VPLIV ZAČETNE STRUKTURE NA LASTNOSTI PESKA CHLEF

NOUREDDINE DELLA, AHMED ARAB, MOSTEFA BELKHATIR, HANIFI MISSOUM, CLAUDE BACCONNET in DANIEL BOISSIER

o avtorjih

Noureddine Della *
Université de Chlef,
Département de Génie Civil,
Route de sendjas BP 151,
Chlef 02000, Alžirija
E-pošta: nour_della@yahoo.fr

Ahmed Arab
Université de Chlef,
Département de Génie Civil,
Route de sendjas BP 151,
Chlef 02000, Alžirija
E-pošta: ah_arab@yahoo.fr

Mostefa Belkhatir
Université de Chlef,
Département de Génie Civil,
Route de sendjas BP 151,
Chlef 02000, Alžirija
E-pošta: abelkhatir@yahoo.com

Hanifi Missoum
Université de Mostaganem,
Département de Génie Civil
Site 1,route de Belahcel BP 300,
Mostaganem 27000, Alžirija
E-pošta: hanifimissoum@yahoo.fr

Claude Bacconnet
Polytech'Clermont,
Ecole d'ingénieurs (CUST),
BP 206-63174 Aubière Cedex, Francija
E-pošta: claude.bacconnet@polytech.univ-bpclermont.fr

Daniel Boissier
Polytech'Clermont,
Ecole d'ingénieurs (CUST)
BP 206-63174 Aubière Cedex, Francija
E-pošta: daniel.boissier@polytech.univ-bpclermont.fr

* vodilni avtor

izvleček

Že vrsto let je znano, da začetna struktura igra pomembno vlogo pri rezultatih laboratorijskega preskušanja naravnih meljnih peskov. V ta namen se je izvedla vrsta nedreniranih triosnih tlačni preskusov na vzorcih, sestavljenih iz peska Chlef z 0,5% vsebnostjo neplastičnega melja z uporabo dveh sedimentacijskih metod in pri različnih začetnih relativnih gostotah (Dr = 29%, 50% in 80%). Vsi vzorci so bili izotropno konsolidirani pri 50 kPa, 100 kPa in 200 kPa. Ugotovljeno je bilo, da ima začetna struktura tal bistveni vpliv na nedrenirani strižni odziv izražen z maksimalno deviatorično napetostjo, vrhnjo trdnostjo in prirastkom pritiska porne vode.

ključne besede

utekočinjenje, pesek, suho odlaganje, mokro odlaganje, gostota, deviatorična napetost, porni tlak

EFFECT OF THE INITIAL STRUCTURE ON THE BEHAVIOR OF CHLEF SAND

NOUREDDINE DELLA, AHMED ARAB, MOSTEFA BELKHATIR,
HANIFI MISSOUM, CLAUDE BACCONNET and DANIEL BOISSIER

about the authors

Noureddine Della *
Université de Chlef,
Département de Génie Civil,
Route de sendjas BP 151, Chlef 02000, Algeria
E-mail: nour_della@yahoo.fr

Ahmed Arab
Université de Chlef,
Département de Génie Civil,
Route de sendjas BP 151, Chlef 02000, Algeria
E-mail: ah_arab@yahoo.fri

Mostefa Belkhatir
Université de Chlef,
Département de Génie Civil,
Route de sendjas BP 151, Chlef 02000, Algeria
E-mail: abelkhatir@yahoo.com

Hanifi Missoum
Université de Mostaganem,
Département de Génie Civil
Site 1,route de Belahcel BP 300, Mostaganem 27000, Algeria
E-mail: hanifimissoum@yahoo.fr

Claude Bacconnet
Polytech'Clermont,
Ecole d'ingénieurs (CUST),
BP 206-63174 Aubière Cedex, France
E-mail: claude.bacconnet@polytech.univ-bpclermont.fr

Daniel Boissier
Polytech'Clermont,
Ecole d'ingénieurs (CUST)
BP 206-63174 Aubière Cedex, France
E-mail: daniel.boissier@polytech.univ-bpclermont.fr

* Corresponding author

abstract

It has been known for many years that initial structure, plays an important part in the results of laboratory testing of natural of silty sands. For this purpose, a series of monotonic undrained triaxial compression tests were carried out on samples composed of Chlef sand with 0.5% non-plastic silt content using two depositional methods (dry funnel pluviation and wet deposition) at different initial relative density (RD= 29%, 50% and 80%). All specimens were subjected to isotropic consolidation of 50 kPa, 100 kPa and 200 kPa. It was found that the initial structure of the soil influences considerably the undrained shear response in terms of maximal deviatoric stress, peak strength and excess pore water pressure.

keywords

liquefaction, sand, dry funnel pluviation, wet deposition, density, deviatoric stress, pore pressure

1 INTRODUCTION

It is widely recognized that the mechanical behavior of sands very much depends on their initial state in terms of the void ratio (or relative density) and the effective stresses. Polito and Martin [10] asserted that the relative density and skeleton void ratio were factors that seemed to explain the variation in the different experimental results. Many studies concluded that complete static liquefaction (zero effective confining pressure and zero effective stress difference) in laboratory testing is most easily achieved in silty sands at very low pressures (Yamamuro and Lade [14]; Yamamuro and Lade [15]; Yamamuro and Covert [13]). Kramer and Seed [6] also observed that the liquefaction resistance increased with an increasing confining pressure.

Numerous studies have reported that the behavior of sands can be greatly influenced by specimen reconstitution. The effect of the preparation method used for the samples has been subject to many controversial researches, and several studies have reported that the resistance to liquefaction is more elevated for samples prepared by the method of sedimentation than for samples prepared by other methods, such as dry funnel pluviation and wet deposition (Zlatovic and Ishihara [18]); other studies have found that the specimens reconstituted by the wet deposition method are more resistant than those prepared by the dry funnel pluviation method (Mulilis et al. [9]; Yamamuro and Wood [16]). Other researchers indicated that the tests prepared by dry funnel pluviation are more resistant than those prepared by wet deposition (Benahmed et al. [1]; Canou, [3]). Vaid et al. [11] confirmed this result while showing that wet deposition encourages the initiation of the liquefaction in relation to a setting up by pluviation under water. Yamamuro et al. [17] concluded, after their laboratory investigation, that the method of dry pluviation supports the instability of the samples, in contrast to the method of sedimentation. Wood et al. [12] found that the effect of the method of deposition on the undrained behavior decreases when the density increases. They also found that this influence decreases with the increase of the fines content, particularly with the lower densities. Indeed, two sets of undrained triaxial tests were carried out, using two methods of deposition, such as dry funnel pluviation and wet deposition, in order to define the effect of the method of preparation of the samples on the resistance to liquefaction. Since there were different possible modes of formation for the natural sandy solid masses, the use of the two modes of deposition for the Chlef sand allows us to approach to the reality of the area, the final purpose being the characterization of the behavior of this sand to liquefaction. According to Durville and Méneroud [4] the phenomenon of liquefaction appeared during the last earthquake (10 October 1980) on a vast alluvial valley crossed by the Chlef river and the zone of confluence of this river with the Fodda river, as shown in Fig. 1.

Figure 1. Sand boils due to the liquefaction phenomenon.

2 MATERIAL TESTED

All the tests in the present study were performed on the sand of Chlef (Algeria) containing 0.5% of silt of the river of Chlef that crosses the city of Chlef to the west of Algiers. The granulometric curve of this sand is given in Fig. 2. The sand of Chlef is a medium sand, rounded with a medium diameter D_{50}=0.45mm. The contained silt is non-plastic with a plasticity index of 5.81%. Table 1 gives the physical properties of the used sand. The tests were carried out on specimens collected from the region where the phenomenon of liquefaction was observed during the last earthquake (10 October 1980) near the Chlef river (see Fig. 1) for three relative densities RD =29%, 50% and 80%, respectively, representing the loose, medium dense and dense states, for three initial confining pressures of 50, 100 and 200 kPa.

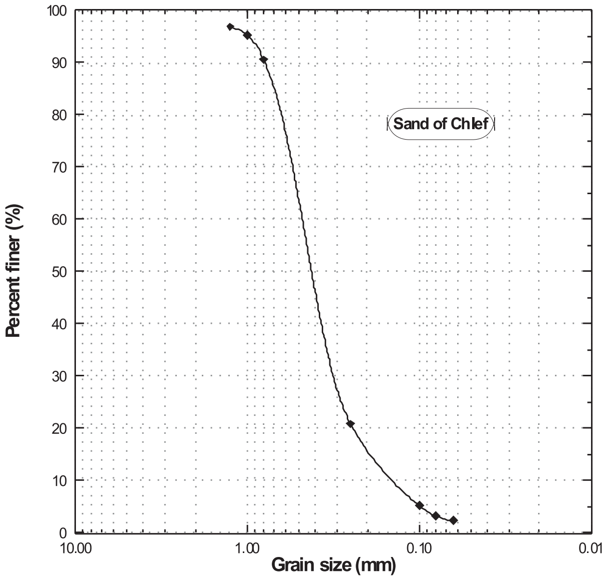


Figure 2. Grain size of the sand.

Table 1. Properties of soil.

Material	e_{min}	e_{max}	γ_{dmin} g/cm^3	γ_{dmax} g/cm^3	γ_s g/cm^3	Cu D_{60}/D_{10}	D_{50} mm	D_{10} mm	Grains shape
O/Chlef	0.54	0.99	1.34	1.73	2.67	3.2	0.45	0.15	Rounded

3 EXPERIMENTAL PROCEDURES

The experimental device is presented in Fig. 3. It contains:

- an autonomous triaxial cell of the Bishop and Wesley type (Bishop and Wesley, 1975),
- three controllers of the pressure/volume type GDS (200cc),
- a void pump joined to a reservoir in order to deaerate the demineralized water,
- a microcomputer equipped with software permitting the piloting of the test and the data acquisition.

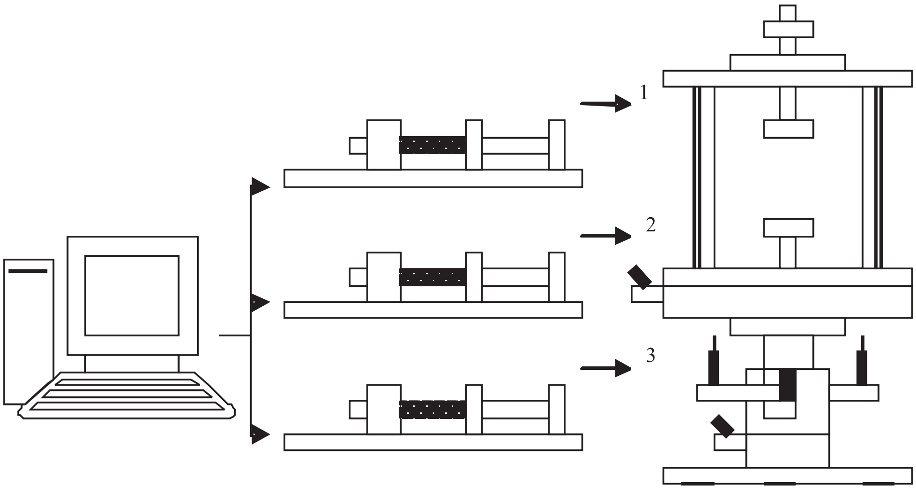
3.1 SAMPLE PREPARATION

The samples were prepared with the help of a mold consisting of two semi-cylindrical shells. The two shells can be easily joined or embossed, one from the other, with the help of a hose clamp. In order to maintain the cuff made of latex along the partitions of the mold, four ducts of aspiration were pierced in the conducted shells. Cylindrical soil specimens of 70 mm × 70 mm (H/D= 1.0) (Yamamuro and Wood [16]; Lanier [8]; Hettler and Vardoulakis [5]; Bouvard and Stutz [2]) were created. The mass of sand to be put in place is evaluated according to the required density (the initial volume of the sample is known), the state of density of the sample being defined by the relative density:

$$I_D = (e_{max} - e) / (e_{max} - e_{min}) \qquad (1)$$

3.2 DEPOSITIONAL TECHNIQUES

Two methods were used to reconstitute the specimens of sand: wet deposition and dry funnel pluviation. The first method consists of mixing, in the most homogeneous manner possible, the sand previously dried with a small quantity of water fixed at 3% and the deposition of the humid soil in the mold with the control of the content in the water. The soil is finely placed in successive layers. A constant number of strokes were applied to get a homogeneous and isotropic structure. This method is more convenient for the sand, because it can provide some samples with a large range of void ratios. In the dry



(1) application of the pressure in the cell
(2) control of the interstitial pressure or variation of volume of the sample
(3) control of the deviator

Figure 3. Experimental device used.

funnel pluviation method, the dry soil is deposited in the mold with the help of a funnel for control of the height. This method consists of filling the mold by tipping in rain of the dry sand. In order to have loose samples, it is necessary that the height of fall is quasi-nil.

3.3 SATURATION AND CONSOLIDATION OF THE SAMPLE

The saturation is an important stage in the experimental procedure because the response of the sample under undrained loading depends on its quality. To get a good degree of saturation, the technique of carbon dioxide elaborated by Lade and Duncan [7] was used. This technique consists of making the carbon dioxide circulate through the circuits of drainage and the sample to weak debit during a certain time, in order to occupy all the voids and to chase the air contained in the sample. Then, we make the deaerated and demineralized water circulate to chase the interstitial gas and to occupy its place. In spite of the passage of water, some voids remain occupied by the carbon dioxide. As the solubility of the gas is raised, water can dissolve what remains of the carbon dioxide after its passage, it generally permits us to ensure a good saturation of the sample. In order to consolidate the sample, we apply in the same way, an increase in pressure in the cell (GDS n1) and inside the sample (GDS n2). The application of a back pressure, with the help of the GDS n2, improves the quality of the saturation, while compressing the micro-bubbles of the interstitial gas that can still be present after the phase of saturation. These two pressures (in the cell and inside the sample) were maintained during a whole night to ensure good consolidation.

The quality of the saturation is evaluated with a measure of the coefficient of Skempton (B), according to a classic process: an increment $\Delta\sigma$ of the confining pressure of 100 kPa in an undrained condition was given, the response of the interstitial pressure Δu was measured and the degree of saturation by the formula $B=\Delta u / \Delta\sigma$ was evaluated.

4 RESULTS OF THE TESTS CONDUCTED

4.1 EFFECT OF CONFINING PRESSURE

The effect of the variation of the effective confining pressure on the liquefaction resistance of the sand is shown in Figs. 4 and 5. As the confining pressure is increased, the liquefaction resistance of the sands increased for both the dry funnel pluviation and wet deposition methods. The results in Figs. 4a and 4b with an initial density of 29% (loose state) for specimens reconstituted by the first method at a confining pressure of 50 kPa show a weaker resistance than those shown at confining pressures of 100 kPa and 200 kPa. Its resistance increases at the beginning of the loading up to a value of 20 kPa, corresponding to an axial strain of 0.5%, then it decreases up to an axial distortion strain of 5% to stabilize passing nearly a quasi steady state (QSS); then the sample mobilizes a residual strength, increasing the resistance of the sample in the steady state. The stress path diagram presents a reduction of the effective mean stress until a value of 20 kPa, then a migration toward higher values characterizing a dilating state. The same trends are signalled for the samples at confining pressures of 100 and 200 kPa, with peak deviatoric stresses of 40 kPa and 80 kPa, respectively.

The results of the Figs. 4c, 4d, 4e and 4f, for medium and dense samples, show a more resistant behavior of the sand. A change in the confining pressure from 50 to 200 kPa caused a variation in the peak deviatoric stress from 25 kPa to 115 kPa, associated with a higher residual strength at steady state.

The effective stress paths for undrained triaxial compression tests on Chlef sand for samples prepared by the wet deposition method with initial relative densities of 29%, 50% and 80% are plotted on the p'-q diagrams shown in Figs. 5b, 5d and 5f. As can be seen, complete static liquefaction occurred in the three tests with the lowest confining pressure (50 kPa). Static liquefaction coincided with the formation of large wrinkles in the membranes surrounding the specimens.

Figs. 5b, 5d and 5f also show that when the initial confining pressure is increased beyond 50 kPa, the effective stress paths exhibit behavior that is characterized by increasing stability or increasing resistance to liquefaction. This is demonstrated by examining the stress-strain curves in Figs. 5a, 5c and 5e. The initial confining pressures and densities are shown for each test. The stress-strain curves of the 100 and 200 kPa initial confining pressure tests show that the stress difference does not reach zero, as in the tests indicating complete liquefaction, but decreases to a minimum before increasing to levels well above the initial peak (medium and dense states) or with progressive stabilization around an ultimate stationary value very weak (loose state). This is the condition of temporary liquefaction. The effect of increasing the confining pressure is to increase the dilatant tendencies in the soil.

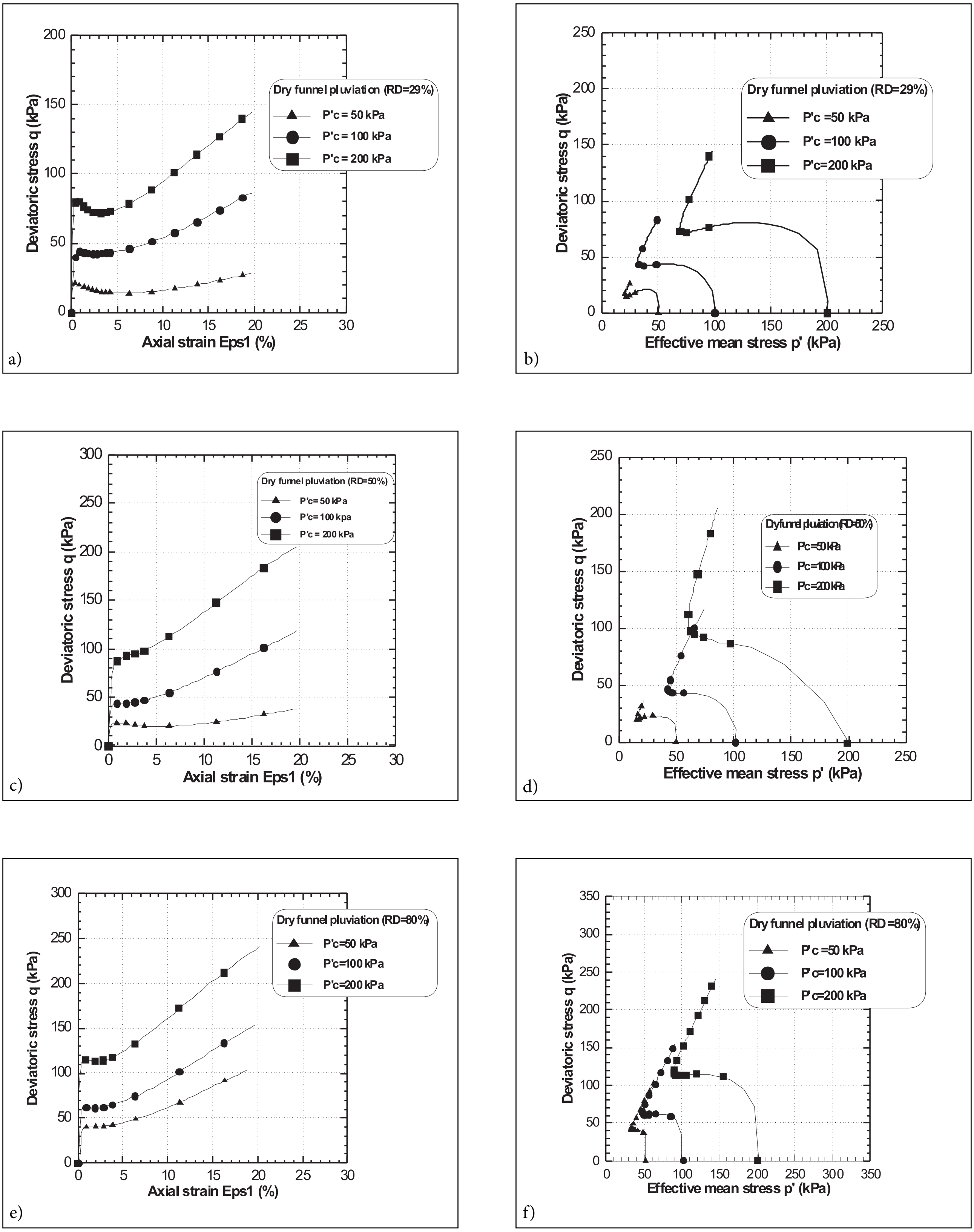


Figure 4. Undrained tests for samples prepared by the dry funnel pluviation method: (a, c, e) deviatoric stress-strain curve, (b, d, f) stress path.

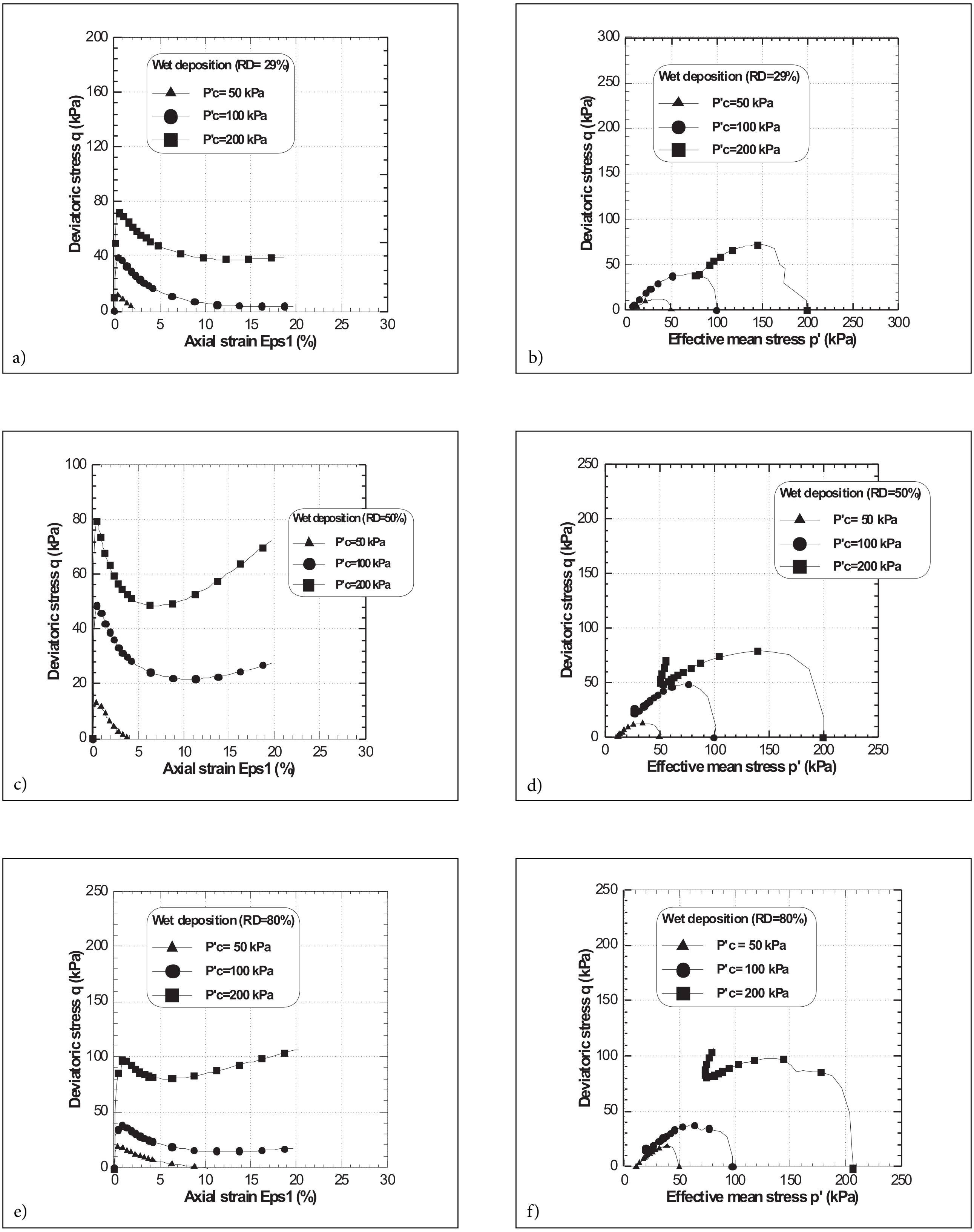
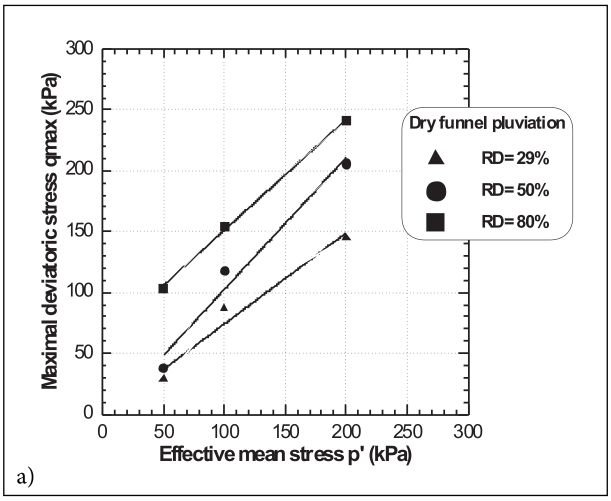


Figure 5. Undrained tests for samples prepared by the wet deposition method: (a, c, e) deviatoric stress-strain curve, (b, d, f) stress path.

4.2 EFFECT OF INITIAL DENSITY

The effect of increasing the relative density was investigated by performing undrained tests on Chlef sand with initial relative densities of 29, 50 and 80%. The results of these tests are plotted in the p'-q_{max} diagrams shown in Figs. 6a and 6b. We note that the resistance to the liquefaction represented by the maximum deviatoric stress (q_{max}), increases with the density of the soil for both the dry funnel pluviation and wet deposition methods, with a more pronounced increase for the dry funnel pluviation method (Fig. 6a), where the values of the maximum deviator pass from 28.23 kPa for a loose soil and a confining pressure of 50 kPa, to 240.97 kPa for a dense soil and a confining pressure of 200 kPa. This shows that the effect of increasing the relative density is to increase the resistance of the soil to liquefaction by making the soil more dilatant. Fig. 6b shows that static liquefaction still occurred for the specimens reconstituted by the wet deposition method for the three densities at the 50 kPa confining pressure. Fig. 6b also indicates that the evolution of the resistance is less pronounced.



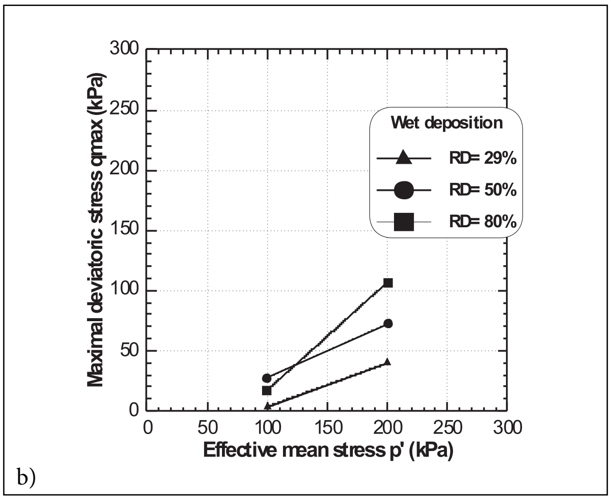


Figure 6. Effect of the relative density on the undrained response of sand: (a) dry funnel pluviation method, (b) wet deposition method.

4.3 INFLUENCE OF SAMPLE RECONSTITUTION METHOD

The effect of the specimens' reconstitution method on the maximum deviatoric stress is shown in Figs. 7a, 7b and 7c. It is clear from the results in these figures that the dry funnel pluviation method (DP) gives more significant values for the maximum deviator; therefore, a much higher resistance to liquefaction, contrary to the wet deposition method (WD) where some weaker values of the maximal deviator for low or medium densities (RD=29% and RD=50%) were noted, with progressive stabilization around a very weak or nil ultimate stationary value meaning the liquefaction of the sample.

The same tendencies are noted for the variations of the values in the peak deviatoric stress given in Figs. 7d, 7e and 7f. It is clear that the samples conceived by the dry funnel pluviation method exhibit a resistance to the monotonic shearing, superior (q_{pic}=240.97 kPa to the dense state and to confining pressure of 200 kPa) to those made by the wet deposition method (q_{pic}=106.73 kPa to the dense state and to a confining pressure of 200 kPa).

The influence of the sample preparation methods on the excess pore pressure is illustrated in Fig. 8. As shown by Figs. 8a, 8b and 8c for the dry funnel pluviation method, the variation of the pore-pressure curves represents two phases: the first shows a very high initial rate of generation, giving an account of the strongly contracting character of the Chlef sand. In the second phase, this rate decreases progressively with the axial strain, indicating the dilating character of the material. The developed excess pore pressure in the samples prepared by the wet deposition method is presented in Figs. 8d, 8e and 8f. It can be seen that the samples exhibit a very high contracting character, with an expansion rate very much elevated from the beginning of the shearing and progressive stabilization towards an ultimate value, to associate with the stabilization of the deviatoric stress.

The results in Figs. 7 and 8 are in perfect concordance with those of Figs. 4 and 5, knowing that the method

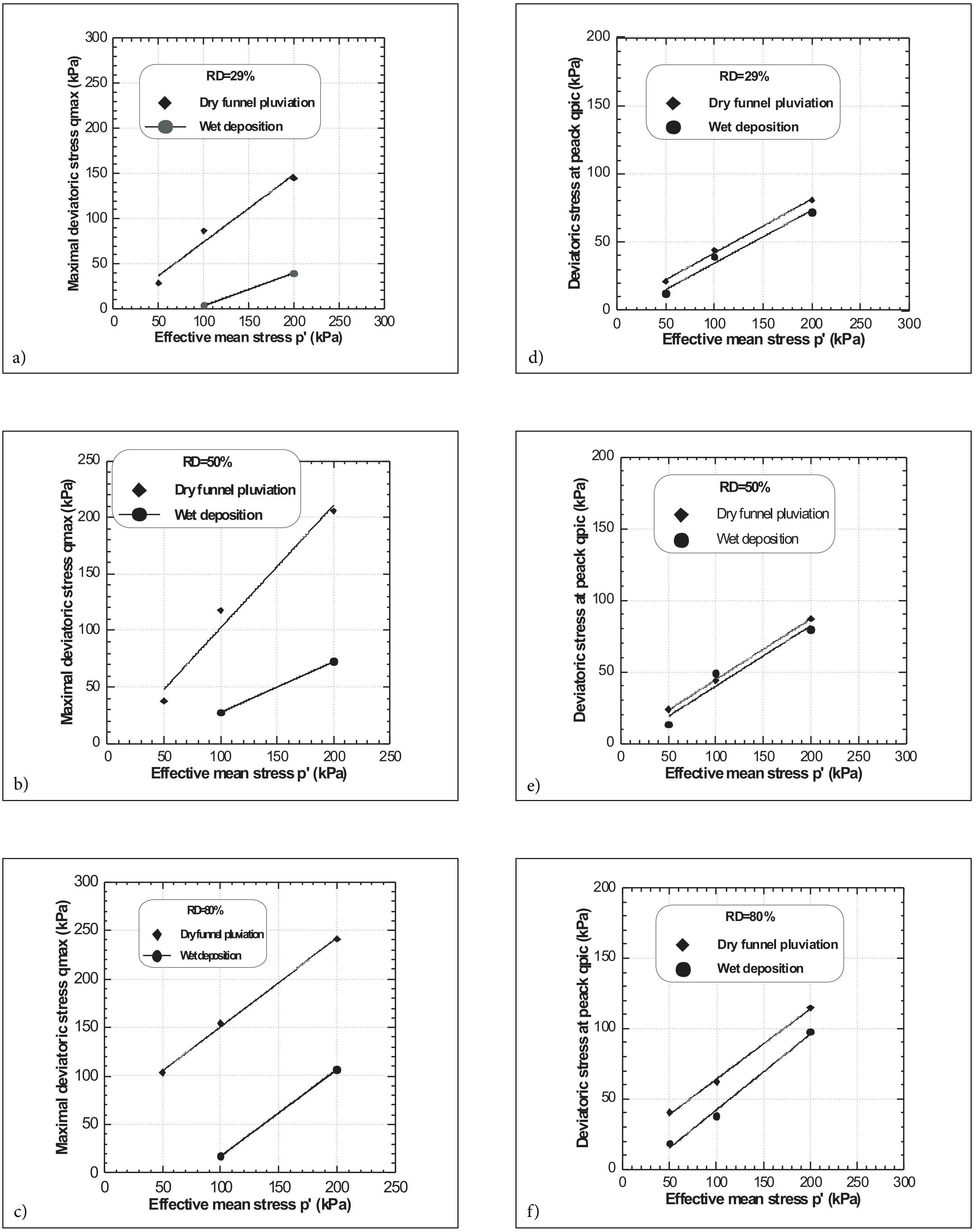


Figure 7. Effect of the depositional method on the maximum deviatoric stress (a, b, c) and the peak deviatoric stress (d, e, f).

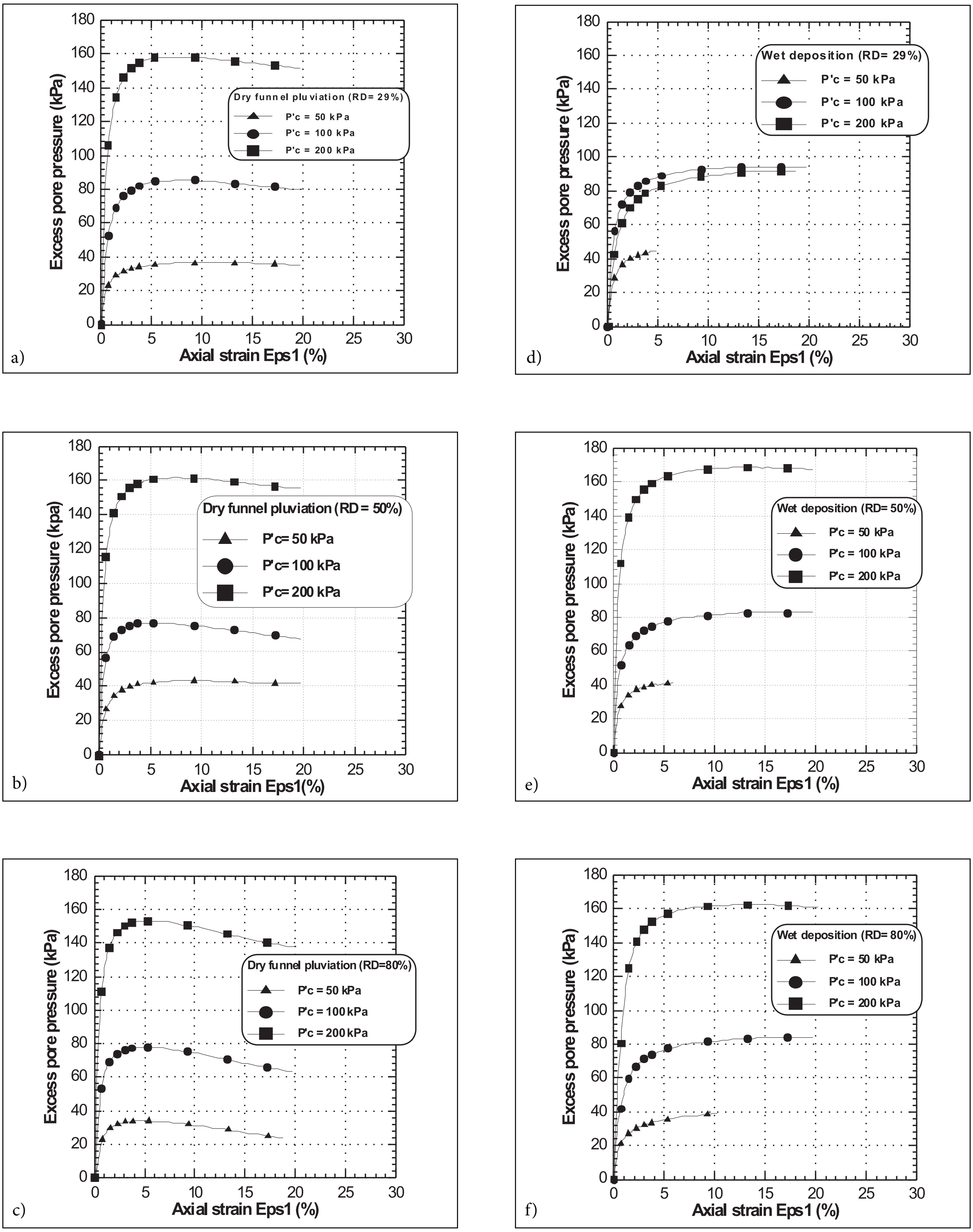


Figure 8. Effect of sample reconstitution methods on the excess pore pressure.

of dry funnel pluviation encourages an increase of the resistance to the monotonic shearing of the samples, in contrast to the wet deposition method, which accelerates the instability of the samples that show a very weak resistance and even provokes the phenomenon of liquefaction of the sand for the weak densities and weak confinements leading to a collapse of the sample. These differences of behavior noted on Chlef sand can be explained by the fact that the molecules of water contained in the structures prepared by the wet deposition method constitute some macropores that are easily compressible at the time of the shearing of the sample and at the same time prevent the grain-grain adhesion from which the faculty of the sample is to contract, in contrast to the structures of the samples prepared by the method of dry funnel pluviation that show a more dilating behavior.

5 CONCLUSION

The effect of the initial structure of a soil was studied in the laboratory. A series of monotonic triaxial tests were performed on chlef silty sand at a range of three relatives densities 29%, 50% and 80% representing loose, medium and dense state, for confining pressure of 50 kPa, 100 kPa and 200 kPa. In the light of evidence, the following conclusion can be drawn:

1. The excess pore water pressure increases for both the two depositional methods (dry funnel pluviation and wet deposition) with a decrease tendency for the first one and a stabilization for the second one.

2. The maximal deviatoric stress and the peak strength increase with the increase of the initial relative density and the initial confining pressure.

3. The initial structure made by the dry funnel pluviation method exhibits dilatant character inducing an important liquefaction resistance of the soil.

REFERENCES

[1] Benahmed, N., Canou, J. and Dupla, J. C. (2004). Structure initiale et propriétés de liquéfaction statique d'un sable. Comptes Rendus Mécanique 332, 887-894.

[2] Bouvard, D. and Stutz, P. (1984). Détermination expérimentale des caractéristiques rhéologiques d'un sable en grandes deformations. CRAS, 299, II, 12.

[3] Canou, J. (1989). Contribution l'étude et à l'évaluation des propriétés de liquéfaction d'un sable. Thèse de Doctorat de l'Ecole Nationale Des Ponts et Chaussées, Paris.

[4] Durville, J. L. and Méneroud, J. P. (1982). Phénomènes géomorphologiques induits par le séisme d'El-Asnam, Algérie. Bull. Liaison Labo. P. et Ch., 120, juillet-août, 13-23.

[5] Hettler, A. and Vardoulakis, I. (1983). Behavior of dry sand tested in large triaxial apparatus. Geotechnique 33.

[6] Kramer, S.L. and Seed, H.B. (1988). Initiation of soil liquefaction under static loading conditions. J. Geotech. Eng 114, 4, 412-430.

[7] Lade, P. V. and Duncan, J. M. (1973). Cubical triaxial tests on cohesionless soil. Journal Soil Mechanics and Foundations Division ASCE 99, SM10, 793-812.

[8] Lanier, J. (1987). Développements récents des essais en laboratoire. Manuel de Rhéologie des Géomatériaux, Presses des Ponts et Chaussées, 15-31.

[9] Mulilis, J. P., Seed, H. B., Chan, C. K., Mitchell, J. K. and Arulanadan, K. (1977). Effects of sample preparation on sand liquefaction. Journal of Geotechnical Engineering Division, ASCE 103, GT2, 91-108.

[10] Polito, C.P. and Martin II J.R. (2003). A reconciliation of the effects of non-plastic fines on the liquefaction resistance of sands reported in the literature. Earthquake Spectra 19, 3, 635-651.

[11] Vaid, Y. P., Sivathayalan, S. and Stedman, D. (1999). Influence of specimen reconstituting method on the undrained response of sand. Geotechnical Testing Journal 22, 3, 187-195.

[12] Wood, F. M., Yamamuro, J. A. and Lade, P. V. (2008). Effect of depositional method on the undrained response of silty sand. Canadian Geotechnical Journal 45, 11, 1525–1537.

[13] Yamamuro, J.A. and Covert, K.M. (2001). Monotonic and cyclic liquefaction of very loose sands with high silt content. J. Geotech. Geoenvironmental Engineering ASCE 127, 4, 314-324.

[14] Yamamuro, J.A. and Lade, P.V. (1997). Static liquefaction of very loose sands. Canadian Geotechnical J. 34, 6, 905-917.

[15] Yamamuro, J.A. and Lade, P.V. (1998). Steady state concepts and static liquefaction of silty sands. J. Geotech. Geoenv. Eng. ASCE 124, 9, 868-877.

[16] Yamamuro, J. A. and Wood, F. M. (2004). Effect of depositional method on the undained behavior and microstructure of sand with silt. Soil Dynamics and Earthquake Engineering 24, 751-760.

[17] Yamamuro, J. A., Wood, F. M. and Lade, P. V. (2008). Effect of depositional method on the microstructure of silty sand. Canadian Geotechnical Journal 45, 11, 1538–1555.

[18] Zlatovic, S. and Ishihara, K. (1997). Normalized behavior of very loose non-plastic soils: effects of fabric. Soils and Foundations 37, 4, 47-56.