CHAPTER 145

SETTLING COLUMNS PARAMETRIC TESTS APPLIED TO COASTAL SEDIMENT CONSOLIDATION

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ABSTRACT

This paper presents a set of devices and a study both experimental and original in order to determine the influence of various parameters on the sedimentation-consolidation process of soft soils.We use this system to investigate the behaviour of a natural estuarine mud. A series of tests is performed, in which each test differs from the reference test in the value of only one parameter.We give a synthesis allowing the comparison of the action of each parameter on the mud behaviour.This systematic parametric experimental study builds an original data base, which is obviously necessary to validate theoretical modelization.

1.INTRODUCTION

The behaviour of cohesive sediments is one of the main components of coastal engineering processes. These sediments are in an intermediate state between solid and liquid. Their theoretical study requires geotechnical or hydraulical modelization, both conceived with their own approach. We have proposed (ALEXIS et *al.*, ICCE' 93) a unification of consolidation theories, pointing out the interest of the use of Gibson's law. The application of these theoretical models requires the knowledge of constitutive relationships (permeability, effective stress) of the muddy material. In this paper, we are proposing an original and experimental set of devices and study in order to determine the influence of various parameters on the sedimentation-consolidation process.

2. EXPERIMENTAL SET

Our topic is to perform experiments characterised by :
- One-Dimension-Vertical experimentation by means of

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instrumented settling columns.

- No-disturbance of the evolutive material which is a natural mud with a natural estuarine water.
- Continuous tracking of its evolution.
- Simultaneous measurements on several columns under different conditions.

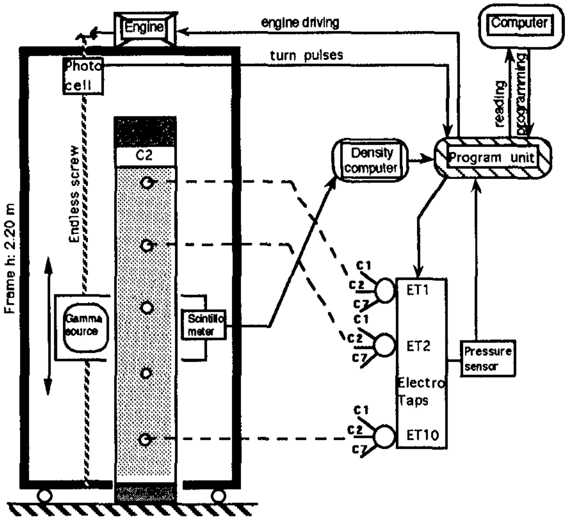
Our bibliographic research has shown the present lack of convenient experimental set.

So, we propose an original experimental set in order to reach these aims.

This experimental set needs a particular environment of the experiments to reduce the biochemical evolution of mud : the set is in a blind climatized room, the temperature is 10 degrees Celsius.

The experimental set (fig.1) is composed of a servo gammadensimetric bench and 7 columns in different conditions with acquisition, piloting and delayed processing.

Fig.1: Experimental set (example on column 2)



The bench is 2.2 meters high.

It is shiftable for simultaneous measurements on the 7 columns.

It also uses a driving engine for moving the gammadensimeter which consists of a gammasource and its scintillometer.

The experiments require a localisation set by photocell and 10 pressure locations for each columns.

By means of an hydraulic network, these pressure locations are connected to a unique pressure sensor by pipes via electrotaps.

These phases of acquisition, piloting, and delayed processing require a specific programmation and adaptation of program unit for the measurement and acquisition of density, pressure, position and also for piloting the driving engine and the electrotaps.

This system has several specificities:

-*experimentation systematisation:* simultaneous measurements on seven parallel columns, shifting the movable gammadensimeter to each column. All the columns are connected by plastic pipes to the pressure sensors through the set of electrotaps.

-*specific procedure*: the adjustement of the number of measurements unables the compromise between accuracy and speed: profile duration can vary from 2 min (continuous profiles) to 20 min (step by step profiles) in order to identify the mud behaviour during the initial stage of the process and to obtain a good accuracy in the final phase as well.

- *search of reliability*: the use of a unique pressure sensor allows the avoiding of drift errors and the obtaining of automatic pore pressure profiles throughout the whole experiment.

3. EXPERIMENTAL STUDY

3.1 Experimental method

The phenomenon is characterized by its complexity because of :

- superposition of spatial and time evolutions.
- large variations of evolution with geometric conditions and composition of material.
- numerous interactions between characteristics.

So, we propose an experimental methodology.

We have 2 steps of procedure :

- on line for measurement acquisition and also for concentration and pore pressure profiles performing
- and delayed processing of profiles evolution.

So, we tackle this parametric study by changing only one parameter at a time experimentally with respect to one reference case. Our experimental approach is quite similar to partial derivative approach.

There are 16 instants of measurements in a geometrical progresssion of ratio 2.

Among the numerous characteristics governing the cohesive soils settling, the basic parameters are initial concentration (c_o), initial height (h_o), fines proportion (less than 63 μm in size) and organic matter content (ignition loss).

We are using a reference case and 4 other cases.

The reference case is performed with natural mud (LL=65%, PI=18%, OM=13%), h_0=1.50 m, c_0 = 90 g/l, temperature 10°C, natural water. In the 4 other cases, the changed parameter value is respectively: h_0=0.75 m (half height), c_0 = 180 g/l (double concentration), 100% fines, 0% organic matter.

At last, we will obtain 10 000 recorded data issued from measurements of position, density and pressure.

3.2 Results

We propose a full synthesis of our measurements results which allows the comparison between the respective influences of studied parameters upon the evolution of profiles of concentration and pore pressure concentration on the one hand, and on constitutive relationships on the other. We have chosen to present concentration profiles and permeability as examples.

a) General influence of parameters

A great deal of information (fig. 2 and 3) are induced by the observation of the following three special aspects of concentration profiles: soil-water interface downing speed, behaviour during sedimentation ("vertical" part of the profiles) and shape of the curve in the deposit (lower part of each profile).

These 2 figures show the concentration profiles in 5 cases, at 3 instants.

The comparative analysis of these curves and of their slopes give a lot of informations.

- The similarity of the first parts of reference curve and fines only curve implies that the influence of fines particles governs interface downing speed, and it also implies the lack of size segregation of particles during downing.
- in the highest part of profiles, the concentration is lower than initial concentration, so there is probably a swelling, that is a local decreasing of concentration.
- this hypothesis is confirmed by the importance of non-verticality of first part of double concentration profiles.
- consolidation is slowed by the thickness of deposit and by the organic matter. This can be explained in terms of draining path length and of draining speed of pore pressure.

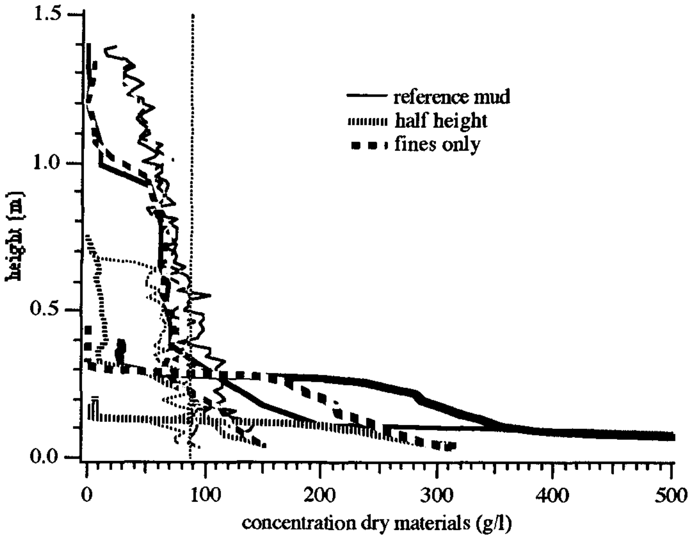


Fig.2: Concentration profiles at t=5 min, 3h and 192 h in the cases reference, fines and half height

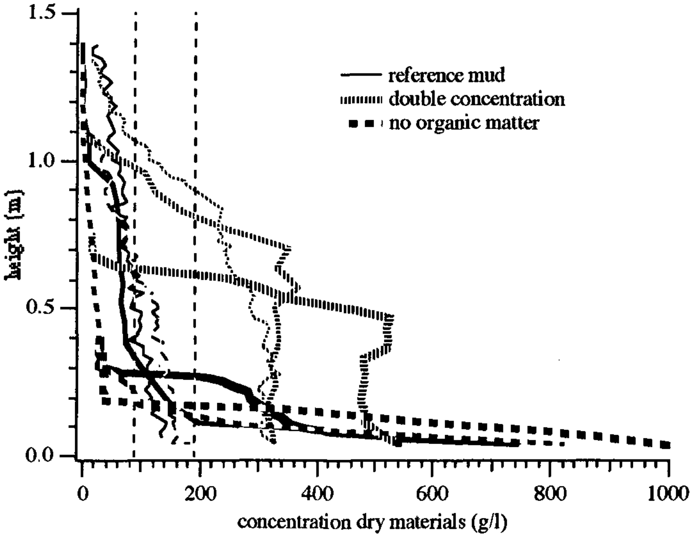


Fig.3: Concentration profiles at t=5 min, 3h and 192 h in the cases reference, double concentration and no organic matter

We propose, also, a set of measurements of excess pore pressure profiles (fig.4).

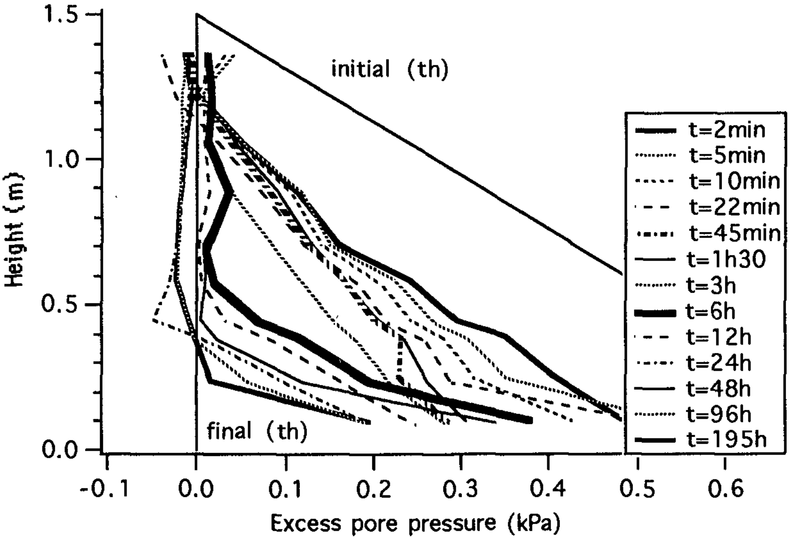


Fig.4: Evolution of excess pore pressure profiles with time

These measurements are original but quite delicate to carry out.

The figure represents the evolution with time of pore pressure excess above hydrostatic pressure for the different pressure locations.

It appears a quite regular dissipation of pore pressure.

During initial phase, there is a fast evolution of pore pressure and during final phase, after 6 hours, ther is a slow evolution curves in the deposit.

We specify that accuracy is about 20 Pascal and that salinity generates a complex geochemical behaviour so, there is an instability of curves around zero over pore pressure.

b) Application to constitutive laws

These different results can be applied for a better knowledge of constitutive laws.

We can use density or pore pressure measurements to obtain new parameters, at each measurement point.

Density measurements give us void ratio e.

By means of an integration of profile, we can obtain total stress σ at each point.

The profile evolution with time gives us settling velocityv_s

Pore pressure measurements u drive us to effective stress σ′ which is the difference between total stress and pore pressure.

Pore pressure profiles *u* give us hydraulic gradient *i*.

Then, we can determine permeability : *k*

So, we obtain 3 essential parameters : effective stress σ′, permeability *k* and void ratio e.

Their linkage is the main part of constitutive laws study.

First, we apply that way of research to permeability.

In figure 5, we propose a set of dots, corresponding to 4 cases material at 3 instants (33 min., 9h., 72h.).

At each instant, we can draw an average curve between the corresponding dots, whatever their case.

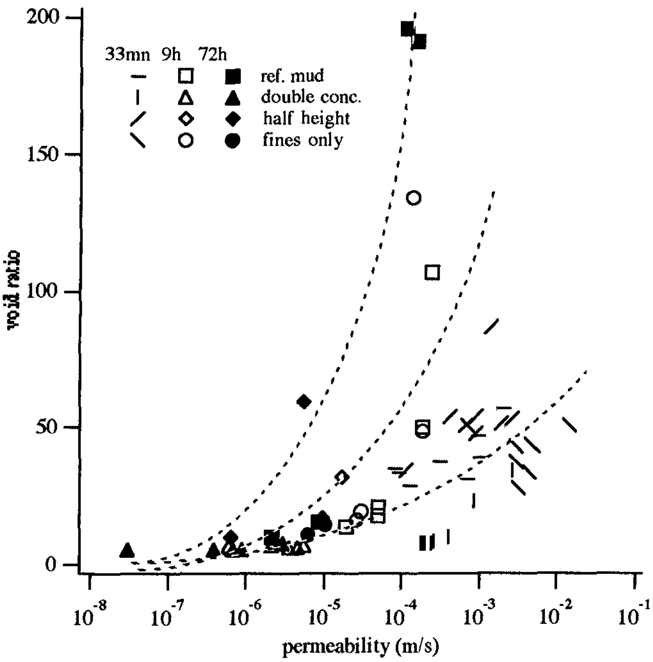


Fig 5 Evolution of permeability with time and void ratio

We observe that permeability decreases with time, for a constant void ratio. So, the permeability is not constant with time. This new and original result underlines the limits of validity of Darcy's law as a flow law through very little consolidated cohesive sediments.

Otherwise, we can remark the good agreement of fines permeability values with references permeability values. We can deduce that fine fraction probably governs the mixture permeability.

The measurements in non-organic mixture, not shown here, are always close to the lowest curve. So, the permeability of non-organic mixture does not depend on time.

Second, we apply that way of research to effective stress.

Figure 6 represents effective stress and void ratio for the reference case at each instant.

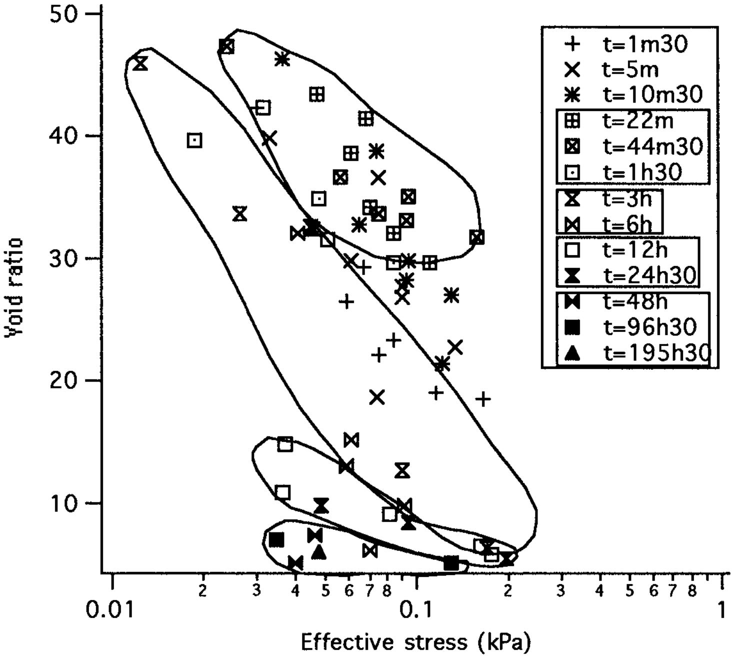


Fig.6: Evolution of effective stress with void ratio and time (reference case)

We must specify that relative accuracy decreases with the decrease of effective stress because of the way of obtention of effetive stess by differnce between total stress and pore pressure.

We can observe gathering dots for 4 instants ranges.

Results show clearly that effective stress increases while void ratio decreases.

From 20 minute, and for a constant effective stress, void ratio decreases with time.

It is an original result : effective stress depends not only on void ratio but also on time, probably by means of strain rate which is linked to the varation of the derivative ratio with time :$\dot{e}$.

That creeping phenomenon could be introduced in sedimentation-consolidation process and we could research later a relation between effective stress, void ratio and derivative of void ratio with time.

4. CONCLUSION

Cohesive sediments are complex materials.

Their specific behaviour implies the complexity of their study.

In this paper, we have proposed :

- an original experimental set including an automatic gammadensimetric bench.
- a systematic approach by changing only one parameter at a time.
- numerous measurements to create a date base.

Our results give the different evolution of concentration profiles for different cases of materials and tests conditions. They give also the evolution of permeability with time and so, the limits of Darcy's law for sedimentation-consolidation modelling.

At last, our results give the evolution of effective stress with time. This evolution implies a possibility of creeping during sedimentation-consolidation process.

These conclusions drive us to a significant progress in the knowledge of cohesive sediment and in the formulation of its behaviour in order to model sedimentation-consolidation process.

Now, new aims could be defined for further studies as : the research of a new flow law (for instance velocity in function of void ratio and hydraulic gradient) and of a new approach of effective stress.

5 - ACKNOWLEDGEMENTS

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6 - REFERENCES

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