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ABSTRACT : DOBRY et al, YOUD have shown the existance of a shearing threshold strain in the vicinty of 10^{-4} which guides the occurence of liquefaction. With tests on glass beads and sand from the Algiers bay, using a proper measuring system, we were able to arrive at a better resolution of this threshold and to the determination of its mechanical signification.

INTRODUCTION

The liquefaction is mostly hnown by the enormous damage to the constructions during the earthquakes of NIGATA and ALASKA (SEED 1979). However according to AMBRASEYS (1984) the majority of the building of structures of the town of Djideli during the quake of 1856 suffered from severe disorders. The same behavior has been noticed during the CHLEF earthquake of October 1980. Four cases of liquefaction have been reported (CLOUGH et Al, 1980). In the town of Algiers we had to consolidate dynamically the site of an important installation having foundations in loose sands containing a very shallow water table (Kaddouri 1984). The importance of the seismic risk in Algeria in general and particularly in Algiers, led us to a serious investigation of the problem of liquefaction.

The numerical solution of a liquefaction problem prerequires the determination of the material's law of behavior. The experimental data has introduced into the laws of behavior models, numerous parameters which induce the occurence of liquefaction. However most of this parameters are interdependant and whithout precise significance in materials mechanics (elastic and elastoplatic behavior etc...)

DOBRY et al, (1981-1982), YOUD (1972) have shown the existance of a shearing threshold strain in the vicinity of 10^{-4} which guides the occurence of liquefaction. Infortunately this threshold has not been investigated. To arrive at a better knowledge of this threshold, we have proceded to a critical study of the technique used by DOBRY et al. (1981-1982) and YOUD (1972) to measure this threshold and have made an attempt to explain this latter mechanically.

EXPERIMENTATION

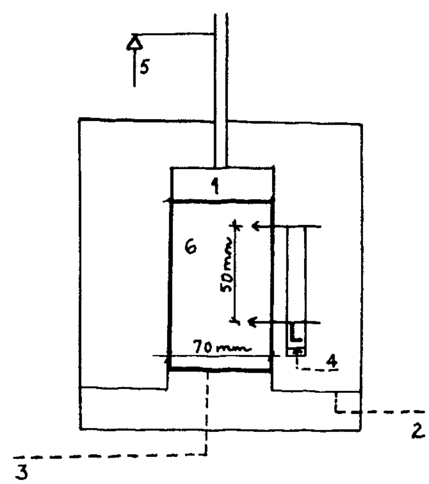
The deformations measured by DOBRY et al. (1981-1982) and YOUD (1972) is not homogeneous for at least two reasons.

1 - Concentration of stress in cyclic rectilinear shearing mode.

2 - The measuring device of longitudinal strain is located outside of the triaxial cell when it has been well established that the shoulder effect shows concentration of stress in the ends.

The shearing treshold is measured in the triaxial cell from the longitudinal strain data, which implicitly assumes a hypothesis on the behavior law.

We have updated the arrangement used by KAKOSHO (1980) and EL-HOSRI (1984) which consists of fixing the measuring devices for stress and displacement inside the triaxial cell. The measuring device for longitudinal strain located in the homogeneous zone and another measuring device for longitudinal displacement located outside the cell (Fig.1).



1 : load cell
2 : cell pressure
3 : pore pressure
4 : Inside displacement captor
5 : outside displacement captor
6 : Sample

Fig. n° 1 : Measuring Apparatus.

Whith the apparatus shown in figure 1, we have carried cyclic tests (f=0.5Hz) on glass beads (Fig.2) and sand (Fig.3).

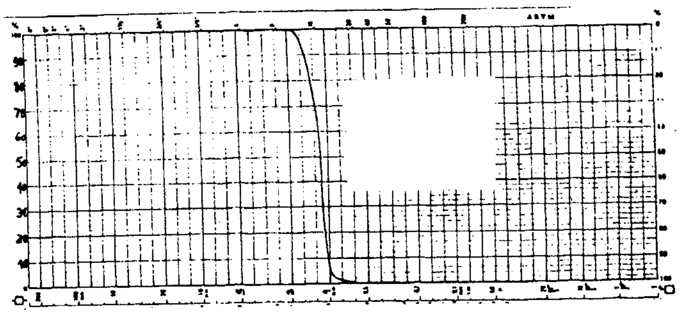


Fig.2 : Grain Size of Glass Beads.

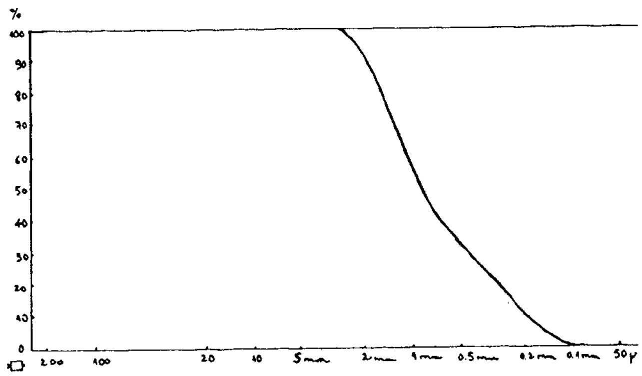


Fig.3 : Grain Size of Sand.

Figures 4 and 5 show the relation of the cyclic deviator and the longitudinal and homogeneous deformation measured inside the cell.

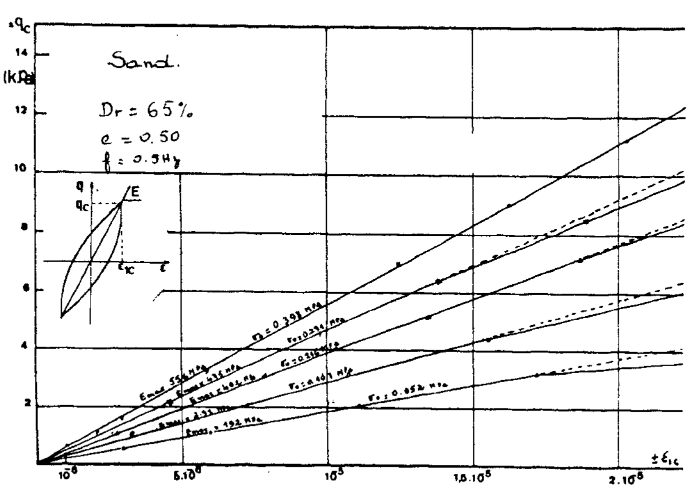


Fig.4 : Deviatoric Stress Versus Axial Homogeneous Strain (Sand).

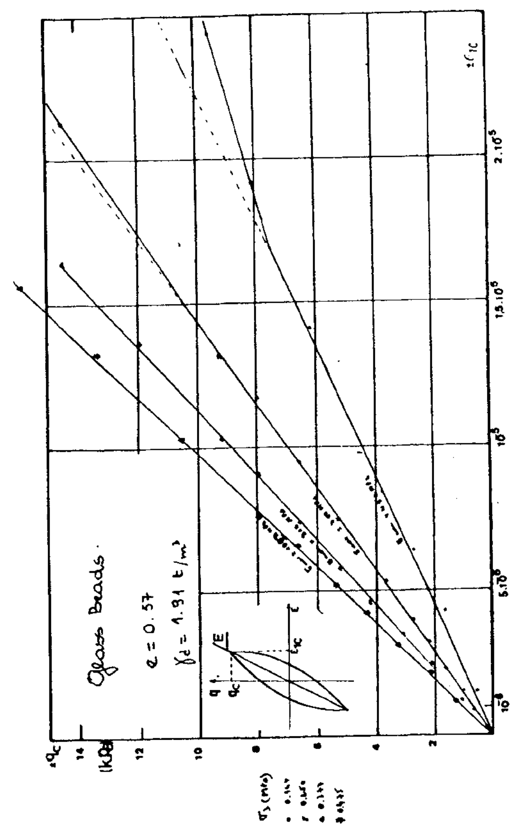


Fig.5 : Deviatoric Stress Versus Axial Homogeneous Strain (glass beads).

We notice the existance of a linear elastic limit in the logitudinal homogeneous deformation.
- This linear elastic limit is in the order of 10^{-5}
- For the frequency, density and the range of stress used, the elastic limit is 10^{-5} for the sand and the glass beads.

On the other hand we have measured the longitudinal non-homogeneous deformation with an LVDT captor located outside the cell. We found that the value of the homogeneous logitudinal deformation of 10^{-5} corresponds to 10^{-4} in non-homogeneous longitudinal deformation mode.

The next step will consist of liquefaction tests with cyclic deformation above and under 10^{-4} in non-homogeneous deformation.

LIQUEFACTION TESTS

Following these results we carried 17 tests on sand from the Algiers shore (Fig. 6) at longitudinal strain levels above and below the threshold of 10^{-4} in non-homogeneous mode which corresponds as we have shown to 10^{-5} in homogeneous deformation.

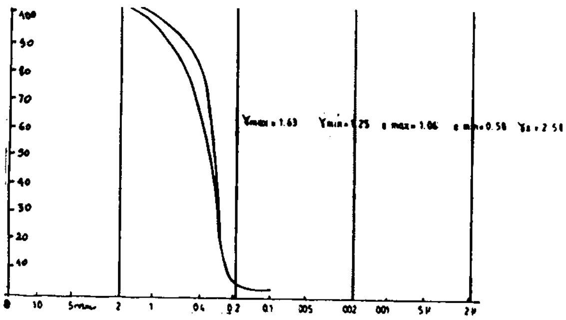


Fig.6 : Grain Size of the Algiers Shore Sand.

The table 1 shows the results obtained.

Samples	Dr (%)	σ'_v (Kpa)	Q_c (Kpa)	ε	Liquefaction Occurence
Alger 1	46	100	± 3	10-4	NO
2	46	100	± 8	10-4	NO
3	46	100	Several	Levels	-
4	46	82	± 40	9x10-4	YES
5	80	100	± 40	3x10-4	NO
6	80	100	± 10	6x10-5	NO
8	46	100	± 30	5x10-4	YES
9	46	100	± 38	7x10-4	YES
10	46	500	± 40	$2.5x10^{-4}$	NO
11	46	500	± 70	3x10-4	NO
12	46	500	± 97	4x10-4	NO
13	46	500	± 190	10-3	YES
14	80	500	± 70	$2.5x10^{-4}$	NO
15	80	500	± 97	3x10-4	NO
16	80	500	± 196	7x10-4	NL > 80
17	80	500	± 283	$1.3x10^{-3}$	NL > 80
18	80	500	± 381	3x10-3	YES

Table n° 1 : Liquefaction Tests data.

The figures 7 and 8 show the three curves for the tests n° 2 and 18.

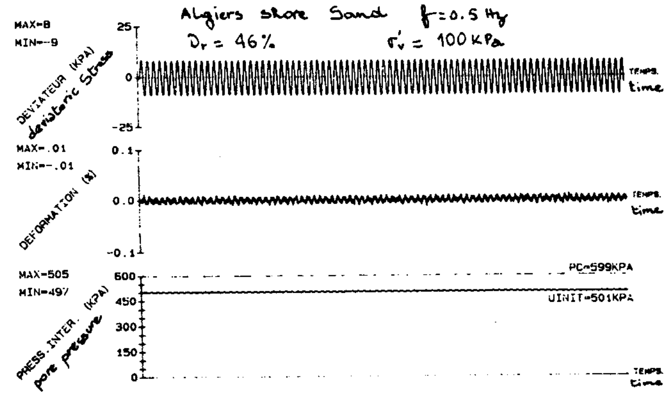


Fig.7 : Liquefaction Test no 2.

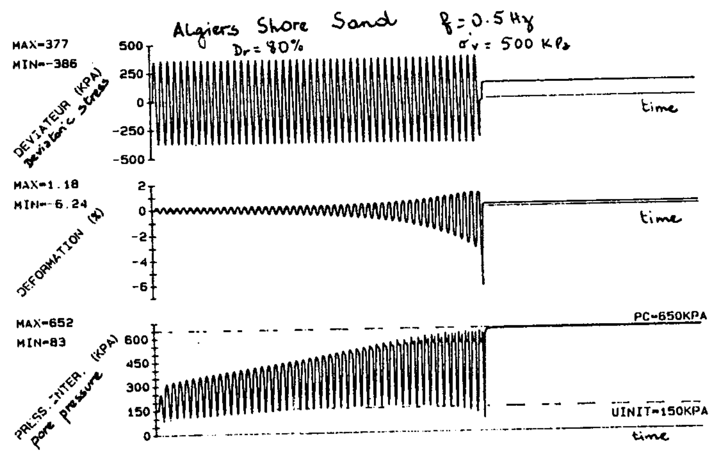


Fig.8 : Liquefaction Test no 18.

It appears clearly that this value of 10^{-4} in non-homogeneous longitudinal deformation mode which corresponds to 10^{-5} in homogeneous mode, constitutes the occurence threshold of liquefaction.

CONCLUSIONS

Cyclic tests on sand and glass beads have shown that the threshold of occurence for liquefaction of 10^{-4} in the shearing deformation defined by litterature is in fact a homogeneous longitudinal strain of 10^{-5} and is defined mechanically as being an elastic threshold. This investigation will help in the orientation of choices for elastoplastic behavior models.

REFERENCES :

- Ambrasseys, N.N, "The seismicity of North Africa. The earthquake of 1956 at JIJELI Algeria. "Workshop on Microzonation-" 1984 - Algiers.

- Clough, C.W. , Salah Mars, S.,HADJ HAMOU , A. , " A Report on Observation of Liquesfaction and Landsliding as a Result of the October 10, 1980 the El-Asnam Algeria Earthquake".

- Dobry, R., Ladd, T., Yokel, F.Y., Chung, R.M. and Powel, D., "Prediction of Pore Water Pressure Buildup and Liquefaction of Sand by Cyclic Strain Methods". 1982. Building science Series no 138.

- Dobry , R. , Stokoe, Ladd, R.S. and Youd T.L., " Liquefaction Succeptibility from Shear Wave Velocity" 1981. A.S.C.E. National Convention Saint Louis. Missouri.

- EL-Hosri : " Contribution à l'étude des propriétés mécanique des matériaux " 1984 - Thèse d'Etat - Paris VI.

- KADDOURI, A. " Dynamic compaction of Sand from the Algiers Shore". 1988. Internal Report . LTPC Algiers

- Kakusho, T. , "Cyclic Triaxial Test of Dynamic Soil Properties for Strain Range". Soils an Foundations, 1980, vol. 20, n° 2 June . Japan.

- Seed, H.B. , " Evaluation of Soil Liquefaction and Cyclic Mobility on Level Ground During Earthquakes". Journal of Geotechnical Engineering Division. 1979. A.S.C.E. February.

- Youd, T.L. , : "Compaction of Sand by Repeated Straining". Journal of Soil Mechanic and Foundation Division. A.S.C.E. 1972 - 98 - SM7.