Plastic Fluid Flow Parameters Identification Using a Simple Squeezing Test

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Abstract:
In this paper after a presentation of the compression test and its classical references in the rheological literature a behaviour parameter identification method is introduced using simple compression tests on concentrated geo-suspensions with a plastic fluid behaviour. The obtained theoretical test response is validated for several materials (natural soils, Kaolin clay ...). It is also compared with previous solutions obtained by other authors to show that most existing solutions miss one or more terms. Elements are also given on two types of test response perturbations: the induced heterogeneity in the case of slow tests (consolidation phenomena) and the fragmentation of the outer part of sample (granular paste breakings). Finally, compression test results for a nano silica paste are presented as a example and treated as an application of the test exploitation method.

Zusammenfassung:
In diesem Artikel wird, nach einer Vorstellung des einachsigen Druckprüfversuches und der dazugehörigen Standardreferenzen in der rheologischen Literatur, eine Parameteridentifikationsmethode konstruiert, welche auf einfachen Druckprüfungen konzentrierter geologischer Suspensionen mit plastischem Fluidverhalten basiert. Die erhaltene theoretische Antwortfunktion wird für verschiedene Materialien geprüft (Naturboden, Kaolinlehm). Sie wird ebenfalls mit früheren Lösungsansätzen verglichen, welche von anderen Autoren erhalten wurden, um zu zeigen, dass die meisten existierenden Lösungen einen oder mehrere Terme nicht berücksichtigen. Ebenfalls berücksichtigt werden zwei verschiedene Perturbationen der Antwortfunktion: die induzierte Heterogenität für langsame Tests (Konsolidierung) und die Zerkleinerung des äusseren Teils der Probe (Bruch körniger Pasten). Schliesslich werden Ergebnisse von Druckversuchen an Kieselerdepasten im Nanometerbereich als Beispiel vorgestellt und als eine Anwendung des Prüf-/Nutzungsverfahrens behandelt.

Résumé:
Après une présentation de l'essai de compression simple et de sa littérature la plus commune dans le monde de la rhéologie, une méthode d'identification des paramètres de comportements est construite dans le cas de géo-suspensions présentant un comportement de fluides plastiques parfaits. La solution théorique obtenue est validée dans le cas de plusieurs matériaux (sols naturels, pâte de kaolin...). Cette solution est comparée avec la littérature existante pour montrer que les relations actuelles sont souvent incomplètes. Dans un deuxième temps, des éléments sont fournis sur deux phénomènes perturbateurs de l'essai : l'hétérogénéité induite par l'essai dans le cas de faibles vitesse d'écoulement (phénomène de consolidation) et la rupture en traction de l'échantillon à sa sortie du volume entre plateaux. Enfin, des résultats d'essais obtenus sur une pâte de nano silice sont présentés comme exemple d'application de la méthode proposée.

Key Words: compression test, plastic behaviour, clay pastes, nano silica

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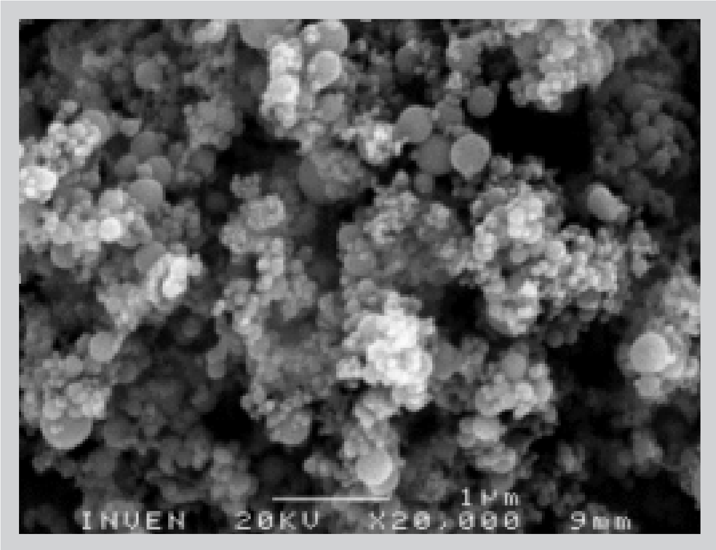

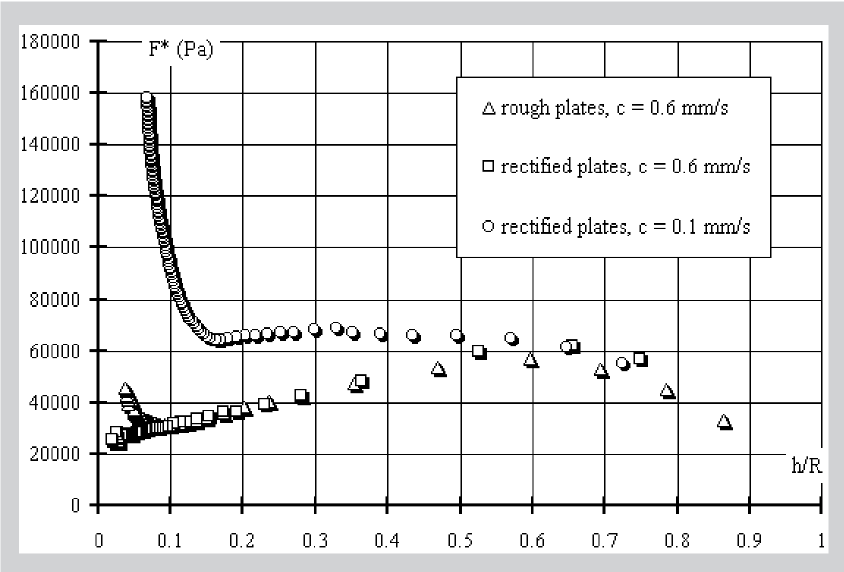

Figure 11 (above): Nano silica powder SEM pictures. The particle maximum size is about 200 nm.

Figure 12 (below): Compression test of nano silica paste. Compared to the particle size, even the rectified plates seems to be rough.

depend on the compression speed and should stay linear in terms of h/R. If the compression force increases while the compression speed decreases, it could be concluded that the tested granular material is sensitive to consolidation phenomena and the test is drained. For further information in the same experimental conditions see reference [19].

- Fourth step: If the plastic yield value calculated from the curve slope and from the reduced compression force value for $h/R \to 0$ during the first step are not the same, the influence of the radial traction stress around the sample can not be neglected. The proper plastic yield value is the one calculated from the reduced compression force value for $h/R \to 0$ and the energy needed for sample breaking sc may then be calculated using Eq. 25 from the number of breaks N_b. It should be noted that, in this particular case, the reduced compression force does depend on the plates radius.
- Fifth step: Validation. The answer of the test with rectified plates (second step) should be predicted using Eq. 25 with K_i being replaced by K_f in the second term.

4 EXAMPLE AND APPLICATION

A paste is prepared with a fine silica powder and water (Fig. 11). The maximum particle size is about 200 nm. The powder volumic weight is 2600 kg/m^3. The initial paste water content is 180%.

- First step: Test at a given speed c = 0.6 mm/s with rough plates. The reduced force is plotted in terms of h/R on Fig. 12. The plastic yield value is calculated from Eq. 20. From the curve slope, K_i is estimated as K_i = 52 kPa. From the reduced compression force value for $h/R \to 0$, K_i however is astimated as K_i = 38 kPa. As there is a difference between the two calculated values, the influence of the radial traction stress around the sample can not be neglected and the experimental procedure fourth step is needed.
- Second step: Test at a given speed c = 0.6 mm/s with rectified plates. The reduced force is plotted in terms of h/R in Fig. 12. For this paste, there is no difference between rough and rectified plates. The particles are so small that the rectified plates roughness is sufficient to make the mixture stick at the interface. In this particular case, $K_f = K_i$ = 38 kPa
- Third step: Test at a given speed c < 0.6 mm/s with rough plates. The reduced force is plotted in terms of h/R in Fig. 12 for c = 0.1 mm/s. As long as the compression speed is high enough (c > 0.5 mm/s) the test answer does not depend on the compression speed and the behaviour stays plastic. But for lower compression speed, consolidation phenomena appear and strongly affect the test answer. For c = 0.1 mm/s, the compression force needed to bring the plates together is much higher. It can be noted that at the end of the slow compression test in Fig. 12 the sample water content is only 122 % instead of the initial 180 %. The speed influence on the rheological behaviour is not linked with a viscous component of the flow but with a change of the liquid/solid mixture composition. It is consolidation phenomena that are observed.

- Fourth step: As the plastic yield value calculated from the curve slope and from the reduced compression force value for $h/R \rightarrow 0$ during the first step are not the same, the influence of the radial traction stress around the sample can not be neglected. The proper plastic yield value is the one calculated from the reduced compression force value for $h/r \rightarrow 0$ and the energy needed for sample breaking sc may then be calculated using Eq. 25 from the number of breaks N_b. The number of sample breakings during the test is constant, $N_b \cong 7-8$. The plastometer test allows the identification of the yield value using Eq. 25: K_i = 38 kPa and s_c = 200 - 300 J/m² is the energy needed to create the breaking surface.
- Fifth step: As there is no difference between rough and rectified plates for this paste, this step is not necessary.

5 CONCLUSION

A quasi plastic flow parameters identification method was built using simple compression tests on concentrated geo-suspensions. The proposed solution does not depend on the initial sample height, the plates radius, the compression speed (as expected for a plastic fluid). This theoretical test answer was validated for several materials (natural soils, Kaolin clay ...). Elements were also given on two types of perturbations of the predicted test answer: the induced heterogeneity in the case of slow tests (consolidation phenomena) and the fragmentation of the outer part of sample (granular paste breaking). An experimental procedure was then suggested and last, compression test results for a nano silica paste served as a practical example. The proposed method to determine the flow properties of perfect or quasi perfect plastic concentrated suspensions is straightforward and easy to use and this makes it suitable for rapid behaviour parameters identification.

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