Triaxial Test — Field Stresses in Compacted Clay Embankment

L'Essai Triaxial — Contrainte In Situ dans Remblais d'Argile Compactée

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SYNOPSIS This paper presents measurements of triaxial stresses in a compacted clay embankment over a period of three years.

The development of porepressures are also recorded. Prior to the embankment construction samples of the borrowpit material were taken and triaxial tests were run to establish parameters to be used in stability calculation.

About two years after the embankment was completed, samples were taken and new triaxial tests were run, to make a comparison with the previous values obtained. This time the tests were run using the measured stresses from the embankment as starting point in each test.

The stress paths from these tests fit in very nicely with the previously obtained ones.

A possible simplified way of looking at the wetting up of compacted clay is discussed. The effect this might have on the soil parameters is also presented.

INTRODUCTION

The horizontal and vertical stresses and the porepressures measured in compacted clay embankments are used to simulate the field conditions in triaxial testing. The resulting stress paths are compared with the stress paths obtained from previously made sample from borrow pit material.

The porepressure during the triaxial test is measured through a central probe as well as at the top and bottom of the sample.

1. A number of triaxial tests at various moisture contents were run in order to establish a simple relationship between stress path characteristics and moisture contents. The results from these tests can be seen in fig. 1. The range of moisture contents is selected to cover the practical field case.

   The soil parameters in this paper refer to a dry crust marine clay described elsewhere. (Østlid 1976)

FROM LABORATORY TESTING				
w %	γ_w kN/m^2	γ_d kN/m^2	a kN/m^2	tan ϕ
20	20.3	16.9	12	0.76
23	20.0	16.3	9	0.67
26	19.7	15.6	5	0.59
30	19.3	14.8	1	0.50
33	19.0	14.3	0	0.45

Fig. 1. Soil parameters derived from triaxial tests on dry crust clay at various moisture contents.

The parameters refer to the specificationcurve in fig. 2.

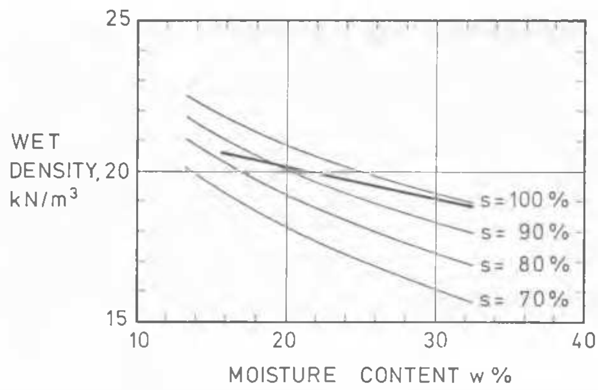

Fig. 2. Specification curve for compacted dry crust clay showing lower limits of densities to be accepted at various moisture contents.

The testing procedure is discribed elsewhere (Østlid 1976).

During construction of a high motorway embankment, a steel cube with 6 earth pressure cells was installed in order to measure the development of horizontal and vertical stresses. (Rygg and Østlid 1979). The porepressures were also recorded and the results can be seen in fig. 3.

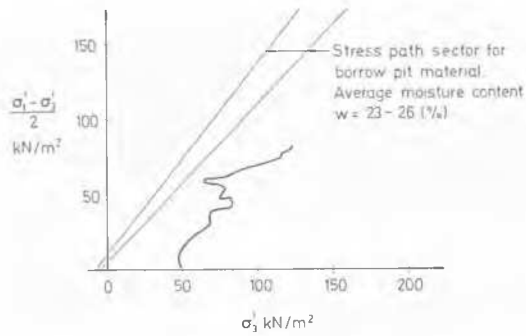

Fig. 3. Areas of expected positions of stress paths and the actual stress path as measured in situ.

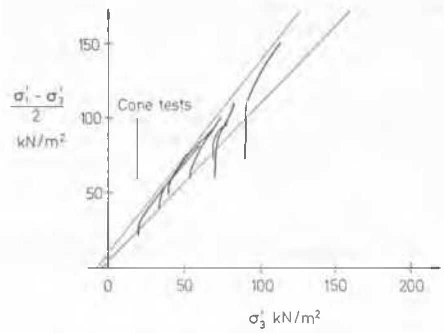

Fig 4. Triaxial tests using in situ stresses. About 2 years after completion of the embankment, samples were taken and new triaxial tests were run. This time the stresses measured by the steel cube were used in an attemt to simulate the field conditions.

The stress paths are seen to fall within the original limits adopted for design.

Safety of embankment

Considering a dry clay compacted to comply with the specifications shown in fig. 2. Such a clay will have an appreciable amount of air included and consequently will not be saturated.

The comparatively high strength may largely be dependent on negative porepressures. In later life this clay probably will be saturated and the effective stress will decrease. Looking at this complex problem in a very simplified manner, let us assume that the air space is filled with water and that the moisture contents increase.

The effect of this increase is shown in fig. 5.

	MODIFIED FOR DESIGN				
w %	w_{ult} %	γ_w kN/m²	γ_d kN/m²	a_u kN/m²	tan ϕ_u
20.0	23.0	20.8	16.9	8	0.68
23.0	25.0	20.4	16.3	6	0.62
26.0	27.9	19.9	15.6	3	0.55
30.0	31.4	19.4	14.8	0	0.47
33.0	33.1	19.0	14.3	0	0.35

Fig. 5. An initial moisture content of w=20% will increase to w_{ult} = 23% if all air is replaced by water. Consolidation will of course occur and the real final moisture content will depend on the real final stress conditions.

Obviously, the space available for water to enter into, is dependent on many factors. For example, a dry unsaturated clay in the lower portion of an embankment will undergo a form of consolidation before any water can enter. This consolidation is probably mainly connected to air going into solution with the porewater and the net result is a volum decrease, higher density and less space for water to occupy in future.

The gradual saturation of compacted dry crust clay has not yet been established, but measurements in completed embankments are being done at intervals at the NRRL and it is hoped that in a few years results will either confirm or reject this idea.

If such mechanisms are at work, some form of delayed failure may occur in these embankments. This is a point to remember when designing high embankments, for the time being a conservative approach seems to be necessary.

The triaxial testing technique is still improving, but perhaps more on the computer and electronic side. It is well to remember that data from triaxial tests not simulating field conditions are of doubtful value.

The "consolidation" stage of triaxial testing should perhaps be considered with new interest. At this stage the specimen should be brought back to its original stress state and not be allowed to consolidate in the true sense of the word.

If consolidation is allowed, the actual shear test is performed on a material having a lower moisture content than it actually has in the field. This may lead to design with lower safety factors than actually calculated. Operating on an effective stress basis the technique of measuring porepressures at the midheight of the specimen seems to yield reasonable results. Regrettably, the form "reasonable" is deliberately chosen, as measuring the correct value of porepressure still is one of the big and difficult problems in triaxial testing.

Very briefly, a triaxial procedure as outlined below is tried out at the NRRL.

Consolidation stage

The sample is placed in the triaxial cell and the vertical stress and cell pressure is raised in steps according to the k_o-condition. Drainage valve closed. Porepressure is measured at top-base through standard filters and at midheight through a ceramic probe in the loading stages. Axial deformation is recorded.

After last loading stage, all variables need to be stable before testing can commence. A very interesting point at this stage is the resulting porepressure. If this is in the vicinity of what is present in the field, the sample should have an excellent starting point before the shear test. If it is not, porepressures can be adjusted through the end filters, but this is not desireable.

Shearing stage

The speed of testing will be a debateable point for a long time yet, for a clay perhaps 0,5 - 1,0%/h will be normal.

However, using a central probe to measure the porepressure, the speed may be increased two to three times. If this can be done there is a clear economic advantage using probes as the time of triaxial testing can be reduced considerably.

CONCLUSION

This paper attempt to show that the triaxial test can be used to simulate field conditions from an actual completed clay embankment. Some thoughts of development of shear strength with time in these materials are presented and a conservative approach in design is recommended. Some technical points in triaxial testing is discusses briefly and the principle of a testing procedure is outlined.

The development of triaxial testing in the future is believed to be dependant on the equipment and procedures to be able to truly simulate the field conditions. In order to be able to do this the field conditions must be known. In other words, there is a great need for reliable measurements of in situ stresses and at present the biggest problem seems to be associated with the measurements of k_o-values. In future, perhaps the soil mechanics profession would benefit greatly if research and investigations consentrated more around field measurements than mathematical calculations based on laboratory data of doubtful value.

In that respect, perhaps the years from now and until the next International Conference in Soil Mechanics is held, we all should consentrate more on measuring actual field behaviour and report more facts and figures that we do now.

REFERENCES

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