# Dynamic Study on the Evaluation of the Settlement of Soil under Sea Dam

Faroudja Meziani, Amar Kahil

***Abstract*—**In order to study the variation in settlement of soil under a dyke dam, the modelisation in our study consists of applying an imposed displacement at the base of the mass of soil (consisting of a saturated sand). The imposed displacement follows the evolution of acceleration of the earthquake of Boumerdes 2003 in Algeria. Moreover, the gravity load is taken into consideration by taking account the specific weight of the materials constituting the dyke. The results obtained show that the gravity loads have a direct influence on the evolution of settlement, especially at the center of the dyke where these loads are higher.

***Keywords*—**Settlement, dynamic analysis, rockfill dam, effect of earthquake, soil dynamics.

## I. Introduction

THE earthquakes, often catastrophic natural events, cause land instability and sometimes collapse structures located in the immediate vicinity. This problem is at present one of the major concerns of the engineers responsible for the seismic design of structures [1].

Soils are materials that can be found in polyphasic form, composed first of a granular skeleton but also of water and/or gas phase. The complexity of this environment necessitated a clear specification of the study framework: monotonic or dynamic loading. For these two cases, the researchers added new conditions depending on whether the material is dry, partially or totally saturated with water; the partial conclusions then made it possible to establish overlaps giving an overview of the behavior of the soils [3].

The occurrence of earthquake compaction in earthquakes is a major area of concern in geotechnics and earthquake engineering, as the assessment of the risk of settlement at a given site and its possible consequences on structures is an economic and social development.

## II. Granular Soil Behavior

A soil is characterized by a set of particles of more or less round shape, of different granulometries. When it is subjected to an external load [14], it deforms to ensure its internal equilibrium again. In the absence of water (drained condition) [3], the deformation of the granular skeleton causes only interactions between the grains [8], [10].

In the presence of water, if the rate of deformation of the skeleton is sufficiently slow, water can flow between the grains, the pressure of the pore water does not change during the loading [6]. The deformation of the skeleton is therefore only managed by the interactions between particles (drained condition) [5]. If the flow is blocked by impermeable boundary conditions, or if excessive velocity does not allow sufficient flow, a change in pore water pressure appears [12], [13]. It originates in a partial recovery of the stress by the fluid. Then the stress is made in an undrained condition (partial or total), the deformations will result from the interactions between the particles, but also between them and the fluid. Thus, draining soils under quasi-static loading (usual stress in civil engineering) can become non-draining under seismic movement (Quick solicitation) [7], [9].

## III. Numerical Modeling

### A. Presentation of the Plaxis Code

Designed by numerical geotechnical engineers, the Plaxis finite element code represents a scientific and practical optimum in dynamic analysis [11]. Scientifically, it is a non-linear elasto-plasticity analysis, taking into account the interstitial pressures (and even linear consolidation), equipped with robust and proven methods of resolution and algorithms. Equipped with robust and proven methods of resolution and reliable in numerical terms, the code uses high-precision elements (triangular element with 15 nodes), as well as recent resolution (arc length method) processes. From a practical standpoint, the PLAXIS menus allow us to use all the simplified options (boundary conditions) in order to predict the behavior of a port structure such as ports, and even achieve more later, another calculation with the same data for more realistic results [13].

### B. Dynamic Plaxis Module

The Plaxis V8 allows us to study a dynamic problem. The dynamic load is generally applied along the substratum of the structure. This action can be represented by a force, velocity, or a variable acceleration as a function of time [11], In the input program, it is necessary to specify which loading system is chosen to represent the dynamic action by the option set dynamic load system. According to the dynamic module program, the dynamic loading can be modeled by a harmonic loading or by introducing the loading corresponding to a natural earthquake (natural earthquake accelerogram) [12].

### C. Material Properties

The properties of the subsoil are given in Table I. The soil consists of brown sand, which is assumed to be with Mohr coulomb behavior [3]. The stiffness is higher than one would

Faroudja Meziani and Amart Kahil are with the Department of Civil Engineering, Faculty of Construction Engineering,University Mouloud Mammeri - Tizi-Ouzou B.P.17 Tizi-Ouzou 15000, Algeria (e-mail: mfaroudja@yahoo.fr, amar.kahil@yahoo.com).

use in this analysis, since dynamic loadings are usually fast and cause very small strains. The presence of the groundwater is taken from generation of the pheriatic level [2].

*D. Mohr Coulomb Model*

The models of soil behavior are very numerous: from the elastoplastic model of Mohr-Coulomb to the most sophisticated laws of behavior allowing to describe almost all aspects of the elasto-visco-plastic behavior of the soils, both under stress monotonous than cyclic.

The behavior of Mohr-Coulomb [4] exhibits a perfectly plastic elastic behavior without strain hardening. It has a great use in geotechnics given the results obtained in the calculations. In the Mohr plane, the envelope curve (Fig. 1) is represented by:

$$\tau=\sigma_n.tg\phi$$

where $\sigma_n$ and $\tau$ are the normal and shear stresses at break on the rupture plane, $\phi$ is the friction angle of the material.

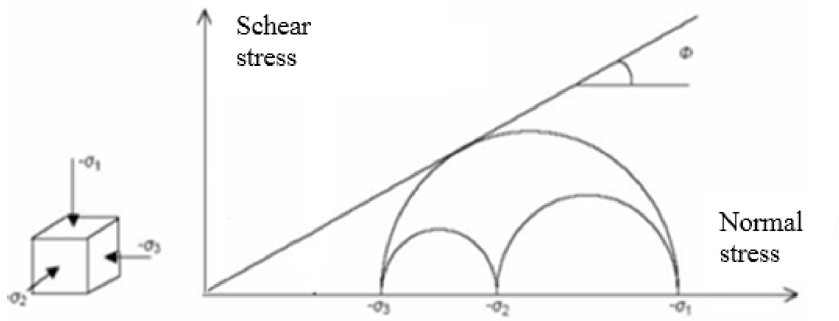


Fig. 1 Envelope curve of the Mohr-Coulomb model

The Mohr-Coulomb model requires the determination of four parameters. The two are E and ν (elasticity parameters). The other two are c and φ, respectively, the cohesion and the angle of friction. These are classical geotechnical parameters, often provided by laboratory tests, and necessary for calculations of deformation or stability.

TABLE I
MECHANICAL CHARACTERISTICS OF THE SAND CONSTITUTING THE MASSIF

| Parameters | Designation | Value | Unit |
|---|---|---|---|
| Type of behavior | Drainé | ---------- | --------- |
| Dry Weight | Ɣunsat | 17 | $KN/m^3$ |
| Saturated density | Ɣsat | 19 | $KN/m^3$ |
| Horizontal permeability | Kh | 1.00 E-04 | M/s |
| Vertical permeability | Ky | 1.00 E-04 | M/s |
| Plastic deformation module | E | 2.45 E+04 | $KN/m^2$ |
| Cohesion term | C | 0 | $KN/m^2$ |
| Friction angle | Φ | 30 | ° |

*E. Mesh*

To make the mesh in the plane, we used the axis symmetry model (i.e. only half of the dike is modeled), and to find more precise results, the mesh is based on triangular elements with 15 nodes (Fig. 2), where each node has two degrees of freedom. For boundary conditions, only vertical displacement is permitted for lateral boundaries, but vertical and horizontal displacements are not permitted (blocking of displacements at the base of the massive soil) for the base of the massif (Fig. 2).

*F. Static Loading*

The static charges applied (Fig. 4) represent the weight of the materials constituting the different layers of the dike (Fig. 3) as shown in Table II, because the dyke presents a perfect symmetry vertical axis, by reason of this symmetry, this article presents only the study of the half of the dike.

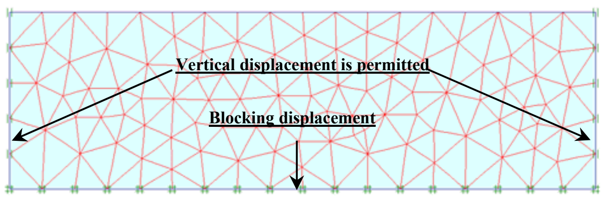


Fig. 2 Mesh with triangular elements with 15 nodes

TABLE II
GRAVITY TONNAGE AND ELEMENTS OF THE DYKE

| Elements | Specified density ($t/m^3$) | Tonnage (t) |
|---|---|---|
| T1 | 2.7 | 43.2 |
| T3 | 2.85 | 45.6 |
| B1 | 2.62 | 0.20 à 1.00 |
| B4 | 2.62 | 4.0 à 6.0 |
| B5 | 2.62 | 6.0 à 10.0 |
| HC | 2.62 | 10.0 à 15.00 |
| TV | 2.62 | -------------- |

*G. Dynamic Loading*

The cyclic loading caused by the earthquake is taken into account by a displacement imposed at the base of the saturated sand mass (Fig. 5), the latter follows the evolution of the accelerogram of a Boumerdes (Algeria) earthquake in 2003 (Fig. 6).

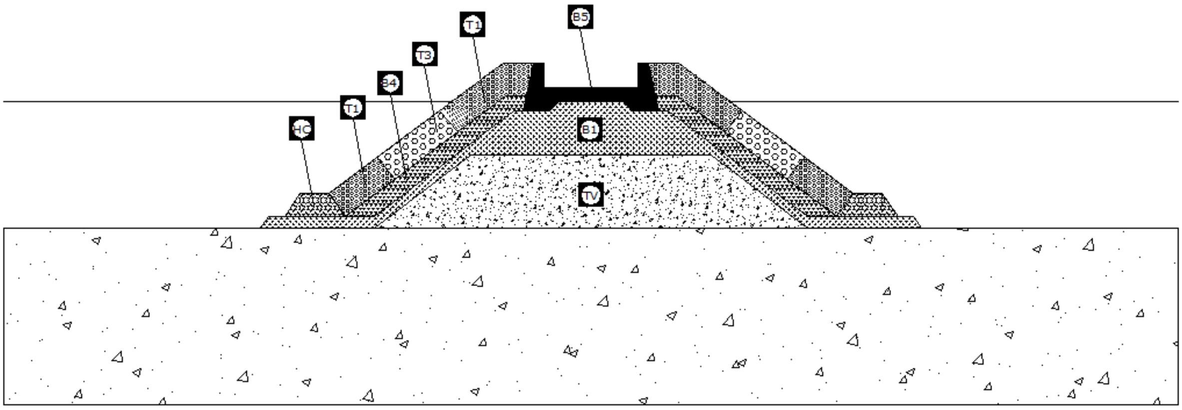


Fig. 3 The different elements constituting the dyke

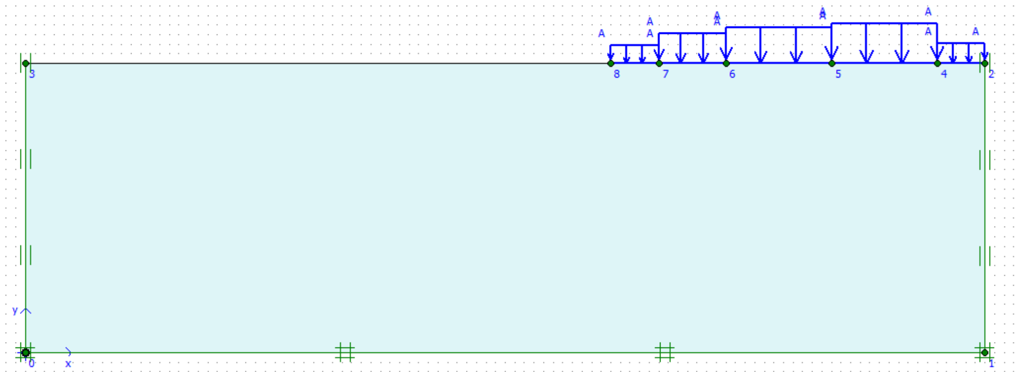

Fig. 4 Schematics of applied static loading

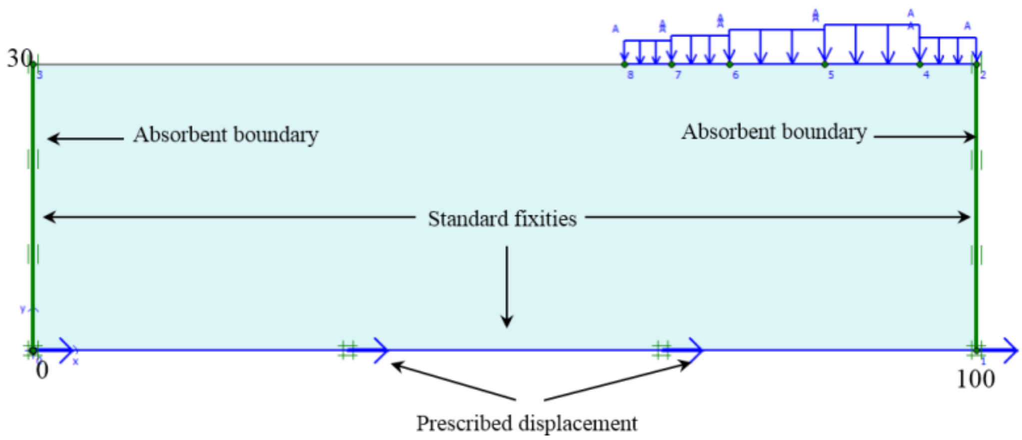


Fig. 5 Boundary conditions of the model

## IV. Modeling Results

Fig. 7 represents the study areas of different settlements with application of dynamic loading, and the results are summarized in Figs. 8-13.

The final settlements are synthesized in Table III for the 06 areas of the study for an acceleration of 2.9 m/s². Here, we will only present graphically the results at this level of excitation.

TABLE III
THE FINAL SETTLEMENT UNDER THE DYKE

| areas | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Final settlement (mm) | -2.13 | -2.06 | -2.05 | -2.09 | -2.11 | -1.73 |

It can be seen (see Figs. 8-13) that the settlements calculated for each area follow the same pace, for very low periods (low frequency). The zones undergo weak uprisings (positive displacements), then when the seismic signal penetrates in the range of high frequencies, the settlement increases rapidly, and at the end of the signal (very low frequencies), the settlement stabilizes around the final settlement (see Table III).

Table III shows the final settlement below the dike, and the study of the stability of the dike shows that the maximum settlement is located in zone 1 and constitutes the central region of the dike, in the case of verification of the stability of the dike, the acceleration to take into account is that corresponding to the central zone of the dike (acceleration at the contact surface between the dike and the sub-soil).

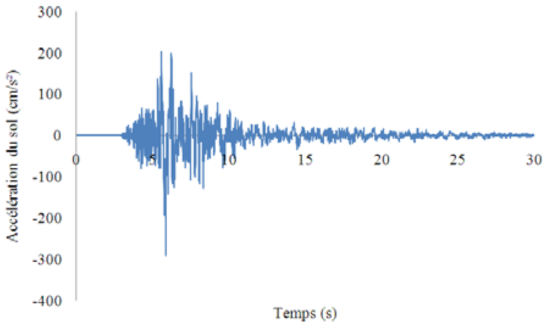


Fig. 6 The seismic signal introduced in the dynamic analysis.

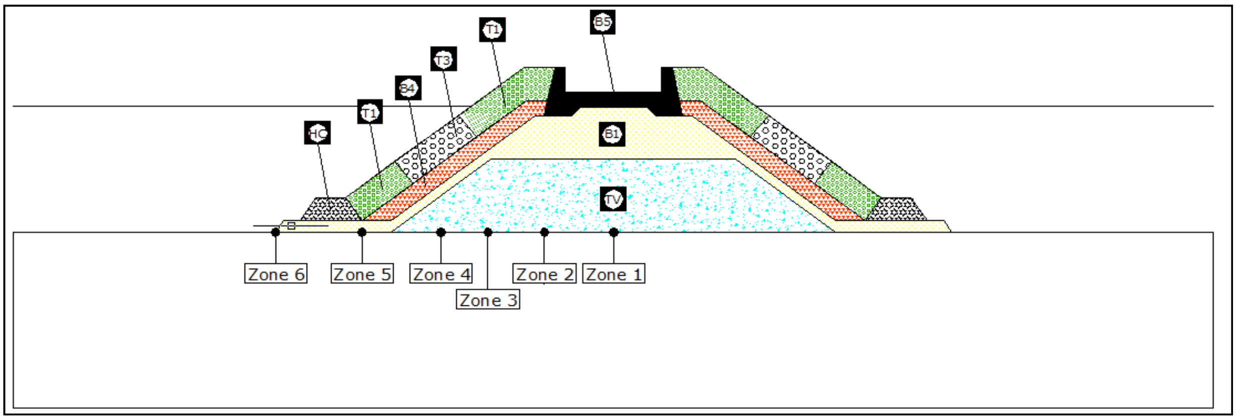


Fig. 7 Identification of study areas

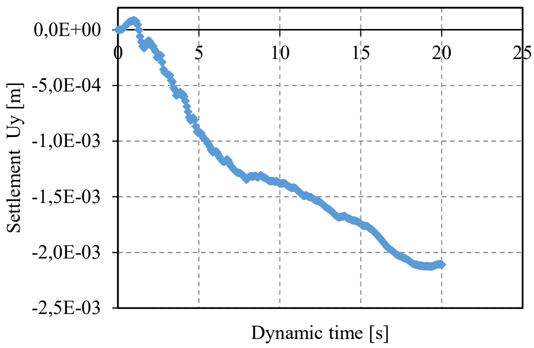


Fig. 8 Variation of settlements under dynamic loading 'Area 1'

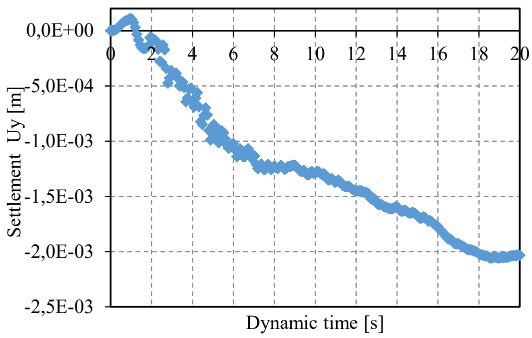


Fig. 9 Variation of settlements under dynamic loading 'Area 2'

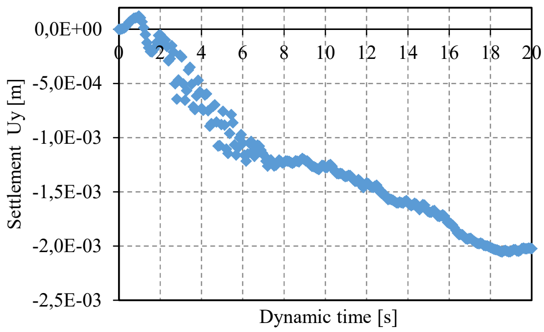


Fig. 10 Variation of settlements under dynamic loading 'Area 3'

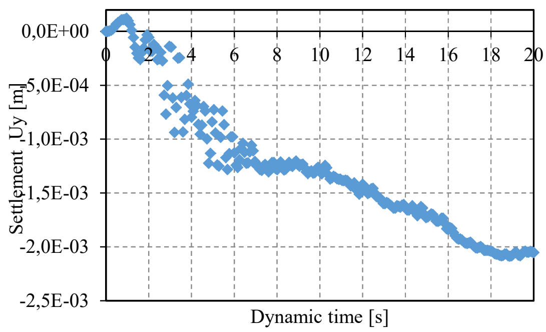


Fig. 11 Variation of settlements under dynamic loading 'Area 4'

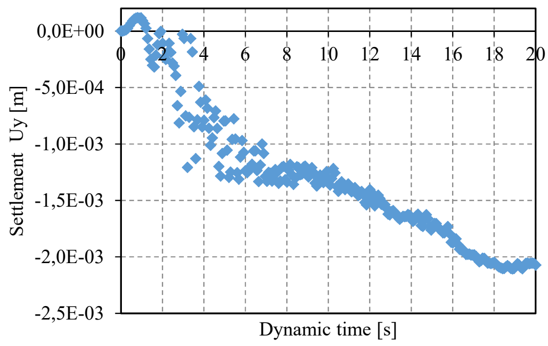


Fig. 12 Variation of settlements under dynamic loading 'Area 5'

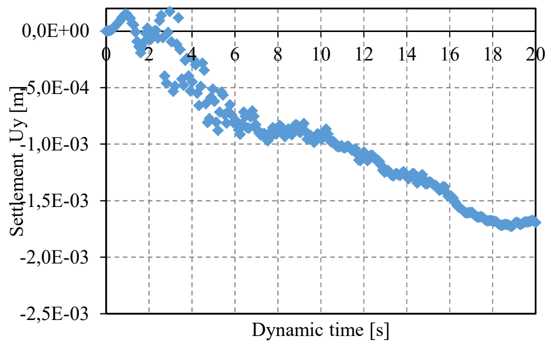


Fig. 13 Variation of settlements under dynamic loading 'Area 6'

## V. Conclusion

The main objective assigned to this work is the numerical study of the phenomenon of soil compaction and its application to the analysis of an Algerian site. According to the results obtained, the curve of settlement under dynamic loading presents a maximum in the vicinity of the center of the dyke, and smaller settlement as it moves away from the center of the dyke. This is due to the influence of the static loading applied and to the different materials constituting the dyke. In order to contribute to the reduction of seismic risk, consideration should be given to the phenomenon of settlements in studies of the stability of sea dams.

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