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Evaluation of preparation techniques of chalk samples for oedometer testing

Evaluation des techniques de préparation des échantillons de craie pour les tests œdométriques

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ABSTRACT: In a geotechnical design of a foundation, proper soil parameters are needed to perform a proper design. In some regions, cretacious soils, such as chalk, are deposited near the ground surface. Hence, they will be the bearing stratum for a foundation. However, chalk is a very brittle material and the sample preparation for laboratory tests is very challanging. This paper presents two methods to prepare chalk samples for oedometer testing, where one showed to have a significantly higher success rate compared to the other. Additionally, the paper presents results from oedometer tests on chalk from Rørdal, Denmark.

RÉSUMÉ: Pour concevoir correctement des fondations géotechniques, il est nécessaire d'avoir une connaissance suffisante des propriétés du sol. Dans certaines régions, des couches sédimentaires du Crétacé, comme la craie, sont présentes près de la surface. De ce fait, elles consitueront les couches de soubassement des fondations d'un édifice. Cependant, la craie est un matériau très friable et la préparation d'échantillons pour des tests en laboratoire est une tâche ardue. Cet article présente deux méthodes de préparation d'échantillons de craie destinés à la réalisation de tests œdométriques. L'une d'entre elles a un taux de réussite beaucoup plus élevé que l'autre. De plus, les résultats de tests œdométriques réalisés sur de la craie de Rørdal (Danemark) sont présentés dans cet article.

Keywords: chalk; sample preparation; oedometer testing; preparation method.

1 INTRODUCTION

At many locations in nothern Europe, chalk is present near the surface of the earth. This is for example seen in the northern part of Denmark, in the north-eastern part of France and at the western part of Great Britain (Ziegler 1990). When building large structures on top of these soils, geotechnical design parameters needs to be determined in order to design a proper foundation. However, most research on chalk is dealing with the effect of extracting oil and replace it with water. This phenomena has among others been investigated by (Teufel et al. 1991, Risnes and Flaageng 1999, Homand and Shao 2000). Nevertheless, these phenomenas do not represent the chalk behaviour in the situation where a „normal“ structure has to be founded on chalk. For this design other geotechnical parameters are needed. As presented in (Mortimore 1989), chalk comes in many variations. Some variations of chalk are very hard and from a geotechnical point of view they may be treated as a rock. Contrary, other variations of chalk are softer and may be treated as a soft soil. When treated as a soft soil, tests as oedometer tests, triaxial tests and unconfined compression tests can be used. One way to classify chalk is from the Intact Dry Density (IDD) (Mortimore and Fielding 1990). They showed that the Natural Moisture Content (NMC) is related to the intact dry density. At the same time the intact dry density was used to classify chalk ranging from extremely soft and very soft to hard and very hard.

This paper will present results from a series of oedometer tests on chalk from Rørdal, Denmark. Using the definition by (Mortimore et al. 2004), the chalk is characterised as Extremely Soft (XS). The paper will present a reliable method for sample preparation of oedometer specimens from block samples of chalk. Furthermore, the paper presents results from oedometer tests on chalk.

2 METHODS

2.1 Test material

The presented results are from laboratory tests on specimens of chalk that were shaped from block samples which were collected at Aalborg Portlands chalk quarry in Rørdal, Aalborg, Denmark (Nielsen et al. 2018).

Table 1. Properties of Rørdal chalk from laboratory tests. * (Hjuler and Fabricius 2009) *presents a carbonate content of 93.8%, whereas* (Leth et al. 2016) *reports a carbonate content of 95-99%.*

Property	Symbol	Value
Water content	w	28%
Total density	ρ	2.11 Mg/m^3
Specific density	ρ_s	2.7 Mg/m^3
Void ratio	ν	0.84
Porosity	n	46%
Intact dry density (IDD)	ρ_d	1.65 Mg/m^3
Carbonate Content	wt	*

The chalk originates from upper Maastrichtian (Stenestad 2006) and the classification parameters are provided in Table 1. Compared to (Hjuler and Fabricius 2009, Leth et al. 2016) the water content, total specific density and void ratio are very similar. The carbonate content by (Hjuler and Fabricius 2009) and (Leth et al. 2016) have been determined to 93.8% and 95-99%, respectively.

2.2 Classification of Rørdal Chalk

A classification of Rørdal chalk after (Mortimore and Fielding 1990, Mortimore et al. 2004) will characterise the chalk as Extremely soft based on the intact dry density of 1.65 Mg/m^3. In comparison, (Hjuler and Fabricius 2009) reports a Rock dry density of 1.44 g/m^3 (no water content is presented) for Rørdal chalk, whereas (Leth et al. 2016) presents a dry density in the range 1.31-1.60 and a water content of 24-39%. This classifies the chalk from Extremely soft to very soft (VS) according to the IDD-NMC diagram.

2.3 Block sampling

Twelve blocks of Rørdal chalk were collected from a local chalk quarry at Aalborg Portland. The blocks were taken from the excavated material as illustrated in Figure 1. The blocks (approx. 20 kg) had been excavated during the night before they were collected and picked up in the following morning. The material was not exposed to the sun and no mist was observed on the surfaces of the blocks. The temperature were in the range of approximately 5-10°C. The 12 blocks were then sealed in plastic bags and stored at a constant temperature of 7°C until smaller specimens were shaped to fit the oedometer cell.

The water content of the block samples was measured just after the samples were collected. The measured water content was measured between 21-31%, with a mean of 28%. The unit weight of the chalk was determined to approximately 21 kN/m^3.

Figure 1: Excavation pit at Aalborg Portland from where the block samples of Rørdal Chalk were taken.

Figure 2 Pressing-out of block sample. The cylindrical ring is placed on top of the chalk ready to be pressed into the chalk by the hydraulic jack.

2.4 Preparation Methods

For oedometer testing two different sampling methods were used to determine the better solution for preparation of chalk samples for oedometer rings with a diameter of 70mm and a height of 35mm. Metod 1: *pressing-out in block sample* and method 2: *Pressing-out in drilled core sample*.

2.4.1 Preparation method 1

The equipment for the sampling method pressing-out consisted of a cylindrical ring, smoothing equipment and a hydraulic jack. The intact block of chalk was sawed into smaller blocks of approximately 20×20×10cm. The larger surfaces (20×20cm) were lightly smoothened to make a more plane surface, making the following procedures easier. The cylindrical ring were then placed on top of the chalk (see Figure 2), and were pressed slowly into the chalk by the hydraulic jack. During the press down of the cylinder the outer parts of the chalk samples started to crack, see Figure 3. Some of these cracks reached the core material (material for testing), see Figure 3. After full penetration of the cylinder into the chalk sample, the core sample in the cylindrical ring were pushed into the consolidation ring.

From Figure 3, it is possible to see that even though the core sample was almost twice the height of the consolidation ring; cracks along the ring were more than 1cm deep. Both end surfaces on the samples in the consolidation ring were then smoothened by a Stanley knife and a special designed plane. After smoothing, the cracks were filled with a mixture of water and very fine chalk particles from the shaping process.

Figure 3 Pressing-out of block sample. The cylindrical ring has been jacket into the chalk, resulting in cracks in the chalk.

After filling the cracks with the chalky mixture, the surfaces were given a final smoothening, like shown in Figure 6. The success rate of this method was very low and therefore needed adjustments to be reliable. This led to the development of method no. 2. Though, preparation method 1 has been used for making smaller samples with a diameter and height of 35mm. These are presented as tests no. 0903, 1001, 1103 and 1201. Only the larger samples were troublesome.

2.4.2 *Preparation method 2*

For the pressing-out in drilled core sample, the equipment from the pressing-out method were used and additionally a spoon bit with a slightly higher diameter and height compared to the oedometer cell, which have a diameter og 70mm and a height of 35mm. Firstly, a core sample was drilled out of the block with the spoon bit as shown in Figure 4. The Ø70mm ring were then used to take a core sample from the material inside the spoon bit in the same way as in the pressing-out method, see Figure 5. This core sample was afterwards pushed into the oedometer ring and the two free ends were smoothned by hand to fit the desired surface level, as seen in Figure 6.

Figure 4 pressing-out in drilled core sample. A spoon bit is used to drill a core sample.

Figure 5 pressing-out in drilled core sample. The Ø70mm ring were pressed into the core sample, which reduced the number and size of cracks significantly.

Figure 6 pressing-out in drilled core sample. Chalk sample prepared in the oedometer ring ready for testing.

This preparation technique led to significantly less and smaller cracks between the ring and sample. Hence, it also demanded less sample restoration to make a fine sample as pictured in Figure 6.

2.5 Oedometer testing

A total of 12 consolidation tests with the sample dimensions given in Table 2 and were performed with the load steps presented in Table 3. The sample name is constructed as XXYY, where XX refers to the block sample no., and YY refers to the consecutive numbering of tests on the specific block sample. A remark should be given on sample 0104. This sample had serious cracks when shaped to the ring. Only 2/3 of the sample was intact and the remaining 1/3 were filled with a paste of moistured chalk.

Table 2. Sample sizes of chalk samples

Test no.	Diameter	Height
0101	70mm	35mm
0102	70mm	35mm
0103	70mm	35mm
0104	70mm	35mm
0901	70mm	35mm
0902	70mm	35mm
1101	70mm	35mm
1102	70mm	35mm
0903	35mm	20mm
1001	35mm	35mm
1103	35mm	20mm
1201	35mm	35mm

*Table 3. Oedometer test overview. Each load step had a duration of 7 days (10080min). *1/3 of the sample was restored with a paste of moisture chalk from the preparation phase. Specimens had a diameter of 70mm and a height of 35mm. Though, samples no. 0903, 1001, 1103 and 1201 had a diameter of 35mm.*

Test no.	Load steps [kPa]
0101	400; 200; 400; 800; 1600
0102	400; 200; 400; 800; 1600
0103	31; 64, 128; 255; 510; 893; 1786; 2598; 1786; 510; 128; 31; 128 510; 1786; 2598
0104*	38; 510; 1786, 2598
0901	31; 64; 128; 255; 510; 893; 1786; 2598; 1786; 510; 128; 31, 128, 510;;1500,
0902	31; 64; 128; 255; 510; 893; 1786; 2598; 1786; 510; 128; 31; 128, 510; 1500
1101	31; 64; 128; 255; 510; 893; 1786; 2598; 1786; 510; 128; 31; 128; 2598; 0
1102	31; 64; 128; 255; 510; 893; 1786; 2598; 1786
0903	122; 255; 510; 1019; 2039; 3568; 7135; 14270; 28540; 7135; 2039; 510; 122; 510; 2039; 7135; 28540; 0
1001	31; 61; 122; 255; 510; 1019; 2039; 3568; 7135; 14270; 28540; 7135; 2039; 510; 122; 510; 2039; 7135; 28540; 0
1103	122; 255; 510; 1019; 2039; 3568; 7135; 14270; 28540; 7135; 2039; 510; 122; 510; 2039; 7135; 28540; 0
1201	31; 61; 122; 255; 510; 1019; 2039; 3568; 7135; 14270; 28540; 7135; 2039; 510; 122; 510; 2039; 7135; 28540; 0

3 RESULTS

3.1 No sample shaping in oedometer testing

After oedometer testing the samples were taken out of the consolidation ring for a measure of water content. It was possible to take out the intact sample from the ring. However, the sample was not a perfect match to the ring. There was clear evidence that flakes along part of the sides had been broken off during sample preparation, as seen in Figure 7. On softer soil, the soil material would deform to fit the ring perfectly. But, this was not observed for the chalk samples. From tests 0903, 1001, 1103, 1201 on smaller specimens (Ø35mm), the preconsolidation stress were determined in the range of 20-100MPa. The smaller samples were loaded up to about 28MPa, and still imperfections from the preparation were clear, as seen in *Figure 8*. The authors therefore question if oedometer testing is an appropriate test method for chalk.

Figure 7 Chalk sample after completed consolidation test. On some parts of the sides, flakes had been broken off during sample preparation.

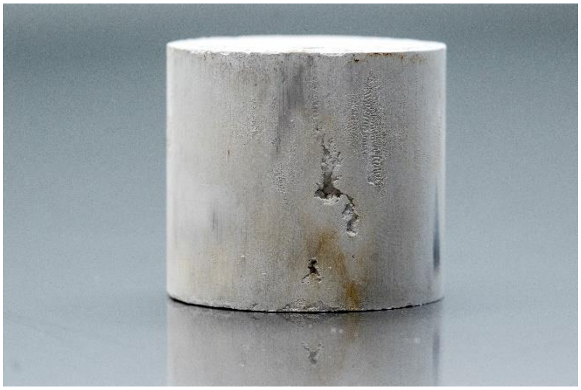

Figure 8 Chalk sample after consolidation. Sample diameter and height is 35mm and a maximum load during consolidation testing of 28MPa.

The water content of the Ø70mm samples were taken before and after testing. The results are presented in Table 4, where very similar values are reached. In a few tests the water content has increased during testing. This is a result of saturation during testing. In other tests the water content, decreases as one would expect for a soil undergoing consolidation. However, the variations in water content are very small, which is also the case for the deformations.

Table 4. Water content of chalk samples

Test no.	Natural water content	Water content after testing
0101	29%	29%
0102	29%	29%
0103	29%	31%
0104	29%	28%
0901	28%	31%
0902	28%	32%
1101	27%	28%
1102	27%	31%
0903	28%	-
1001	25%	-
1103	27%	-
1201	31%	-

3.2 Deformation parameters

The stress-strain curves from the oedometer tests are presented in Figure 9 and Figure 10. From the data presented in Figure 9 the unloading-reloading stiffness have been determined. The lowest measured unloading-reloading stiffness is measured in the range from 180kPa to 370kPa. However, as Figure 9 also shows, some tests, such as 0101, 0902 and 1101 do not undergo elastic deformation when unloaded. Hence, a parameter describing elastic deformation will give infinity.

When the unloading-reloading from a stress state below the preconsolidation stress is compared to unloading-reloading from a stress state above the preconsolodation stress, Figure 9 and Figure 10 show a more reliable result at the higher stress levels.

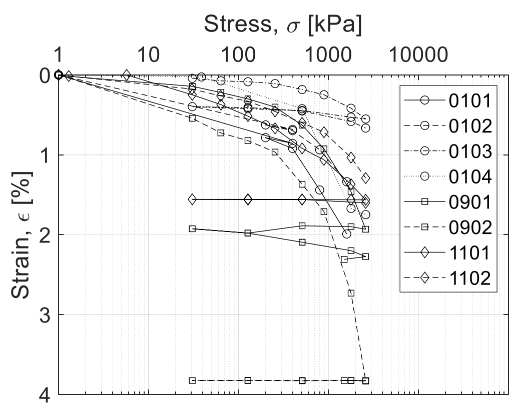

Figure 9 Stress-strain curve from oedometer tests on Ø70mm samples where the maximum load reached 2.7MPa.

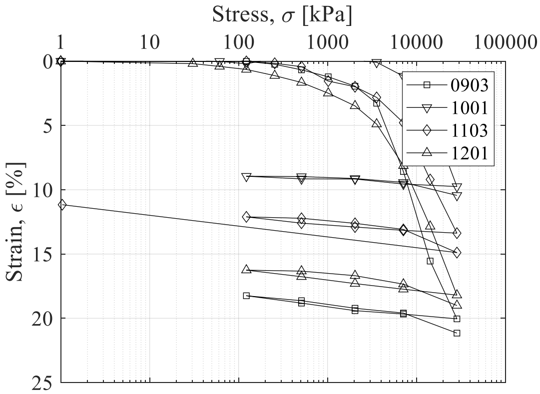

Figure 10 Stress-strain curve from oedometer tests on Ø35mm samples where the maximum load reached 28MPa.

Looking at the stress-strain behavious in Figure 10, there is no clear indication of that the preconsolidation stress have been reached. However, test no. 0103, 0901 and 0902 have two consecutive data point which forms a straight line in the ε(log(σ)) plot. This indicates that the preconsolidation stress is within the range 20-100MPa.

4 DISCUSSION

The oedometer tests with unloading at stress levels lower than the presoncolidation stress show less consistent unloading behaviour compared to unloading initiated at stress levels higher than the preconsolidation stress. This may be a result of fabric of the chalk. (Kågeson-Loe et al. 1993) reports that the deformation of chalk is controlled by destruction of the fabric, and that this is more pronounced at lower stress levels. (Kågeson-Loe et al. 1993) also state that the yielding occuring during consolidation is a result of progressive collapse of the pores combined with crushing at higher stress levels.

The observations by (Kågeson-Loe et al. 1993) also support the observations made on the chalk specimens after consolidation, where no signs of that specimen adjustmet to the oedometer ring were observed.

5 CONCLUSION

The paper presented two different methods for sample preparation for oedometer tests from a block sample. The authors will reccoment methos no. 2 *pressing-out in drilled core sample*. After testing, there were no visible indications on the chalk specimens that they have been undergoing any kind of adjustment to the oedometer ring, which is usally seen on oedometer tests on soft soils. Therefore, the authors question, if an oedometer test is suited for chalk samples.

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7 REFERENCES

Hjuler, M.L., and Fabricius, I.L. 2009. Engineering properties of chalk related to diagenetic variations of Upper Cretaceous onshore and offshore chalk in the North Sea area. Journal of Petroleum Science and Engineering, **68**(3–4): 151–170. Elsevier B.V. doi:10.1016/j.petrol.2009.06.005.

Homand, S., and Shao, J.F.R. 2000. Mechanical Behaviour of a Porous Chalk and Water/Chalk Interaction. Oil & Gas Science and Technology, **55**(6): 591–598.

Kågeson-Loe, N.M., Jones, M.E., Petley, D.N., and Leddra, M.J. 1993. Fabric evolution during the deformation of chalk. International Journal of Rock Mechanics and Mining Sciences and, **30**(7): 739–745. doi:10.1016/0148-9062(93)90016-7.

Leth, C.T., Andersen, J.D., Madsen, T., and Larsen, K.A. 2016. Founding on (un) known chalk in Aalborg. *In* NGM 2016. pp. 249–256.

Mortimore, R.N. 1989. Chalk or chalk? *In* Chalk: International symposium. pp. 15–45.

doi:10.1680/c.15418.0003.

Mortimore, R.N., and Fielding, P.M. 1990. The relationship between texture, density and strength of chalk. Chalk, (January): 109–132. doi:10.1680/c.15418.0011.

Mortimore, R.N., Stone, K.J., Lawrence, J., and Duperret, A. 2004. Chalk physical properties and cliff instability. Geological Society, London, Engineering Geology Special Publications , **20**(1): 75–88. doi:10.1144/GSL.ENG.2004.020.01.05.

Nielsen, S.D., Peri, E., and Nielsen, B.N. 2018. Data report on Rørdal chalk. Aalborg Universitet, Institut for Byggeri og Anlæg.

Risnes, R., and Flaageng, O. 1999. Mechanical properties of chalk with emphasis on chalk-fluid interactions and micromechanical aspects. Oil and Gas Science and Technology, **54**(6): 751–758. doi:10.2516/ogst:1999063.

Stenestad, E. 2006. Fluviokarst in the top of the Maastrichtian chalk at Rørdal, Northern Jutland, Denmark. Bulletin of the Geological Society of Denmark, **53**(1–2): 93–110.

Teufel, L.W., Rhett, D.W., and Farrel, H.E. 1991. Effect of Reservoir Heterogeneities. *In* Rock Mechanics as a Multidiciplinary Science. pp. 63–72.

Ziegler, P.A. 1990. Geological atlas of Western and Central Europe 2. and completely rev. ed. The Hauge: Shell Internationale Petrolium Maatschappij B.V.