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TOPIC 1:

Control methods and instrumentation

Güttler, U., (FRG)

Partly Frozen Artificial Sand Islands as Foundations for Exploration Platforms in Arctic Seas

Presently arctic exploration activities are concentrated mainly in Northern Canada in the area of the Beaufort-Sea, but the permanent future challange of increasing need of energy will surely extend the activities to other regions of the arctic sea. Exploration techniques under those difficult climatic conditions need new engineering intentions to solve the problems of static design of offshore structures.

Building artificial islands to install exploration units on the top characterizes the way to control the forces induced by different types of ice features by activating the shear resistance and energy dissipating effects of adequate soil masses. Special care has to be taken in the level of water table to protect the equipment against the ride up of ice rubble fields and against unallowable deformations of the carrying soil body.

Different types of protections are in use. Their principle is preponderant dependent on the expected height of ice loads. Recently the constructive methods are culminating in the installation of concrete caissons as a vertical barrier.

Permanent low water and soil temperatures and water saturated condition of the islands body beneath the sea level are advantageous preconditions for stabilization of soil portions of critical areas of the islands top by artificial ground freezing.

The idea matured to investigate the applicability of this technique related to artificial islands protection. Several considerations led to the decision to lean on the example of concrete caissons and to investigate the effect of a similar protection supplementing the caissons by a pure frozen body. Ever when analytical calculations do not cover the whole range of designing problems a combination of different investigation methods is necessary. Two main sections had to be clarified:

- How does the construction behave at different static and dynamic ice load conditions?
- Which energy and which time is necessary to build up and conservate a frozen body of those extrem dimensions?

Consequently the entire investigations included basical analytical calculations, mechanical and thermal laboratory and model tests, and numerical calculations.

The mechanical part of the investigation is presented in the same titled paper in Session 9. The thermal part consisted on one hand of heat conductivity tests carried out on the model soil in frozen and unfrozen condition. Heat conductivity is one of the basic soil properties used in thermal numerical investigations. On the other hand thermal model tests were created using an arrangement of vertical model freeze pipes installed in a salt-water saturated sand body of the dimensions of 1.0 x 1.5 x 0.8 (m) in a cooling chamber for simulation of arctic environmental conditions. The time dependent frozen body build-up and the extension of the frost front was controlled by several temperature measurements inside the model. The results of the model tests and the thermal soil properties were used to calibrate numerical finite element calculations for further parameter studies varying cooling temperature and freeze pipe arrangements.

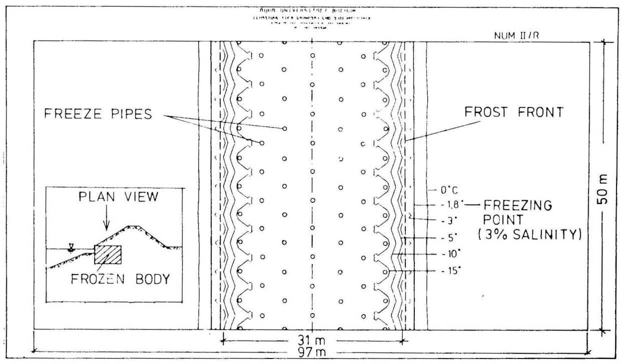

Figure. Thermal FEM-Calculations: Temperature distribution and frost-front-extension of the frozen body.

The figure shows an example of the results of the numerical investigations, the temperature distribution around the frozen body for a special freeze pipe constellation and freezing time (plan view).

In consequence of the experiences made by the combination of different kinds of investigations shall be noticed:

- A variable concept for designing frozen soil elements for stabilizing critical areas of artificial islands in arctic seas against ice loads could be worked out.
- Tools are investigations based on analytical and numerical calculations, model tests and mechanical and thermal laboratory tests for determination of soil properties in frozen and unfrozen condition.

Different questions still have to be solved e.g. the more precise determination of real ice load conditions in situ, being assumed very conservative in these investigations, and the development of tests on suitable freezing systems to build up and conservate the frozen body during the time of use.

Nevertheless the results of this project have shown that ground freezing can be a valuable technique for strengthening soil structures in arctic regions and could serve as an additional stabilizing component in combination with caissons and other constructions especially when considering the flexibility of application and of time limited insertion.

Broms, B., (SGP)*

I have a question to Mr. Holeyman. It refers to the lime piles where unslaked lime was used in bore holes and expansion itself was used to consolidate the surrounding soil. High swelling pressures developed which were on the order of 0,4 to 1,0 MPa. These pressures seem to me so high that they would cause hydraulic fracturing and cause a series of vertical cracks forming in the surrounding soil. The cracks could have a very important function by making the lime to penetrate into the surrounding stabilized soil. This would aid the water from the surrounding soil to move to the lime. It was not clear from the analysis if this fracturing was taken into account. What would your reactions be if this kind of fracturing were occuring? What would be the implications of your analyses?

Holeyman, A., (B)*

We have not considered the possibility of hydraulic fracturing. That is because in the analysis the tendency for expansion is converted into a uniform increase of pore water pressure. That means that hydraulic fracturing would not occur. But, if you have a field test where you can see a fracture then we have to change something in the analysis.

Zolkov, E., (IL)*

I am somewhat distressed by the continued reference to ion exchange as being a mechanism of lime stabilization. I thought it was established some 20 years ago that ion exchange has very little to do with lime stabilization. Could you put me right, please?

The second point I want to make is: One must be very careful judging the changes in clay by plastic index. It changes with time and has no relation to the strength increase.

Anonymous,*

I would like to add a few comments to the paper by Holeyman and Mitchell. There are two aspects involved in their approach which make me suspicious: They take into account only the expansion of the solid, as it expands about 85 per cent. The total expansion of the lime and water involved in the reaction is negative. In fact, there is a small volume decrease. I therefore would not expect a single drop of water to come out of the system, simply because there is no total volume increase according to the approach of the authors. Secondly: They presume that the temperature had not influence in this process. However, in the tests which they refer to, the Japanese tests, temperatures between 120 ^{o}C and 150 ^{o}C were measured. I think that the pressure curve of these tests clearly shows that there might be temperature effects because there was a pronounced peak value some time after the start of the test.

Holeyman, A., (B)*

The tests which were analysed by Kuroda et al. shows that there is pressure due to swelling and I think it cannot be denied that there is an expansion of the solid phase of the skeleton of the slaked lime and that the tendency to expand induces pore pressures. In these tests temperature can have an influence specially when expansion is restrained. In other tests done by Chiu et al. you can see that the final expansion is of the order of 30 per cent which means that the peak value is not observed in the real cases where some expansion can take place.

It is true that we do not consider heat generation and in some recent papers, e.g. Bang et al., 1982, there are reports of high temperature increases in lime columns, up to 400 degrees. If you look at these curves, you can see that the time they measured for the temperature at the periphery of the column and inside the column to reach the peak value grows when approaching the centre of the column. The curves are of the same nature as the ones I presented. Unfortunately in the mentioned papers it is not possible to find a coefficient of consolidation. I think that the people who deal with this type of improvement should include this type of data in their publications.