Particle Fluid Separation in Shear Flow of Dense Suspensions: Experimental Measurements on Squeezed Clay Pastes

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Received: 19.4.04, Final version: 13.8.04

Abstract:
Particle fluid separation is studied in the case of slow squeezing flow of dense clay suspensions. The fluid pressure gradient generated by the test induces heterogeneity in the sample. Experimental water content measurements at different time points through the test allow the quantification of this separation phenomenon. The problem equations are written in the case of purely extensional flow. Based on Terzaghi principle, Darcy's law and a Cam Clay type constitutive equation, the influence of the permeability function on the predicted void ratio evolution is studied. It is then shown that a certain water amount is strongly linked to the grains and cannot be extracted from the sample using simple compression. This critical water amount is then taken in account in the permeability function in order to predict the compression load through the test.

Zusammenfassung:
Die Phasenseparierung in partikularen Flüssigkeiten für eine langsame Quetschströmung wurde anhand einer hochkonzentrierten Lehmsuspension untersucht. Der durch den Versuch erzeugte Druckgradient verursacht dabei Heterogenitäten in der Probe. Basierend auf einer reinen Dehnströmungsbetrachtung, d.h. mit dem Terzaghi Prinzip, Darcys Gesetz und eine Cam Clay Zustandsgleichung wird der Einfluss der Permeabilität auf die sich entwickelnen Hohlräume untersucht. Es konnte gezeigt werden, dass ein bestimmter Wasseranteil an den Feststoffpartikeln gebunden ist und nicht durch einfache Kompression aus der Probe extrahiert werden kann. Dieser kritische Wasseranteil wurde in Folge in der Permeabilitätsfunktion berücksichtigt, um die korrekte Kompressionskräfte der Versuche zubestimmen.

Résumé:
Ce travail traite de la séparation particules/fluide induite par un essai de compression simple réalisé sur des suspensions concentrées d'argile. A basse vitesse de compression, cet essai génère un gradient de pression au sein du fluide interstitiel, qui est lui même à l'origine de l'apparition d'une hétérogénéité au sein de l'échantillon. Des mesures expérimentales de teneurs en eau réalisées au cours de l'essai permettent une étude quantitative de ce phénomène.Dans le cas d'un écoulement purement extensionnel, un modèle analytique basé sur le principe de Terzaghi, la loi de Darcy et une équation constitutive de type Cam Clay est proposé. L'influence du coefficient de perméabilité et de son évolution sur la prédiction de la teneur en eau moyenne de l'échantillon au cours de l'essai est discutée. Cette étude permet de montrer qu'une certaine quantité d'eau fortement liée aux grains ne peut être mécaniquement extraite de l'échantillon. Cette quantité d'eau est alors prise ne compte dans le calcul de la perméabilité pour finalement prédire l'effort de compression nécessaire au rapprochement des plateaux au cours de l'essai.

Key Words: squeezing test, permeability, clay suspension, drainage, yield stress

© Appl. Rheol. 14 (2004) 256-265

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influence of the central part (r small, "lowest void ratio") is equivalent to the influence of the external part ($r \cong R$, "higher void ratio") on the average void ratio value. But, because of the cylindrical geometry, the influence of the central part (r small, "small surface") on the compression load is lower than the influence of the external part ($r \cong R$, "larger surfaces"). The equivalent average void ratio on a compression load point of view should be higher than the real average void ratio. The compression load should then be lower. This local phenomenon cannot be taken into account by the simple global model presented here. However, the correct agreement between predicted and measured compression force shows that the proposed approach, although based on several simplifying assumptions, seems to be able to predict the global consequences of a heterogeneity induced by the flow. Most of the parameters of the model are easily measurable using a permeameter and a squeezing test (high and low compression speeds). Such an approach could prove useful when considering drainage phenomena in industrial processes such as an extrusion process.

CONCLUSION

A simple modelling was proposed in order to take into account the drainage phenomenon that appears when slowly squeezing dense clay suspensions. Their proven plastic behaviour should ensure that the test answer does not depend on compression speed but results presented here show that heterogeneity is induced by slow compression. The model allows the global prediction of the average void ratio evolution through the test in terms of parameters that can be identified on high speed squeezing test. The model also allows the calculation of an apparent permeability in terms of average void ratio. The experimental results presented here have also shown that there exists a limit to the water amount that can be extracted from a sample. A certain quantity of water is strongly linked to the grains and need energy levels far higher than the ones induced by the squeezing test to be extracted. This led to propose a modified Kozeny type relation between permeability and void ratio more suitable to describe the obtained experimental results and the involved physical phenomena.

Finally, this simple model allows the prediction of the compression load through the test when drainage occurs in the sample. This method could also be applied to more complex flow patterns such as the ones obtained during an extrusion process.

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