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Experimental Study of Monotonous and Cyclic Behavior of Silty Sands of Three Hilly Areas in Kinshasa

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Dede Bovulu Gabriel [α] & El Ouni Med. R [σ]

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Because of that, the geotechnical engineer fixes himself like objectives and duties: to ensure to the slopes the stability to prevent possible damage after a careful recognition of the basements to determine the mechanical characteristics and the parameters defining the monotonous and cyclic behavior of grounds of hills of Kinshasa under various stresses.

Keywords: stability of slopes, soil mechanics properties of hills of Kinshasa.

I. Introduction

Each slope, of any stiffness, represents under some conditions a risk for the security of humans, of the buildings or the roads, because it can give place to a more or less fast landslide. The phenomenon of the landslide is regarded as a permanent natural danger met in all the countries of the world because the importance of its effects can generate human and material damage being able to amount to million dollars whose governments must pay much attention.

The town of Kinshasa, the capital of the Democratic Republic of Congo, comprising more than 450 heads of very major erosions deserves a detailed attention or better a real assumption of responsibility. Consequently, some hilly areas risk to disappear in the next years because of their vulnerability to the landslide and gullying.

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Because of that, the geotechnical engineer fixes himself like objectives and duties:

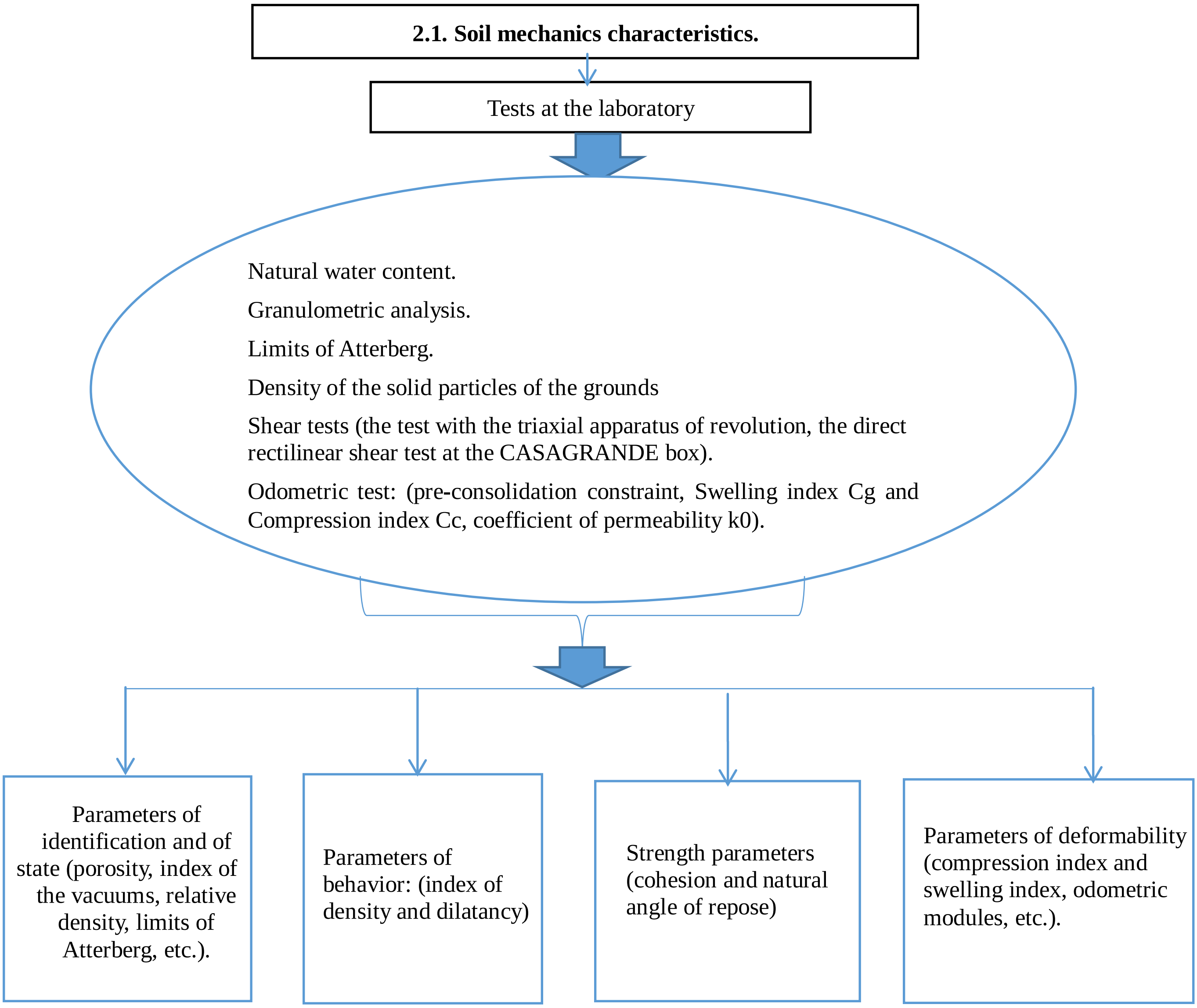
- To ensure itself of the stability of slope to prevent possible damage. There are usually several possibilities. The best is to analyze stability after a careful recognition of the basement, which reflects its temporary degree.
- To take account of this phenomenon, its dangers and the suitable precautions to detect the unstable zones to find the best solutions of protections or processing.

The behavior of the structures requires a detailed study including several stages with knowing: the state of knowledge of the comportment of the grounds under various stresses.

The objective of this study is to understand the behavior of the grounds, their mechanical characteristics, and to determine the parameters d efining their mechanical properties.

II. Flow Chart of the State of Knowledge of the Behavior of the Grounds Under Various Stresses

a) Soil mechanics characteristics



b) Experimental behavior

For better understanding the behavior of the sands studied under various stresses, their aptitudes to support loads, their mechanical characteristics and to determine the enumerated parameters above which define their properties, we carried out at the laboratory a series of tests mentioned above.

i. *Monotonous behavior*

In what follows, the parameters of the experimental comportment of sands in drained conditions are presented.

a. *Parameters of identification and of state of the grounds*

(Case of 3 zones of studies: Mont -Ngafula, Kisenso et Binza Delvaux)

b. *Granulometric analysis*

The granulometric analysis of the samples of grounds taken in the 3 zones of studies give grading curve represented below:

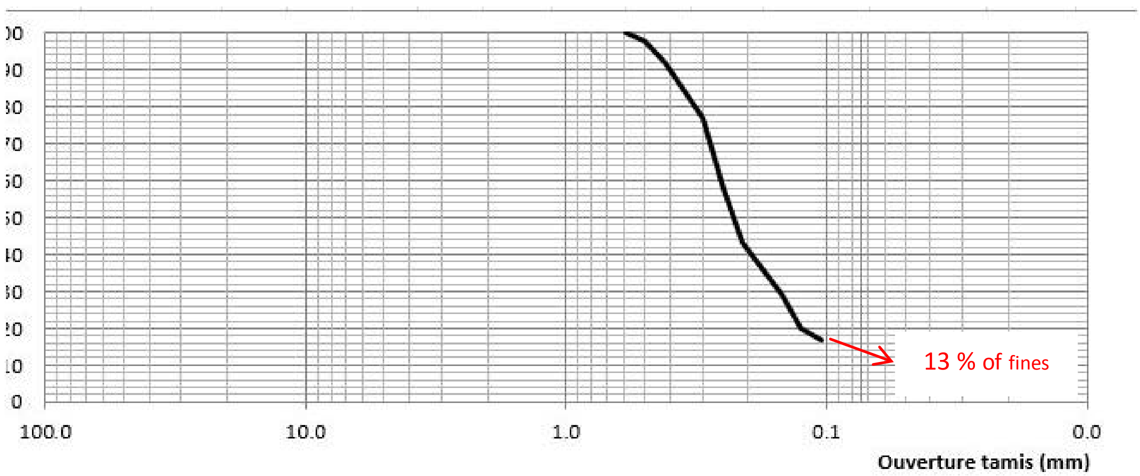


Figure 1: Grading curve of the grounds of Kinshasa

ii. *Parameters of measurement of the behavior of the grounds*

a. *Index of density: ID or relative density:* D_r

It Makes it possible to characterize the behavior of a coarse-grained soil and its aptitude to support loads.

By replacing the data by their values, successive calculations give.

$I_D = \frac{0,687-0,66204}{0,687-0,623}$ = 0,38 < 0,5 for the silty sand of Kisenso;

$I_D = \frac{0,35-0,346}{0,35-0,623}$ = 0,2 < 0,5 for the silty sand of Mont-Ngafula;

$I_D = \frac{0,36-0,3559}{0,36-0,34}$ = 0,205 < 0,5 for the silty sand of BINZA-Delvaux.

b. *Parameters of state: Ψ, angle of dilatancy*

$$\psi = 30° - \varphi°$$

With φ = the angle of friction

If $\psi > 0°$: the behavior of sand is of the loose type primarily contracted and liquefaction will be possible for low values of the parameter of state.

iii. *Shear strength parameters*

Because of the spatial and temporary disparities of the hydromechanics parameters of the grounds, one resorts to the statistics to determine the values of the parameters for the 3 zones of studies.

Table n°1: Shear strength parameters

	C (bars)	$\varphi°$	C (bars)	$\varphi°$
X (average)	0,10	19	0,10	29
σ(Standard deviation)	3,54E – 0,2	-	3,54E – 0,2	-
	(1)		(2)	

1) For the zones of studies of Kisenso and Mont-Ngafula
2) For the zones of studies of BINZA-Delvaux (LALU)

iv. *Monotonous drained tests in compression*

a. *Curves of shear strength - drained for the 3 zones of studies*

a. in the plan(T,ε_a);(Effort of shearing, axial deformation)

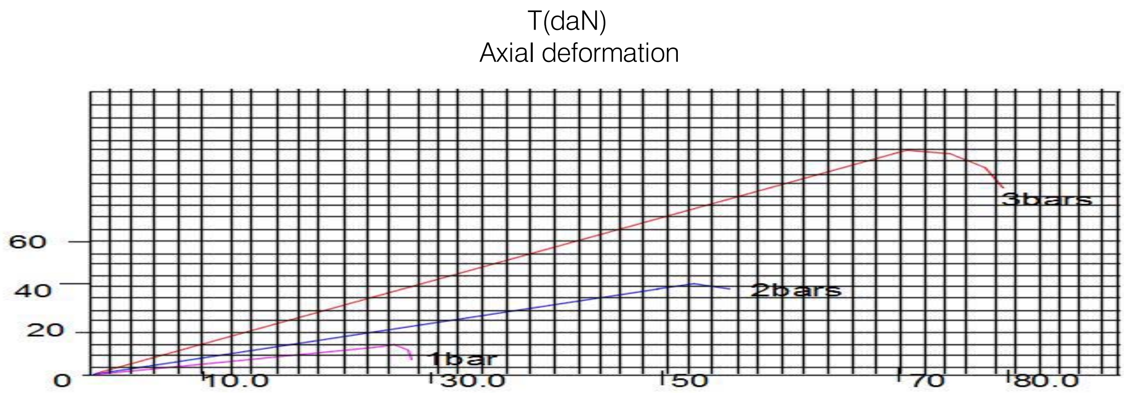


Figure 2: curve constraint -axial deformation of ground of Kinshasa

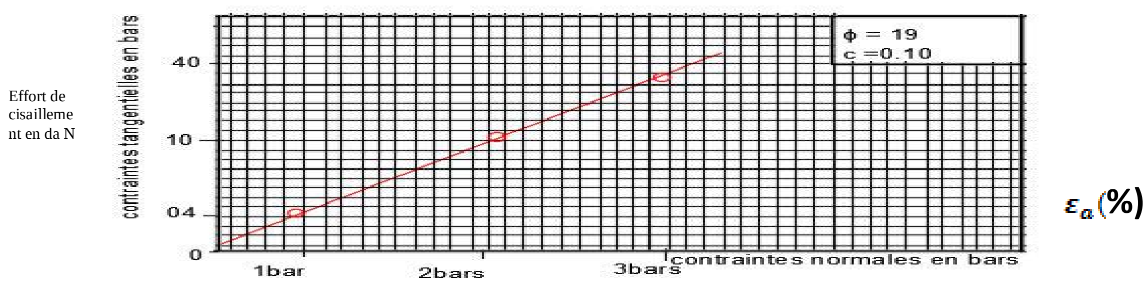


Figure 3: Intrinsic right-hand side of Coulomb (case of Mount-Ngafula and Kisenso)

The criterion of rupture Mohr - Coulomb: the intrinsic line of Coulomb makes it possible to separate the zones from elastic and plastic behavior (Figure 3).

Ways of drained constraints whose ultimate states are on the same line of critical state for a given state of density

a) line of collapse in the plan (q,p')

Line of stable state: CLS

b) line of collapse in the plan (q,p')

Line of stable state: FLS

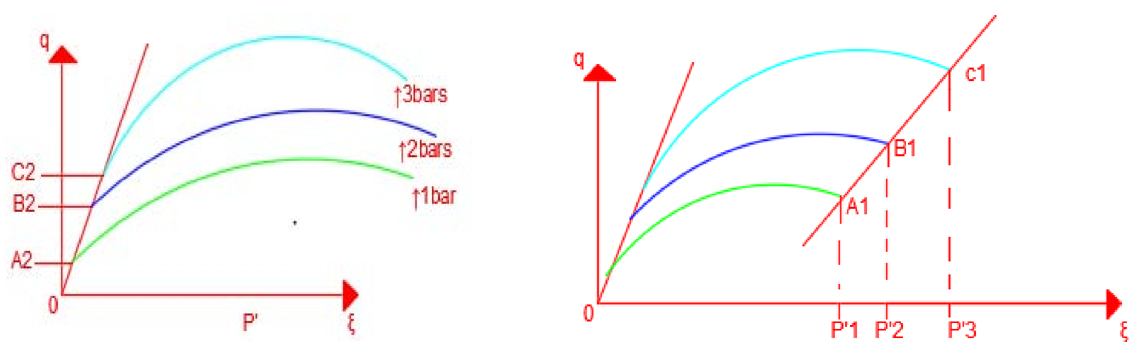
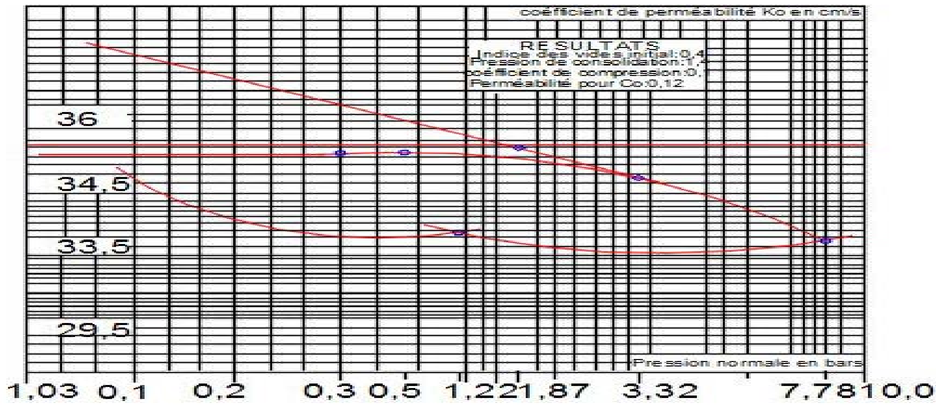


Figure 4: Line of stable state

v. *Parameters of deformability (index of compression cc, initial index of the vacuums e0, k0 = permeability)*



б'p

Figure 5: Odomeric curve

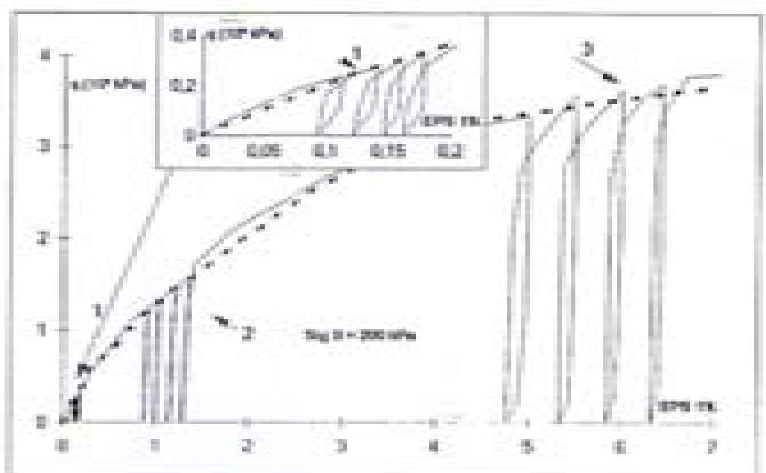


Figure 6: Cyclic tests in imposed deformations (variation of diverter). Loose sand of the hills of Kinshasa

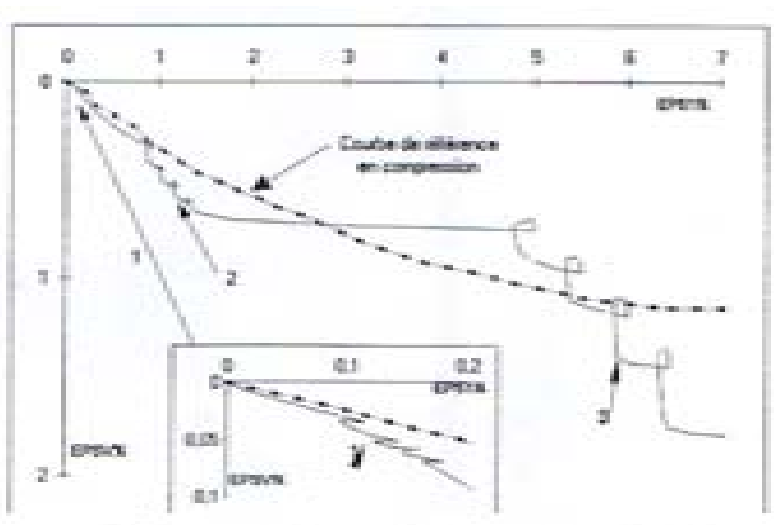


Figure 7: Cyclic Tests in imposed deformations (variation of Volume). Sand Coward of the hills of Kinshasa

III. Results and Discussions

a) For the monotonous behavior

According to the classification of the national laboratory of the bridges and fitted (LNPC[1]), the percentage of the fine particles is 13% > 12% one is in the presence of a yellowish silty sand with WL = 15,4% < 35%;w% natural = 7,6% > 0,9%, non-measurable WP; we can thus classify these grounds in the categories of the liquefiable grounds (figure 1)

In term of relative density $D_r\% = 100$ ID

We obtained the following values respectively: 38 %; 20% and 20,5% < 40% we are in the presence of loose sand.

About the angle of dilatancy ψ

$\psi = 30° - \varphi$ for $\varphi = 19°$ and $29°$, one finds successively $\psi = 30° - 19° = 11° > 0°$ and $\psi = 30° - 29° = 1° > 0°$.

In both cases; one is in the presence of a yellowish silty sand of the loose type primarily contracted.

Line of stable state (CLS) and line of critical state (FLS)

We observe that the points A_2, B_2, C_2 A_2, B_2, C_2 determine the shear strength in a critical state, the line connecting the points A_2, B_2 *et* C_2 A_2, B_2 *et* C_2 is called CLS: the critical state line. While the points A_1, B_1 *et* C_1 A_1, B_1 *et* C_1 indicate the peaks of shear strength then of the shear strength until reaching the zero value; then one speaks about limited liquefaction or a mechanical instability causing a disintegration of the ground or the phenomenon of liquefaction if the shear strength $\tau = 0$

The line of initiation of liquefaction FLS (The flow liquefaction surfaces)(figure 4).

Classification of the grounds towards the compressibility

One notices for the ground studied the constraint of pre-consolidation: $\sigma'_p < \sigma'_{z0} \sigma'_p < \sigma'_{z0}$ (normal pressure). It is about loose sand, ground not inflating (Figure 5).

The behavior of the grounds depending on their consolidation statement

The term $\frac{c_c}{1+e_0} = 0{,}097 \frac{c_c}{1+e_0} = 0{,}097$

One can give the following appreciations:

$\frac{c_c}{1+e_0} < 0{,}015 \frac{c_c}{1+e_0} < 0{,}015$ Incompressible ground

Indeed, $0{,}097 < 0{,}20\, 0{,}097 < 0{,}20$: one is in the presence of a compressible ground. It is also a permeable soil because the coefficient of permeability k_0 is worth 0,12cm/s.

The theory of consolidation allows in plus, to understand the behavior in the time of the grounds under the effect of the permanent loads and also to apprehend the calculation of pressure under the structures.

IV. Conclusion

In comparison with the behavior of the grounds vis-a-vis the various requests and the curve of established shear strength (response), one notes that it is about a yellowish silty sand of the loose type with 13% of the fine particles, primarily contracted, permeable, compressible, not inflating classified in the category of the liquefiable grounds and presenting the line of initiation of liquefaction "FLS" (The flow liquefaction surfaces).

The behavior of loose sand for a series of triaxial compression tests to various effective constraints of consolidation and the same final resistance of material when the constraint of containment increases. This is due to the increase of the perpendicular force at the point of contact of the grains. In addition, the ratio of the constraints σ_1/σ_3 fall when σ_3 increases, which is due partly to the fact that the corners of the grains break and are flattened at the point of contact and thus the overlap of the particles decreases.

This type of behavior is explained by the following concepts: sand has only internal friction. The skidding resistance between the points of contact of the grains with grains is proportional to the existing normal force, one will then have a total resistance which increases if the constraint of consolidation increases.

The overlap also contributes to total resistance, and it remains almost constant when the constraint of consolidation increases because the grains are flattened at the point of contact, their acute corners break.

- Influence of the index of density I_D on the behavior of sand C.D

If the relative density increases and becomes > 50%; mechanical characteristics: the angle of friction and cohesion increase (φ↗, C↗), then sand is dilating, whereas for studied sands, their relative densities are lower than 40% thus we are in the presence of a contracting sand in the plan ($-\xi_v$, ξ_a) (figure 3).

- Pressure of consolidation influence

One observes on figure 4 that an increase in constraint of consolidation σ_c increases the character contracting of material and in addition in a way almost proportional to σ_c in the plan (q, ξ_a)

[1] LNPC means « Laboratoire National des Ponts et Chaussées ». It is the French national laboratory on bridges and roads.

- Fine particles influence in the sand behavior

If the percentage (13%) of the fine particles increases (↗) > 12%, the shear strength decrease (↘).

- Angle of dilatancy influence ψ

In all cases Ψ >0°: it is noticed that sand is contracting in plan ($-\xi_v$, ξ_a)
Ψ is a function of the size of the fine particles and the shape of the grains.

The angle of friction φ in the case of loose sand is a constant and the contraction is much more significant than for dense and average sands. this also confirms the results found by other researchers on loose sand.

a) Cyclic behavior

Cyclic drained tests in imposed constraints

By analyzing the stress- strain curves in compres -sion, we note:

- ➢ The sample of sand undergoes a great irreversible axial deformation during the first cycle and for all the levels of the cyclic loadings (figure 6).

For all the levels of the cyclic constraints applied, the cycles carried out in compression present a significant character at the moment of unloading (third series). At the beginning of the discharge, the curve is almost vertical, it is what gives a very high module u. At the time when we approach the isotropic state, we noted the appearance of the significant axial deformations and the curve is accentuated. It is noticed however, that the modules of refill and discharge are stronger than the initial tangent module. The irreversible axial deformations accumulated between the first and the last cycle of each series, measured with the thresholds high and low of the cycles are higher in bottom than in top.

- ➢ Notwithstanding the various requests applied, in small deformations, nevertheless the sample tends to find a behavior or an evolution similar to the case of the monotonous loading (curve of reference). In the case of the cycles to which the amplitude is close to maximum resistance (cf. 3rd series), we see an increase in the resistance, followed by a reduction during final, consecutive crushing with the cycles. It seems that the material does not forget the history of these stresses (figure 6).
- ➢ By analyzing the voluminal curves of deformations (figure 7), we noted a contraction reloads some and the first phase without variation followed by the compaction of material in discharge. The results obtained are in agreement with those obtained by several researchers[2]. For the rather significant deformations, we observed in refill a contraction, discharge and a dilatancy followed by compaction. After the cyclic levels of loadings, the curve of variations of volume tends to join the curve of variation of monotonous tests (figure7).

Cyclic drained tests in imposed deformations

The analysis of the results shows that:

- ➢ The module of discharge is very high, and does not change the six cycles applied.
- ➢ The imposed axial deformation is all the weaker as the average slope in the refill is stronger. In general, the average slope increases by a cycle to another because of the material compaction.
- ➢ A dilatancy of material is observed at the beginning of discharge and a contraction with the beginning of refill.
- ➢ Notwithstanding the various requests applied the sample tends to find a behavior where an evolution similar to the case of the monotonous loading (curve of reference in compression).

V. Conclusion

The analysis of the results obtained made it possible to draw the following conclusions:

- ➢ The application of shear stresses of low amplitudes to a sand sample in drained condition produces a progressive reduction in volume (contraction). Consequently when a saturated sand is subjected to a propagation of waves of shearing during a request of great scale: The period of validity of the cyclic constraint is in general shorter in comparison with that necessary with the drainage of water. An increase in the pore water pressure causes a reduction of the effective pressure what corresponds to a fall of the shear strength which will lead to a rupture of the structure by shearing with catastrophic consequences.

Factors such as:

- ➢ The relative density, the initial state of the constraints, the distribution of the size and the shape of the grains, the history of the constraints in the plan (q, Ɛa) and of the way of the constraints followed in the plan (q, p '), play a role in the characterization of the behavior of the ground subjected to a cyclic and monotonous loading.
- ➢ During the cyclic loading the interstitial pressure increases until reaching the pressure of initial consolidation. The effective constraint is cancelled. It is said that sand is liquified although this phenomenon is temporary. The relative density is one of the essential parameters which govern the phenomena of compressibility under a loading of shearing. It is clear that larger east the tendency to the contraction of the solid skeleton, stronger is the increase in the pore water pressure as well as the potential of liquefaction under the cyclic loading.

[2] El Ouni et al., 1995;1997 and El Ouni, 2000

- It should be noticed that in the case of an isotropic state of stress the pore water pressure reaches the value of the pressure of the consolidation only when the diverter of the constraints is equal to zero in the plan (q, p ').
- The presence of the pore water pressure more reduced the hydraulic parameters of the ground in fact: cohesion, the natural angle of repose, effective pressure and shear strength.

Bibliography

1. Belanteur N., Tacherifet S.et Pakzad M., (1997), Etude des comportements mécaniques, thermomécaniques et hydromécaniques des argiles gonflantes et non gonflantes fortement compactées, Revue Française de géotechnique, n°78,1er trimestre, pp.31-50.
2. DUNCAN J.M., Finite element analyses of stresses and movements in dams, excavations and slopes. Applications of the finite elements method in geotechnical engineering, CR, symposium de Vicksburg (1972).
3. El ouni M.R., (1990), comportement des argiles compactées : Application au barrage de lebna, Thèse de Doctorat, novembre, INPG-Grenoble.
4. El ouni M.R., Flavigny E., et Raboudi L. (1995), comportement mécanique d'un matériau cohérent compacté au laboratoire et en place, les annales Maghrébines de l'ingénieur, vol.9, n°2, octobre.
5. VOGIEN M., Etude du comportement avant la rupture d'un remblai expérimental construit sur le sol mou à Cubzar –les – Pont, Thèse de docteur – ingénieur, Université paris VI, Paris (1975).