MODELLING OF IN EARTHEN DAM UNDER THE EFFECT OF SEISMIC LOADING, CASE OF THE TAKSEBT DAM (ALGERIA)

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ABSTRACT:

The prediction of displacements in earthen dams after seismic loading is necessary to ensure their proper functioning. In this study, the finite element software plaxis 2D is used to model the nonlinear dynamic behavior (elasto-plastic) of the embankment dam solicited by real seismic records. The earth dam considered in our case study is the Taksebt dam located in the north-east of Algeria. The main steps of the modeling are the following: first the dam of Taksebt was analyzed under seismic stresses without water (empty). Then the dam of Taksebt is subjected to the same seismic records with water (full). The comparison of the study cases allows us to estimate the displacements in the two main directions (horizontal and vertical).The results obtained show the ability to estimate the displacements in an embankment dam under seismic excitation. In addition, the analysis time will be reduced considerably by considering the two extreme cases of seismic loading.

1. INTRODUCTION

Dams are vital structures to ensure human lives (Larsen et.al. 2013). Monitoring the actual behavior, not only during construction and impoundment, but throughout the operation of embankment dams is necessary to ensure the proper behavior of these structures and to have a warning system in case of abnormal behavior of these embankment dams (Abdulhadi, 2009; Ladd & Degroot, 2003) In tectonically active areas (such as the northern region of Algeria), measurements of deformations, displacements, pressures and pore stresses by the finite element method provide more information on the effects of seismic disturbances (Kim et.al., 1999; Larsen et.al., 2013) The paper analyzes the seismic behavior of Taksebt dam subjected to horizontal loads due to water pressure and seismic loads, the influence and impact of these on the displacements of the dam (Gregoretti et.al, 2010).

The evaluation and prediction of ground displacements has always been one of the most important problems in geotechnical engineering. Although the first part of this problem has been widely studied (CIGB, 1998). Elasto-plastic behavior, cracking and also nonlinearity of materials lead to nonlinear behavior (Araei et.al. 2010; Chen S., 2015; Gregoretti et.al, 2010).

The evaluation and prediction of soil displacement has always been one of the most important problems in geotechnical and seismic engineering (Edil, 2001; Rippi, 2015; Kurimoto et.al. 2017).

Although the first part of this problem has been widely studied (CIGB, 1998; Awal et.al., 2008). There is no doubt that nonlinear analysis by traditional methods is very useful but it is very time consuming. Also, when it is necessary to provide an accurate numerical model to model the nonlinear behavior of the dam (Casagli et.al. 2003; Chen S., 2015; Dong et.al. 2009). It is necessary to identify the soil resistance parameters (Rippi, 2015; Awal et.al. 2009). For this purpose it is necessary to collect data from experimental reports. Then, it is necessary to try to define the soil and material parameters to be used in the computer programs, so that the simulated response is as close as possible to the observed response.

2. DAM DATA

2.1 Situation

The Taksebt dam is located in the Oued Aissi tributary of the Sebaou in the Willaya of Tizi Ouzou, about 7 km south east of the city of Tizi Ouzou and 100 km from the city of Algeria.



Figure 1. Location of the Taksebt dam

2.2 Site geological formation

The geology of the site highlighted during the ADP, was largely confirmed during the excavation of the works. Located of the edge the Kabylian crystal massif, the site consists of shale Palaeozoic substratum with a general slope of 10° to 15° downstream on the roof the main complementary findings or modifications to be made to these descriptions are the absence of a fault, properly speaking, crossing the site in bevel in river left. Upon examination of the excavations, only local alterations were observed. The more marked irregularity of the rock roof under the alluvium. The maximum expected depth (33 m) was not reached, the rock roof being reached before 26 m, but the shale relief was more marked with a channel of 3 to 5 m oblique to the current valley. The channel was intersected by the work of the plastic concrete wall in the left part of the valley. The Shalero of was confirmed to be heavily decompressed. In rive right, under the flood evacuator, in the right of courier proper, a flexure of the Miocene ground layers was confirmed and gave rise to instabilities during earthmoving (local landslide). These were checked without requiring heavy work. Apart from the superficial zones, showing altered and relaxed rocks over a few meters, mainly on the side of the river right support and the zone of the flood evacuation, the terrain proved massive and compact. In particular, the tertiary formations of the low-tectonized cover showed very high resistance and very satisfactory resistance. The excavation of underground tunnels, in particular, required the use of explosives and slowed down the development of the site. On the other hand, virtually no landslide was observed in spite of light supports or poorly placed supports.

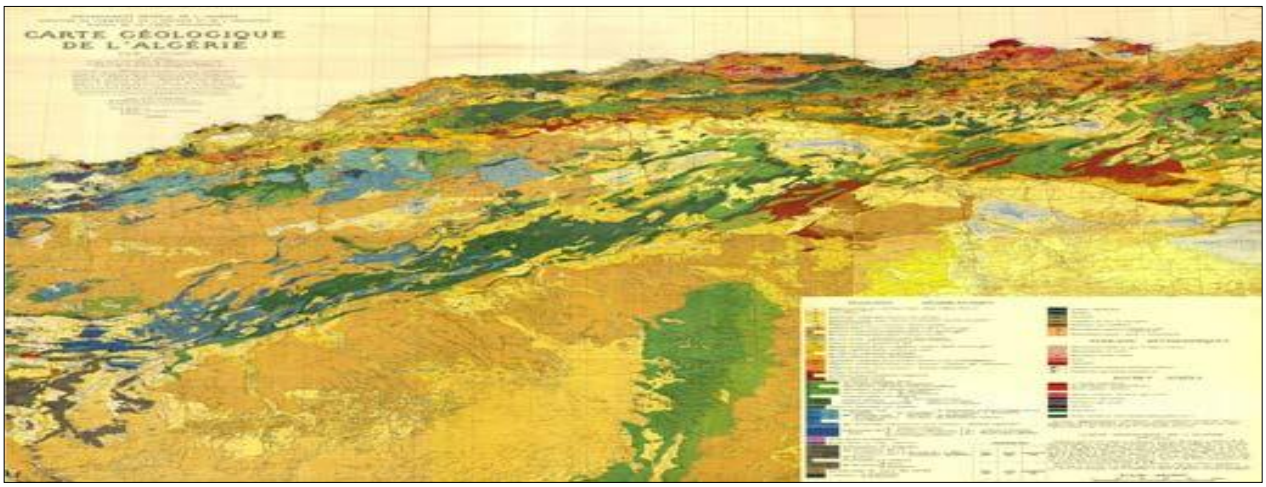


Figure 2. Geological map of Algeria

2.3 Site hydrology

The Oued Aissi drains to the right of dam site a watershed of 448 Km^2 whose altitude varies from 2,300 m to the south of the basin, to100 m to the right of site. The average altitude is about 655 m. The Oued Aissi descends the slopes of the massif of Djurdjura following a general direction almost north/south, for this thrown in the Oued Sebaou of course east/west, a few kilometres from the gorges of Balloua. The flow regime of Oued is characterized by very clear and regular separations in dry months from (June to October) and wet months from (November to May). During the seven impregnated months, 88% of the total intake of the year flow son average, this phenomenon is of course there flexion of the regime of precipitation, but its regular characters reinforced by the influence of the melting of the snow of the Mountains of Djurdjura (table 1).

Geometric Characteristics		**Hydraulic Characteristics**	
Basin area	448 Km^2	Average annual contribution	196 Hm^3
Perimeter	99 Km	Instantaneous fictitious flow	6.2 m^3/s
Main thalweg length	39 Km	Average specific flow	13.87 $l/s/Km^2$
Maximum length of pond	31 Km	Blade of water drained	438 mm
Equivalent rectangle length	37 Km	Equivalent average rain	930 mm
Equivalent rectangle width	12.1 Km	Average runoff coefficient	45.6%
Average altitude	655 m	Average flow deficit	506 mm
Maximum altitude	2300 m	Ten-year dry intake	117 Hm^3
Form factor	3.3	Ten-year wet supply	296 Hm^3
Graveluis Compactness Index	1.3	Flood of works (20 years)	1250 m^3/s
Average slope	0,23	Project flood (1000 years)	2450 m^3/s

Table 1.Watershed geometric and hydraulic characteristics

3. SEISMIC DATA FROM THE STUDY REGION

The seismic recording considered for the modelling of the takes dam is given in the figure below (figure 3):

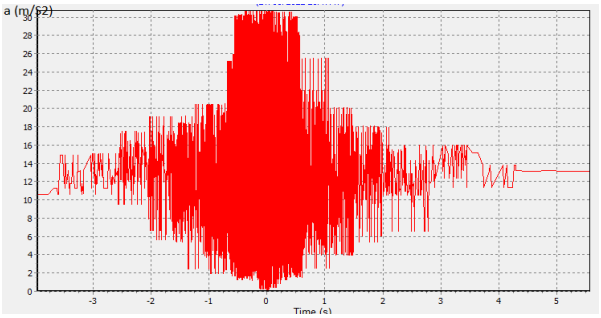


Figure 3. Seismic recording (Boumerdes 2003)

a. Modelisation

The Takes dam is modelled by the software plaxis version 10 taking into account the seismic records, we considered the shale massifs substratum with a thickness of 10m on mounted by an alluvial layer of about 3m in height, the dam is composed laterally of two layers of alluvial, one from the right side and the other from left side. They are separated in the middle by the clay core; the global modelling scheme is given in the following figure (figure 4).

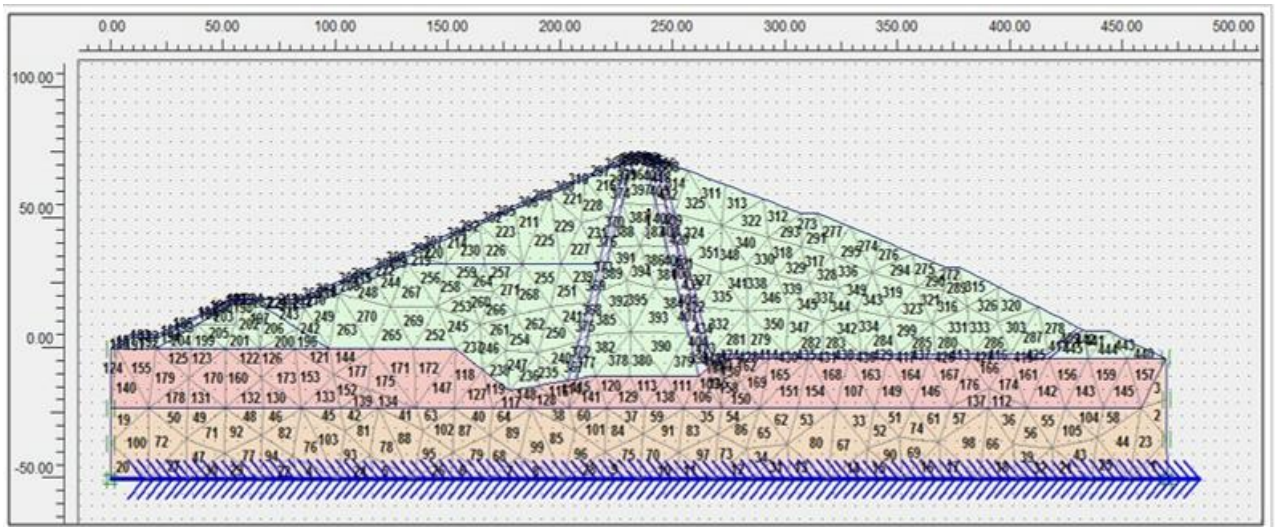


Figure 4. Modelling of Taksebt Dam

The geotechnical characteristics of the materials used in the modelling of the dam are presented in the table 2.

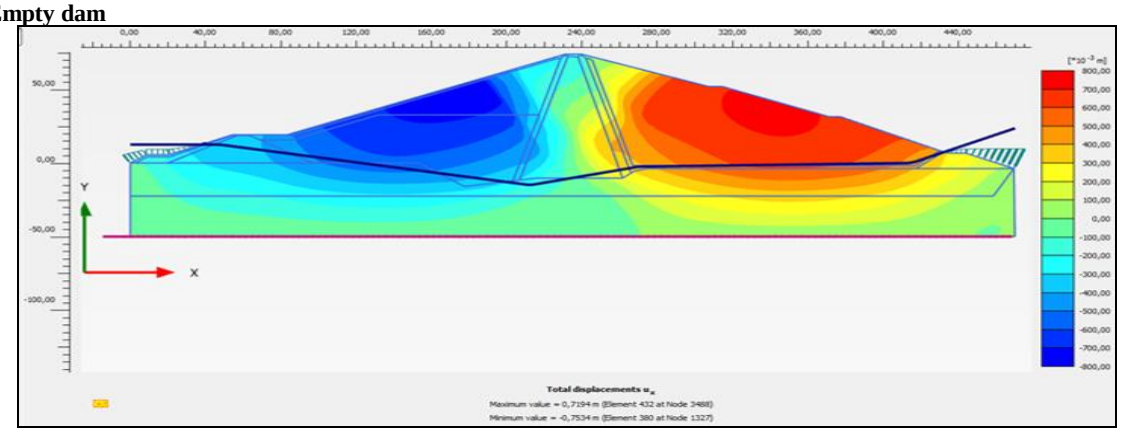
Materials	γh (KN/m³)	γsat (KN/m³)	C' (KN/m²)	Ø' (°)	E (Mpa)	μ
Clay core	18,60	19,70	10	15	15	0.30
Drain	19,60	21,80	2	28	30	0.23
Upstream Transition	19,30	21,20	2	32	120	0.25
Filtre aval	19,30	21.20	2	32	120	0.25
Upstream recharge	21,00	22.10	2	30	90	0.30
Downstream recharge	20,40	21.50	2	28	90	0.23
Upstream and downstream protection	20,60	22.50	2	40	190	0.23
Cofferdam	21,00	22.00	5	20	30	0.30
Alluvial foundation	20,40	21.50	2	28	30	0.23
Rock	21,30	21.80	20	28	300	0.30

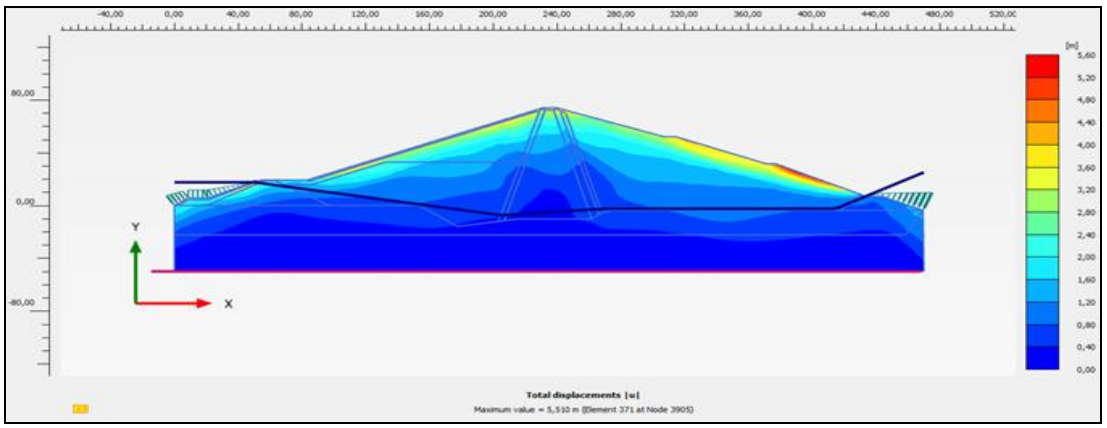
Table 2. Geotechnical characteristics of materials

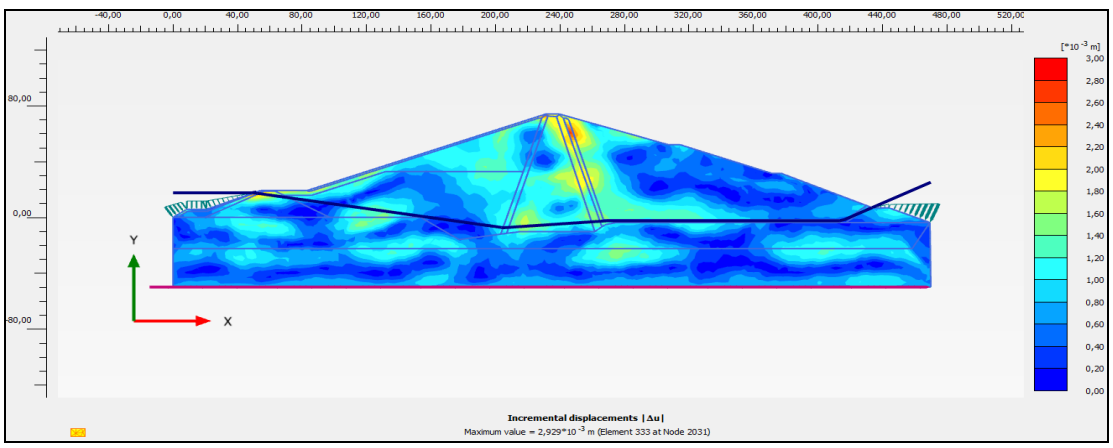
4. PRESENTATION OF RESULTS

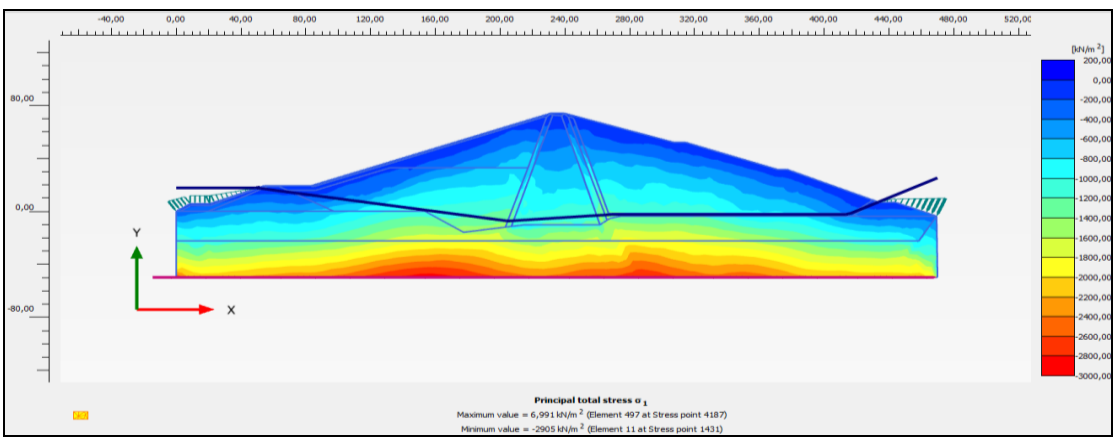
The movements of a dam during an earthquake cause dynamic pressures in the impounded water. Which act on the upstream face of the dam to alter the dam's motions, which in turn impudence the hydrodynamic pressures and displacement. The results obtained by considering the dam filling cases and the dam empty are given in the figures below (figures 5, 6), the displacement is in [m] and the pressures in [kn/m^2].

Case 1: Empty dam









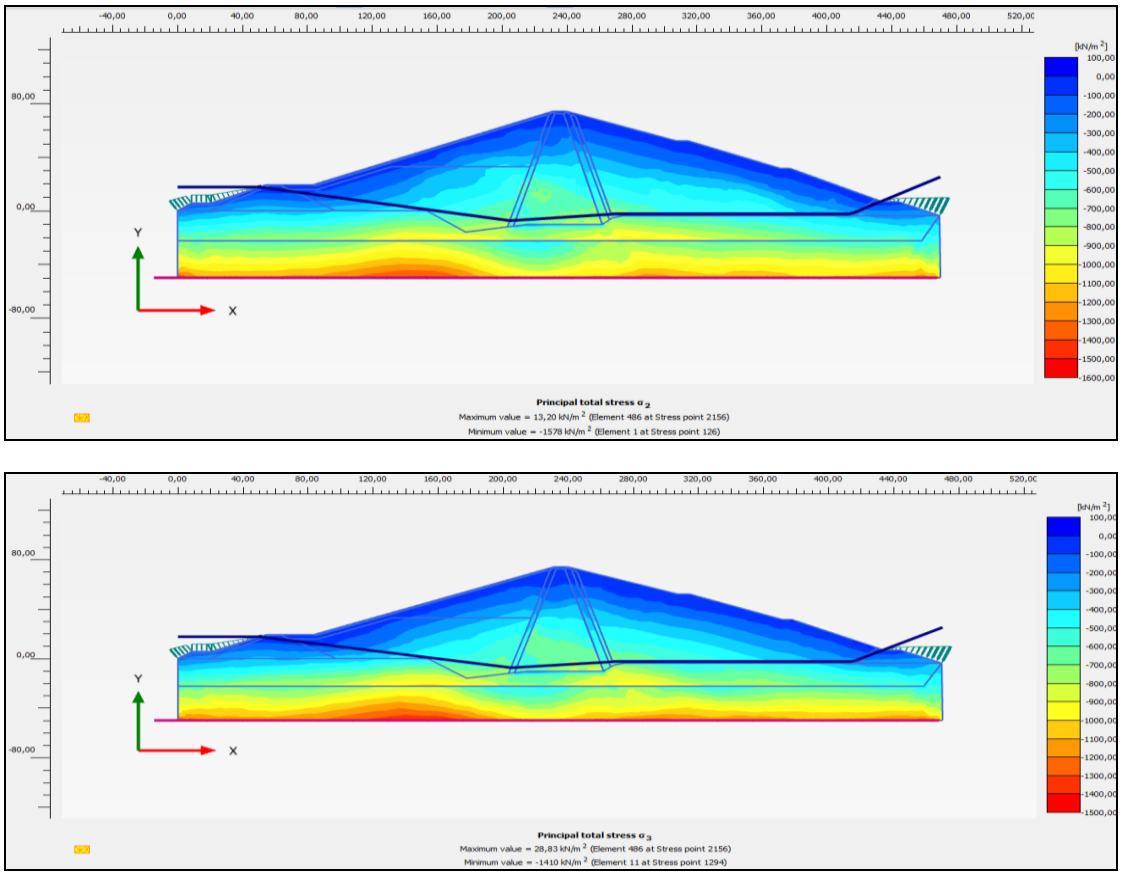
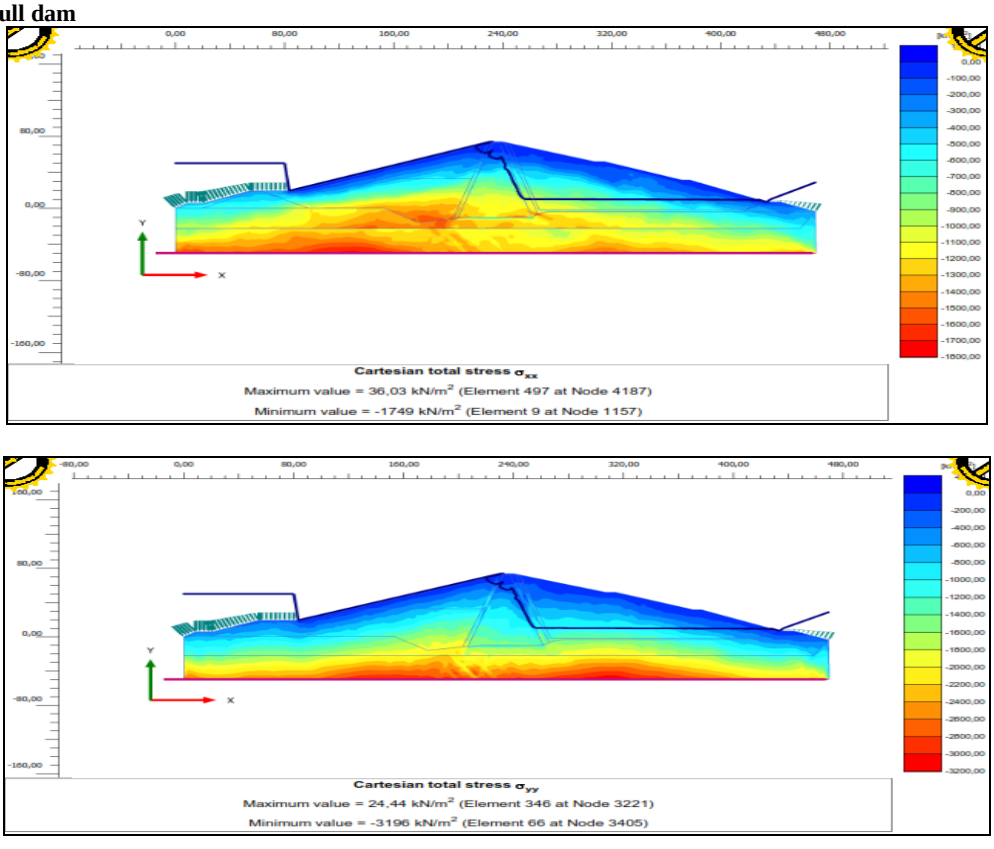
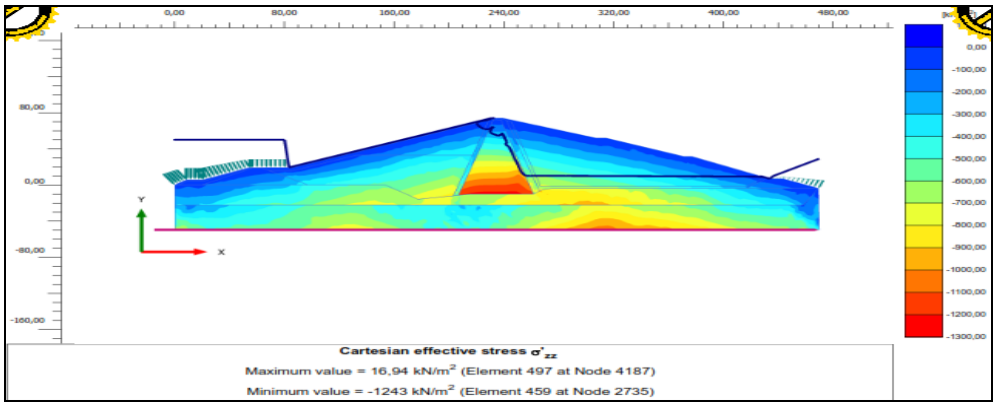
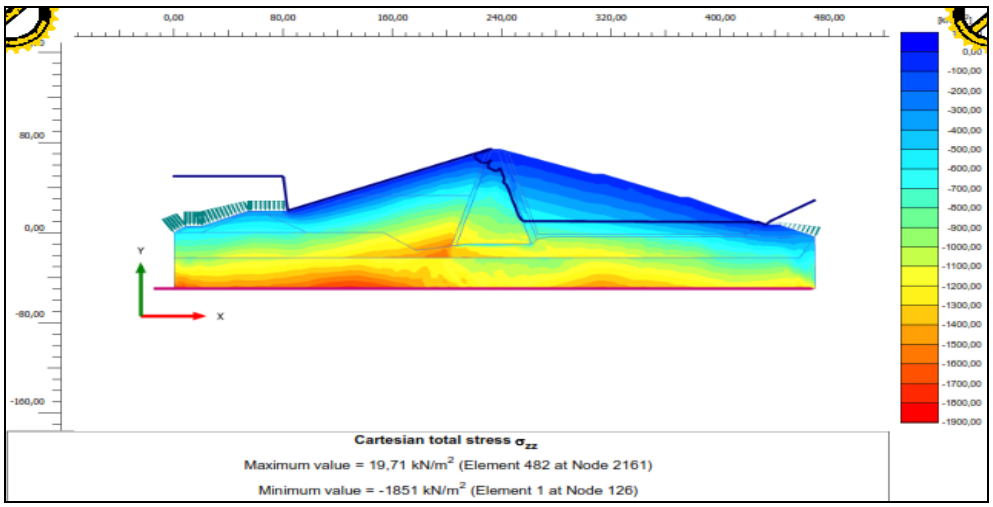


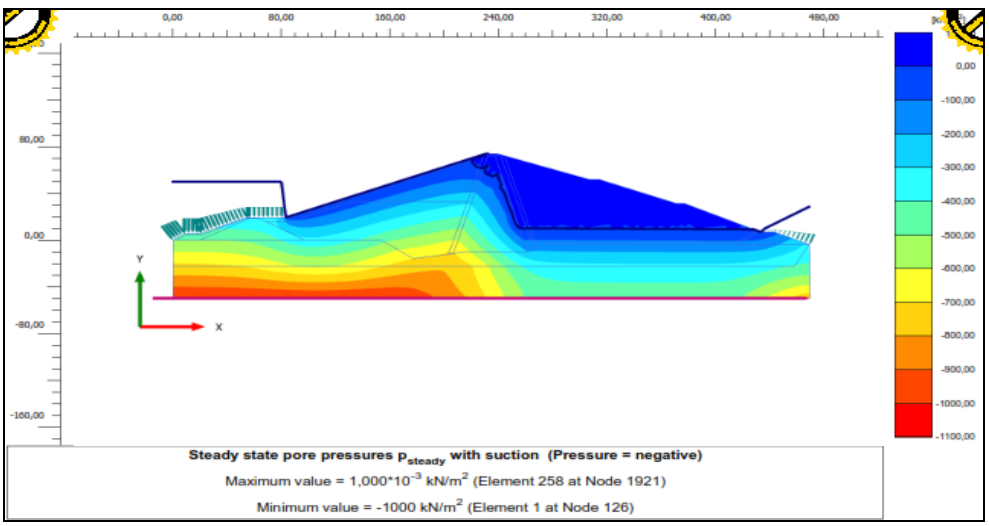
Figure 5. Diagram of movements of the Taksebt Dam under seismic stress

Case 2: Full dam




Cartesian effective stress σ'zz
Maximum value = 16,94 kN/m2 (Element 497 at Node 4187)
Minimum value = -1243 kN/m2 (Element 459 at Node 2735)


Cartesian total stress σzz
Maximum value = 19,71 kN/m2 (Element 482 at Node 2161)
Minimum value = -1851 kN/m2 (Element 1 at Node 126)


Steady state pore pressures psteady with suction (Pressure = negative)
Maximum value = 1,000*10-3 kN/m2 (Element 258 at Node 1921)
Minimum value = -1000 kN/m2 (Element 1 at Node 126)

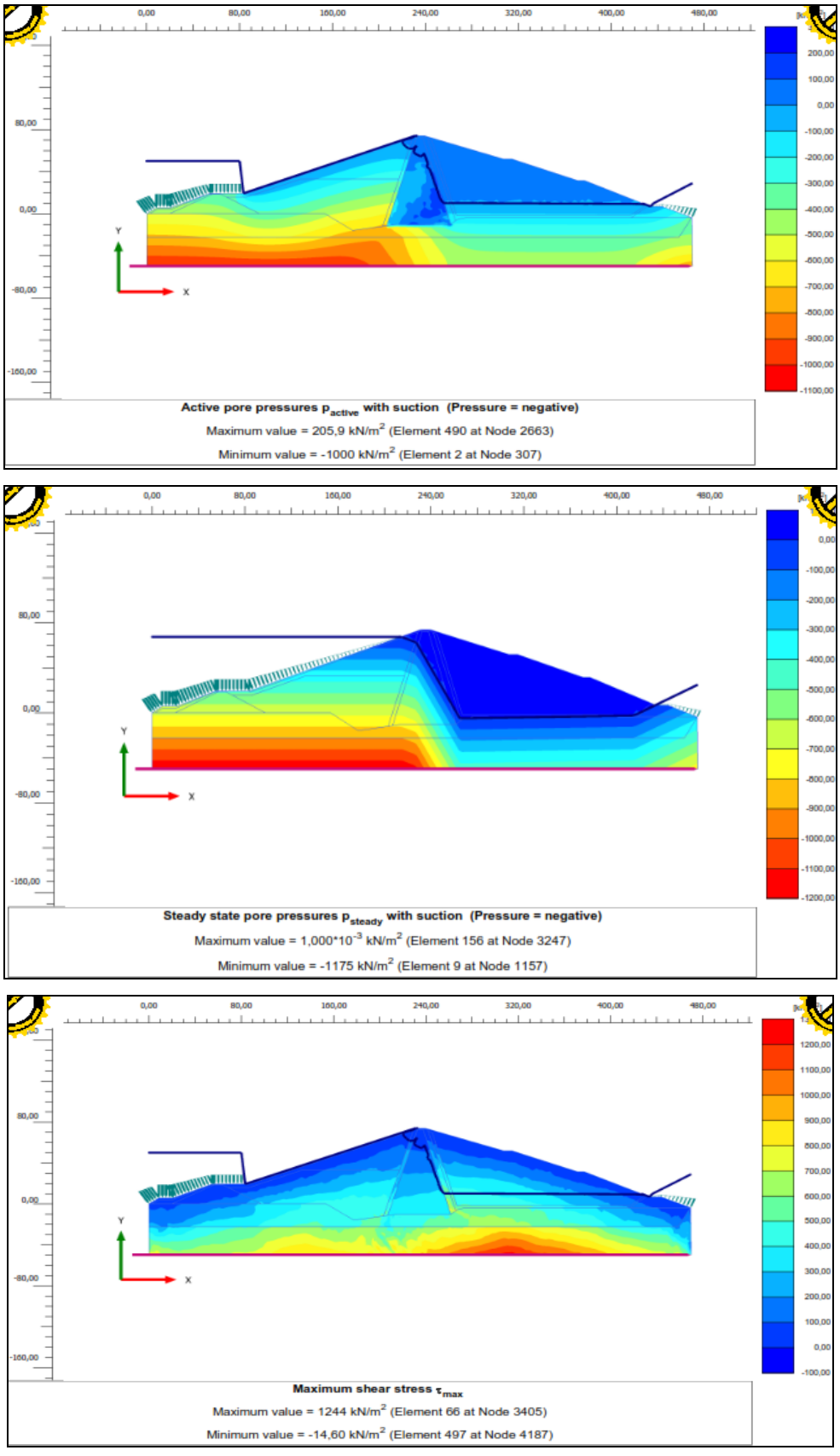


Figure 6. Diagram of the displacement of the Taksebt Dam with filling under seismic stresses

5. ANALYSE AND DISCUSSION

The results obtained show a uniform distribution of deformations along the embankment dam in the first loading case (empty dam without water). The maximum stress value is 3196 Kn/m^2 is exerted on the ox axis. The maximum displacement is 5 cm. In the second case of loading, the stress distribution is disturbed by the effect of filling (full dam), so we have hydrostatic forces which are amplified by seismic stresses and which act in all directions. The order of magnitude of the stresses is 1243 Kn/m^2. The maximum displacement is 7 cm. A comparison between the values found in the first and second case of seismic loading shows that the values of effective stresses decrease under the effect of hydrostatic pressure and seismic wave what justifies the disturbance of effective stress diagram but it is the opposite for the displacements there is an increase and this is due to the loss of resistance of the dam soil mass implied by the disturbance of stresses what justifies this increase of displacements. The values found are very satisfactory in comparison with the stresses and displacements found in the literature which are in the same order of magnitude (between 10 cm and 15 cm).

Comparing the response of the dam to horizontal and vertical ground motions in the two cases of loading (Figures 5, 6), it appears in accordance with the general opinion that without water (empty dam), the response to vertical ground motion is relatively small, because the amplification factor of the loadings has the response to vertical ground motion is relatively influential and the augmentation term is much smaller for vertical ground motion compared to horizontal motion. With the solid dam, the response is affected by the added hydrodynamic mass, damping and force. Because the added hydrodynamic mass and damping are independent of the direction of excitation, the response functions due to horizontal and vertical ground motions exhibit the same resonance. The vertical forces exhibit the same resonant frequency and effective damping. However, the added force is associated with hydrodynamic pressures acting in the horizontal direction on the upstream vertical face of a rigid dam, whether the ground motion is horizontal or vertical.

As a result, hydrodynamic effects (including water compressibility) cause a greater increase in response to vertical ground motion than the response to horizontal ground motion. This is apparent by comparing the response curves of the dam without water and with water associated with the two excitations (Figures 9, 10) if this issue is placed in a historical context, the response of embankment gravity dams to the vertical component of ground motion was overestimated in early studies based on the assumption of a non-absorbent reservoir bottom (Chopra and Chakarabarti, 1972). An absorbing reservoir bottom gives a more acceptable estimate of the vertical ground motion response and its smaller contribution to the total earthquake. It's a smaller contribution to the total earthquake response of the dam (Fenves and Chopra, 1983). Although not negligible, this contribution is of secondary importance. Thus, the response to only the horizontal component of ground motion is considered in the development of the simplified analysis procedure for two-dimensional dam-water-foundation systems.

5.1 In the upstream/downstream section

The orientation and magnitude of the stresses seem satisfactory, except in the peak where the last elements laid do not benefit from a sufficient number of iterations (at least in this calculation) and are not significant; the field of the displacements is very regular. In the center, at half the height of the core, the displacement is 1.8 cm; it is on the representation of the green iso-stresses that the consequences of the differences in stiffness between the various materials forming the embankment can be assessed: the fillings located upstream and downstream of the core bear part of this core, the lower part of which is therefore somewhat discharged (vertical stress of the order of only 2,7 MPa on the foundation rock, representing 75% of the weight of the earth column). At the interfaces, especially with the filter zones and drains surrounding the nucleus, the iso-stress curves present some Arabs due to the interplay of interpolation functions. But you can see in the upper part that the filters also carry the kernel. At the end, by comparing the results obtained from a technical point of view, there is an increase or amplification of the static forces (horizontal and vertical) which give us constraints and important displacement. In the first case with out filling the stress diagrams is homogeneous according to the barrier body in the three main directions (x, y, z) and the displacements are negligible of the order 1.8 cm, therefore the effect of the seismic wave son the physical and mechanical characteristics of the soil composing the dam body is modest.

The concentration of normal and tangential stresses at the dam base or at the foundation level. The figure below (figure 7) shows the results obtained.

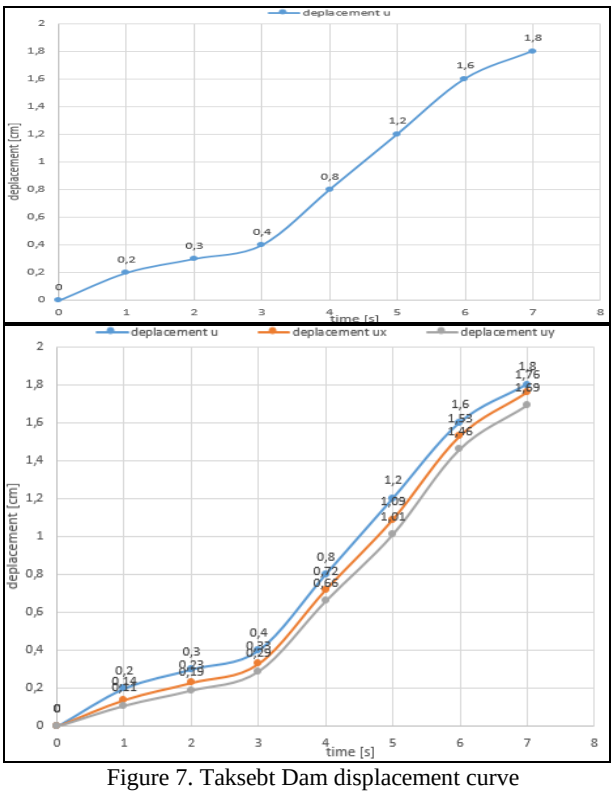


Figure 7. Taksebt Dam displacement curve

5.2 Effects of saturation on the natural frequency

Figure 8 shows that saturation of the dam lengthens the period of vibration, this effect being particularly small but increasing rapidly with water depth (Chakrabarti and Chopra 1974).

In addition, the ratio of the period of vibration increases with the ratio of frequency, decreases (i.e., the modulus of elasticity increases).

Due to the interaction between the closely spaced fundamental vibrational frequencies of the dam and the water (Figure 8); these observations first appeared in Chopra (1968).

As the bottom of the dam becomes more absorbent, the fundamental resonance period is reduced from its initial value for a non-absorbent tank bottom.

This occurs because the absorption of the reservoir bottom reduces the hydrodynamic terms, thus reducing the value of the added mass. The figures below show the results obtained of the dam saturated (full dam).

In the bank-to-bank section; the stress distribution does not reveal arcing and associated discharge from the base of the core to the bottom of the valley.

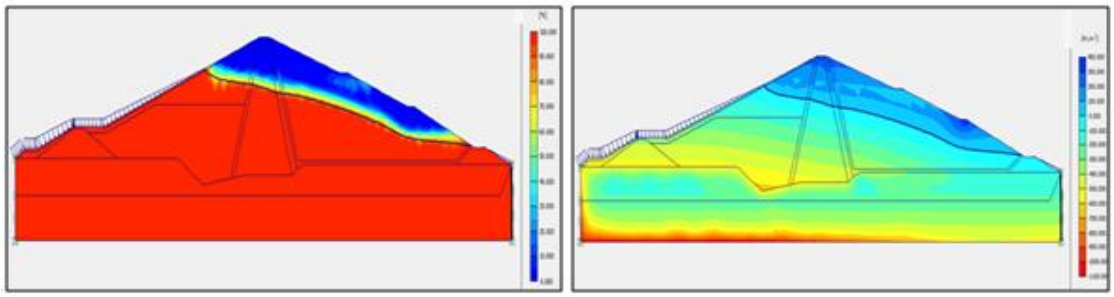


Figure 8. Saturation curves of the Taksebt Dam

The vertical stresses are close to 3 MPa, a slightly higher value than in the upstream downstream section. This shows the limits of the cross-section analyses with the hypothesis of flat deformations on the slopes, by analysing the direction of the supporting stresses on the rock, we can verify that the friction angle mobilized of the order of 26 degrees, does not exceed that which can be expected from the core/ rock contact, given the inter position of the thin earth strip. Unless there are local irregularities, there should be no embankment slides along the sides of the valley during construction.

6. CONCLUSION

Our work aims to modelling of in earthen dam under the effect of seismic loading case of the Taksebt Dam (Algeria), the following conclusions should be drawn:

- This modelling technique by plaxis 2D software allowed us to estimate the displacements in the embankment dam under seismic loading in horizontal and vertical directions in a reduced time. The stresses gave imperceptible displacements and deformations.
- The comparison between the two extreme cases allowed us to estimate the displacement at any point of the dam.
- The results obtained by this study are similar to those calculated on the dam.
- The results obtained show a uniform distribution of deformations along the embankment dam.
- In case the dam is empty, the maximum stress value is 3196 Kn/m^2 is exerted on the ox axis and the maximum displacement is 5 cm.
- second case of loading, the stress distribution is disturbed by the effect of filling (full dam), so we have hydrostatic forces which are amplified by seismic stresses and which act in all directions. The order of magnitude of the stresses is 1243 Kn/m^2.
- The values found are very satisfactory in comparison with the stresses and displacements found in the literature which are in the same order of magnitude (between 10 cm and 15 cm).

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