

Fig. 6 Effect of  $\eta$  parameter on limit pressure value.

### 6.2. Effect of the consolidation pressure on the pressuremeter curve

Fig. 7 presents the consolidation pressure effect on the pressuremeter curve. The corrected limit pressure is almost proportional to the pressure of consolidation, which is in accordance with experimental observation [8].

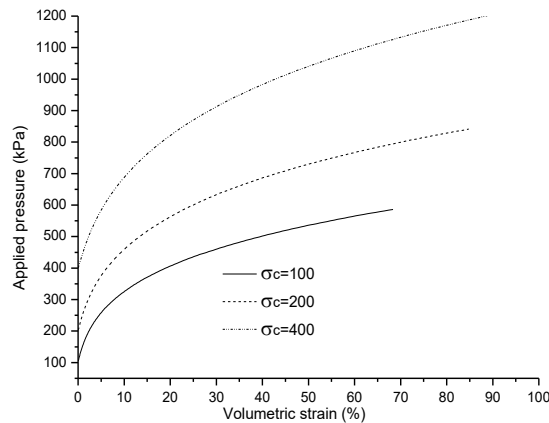


Fig. 7 Consolidation pressure effect on the pressuremeter curve

### 6.3. Influence of the finite length of the pressuremeter probe

To study the influence of the finite length of the pressuremeter probe, a series of simulation of slenderness ratio ( $L/D = 5, 10, 15$  and  $20$ ). It appears in Fig. 8 that the geometry of the probe has a considerable influence on the pressuremeter curve. This difference is inversely proportional to the ratio  $L/D$  which is consistent with the results of (Zanier 1985).

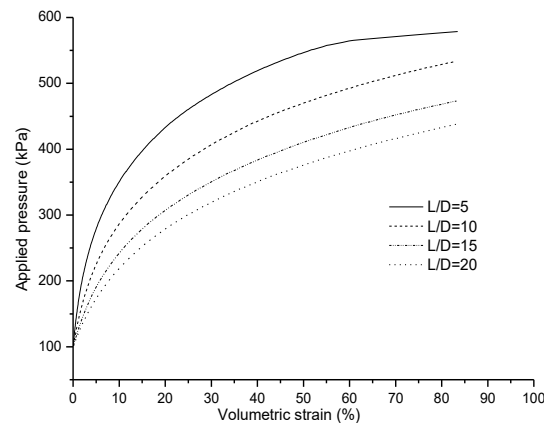


Fig. 8 Slenderness ratio effect

#### 6.4 Disturbance effects around pressuremeter

A remoulded annulus surrounding the pressuremeter probe reduces the mechanical characteristics, in particular the deformation modulus. The degree of disturbance in the annulus varies with distance from the borehole. In the conventional pressuremeter test, disturbance is also caused by the temporary unloading of the borehole until the probe is inserted and inflated to restore original stress conditions. The use of the Self Boring Pressuremeter can reduce remoulding disturbance considerably, although is not eliminated completely (Praharam & al., 1990).

The effect of a remoulded annulus with reduced modulus and strength around the probe was analyzed theoretically by (Baguelin & al. 1972). They adopted different stress-strain relationships for the intact and the remoulded zones in the analysis. The stress-strain curve of the remoulded soil was chosen with a modulus equal to 10% of the modulus of the intact soil. We adopting the same hypothesis expansion curves predicted for Hostun sand with different thickness of disturbed zone. The error in strength and modulus due to the presence of a disturbed annulus is plotted against the thickness of the annulus in Fig. 9. The error is calculated with reference to the strength and modulus values predicted for the undisturbed soil.

We remark that the elastic modulus  $E$  is very sensitive to the disturbance; the error on this parameter varies from 0 to 60%, while the friction angle, the error varies from 0 to 8% Fig. 10.

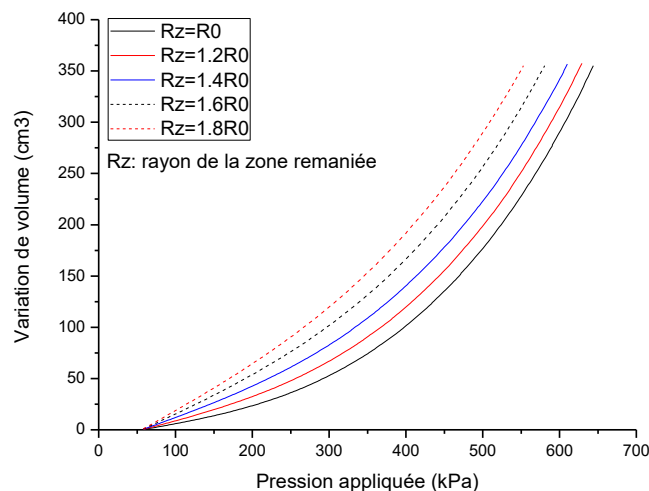


Fig. 9 Slenderness ratio effect

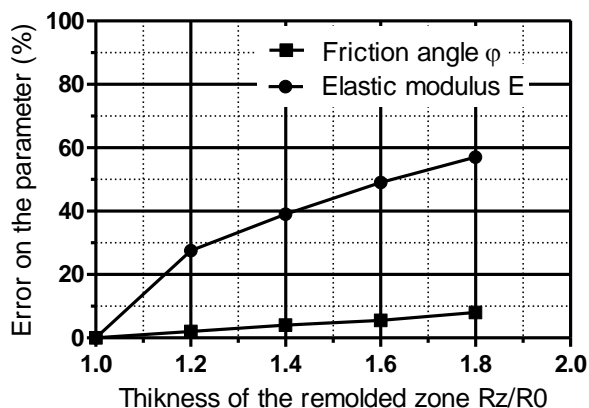


Fig. 10 Slenderness ratio effect

## 7. STRESSES PATH AROUND PRESSUREMETER

The proposed method allows visualising stresses path in all the point of a chosen discretization. Fig. 11 indicates the distribution of the main stresses at the end of loading for the self-boring pressuremeter test undertaken on the Hostun sand. Three different areas of soil from the borehole wall to the infinite radius are considered. Plasticity appears between the radial stress  $\sigma_r$  and circumferential stress  $\sigma_\theta$  in the horizontal plane. This first plastic area extends between the radius  $a$  (borehole wall) and  $b$  (external radius of the plastic area). As shown by (Wood & Wroth 1977 and Monnet 2007), plasticity may also appear in the vertical plane between the vertical stress

$\sigma_z$  and circumferential stress  $\sigma_\theta$  in an area between the radius  $b$  and radius  $c$  (external radius of both plastic areas). An elastic area extends beyond the radius  $b$ .

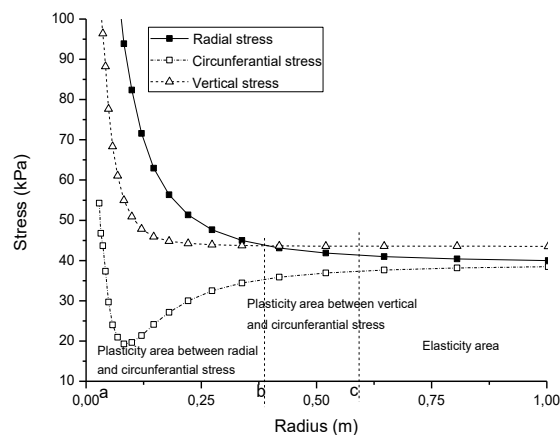


Fig. 11 Distribution of main stresses at end of loading

## 8. CONCLUSIONS

The results of the present study are based on the identification method developed that allows the identification of the behavior parameters of generalized Prager model, associated with the Drucker and Prager criterion failure.

The analysis of the effect of some parameters on the pressuremeter curve led to the following conclusions:

Taking into account the dilatancy effect in the present study confirms that the pressuremeter curve is very sensitive to the dilatancy phenomenon; the limit pressure increases with dilatancy. This means that for a dilatant material (dense sand), this phenomenon is to take into account.

The corrected limit pressure is almost proportional to the pressure of consolidation, which is consistent with experimental observation.

The present study shows that the pressuremeter curve is sensitive to the probe slenderness. However, the assumption of plane strain is verified with the increase of the probe slenderness.

The presence of remolded annulus can result in an error on the estimation of elastic modulus and shear strength. Obtained results shows that the elastic modulus  $E$  is very sensitive, the error on this parameter varies from 0 to 60%.

The distribution of main stresses at the end of loading shows that the plasticity may occur between the radial stress,  $\sigma_r$  and the circumferential stress,  $\sigma_\theta$  and between the vertical stress,  $\sigma_z$  and the circumferential stress,  $\sigma_\theta$ .

## 9. REFERENCES

Abed, Y. and Bahar, R. (2010), "Pressuremeter identification procedure based on generalised Prager model", *Medwell Journals, Eng. Appl. Sci.* **5**(2), 50–55.

- Abed, Y.; Bahar, R.; Dupla, J-C. and Amar Bouzid, Dj. (2014), "Identification of granular soils strength and stiffness parameters by matching Finite Element results to PMT data", *International Journal of Computational Methods*, **2**(2), 231-253.
- Baguelin F., Jezequel J.F., Lemée E. & LeMéhauté A. (1972), "Expansion of cylindrical probes in cohesive soils", *J. of the Soil Mechanics and Foundations Division* **98**: 1129-1142.
- Cambou, B.; Boubanga, A.; Bozetto, P. and Haghgou, M. (1990), "Determination of constitutive parameters from pressuremeter tests", *3rd Symp. Pressuremeter and Its Marine Applications, Oxford University*, 243–352.
- Carter, J.P.; Booker, J.R.; Yeung, S. K. (1986), "Cavity expansion in frictional cohesive soils". *Géotechnique*, **36**(3), 349–58.
- Chen W. F. and Baladi G. Y. (1985), "Soil plasticity: theory and implementation", *Elsevier, Amsterdam* (1985), 231 pp.
- Chen W. F. and MIZUNO E. (2001), "Non linear analysis in soil mechanics, theory and implementation", *Elsevier, Amsterdam* (1990), 351 pp.
- Cudmani, R. and Osinov, V. A. (2001), "The cavity expansion problem for the interpretation of cone penetration and pressuremeter tests", *Canadian Geotechnical Journal*, **38**(3), 622–38.
- Drucker D. & Prager W. (1952), "Soil mechanics and plastic analysis of limit design", *Quart. Appl Math.*, vol **10**, pp 157-165.
- Dupla J. C. (1995), "Application de la sollicitation d'expansion d'une cavité cylindrique à l'évaluation des caractéristiques de liquéfaction d'un sable", *Thèse de doctorat, Ecole Nationale des Ponts et Chaussées*, 1995. P. 422
- Fahey, M. and Carter J.P. (1993), "A finite element study of the pressuremeter test in sand using a nonlinear elastic plastic model", *Canadian Geotechnical Journal*, **30**(2), 348–62.
- Hsieh, Y.M.; Whittle, A.J. and Yu, H.S. (2002), "Interpretation of pressuremeter tests in sand using advanced soil model" *ASCE Journal of Geotechnical and Geoenvironmental Engineering*, **128**(3), 274–8.
- Javadi A. A. and Rezaia M. (2009), "Applications of artificial intelligence and data mining techniques in soil modelling", *Geomechanics and Engineering*, **01**, 53-74
- Levasseur S, Malecot Y, Boulon M, Flavigny E. (2010), "Statistical inverse analysis based on genetic algorithm and principal component analysis: applications to excavation problems and pressuremeter tests", *International Journal for Numerical and Analytical Methods in Geomechanics*, **34**, 471–91.
- Levasseur, S. (2008), "Soil parameter identification using a genetic algorithm", *Int. J. Numer. Anal. Meth. Geomech.* **32**(2), 189–213.
- Liang, R.Y. and Sharo, A. (2010), "Numerical investigation of the pressuremeter results affected by anisotropy of geomaterials", *GeoFlorida 2010, Adv. Analysis, Modeling & Design*, 1090–1098.
- Monnet J. (2007), "Numerical analysis for an interpretation of the pressuremeter test in granular soil", *18<sup>ème</sup> congrès Français de mécanique*, Grenoble, France.

Mousavi S. M., Alavi A. H., Mollahasani A., Gandomi A. H. (2011), "A hybrid computational approach to formulate soil deformation moduli obtained from PLT", *Engineering Geology*, **123**, 324-332.

Olivari G. & Bahar R. (1993), "Analyse de la réponse du modèle de Prager généralisé sur chemin pressiométrique", *6ème Colloque Franco-Polonais de Mécanique des sols appliquée, Douai*.

Olivari, G. and Bahar, R. (1995), "Response of generalized Prager's model on pressuremeter path", *Proc. 4<sup>th</sup> Int. Symp. Pressuremeter, A. A. Balkema, Sherbrooke, Canada*, pp. 207–213.

Paraharam S., Chameau J.L., Alischaeffl A.G. & Holtz R.D. (1990), "Effect of disturbance on pressuremeter results in clays", *Journal of Geotechnical Engineering*, vol. **116**, No 1, 35-53.

Rashed A., Bazaz J. B., Alavi A. M. (2012), "Nonlinear modeling of soil deformation modulus through LGP-based interpretation of pressuremeter test results", *Engineering Applications of Artificial Intelligence*, **25**, 1437-1449.

Shahin, M.A.; Jaksa, M.B. and Maier, H.R. (2008), "State of the Art of Artificial Neural Networks in Geotechnical Engineering", *Electronic Journal of Geotechnical Engineering* **8**, 1-26.

Wood D.M. & Wroth P.C. (1977), "Some laboratory experiments related to the results of pressuremeter tests", *Geotechnique*, **27**(2), pp 181-201.

Yu, H.S. and Houlsby, G.T. (1991), "Finite cavity expansion in dilatant soils: loading analysis", *Géotechnique*, **41**(2), 173–83.

Yu, H.S. and Houlsby, G.T. (1995), "A large strain analytical solution for cavity contraction in dilatant soils", *Int J Numer Anal Methods Geomech.*, **19**(11), 793–811.

Zanier F. (1985), "Analyse numérique de l'essai pressiométrique par la method des éléments finis, Application au cas des sols cohérents", *Thèse de Docteur-Ingénieur, Ecole Centrale de Lyon, France*.

Zhang Y, Gallipoli D, Augarde CE. (2009), "Simulation-based calibration of geotechnical parameters using parallel hybrid moving boundary particle swarm optimization" *Computers and Geotechnics*, **36**, 604–15.

Zhang, Y.; Gallipoli, D. and Augarde, C. (2013), "Parameter identification for elasto-plastic modelling of unsaturated soils from pressuremeter tests by parallel modified particle swarm optimization", *Computers and Geotechnics*, **48**, 293–303.