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# Study of the Temperature Distribution in the Bituminous Concrete Facing Used in Fill Dams in the Semi Arid Region of West Algeria

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**Abstract:** The main objective of this research was first of all to establish a mathematical relationship for the maximum temperature on the surface of the bituminous concrete facing used in existing and future earth dam's construction in the semi arid region of west Algeria without taking any in-situ experimental measurements. Secondly it was to study the influence of some factors on this temperature. The results which have been obtained showed that the maximum temperature on the surface of the bituminous concrete facing was proportional to the air temperature of the site and also depend on the climatic, geographical and geometric factors.

**Key words:** Bituminous, facing, fill dams, surface, temperature

## INTRODUCTION

Bituminous surfacing techniques were the subject of a significant development in France particularly in the field of fill dams were bituminous concrete facing are used. Dams such as Dorlay (1972), Plan d'Arem (1970) and Carabonne (1970) are good examples of this use (CFGP, 1973).

The Genekel dam in Germany (1952) is the first example in which the bituminous facing consists of a sandwich structure made of a draining bituminous concrete bed lain between two impervious layers of dense bituminous concrete (Asbeck, 1969). The external coating is generally made of such these two layers laid on an opened asphaltic concrete drainage or on a binder course (Fig. 1). The main objective of this structure is to collect and measurement of the water infiltration (Asbeck, 1969; CIGB, ICOLD, 1999), The Montgomery dam in the United States (1957) is one of the first examples whose protecting surface was constructed with an open asphaltic concrete drainage and a binder course generally supporting two impermeable dense bituminous concrete beds whose joints are alternate (CIGB, ICOLD, 1982; 1999). The whole unit rests on a layer which adjusts of the upstream face. In the last sixty years more than 300 dams of 30 m height and water tanks with more than 15m height have been sealed by the asphaltic concrete. Sixty thee dams among then are located in Germany.

In Algeria, the upstream asphaltic concrete blankets waterproof is not widely used in construction of dams. Only few have used this technique. Those are: Ghrib dam (1926-1938), Bouhnifia dam (1930-1941) and Sarno dam (1947-1954) (Belbachir *et al.*, 1973).

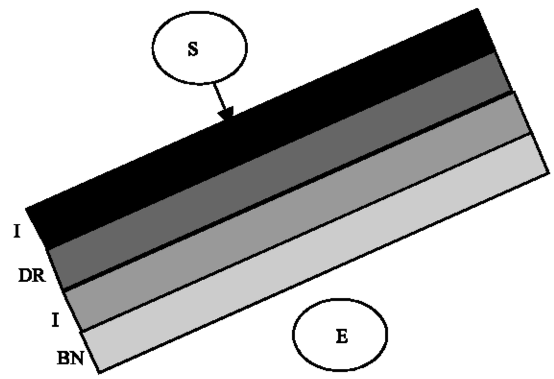


Fig. 1: Sandwich structure, I: Impervious layer, DR: Draining layer, BN: Binder layer (connection), E: Fill, S: Seal coat

This technique did not have much attention because of the rise of the country climate temperature.

Therefore main objective of this research is to find out some means to evaluate the surface temperature of the bituminous concrete facing of earth dams in these region and the different factors which controls it.

**Variation in the temperature with the depth:** The temperature T versus the depth X relationship in a vertical cross section at the instant T (Estienne and Godard, 1998), is given by the Fourier relationship:

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$$\frac{dT}{dt} = a\frac{d^2T}{dX^2} \quad (1)$$

a: Coefficient of heat propagation calculated by the Eq. 1:

$$a = \frac{\lambda}{\rho.c}(m^2/s) \quad (2)$$

$\lambda$: Coefficient of conductivity of heat (w/m.k)
$\rho$: Bulk density (kg $m^{-3}$)
c : Specific heat (ws kg.k)

The factors, a, $\lambda$, c, and ñ are the characteristics defined from Table 1 for each material used (Estienne and Godard, 1998).

**The sun radiation assesment:** The sun radiation assessment shown in Fig. 2 is generally the algebraic sum of the various factors as given by the Eq. 3 (Chiblak, 1989):

$$[I + D - A - (E - GW) \pm K]\Delta t \pm B = 0 \quad (3)$$

Where:

$\Delta t$: Time increment.

The Eq. 3 shows that the determination of the maximum temperature does not take into account the water content in the air on the level of the bituminous screen surface and thus the possibility of reaching a maximum of temperature decreases.

To estimate the surface temperature at various depths by the Eq. 3, the previous sun radiations are subdivided in two major groups.

The first group is independent of the surface temperature. It includes the following sun radiations: GW, A, D and I which are defined below:

- GW: Reflexion or Albedo of the ground,
- A: Reflected solar radiation,
- D: Diffused solar radiation,
- I: Direct solar radiation.

The second group however is related to the surface temperature and includes sun radiations B, K and E defined as follow:

- B: Absorbed or released earth energy.
- K: Calorific exchange between the facing and the atmospheric mass.

Table 1: Materials characteristics values

| Materials | a($m^2$/s) | $\lambda$(w/m.k) | c(ws/kg.k) | $\rho$(kg $m^{-3}$) |
|---|---|---|---|---|
| Asphaltic concrete | $56.17.10^{-8}$ | 1.165 | 930 | 2230 |
| Drainage layer | $58.34.10^{-8}$ | 1.270 | 942 | 2310 |
| Sand and gravel | $131.12.10^{-8}$ | 2.488 | 1206 | 1990 |
| Concrete | $55.56.10^{-8}$ | 1.63 | 1047 | 2000 |

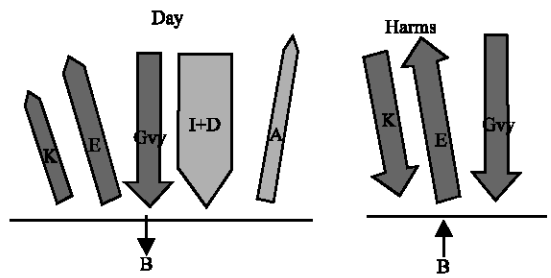


Fig. 2: Explanatory diagram of Eq. 3

- E: The facing radiation transmitted in the atmospheric.

**The surface temperature ($t_0$) calculation:** To calculate the surface Temperature ($T_0$) with various depths, the Eq. 1 and 3 have been solved by using the model (Djemili *et al*., 2005).

**The model validation:** To validate the model (Djemili, *et al*., 2005) the measurements obtained in 1959 by EDF «Electricité de France" on the GHRIB dam (Kreitmann, 1959) were used in the calculations these are:

- Variation in the maximum temperature measured and calculated on surface
- Variation in the maximum temperature on the surface of the facing with and without white paint coating.
- Variation in the maximum temperature on the surface of the facing with and without concrete bed

The EDF measurements and the model calculated results are given in the Table 2.

This table shows that the results from EDF measurement and the results obtained from the model calculation are very close. Indeed they are practically the same.

**Dams study characteristics:** The dams studied in the present research work are: Bouhanifia (Maskara), Ouizert (Maskara), Dahmouni (Tiaret), Sarno (S.B. Abbes), Bakhada (Tiaret), Sidi Mhamed Ben Ada (Relizane) and Koudiat Rosfa (Chilef).

In all these dams, the facing used are similar to the one of Genekel dam in Germany.

The angular, geographical and geometrical characteristics of the above named dams are:

- Air temperature: $T_L$,
- Dam's slope: Alpha

Table 2: EDF measurements and model calculated results

| References | EDF | Model | Erreur (%) |
|---|---|---|---|
| Maximum temperature on the facing surface (°C). | 65.0 | 66.7 | 2.6 |
| Maximum temperature to 6 cm of depth-facing under coat of paint (°C). | 34.2 | 34.7 | 1.4 |
| Maximum temperature to 10 cm of depth-facing under concrete layer (°C). | 35.8 | 36.7 | 2.5 |

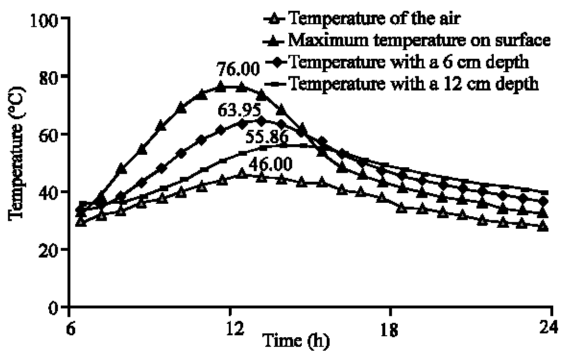


Fig. 3: Distribution of the maximum temperature on surface of the Facing with various depths

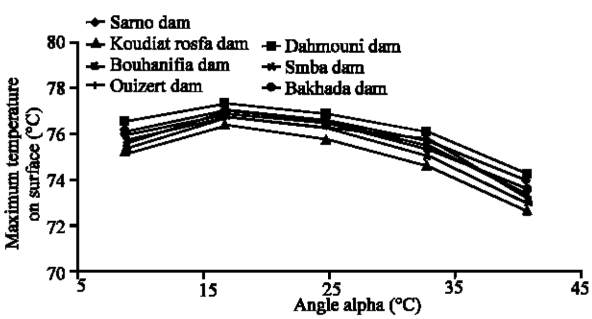


Fig. 4: Variation of the maximum temperature on the surface of the facing with the slope dam's

- Solar variation: delta,
- Azimuth: AF,
- Latitude: Fi,
- Atmospheric pressure on sea level: $P_0$,
- In-situ atmospheric pressure: P,
- Pressures ratio: $P/P_0$,
- Pollution factor: T,
- Color factor: ε,
- The region reflexion factor: ru,
- The facing reflexion factor: ro.

## RESULTS AND DISCUSSION

To evaluate the stability of the concrete bituminous surfacing of earth dams discussed above and the construction of dams in the future in the semi arid region of west Algeria; some calculations have been made on the basis of the in situ maximum air temperature ($T_L$) data and the angular, geographical and geometrical characteristics s hown on Table 3. These calculations have shown that the difference of the maximum air temperature and the maximum surface temperature are in the range of 30 to 33°C. Table 4 shows the results obtained from which a mathematical relationship has been drawn as follow:

$$T_0 = T_L + (30 \div 33)$$

Where:

$T_0$: The stability maximum bituminous layer temperature evaluated in °C,

$T_L$: The in situ maximum air temperature studied in °C.

This Fig. 3 shows that the maximum temperature decreases with the increase of depth. For a depth of one centimetre the temperature decreases by 2°C.

Figure 4 shows that the maximum temperature on the surface of the facing increases to a maximum value then decreases with the increase of the slope of earth dam. A maximum value of the temperature is reached for a slope of 1/3, 5. Corresponding to.a = 15°C.

Table 3: Angular, geographical and geometrical characteristics of different dams

| Characteristics | Bouhanifia | Ouizert | Dahmouni | Sarno | Bakhada | Smba | K.rosfa |
|---|---|---|---|---|---|---|---|
| $T_L$ (°C) | 46.0 | 46.0 | 45.0 | 45.0 | 43.5 | 42.5 | 43.0 |
| Alpha (°C) | 30 | 30 | 25 | 25 | 25 | 25 | 25 |
| Delta (°C) | 15.80 | 15.65 | 15.30 | 18.20 | 16.99 | 18.54 | 16.42 |
| AF (°C) | 359 | 354 | 355 | 352 | 353 | 358 | 356 |
| FI (°C) | 35.36 | 35.18 | 35.25 | 35.34 | 35.35 | 35.55 | 35.75 |
| $P/P_0$ | 0.92 | 0.89 | 0.93 | 0.95 | 0.94 | 0.89 | 0.90 |
| T | 2.5 | 2.5 | 3.0 | 3.0 | 3.0 | 2.5 | 2.5 |
| ε | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| $r_u$ | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 |
| $r_o$ | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |

Table 4: Maximum temperatures of the air and the facing surface of dams

| Dams | Maximum temperature of the air $T_L$ (°C) | Maximum temperatureon the facing surface $T_o$(°C) | Difference intemperature ($T_o$- $T_L$) (°C) |
|---|---|---|---|
| Bouhanifia | 46.0 | 76.00 | 30.00 |
| Ouizert | 46.0 | 76.00 | 30.00 |
| Dahmouni | 45.0 | 77.00 | 32.00 |
| Sarno | 45.0 | 76.50 | 31.50 |
| Bakhada | 43.5 | 76.50 | 33.00 |
| S.M.B.A | 45.5 | 76.00 | 30.50 |
| Koudiat rosfa | 45.0 | 75.50 | 30.50 |

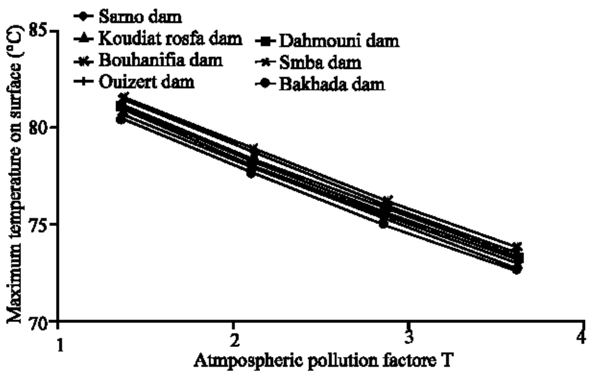


Fig. 5: Variation in the maximum temperature on the surface of the facing with the increase of atmospheric pollution factor

Figure 5 reveals that the maximum temperature on the surface of the facing decreases with the increase of atmospheric pollution factor. An atmospheric pollution factor of 1.0 gives a decrease in temperature in the range of 2 to 2.5°C in the maximum temperature on the surface of the facing of the earth dam.

## CONCLUSION

- The maximum temperature decreases with the increase of the depth.
- The maximum surface temperature deceases with the increase of the slope of dams.
- It is recommended to use a slope of dam which provides both the stability and a minimum surface facing temperature.
- The maximum surface temperature of the surfacing decreases with the increase of atmospheric pollution.
- The use of "$T_0$" relationship to evaluate the maximum temperature at the concrete bituminous facing seems to be appropriate in the semi arid regions of west Algeria.


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