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The effect of initial conditions on the consolidation of mud

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Introduction

Sediment is becoming scarce. Therefore, soft sediments are progressively being used for nature building. The MarkerWadden is an example of an ongoing *Building with Nature* (BwN) project which aims to improve the ecology of Lake Markermeer (The Netherlands) by creating a wetland with the cohesive sediments from the bed of the lake. It represents one of the first projects using fresh unconsolidated mud as a filling material. However, building with these fine sediments represents a great challenge, because of their complex properties.

Various authors have studied the settling and consolidation behaviour of mud at initial concentrations below the gelling point, e. g. Merckelbach (2000), Dankers (2006). However, slurries at much higher initial sediment concentrations are used for BwN, and the consolidation behaviour of such mixtures has been less studied.

In this research, the influence of the initial concentration c_0 on the consolidation behaviour of mud was studied for mud mixtures with an initial concentration above the gelling point.

Methods

The material parameters of Markermeer mud were obtained with two different experimental methods: settling columns and the Seepage Induced Consolidation test (SIC). The two sets of parameters were used as input for a 1DV model to compute density profiles. To account for over-consolidated initial conditions, the effect of swelling was implemented in the 1DV-model. These computed profiles were then compared with the profiles measured with an Ultrasonic High Concentration Meter (UHCM). Further, the sensitivity of the model results was evaluated by interchanging the coefficients of the material properties.

Results and discussion

In our analysis, we presume self-similar sediment properties, and apply a fractal material model. The fractal dimension n_f and the effective stress coefficient K_p obtained with the settling columns and the SIC tests appeared to be of the same order of magnitude. However, the permeability coefficient K_k differed by a factor of 20, suggesting dependency on the initial concentration and/or sample preparation and/or accuracy problems with the methods deployed. Consequently, the final bed heights are predicted correctly when using the different sets of material parameters to model a hypothetical settling column of arbitrary height. However, the consolidation time may vary considerably due to the high variability of K_k.

Both sets of material parameters predict the density profile and bed height well for equilibrium conditions. The differences are minor, but the SIC material parameters provide a better agreement with respect to final bed height and shape of the density profile (Fig. 1).

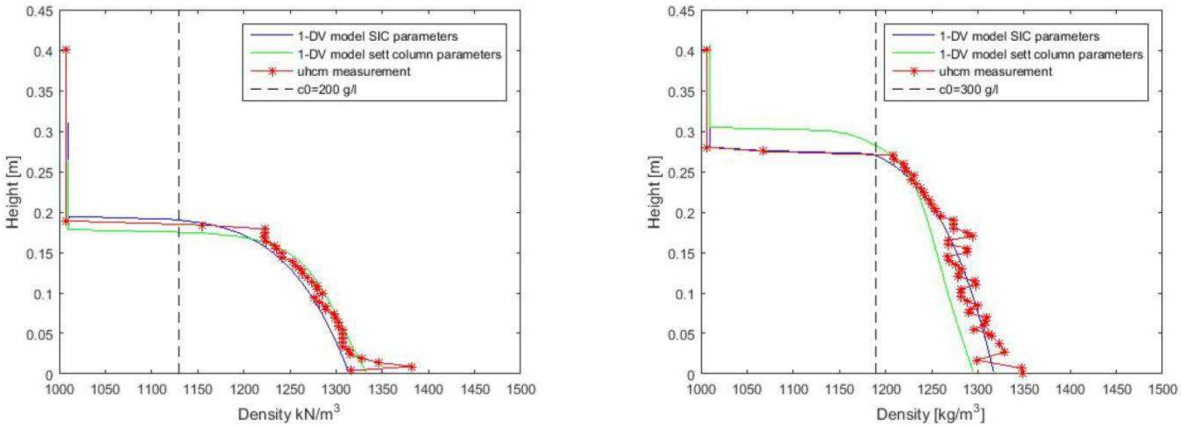

Fig. 1. Left panel: density profiles for c_0 = 200 g/l computed with material parameters obtained from the settling column experiment and SIC test. Both profiles are compared with UHCM measurement at t = 67 days. Right panel: density profiles for c_0 = 300 g/l computed with material parameters obtained from the settling column experiment and SIC test. Both profiles are compared with UHCM measurement at t = 67 days.

When the material parameters from columns with different c_0 were interchanged, the bed height and density profile agree less to the measurement (see Table I).

Table I. Offsets of the computed density profiles with respect to the measured ones.

C_0=200 g/l. Parameters:	*Offset Profile [%]*	*Offset Bed height [%]*	*C_0=300 g/l. Parameters:*	*Offset Profile [%]*	*Offset Bed height [%]*
SCE	2	7	SCE	8	9
SIC300	2	2	SIC300	4	0
SIC200	9	7	SIC200	5	6

Discussion and conclusions

This research presented two different experimental procedures, the settling columns and the SIC tests, which showed consistent results.

The results showed to be highly sensitive to the experimental procedure, notably to the sample preparation. The mixing method, together with the room temperature and light conditions, seem to be the most critical factors. The mixing procedure likely affects the size of flocs and the environmental conditions may induce gas production and the development of biofilms. Our results suggest that these factors affect in particular the consolidation time. We are carrying out further research on these effects.

The initial concentration of sediment was also found to play an important role in the consolidation behaviour. In the case that part of the initial column is over-consolidated, the consolidation curves showed an initial linear phase caused by a higher density than at equilibrium in the uppermost part of the mud layer. This excess of density acts like an overburden inducing what we defined as “piston effect”. Further, under over-consolidated conditions, swelling needs to be taken into account and be included in the model.

Thus, our study gives insight in the effect of the initial conditions on the consolidation of high concentrated mud mixtures. These initial conditions are particularly important for land reclamation and wetland construction, where the initial density may be high but the flocs may have been broken due to the mixing during the dredging process.

References

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