Improvement of the characteristics of the bituminous concrete employed for the waterproofness of dams by the filler Bouhnifia dam (Algeria)

Amélioration des caractéristiques du béton bitumineux employé pour l'étanchéité des barrages en remblai par le filler barrage Bouhnifia (Algérie)

Zoulikha Bounaadja[1]*, Lakhdar Djemili[1] & Mouhamed Mansour Chiblak[2]

[1] Department of Hydraulic, Faculty of Sciences Engineering, Badji Mokhtar University, Po Box 12, Annaba, 23000, Algeria.
[2] Faculty of Civil Engineering, Damascus, Syria.

Article Info

Article history:

Received 18/02/2019
Revised 11/04/2019
Accepted ##/ /####

Keywords

Dam, Waterproofness, Bituminous concrete, Filler Stability.

ABSTRACT

Bituminous concrete masks have historically been a real solution to the sealing organ of the dams and other hydraulic works, given the mechanical and hydraulic qualities of the material. The continuous progress in the design and construction of the masks of this type led us to carry out a study of its characteristics. A study in this direction to verify the resistance of the bituminous concrete mask from Bouhnifia dam to the solar effects shows that this mask can withstand these effects without the need for the thermal protection layer. In this work and to improve the characteristics of bituminous concrete, we studied the mechanical and physical characteristics of bitumen and stability on the slope. To do this, the percentage of filler in the mixture must be changed. Then samples must be prepared in the laboratory and tested. This study shows that the improvement of bituminous concrete with appropriate amounts of filler reduces the volume of vacuums; make the mixture denser and impermeable. However, excessive amounts of filler will significantly increase bitumen demand due to increased specific surface area, decrease creep, and increase percentages of imbibition and swelling.

Mots clés
Barrage , Etanchéité, Béton bitumineux, Filler, Stabilité.

Résumé

Les masques en béton bitumineux ont été historiquement une réelle solution pour constituer l'organe d'étanchéité des barrages en remblai et autres ouvrages hydrauliques, étant donné les qualités mécaniques et hydrauliques du matériau. Les progrès continus dans la conception et la construction des masques de ce type nous ont conduits à procéder à une étude de ses caractéristiques. Une étude faite dans ce sens, visant à vérifier la résistance du masque en béton bitumineux du barrage Bouhnifia aux effets solaires, montre que ce masque peut résister à ces effets sans la nécessité de la couche de protection thermique. Dans ce travail et pour l'amélioration des caractéristiques du béton bitumineux, nous avons étudié les caractéristiques mécaniques et physiques du bitume et la stabilité sur le talus ; pour ce faire on doit changer le pourcentage de filler dans le mélange. Ensuite, les échantillons doivent être préparés en laboratoire et testés. Cette étude montre que l 'amélioration du béton bitumineux avec des quantités convenables de filler fait baisser le volume des vides, rend le mélange plus dense et imperméable. Par contre, des quantités excessives de filler accroitront notablement la demande en bitume en raison de la surface spécifique accrue, diminue le fluage et augmente les pourcentages d'imbibition et du gonflement.

***Corresponding Author**
Zoulikha Bounaadja
Department of Hydraulic, Faculty of Sciences Engineering, Badji Mokhtar University,
Po Box 12, Annaba, 23000, Algeria.
E-mail :bounaadja_z@yahoo.fr

©UBMA - 2019

1. INTRODUCTION

The problem of the waterproofness of the massif is raised every time the calculation of the infiltration in the superstructure indicates inadmissible losses; these losses may either lead to the destruction of the element by formation of piping, or, without harming its security, to be awkward for the exploitation of the dam. The problem of water leaks is very complex because it threatens the quantities of water accumulated in most of the dams all over the world, and engenders a worry about the stability of these installations, especially if this problem persists. A bituminous concrete mask, adopted like a water barrier of the embankment dam, is often competitive in consideration to costs, comparing to other more classical measures, such as ground core, or other replacement solution like an armed concrete mask, or an internal screen of bituminous concrete. The bituminous concrete upstream masks present the most technical and economic organ, this type is used for a long time to ensure the sealing of the embankment dam. [1, 2, 3]. 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 behavior of the bituminous concrete masks of the Algerian dams during their life is generally satisfactory, except for the problems presented in the layer of protection which requires each time maintenance or a full renovation. [4, 5]. The bituminous concrete mask must be tight and stable; the sealing depends on the granulometry of the aggregates, the pc ercentage of bitumen binder and the compaction. The stability depends on the type of the bitumen, of the percentage of the voids after compaction and the granulometry of the aggregates. The principal materials constituting these masks are: bitumen, aggregates and filler.In the present work, we will study the mechanical and physical characteristics of the bituminous concrete by adding to it the fines, and study its influence on the stability and the sealing of the mixture

2. MATERIAL AND METHODS

2.1 Characteristics of the 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 [6, 7]. 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. The main characteristics of the dam and the structure of the bituminous concrete lining are given respectively in figures 1 and 2.

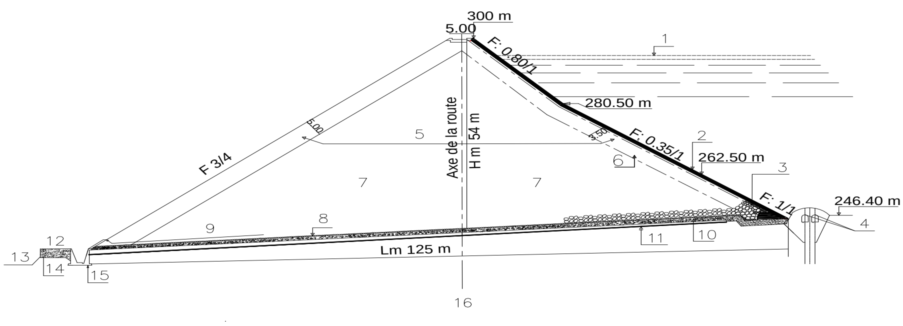

Figure 1. Cross the mask Bouhnifia dam

©UBMA - 2019

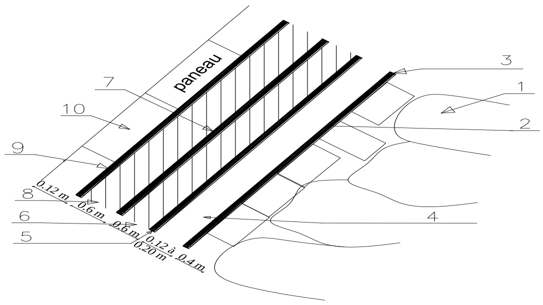

Figure 2. Structure of the mask seal

2.2. Experimental process

Formulation of the bituminous concrete

The study of the composition of a bituminous concrete mask consists of choosing among the available materials: aggregates with big elements, thin elements, fines as well as a quantity of bitumen to constitute a steady and impervious material after compaction [8]. To make that, it is necessary to determine a correct granulometric composition in order to reduce to the minimum the percentage of the voids in the compacted mixture on dry (Fig. 3 (3a, 3b, 3c)). The voids must be filled of bitumen to achieve the imposed limits of practical considerations, a specific weight as high as possible [9, 10].

- **Coarse aggregates**: 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 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 N° 200 and constituted by dry chalky fine grains, or cement, or by all other fine and inert material. Fillers must be exempt of lumps. We can accept fillers of fines which passé in totality in the sieve N° 80 among which 65% at least pass in the sieve N° 200.

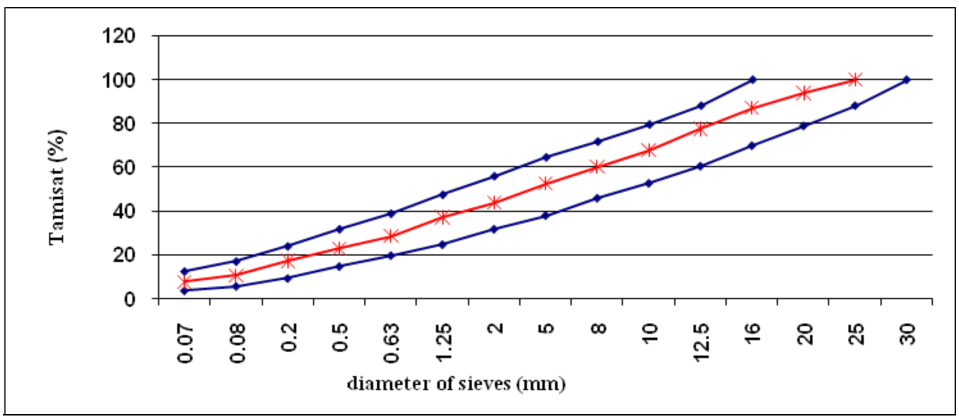

Figure 3.a. Grading curve of the 1st mixture « Filler 10 % »

©UBMA - 2019

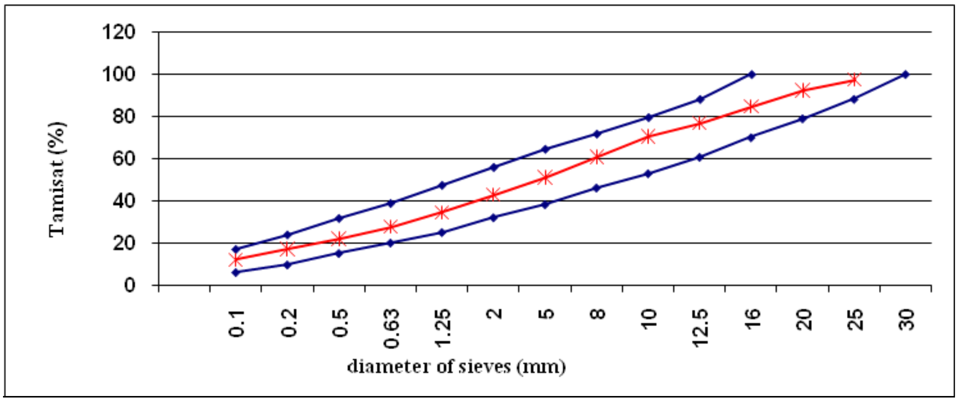

Figure 3.b. Grading curve of the 2nd mixture « Filler 15 % »

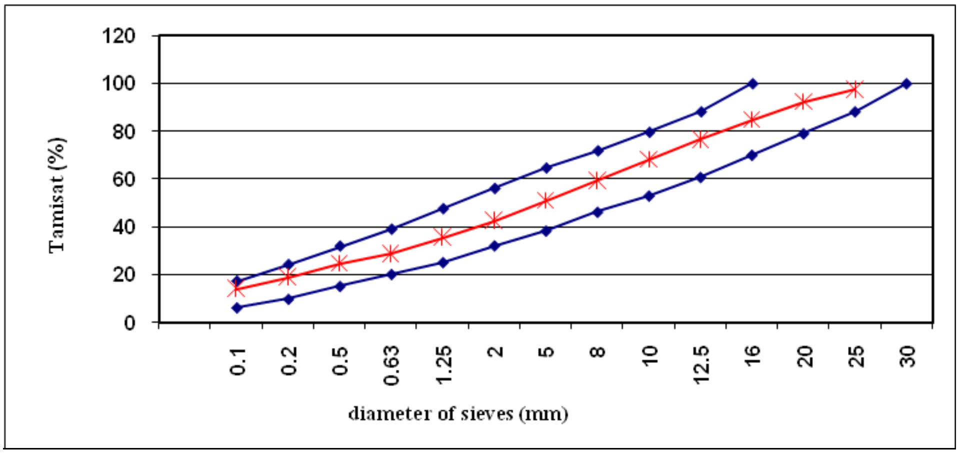

Figure 3.c. Grading curve of the 3rd mixture « Filler 20 % »

Figure 3. Grading curve of the mixture

These aggregations must not be dismayed by the bad weather, to be not frost-riven, clean and exempt of dusts in excessive quantity, of homogeneous quality and must not include more than 5% of flat elements; they must possess a good affinity for the bitumen [11]. The values taken are the average of three results which are given in table 1.

Table 1. Physical characteristics of the granulates" mélange"

Pourcentage of the filler	Specific gravity (t/m^3)	Sand équivalent (%)
10 %	2.66	77.33 %
15 %	2.86	54.79 %
20 %	2.39	54.79 %

Bitumen

The bitumen is obtained by refinement of oils. They must be of homogeneous composition, exempt of water, and must comply with some specifications. The used bitumen is characterized by: The penetration index and Softening point which are given in table 2.

Table 2. Physical characteristics of the bitumen

Number of samples	Index penetration	Softening point
03	84	51°

©UBMA - 2019

The composition of bituminous concrete for each percentage is given in table 3.

Table 3. The composition of bituminous concrete for each percentage

materials	**1st mixture**	**2nd mixture**	**3rd mixture**
Gravel of 12 à 25 mm	35.19 %	31.60 %	28.50 %
Gravel of 5 à 12 mm	19.71 %	18.50 %	16.40 %
Crushing sand of 0 à 5 mm	20.00 %	20.00 %	20.00 %
Sand of dune	15.10 %	15.10 %	15.10 %
Filler	10.00 %	15.00 %	20.00 %
Bitumen 40/50	8.00 %	8.00 %	8.00 %

Mixture preparation of samples confection [9, 10]

- ✓ We weigh successively the fixed quantities of different composing aggregates, these quantities must be calculated for a spoiled from 1000 to 1200 g.
- ✓ The author holds 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 achieving the temperature where the spraying of oils would become excessive. (Bitumen should not release steam).
- ✓ Immediately removed from the oven, the aggregations are spoiled in the binder's container. We add after, the filler, which doesn't need to be heated, but which must be dry. We mix everything during 30 minutes.
- ✓ We fill the moulds, by packing each time with the spoon; we pour the totality of the batch. We adjust the full cylinder and we carry the whole between the plates of the press for compacting.
- ✓ We measure to the slide gauge, at 1/10 mm close to the diameters and the heights of the samples and we weigh them at 0.5 g meadows (Fig. 4).

Figure 4. Test specimen characteristics

In view of the preliminary study of the best composition to be adopted for making a mixture with recommended characteristics, Determines: [9], [10] Stability; Creep; Apparent density; Percentage of the voids occupied by the air and Percentage of the voids of aggregates. After verification of the features of the formulated bituminous concrete, we carried out the following tests: [9], [10] Resistance to compression; Imbibitions percentage; Inflation percentage; Stability following Marshall after immersion during 28 days (Fig.5); permeability and Stability on the slope.

©UBMA - 2019

Figure 5. Marshall Test

The resistance to compression

After confection of the test specimen, 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. The results are given in table 4.

Percentage of imbibition

Two samples are maintained under water at a temperature of 18°C during 14 days and then weighed in view of imbibition calculation. The percentage of imbibition is calculated from the following formula:

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

P_h: Weight of the sample moistened after 14 days,
P_o: Weight of the sample before the immersion.

The results are given in table 4.

Percentage of inflation

The same samples immersed under water during 14 days to the same temperature are measured to determine the inflation. The percentage of inflation is calculated according to the following formula:

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

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

The results are given in table 4.

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 [4, [9]. The coefficient of permeability K is calculated with the following relation:

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

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).
The results are given in table 4.

©UBMA - 2019

Verification of the stability on the slope

Tests specimens have been pasted on an inclined holder 1/1 (dam slope) (Fig. 6), after 48 hours of conservation in a hot room at a temperature of 70°C (temperature on the surface of the mask [9, 12]. The samples must not deform during the test.

Figure 6. Preserved test-tubes 48h in the drying oven

3. RESULTS AND DISCUSSION

- According to the figure 3 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 (and we tried to reduceto the maximum the percentage of the voids occupied by air). The three results are between (1, 5% and 2, 3%) which is within the standards.
- 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 4, we noticed that the three percentages are respecting the advisable norms.

Table 4. Results Table

Studied characteristics	Mean obtained values **Filler 10%**	Mean obtained values **Filler 15%**	Mean obtained values **Filler 20%**	Recommended values
Density (g/cm^3)	2.39	3.36	4.31	Maximal
Creep (mm)	2.72	2.50	1.40	≤ 8.0
Stability (KN)	8.00	20.0	27.0	≥ 6.0
% Air voids	1.75	1.70	1.65	(1.5-2.3)%
% Aggregate voids	21.68	20.9	20.00	> (16-19) %
Compressive strength R20 (kg/cm2)	79.62	109.47	109.47	> 30
Compressive strength R50 (kg/cm2)	19.90	29.86	19.90	> 15
Coefficient of thermal stability K_t	4.00	3.67	5.50	> 2.5
Flexibility coefficient K_e	1.50	1.27	0.91	< 2.8
Imbibition percentage (%)	0,391	0.482	0.87	< 1.50
Inflation Percentage (%)	0.392	2.01	2.00	< 0.5
Marshall stability after immersion 28 days.	9.50	23.75	26.0	> 5.4
Permeability (cm/s)	$7.05.10^{-8}$	$7.00.10^{-8}$	$6.80.10^{-8}$	m/s -8 5.10

For Verification of the stability on the slope, we found the following results:

- For a percentage of filler 10%: Tests specimens have conserved their initial form (Fig. 7).
- For a percentage of filler 15% and 20%: Tests specimens have lost their shape (Fig. 8).

©UBMA - 2019

Figure 7. Specimens after storage 48 h in the oven.(Filler 10%)

Figure 8. Test of stability on slope (Filler 15% and 20%)

According to the found results, can say that the improvements of the asphaltic concrete with suitable quantities of filler make:

- Lower the volume of voids,
- Make the mixture denser and impermeable.
- Decrease creep,
- Increase the percentages of imbibitions and swelling.
- On the other hand, excessive quantities of filler will increase the request, notably bituminous some because of increased specific surface.

According to the got results, one can conclude that the increase in the percentage of the filler makes decrease the stability on the slopes under the influence of the temperature.

4. CONCLUSION

The bituminous concrete mask is certainly the easier solution to realize and the most economical which can be conceived for perfect waterproofness of embankment dam.
The filler is used to facilitate the handiness and the compaction of the mixture. the handiness is important because rough mixtures, tend to get teared at the time of their installation, the improvement of the handiness with suitable quantities of filler make lower the volume of the voids and make the mixture denser and impermeable.
On the other hand, excessive quantities of filler will increase the request, notably bituminous some because of increased specific surface and make it unstable under the influence of the temperature.

Acknowledgments

The authors address their acknowledgments to: the technical Director of the Laboratory of the Public Works of Annaba (LTP EST ANNABA), the department of hydraulics and the department of civil engineering, who brought an efficient help for the preparation of this work, and to all those who contributed to the execution of this work.

©UBMA - 2019

REFERENCES

[1] CFBR. 2012, Technologie des barrages, Comité français des barrages et réservoirs. Cedex. Paris.

[2] Ledelieu. 2008, Grands barrages, Petits barrages, Le Comité Technique permanent des Barrages et Ouvrages Hydrauliques, Revue Risques Infos 20 6.

[3] E. Alonso., J.P. Becue., G. Bolle., J.L. Brodin., P. Brunel., A. Cassard., G. Degoutte., M. Dore., D. Lautrin., J. Lafevre., G. Michel., P. Royet. & G .Tratapel. 2002, Barrages en remblai : Petits barrages et recommandations pour la conception, la réalisation et le suivi. CEMAGREF ED 67-111.

[4] K. Belbachir., B. Montel., L. Chervier. 1973, Comportement des masques d'étanchéité en béton bitumineux des barrages. XI^{éme} ICOLD 3 1053-1073.

[5] Z. Labiod., B. Remini., M. Belaredj. 2004, Traitement de la vase du barrage Bouhnifia en vue de sa valorisation. Laboratoire de recherche en hydraulique souterraine et de surface, Larhyss journal, ISSN 1112-3680, 03 7-12.

[6] CFGB. 1973, L'expérience française des masques amont en béton bitumineux. XI^{ème} ICOLD 124 101 – 124.

[7] V. Drouhin. 1936, Barrages du Bakhadda et de Bou-hanifia. Annales institut technique du bâtiment.

[8] M. Duriez, J. Arrambide, 1962. Nouveaux traités de matériaux de construction : Liants et bétons hydrocarbonés, Tome III. 2ème édition, DUNOD Paris

[9] W.F.V. Asbeck,1969. le bitume dans les travaux hydraulique. Vol II Dunod paris.

[10] J.G. Mallouk, 2012. Les enrobés bitumineux. Tome 1. Modulo Editeur.

[11] CIGB.1999, Barrages en remblai avec masque en béton bitumineux. ICOLD 114. 4 13 - 91.

[12] L. Djemili., M. Chiblak. 2007, Study of the temperature distribution in the bituminous concrete facing used in fill dams in the semi arid region of west Algeria. Courrier du savoir scientifique et technique, Algérie.

[13] N. Larcher, M. Takarli, N. Angellier, C. Petit & H. Sebbah, 2014. Towards a viscoelastic mechanical characterization of asphalt materials by ultrasonic measurements, Materials and Structures.

[14] A. Béghin, M. Peyronnet, 2014. Entrerpise Malet : le maniabilimètre au service des enrobés tièdes. Revue Générale des Routes et de l'Aménagement, 922: 118-119.

[15] A. Hanz. A & H. Bahia, 2013. Asphalt Binder Contribution to Mixture Workability and Application of Asphalt Lubricity Test to Estimate Compactability Temperatures for Warm-Mix Asphalt. In Transportation Research Record: Journal of the Transportation Research Board, 2371: 87-95.

[16] B. Bidewell, B. Birgisson & N. Kringos .2013. Evaluation of environmental susceptibility of bituminous mastic viscosity as a function of mineral and biomass filler. In Transportation Research Record: Journal of the Transportation Research Board, 2371: 23-31.

©UBMA - 2019