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2000

Link to publication

Citation for published version (APA):
Lindh, P., Dahlin, T., & Svensson, M. (2000). *Comparisons between different test methods for soil stabilisation*. Paper presented at ISRM International Symposium 2000, IS 2000, Melbourne, Australia.

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COMPARISONS BETWEEN DIFFERENT TEST METHODS FOR SOIL STABILISATION

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ABSTRACT

Soil stabilisation is a very useful technique for road construction. To utilise the full advantage of the technique the quality control must be adequate. In this study three main groups of test methods are tested and discussed. The first group deals with methods for determination of bearing capacity e.g. complete surface compaction control, static plate load test and light drop weight tester. The second group of method deals with workability and homogeneity tests e.g. moisture condition value (MCV), core sampler and pulverisation test. The third group deals with geophysical methods e.g. spectral analysis of surface waves (SASW) and resistivity.

INTRODUCTION

Shallow soil stabilisation has been used in Sweden since the late 50´s but during the 80´s it was only occasionally applied, due changed regulations. However the method has met a renaissance during the late 90´s partly because of the environmental advantages of the method. During the construction of the new connecting road for the Öresund fixed link, soil stabilisation has been used to ensure sufficient bearing capacity and homogeneity. In the first phase 300,000 square metres of clay till have been stabilised with lime. At three different sites full-scale tests have been performed during the construction of the ring road. At all the sites both conventional testing and geophysics have been used for evaluation. The test methods that have been used are static plate load test (SPLT), light drop weight tester (LDWT), roller-mounted compaction meter, moister condition value (MCV), core sampler, pulverisation, spectral analysis of surface waves (SASW) and resistivity measurement.

BACKGROUND

In 1996 the construction of Yttre Ringvägen, a ring road around Malmö Sweden, was started, see Figure 1. The soil in the area consists of clay till and silty till. This type of soil is very sensitive to variation in water content. At an early stage it was discovered that the bearing capacity of the embankments was too low to meet the requirement in ROAD 94, which is the general technical construction specification for roads from the Swedish National Road Administrations (SNRA). To fulfil the requirements in ROAD 94, either soil stabilisation or soil replacement can be used.

REQUIREMENTS FOR THE BEARING CAPACITY OF SUBGRADES

According to ROAD 94, the bearing capacity can be verified in two different ways, both with an inspection area ≤ 4,500 m^2. In the first alternative, eight random samples of the inspection area are chosen and a static plate load test is performed at each test point. The modulus of elasticity (E_{v2}) has to be at least 25 MPa. The second way to verify the bearing capacity is to use a roller-mounted compaction meter and use the obtained information to choose the two areas with lowest response, see Figure 2. In these low response areas static plate load tests are performed. The requirement is a mean modulus of elasticity (E_{v2}) ≥ 10 MPa for those two points (SNRA). In this study, results before and after stabilisation were to be compared, and therefore four test points had to be chosen in advance.

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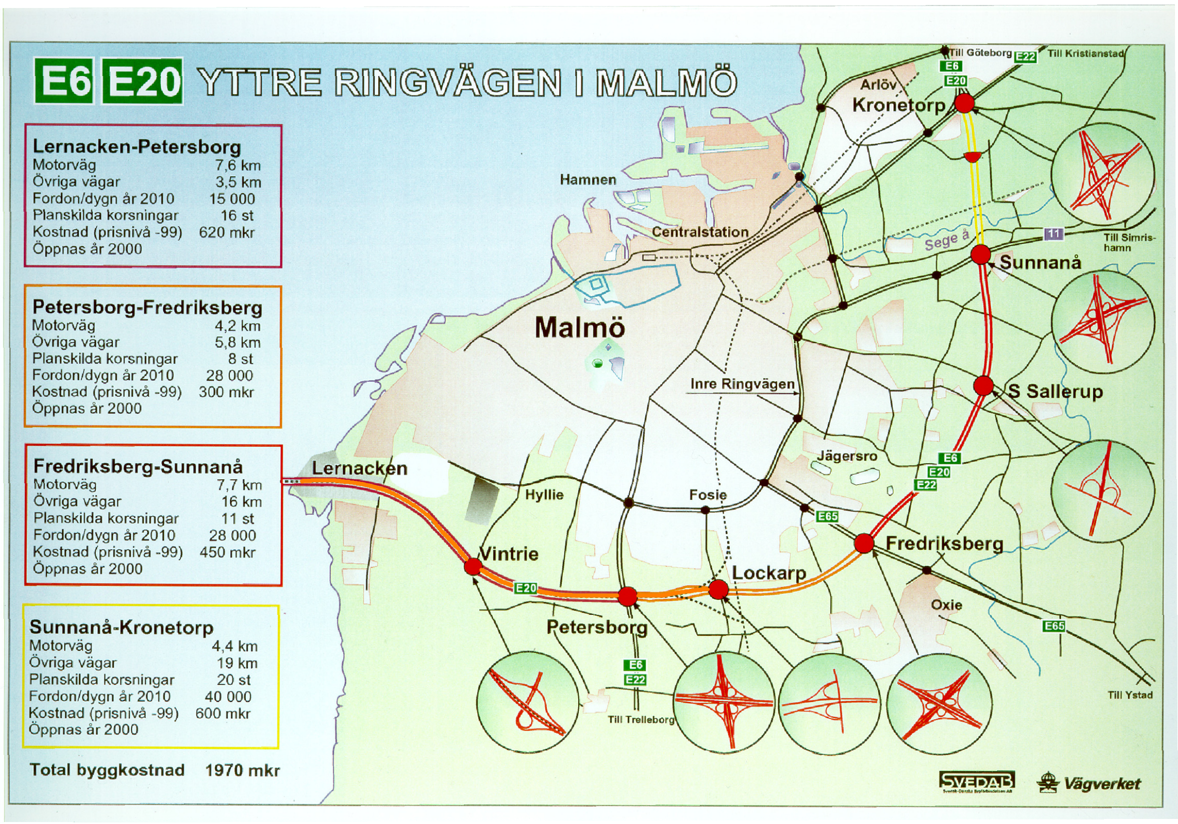

Figure 1 : The connecting road for the Öresund fixed link, a ring road Yttre Ringvägen, around Malmö City.

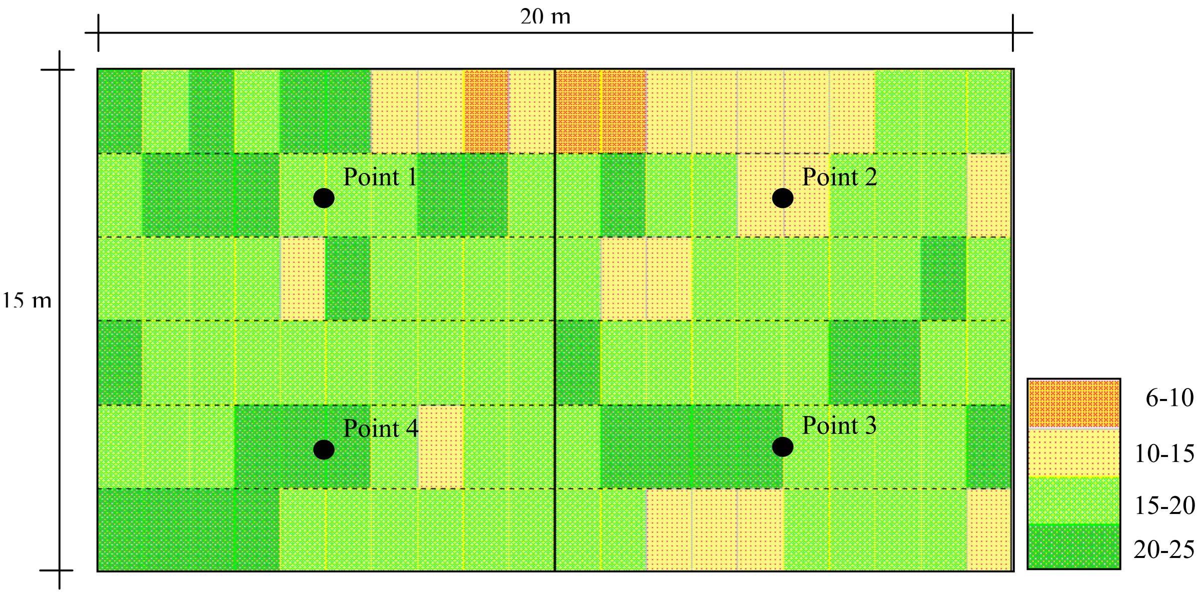

Figure 2 : A sketch over the test field with the four test points and the CM-value over the area.

TEST FIELD

The test field chosen was an area of twenty by fifteen metrs and a part of the ring road. This area was an embankment with a height of two metres and was divided in four squares with a test point in the center of each square, see Figure 2. To test resistivity and SASW, four lines were chosen. These lines went through the test points. Two of the lines were parallel to the highway and the other two were perpendicular to the highway. The soil is clay till with a clay content of approximately 15% and a natural water content of around 13%.

METHODS AND RESULTS

Methods for determination of bearing capacity

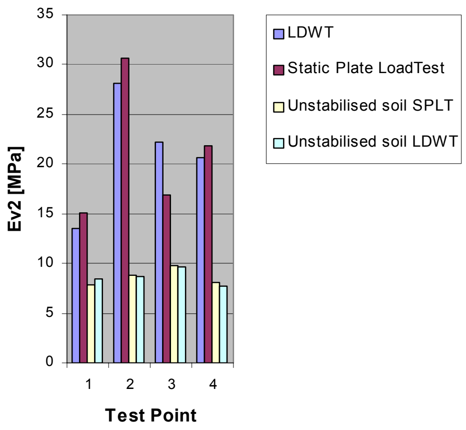

Figure 3 : Modulus of elasticity from static plate load test (SPLT) and light drop weight tester (LDWT) on stabilised and unstabilised soil.

The complete surface compaction control method is performed with a roller-mounted compaction meter in combination with static plate load tests. Compaction meter values (CMV) obtained at the test area are presented in Figure 2. The surface is relatively homogenous with respect to the CMV. The static plate load tests were performed at the test points and LDWT was also performed.

Results from the static plate load test and light drop weight tester are presented in Figure 3. The values from the light drop weight tester are converted from a dynamic modulus to a static modulus. This conversion is based on unpublished results from the Swedish Road and Transport Research Institute (VTI). The results in Figure 3 show that static plate load test and light drop weight tester gives very similar results on the unstabilised soil.

On the stabilised soil, however, the LDWT gives lower values for three out of four points. The results from CMV shown in Figure 2, indicate that the stabilised soil responds rather uniformly over the test area. In Figure 2, point 2 shows the lowest value, which is contrary to the results in Figure 3 where point 2 gives, the highest value. The contradiction could be explained by the difference in influence depth of the two methods. The CM value depends on the weight of the roller and in this case takes a greater depth than the stabilised layer into account.

Workability and homogeneity tests

The MCV method is developed at Transport and Road Research Laboratory in Great Britain (Parsons, 1976). The method is a field method that rapidly measures the moisture condition of earthwork material. The test is carried out by placing 1500 g sample soil where all material greater than 20 mm has been excluded in a mould with a diameter of 100 mm. On top of the soil a disk with a diameter of 99 mm is placed. A 7 kg rammer, 97 mm in diameter with a falling height of 250 mm, hits the soil until the soil is

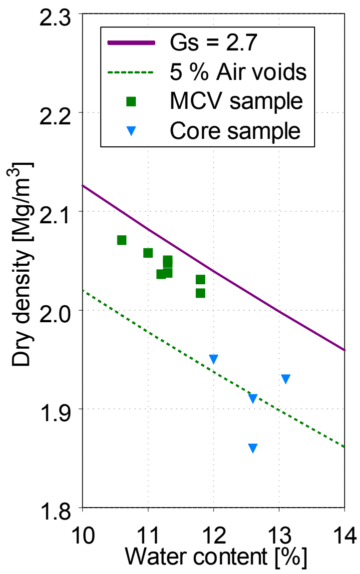

Figure 4 : The comparison between the core samples and the MCV samples dry density and water content is presented.

compacted to maximum bulk density. In other words the moisture condition test gives the minimum compaction work required to produce full or nearly full compaction. The MCV is then determined for different water contents of the soil. From this, a correlation between MCV and water content can be done. When the relationship between MCV and water content is known the water content can be determined within five minutes at field conditions. Research in England has shown that an upper value for MCV is between 12-14 to ensure compacting on the "wet" side (Perry, et al. 1996).

The core sampler is used to determine the in-situ density and void ratio. For this purpose a core sampler according to British Standard (BS 1924:1990) was manufactured. From earlier tests, nuclear methods have shown to give unsatisfactory results. The same conclusions were drawn in England (Sherwood, 1993). In Figure 4 dry density determined by the core sampler is compared to dry density determined by the MCV samples. The core sample results show both lower dry density and higher water content when compared to the MCV results. One plausible explanation to the lower dry density could be that the embankment below the stabilised layer had to high water content too be able to respond to compaction.

The pulverisation test was performed according to British Standard (BS 1924:1990). This test is a method to control how the rotovator have managed to break up the soil. Indirectly, it also tests how homogenised the soil-binder blend is. The soil sample, approximately 1 kg, is spread over a 5 mm sieve and gently shaken. Then the weight of the soil that has not passed the 5 mm sieve is determined. All lumps should then be broken until all individual particles finer than 5 mm are separated. Then the sample has to be replaced on the 5 mm sieve and shaken until all the material finer than 5 mm has passed through it. From this the degree of pulverisation can be determined (P, in %) see Equation 1.

$$P = 100(m_1-m_2)/(m_1-m_3) \qquad (1)$$

where
m_1 is the total mass of the sample
m_2 is the mass of the unbroken material retained on the sieve
m_3 is the mass of the material finally retained in the sieve

Specifications from Department of Transport requires that at least 90% of the stabilised soil is passing the 28 mm sieve and a minimum of 30% is passing the 5 mm sieve (British Lime Association, 1990). A result from the pulverisation test is presented in Figure 5. From Figure 4 it is clear that the P value at the site is > 30% and pass the requirements.

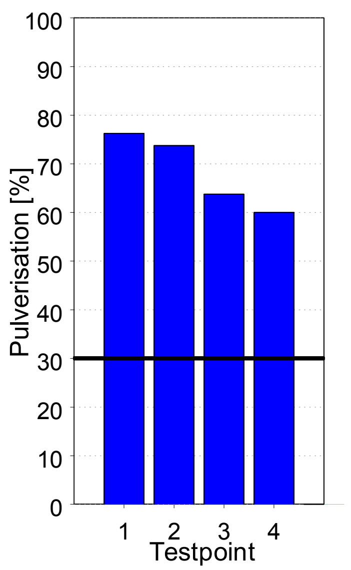

Figure 5 : Degree of pulverisation from the different test points.

Geophysical methods

In this study two different geophysical methods were also tested, the SASW method and 2D resistivity. The SASW method was tested to be compared, principally with static plate load test but also with LDWT. The SASW technique (Spectral

Table 1 : G modulus for the four different test points.

Depth (m)	Point 1 G(MPa)	Point 2 G(MPa)	Point 3 G(MPa)	Point 4 G(MPa)
0,15	**71,3**	14,1	10,8	**49,5**
0,30	**63,6**	**63,6**	**49,5**	**59,9**
0,80	39,2	64,8	54,5	51,2
1,30	28,8	26,5	33,8	26,5
1,80	16,2	12,8	12,8	12,8
2,30	14,5	7,2	14,5	7,2
2,80	16,2	16,2	16,2	16,2

Analysis of Surface Waves) is based on the dispersive character of the Rayleigh wave (Svensson, 1998). With two vertical receivers (geophones or accelerometers) and a Spectrum analyser different velocities and hence different moduli can be determined for different depths when recording the wave field produced by an impulse or vibrating source. The shear moduli, G, which is the mechanical parameter determined, is most often compared to moduli produced by SPLT, FWD etc. The evaluated moduli are presented in Table 1. The SASW method was able to obtain the increase in stiffness in the stabilised layer. Though in the shallowest part of point 2 and 3 at a depth of 0.15 metre the results were disturbed. Another observation is that the G modulus profile had the lowest value at the bottom of the embankment 2 metres below surface. Then the moduli started to increase in the natural soil.

The resistivity method was used to evaluate the method in stabilised soil. The idea was to find out if the method can measure the homogeneity of the stabilised layer. The surveying was made as two-dimensional resistivity imaging, also called continuous vertical electrical sounding (CVES), presenting as cross sections

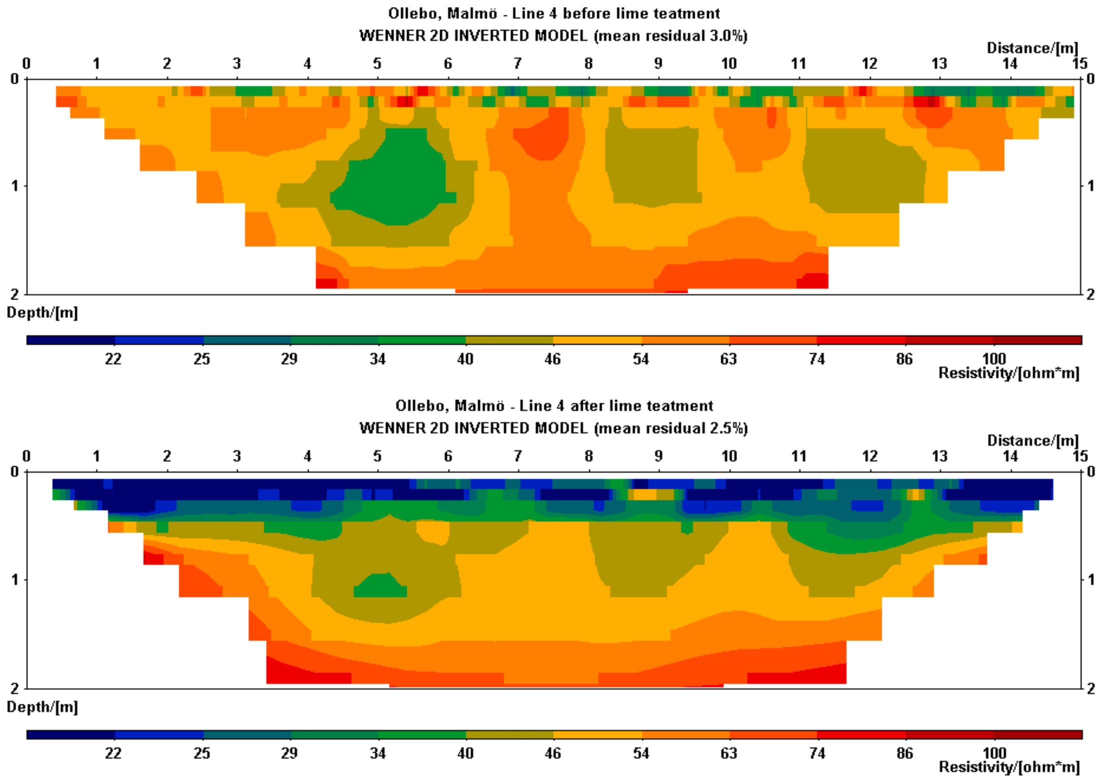

Figure 6 : Results from resistivity measuring before and after stabilisation at the test field.

of the resistivity of the ground. The measurements were carried out with the Wenner array, with 12 different electrode separations. The ABEM Lund Imaging System was used for the data acquisition, a computer controlled multi-electrode system. Four electrode cables with 21 take-outs each were laid out on a line using an electrode separation of 0.25 metre (Dahlin, 1996). The data was processed using inverse numerical modelling (inversion), in which a finite difference model of the subsurface resistivities is automatically adjusted to minimise the residuals between the model response and the measured data. The software Res2dinv was used for the inversion (Loke, 1999). The resistivity results before and after stabilisation is presented in Figure 6. There is a clear difference in resistivity between unstabilised and stabilised soil. The differences in resistivity before and after stabilisation depend on some major effects. These effects are change in water content, change in porosity and the change in ion content. In this study there is no possibility to separate these effects.

CONCLUSIONS

There are several useful methods to measure bearing capacity, workability and homogeneity. For quality control of the bearing capacity the complete surface compaction control method have a big advantage. This method can be used on all of the passes with the roller mesuring the increase in stiffness with a very limited effort. This method is the only method that covers the whole area. To calibrate the CM-value at least two static plate load tests have to be performed on each control object (4,500 m^2). As an alternative to complete surface compaction control the SASW method could be used but the technique must be faster and more automatic to be economical. On the workability control the MCV method is very useful and can be performed both at laboratory and on site. The limitations for this method is the grain size of the stabilised soil that is, MCV is developed fine grained soils.

For the homogeneity tests a more flexible method is requested, and the study shows that the resistivity method has a large potential as a complement to traditional testing. The technique could also give a 3-D model of the stabilised area. However, there is a need for faster data acquisition, and this could for example be solved with a fast multi-electrode system that could be pulled after a vehicle. There is also a need of a more efficient data processing used in routine applications.

ACKNOWLEDGEMENT

The Swedish National Board for Industrial and Technical Development (NUTEK), Peab (contractor). The authors also gratefully acknowledge the valuable assistance of Per Löwhagen.

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