
77 in Table 2 -Bitumen: The bitumen is gotten by refinement of oils. They must be of homogeneous composition,
78 exempt of water, and must be in conformity with some specifications. The used bitumen is characterized by:
79 The penetration index and Softening point (Table 2)

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

82 The apparent density; the percentage of the voids occupied by the air; the percentage of the voids of the
83 aggregations and the percentage of the voids occupied by the bitumen [6]. a) Mixing and preparation of the
84 samples ? We weigh successively the fixed quantities of different composing aggregates, these quantities must be
85 calculated for a spoiled from 1000 to 1200 g, (binder not included). ? We carry the container and its content in
86 an oven adjusted in 140° C during one hour. In another container, we put the quantity of the binder; we heat
87 it to a temperature between 140 °C and 160 °C during 30 to 45 minutes in order to confer it to the necessary
88 fluidity of the coating without attending the temperature where the spraying of oils would become excessive.
89 ? Immediately retired from the oven, the aggregations are poured in the binder's container. We add the filler,
90 which doesn't need to be heated, but it must be dry. The mixture is introduced in a normalized mixer and it is
91 homogenized during 30 minutes. ? We fill the molds, while packing every time with the spoon; we adjust the full
92 cylinder and we carry it all between the trays of press. The samples are compacted by 50 strokes. For the aim of
93 letting the samples cool, it is kept during 24 hours in the ambient temperature. ? We measure to the slide gauge,
94 to the 1/10 of mm meadows the diameters and the heights of the samples and we weigh them at 0.5g meadows.
95 (Figure ??) b) Determinations of the properties of the bituminous Mixing "samples"

97 After verification of the features of the formulated bituminous concrete, we undertook the following tests: The
98 compression resistance; the percentage of imbibition; the percentage of inflation; the stability following Marshall
99 after immersion during 14 days; the permeability and the stability on the slope.
100 $V(2)$

101 In which:

102 V_0 and V_h : are respectively the volumes of the samples before and after the immersion during 28 days.

103 **8 iv. Stability following Marshall after immersion during 14** 104 **days**

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

107 **9 v. Permeability**

108 The seal is the fundamental quality of a mask; all samples have been tested under a water pressure of 6 kg.
109 They are all stayed sealed after 24 hours of contact. The value of the favorite permeability must be lower to the
110 recommended value of 5.10 -8 cm/s [2][3][4][5].

111 The coefficient of permeability is calculated with the following relation: $f = \frac{q \cdot l}{h \cdot K} \times 10^{-8}$ (3)

112 In which : q: debit of flight of (cm³/s), l: the thickness of the plate of (cm), h: pressure of (cm) of water,
113 measured since the lower face of the plate,, f: surface of the sample of (cm²).

114 **10 vi. Verification of the stability on the slope**

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

118 The results of the tests are presented in Table 3.

119 **11 IV.**

120 **12 Results and Discussion**

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

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

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

135 V.

136 **13 Conclusion**

137 The gotten results and observations during the exploitation of the four Algerians dams with bituminous concrete
138 masks are: ? Excellent holding of the upstream mask, which followed the massif deformations without losing its
139 qualities, in spite of the slope equals 1/1 and temperatures reach 60-70 ° C. ? Competitive cost price: the mask
140 of Ghrib cost only 1/100th of the cost of the work, that of the Ighil Emda 5/100th. These costs are lower than
141 those of an impervious core or concrete face, taking into account local circumstances.

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

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

149 14 VI.

150 15 J

151 Cross the mask Bouhnifia dam

152 Figure 2 :



Figure 1:

153 1 2 3

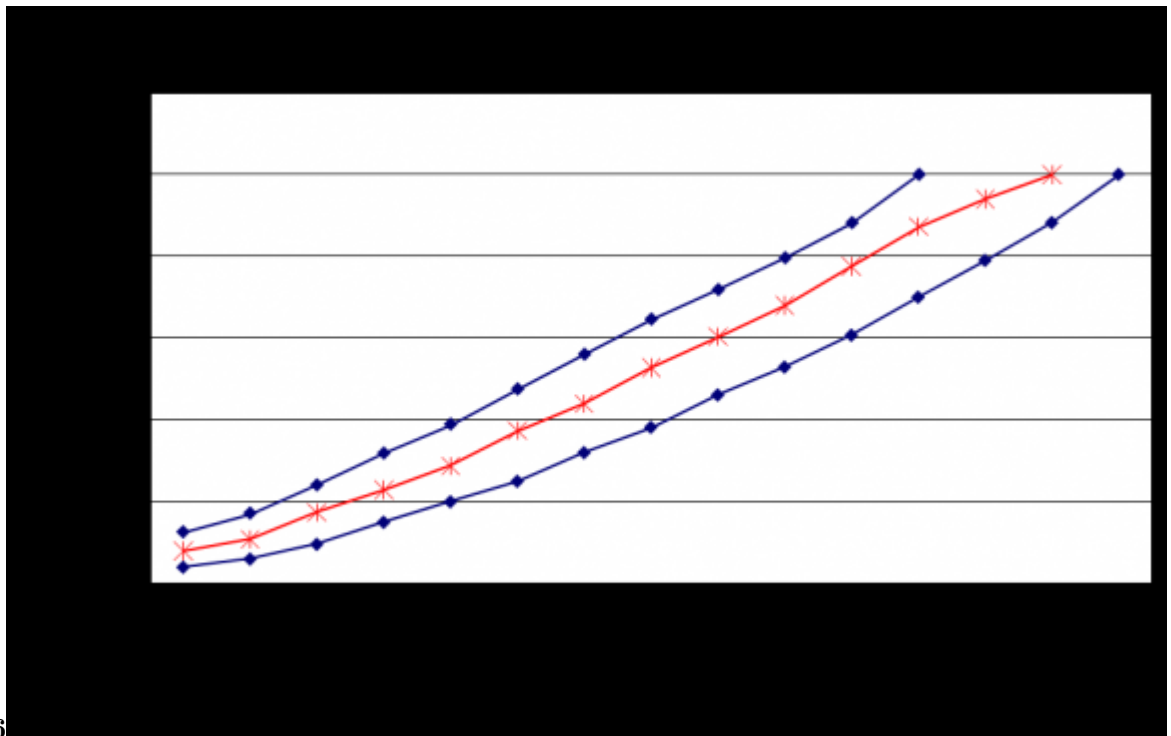
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Figure 2:



36

Figure 3: Figure 3 : 6 J



Figure 4: Figure 4 :Legends 1 -

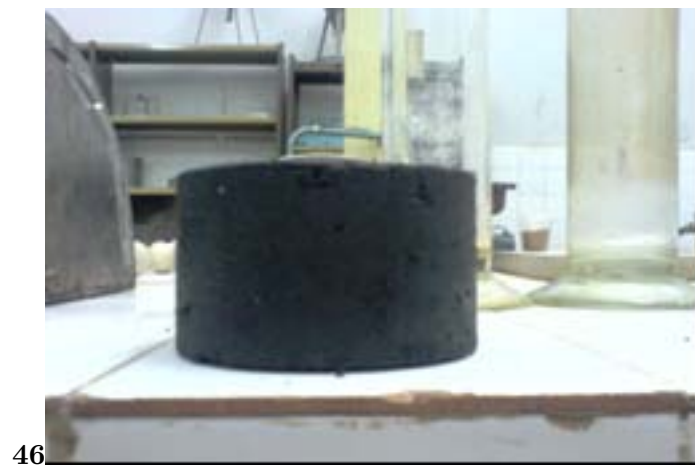


Figure 5: Figure 4 :Figure 6 :

1

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

Figure 6: Table 1 :

2

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

Figure 7: Table 2 :

3

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/cm ²)	79.62	> 30
Compressive strength R50 (kg/cm ²)	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	0.39	< 0.5
Percentage of swelling after immersion 28 days.	9.50	> 5.4
Permeability (cm/s)	4.10.10 ⁻⁸	5.10 ⁻⁸

[Note: © 2014 Global Journals Inc. (US)]

Figure 8: Table 3 :

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