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KAREG Consulting Engineers

UNBRACED PIPE TRENCH STIFF FISSURED CLAY LAYER ON SOFT CLAY

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INTRODUCTION

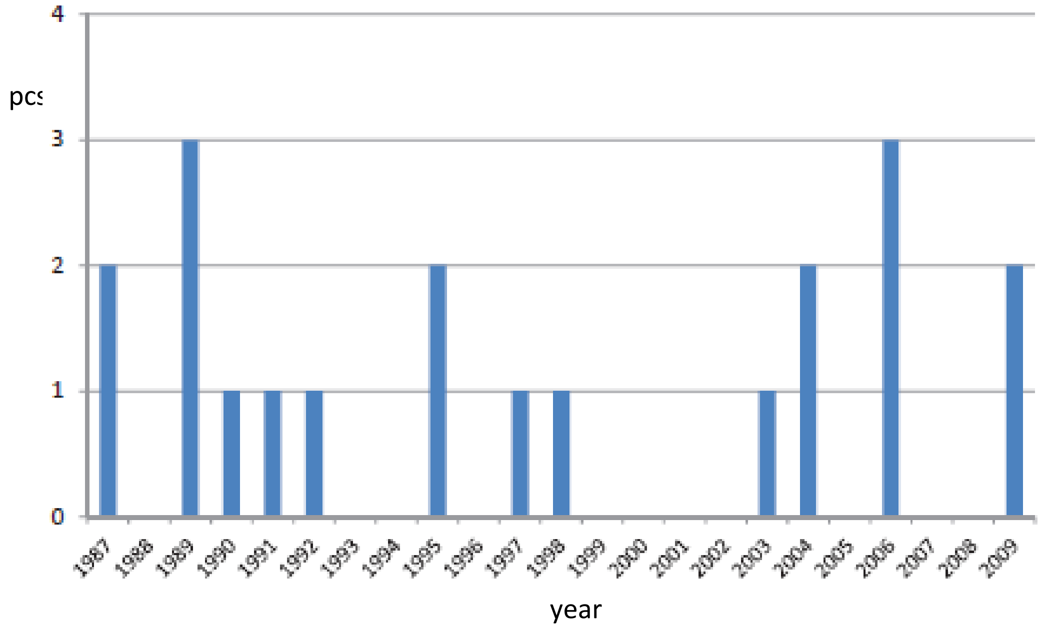

Figure 1. Statistics of deadly accidents in trenches in Finland. Research concerning safety of trenches, The Finnish Transport Agency.

Working in trenches is dangerous.

Pipe trenches often seem harmless and safety of workers is many times underestimated.

In Finland there are reported between1-3 deadly accidents per year caused by collapsed trenches. Number of serious accidents is much higher.

In Finland there is around 40% of deadly work accidents that occur in the field of civil engineering.

According to the regulations , the trenches have to be carefully predesigned. The designs have to be based on sufficient number of soil investigations.

Case in southern Finland, crossing pipe trenches. Failure due to tension crack in stiff clay. Collapsed edge 4 m x 2,3 m (L x H).

COMMON ENGINEERING PRACTICE

Common engineering practice is to predict possible tension cracks in slope-stability engineering for predicting safety factor of existing slope or to calculate safety factor for new excavation (Fig. 3, Fig. 4).

In Scandinavia (including Finland) it is a common situation if a slop consists of stiff clay ($C_u > 40$ kN/m^2) as upper layer and soft clay ($C_u < 20$ kN/m^2) as lower layer.

When upper slope material is stiff clay, we have to estimate the compatibility between overlying stiff clay and underlying soil material (clay).

Depths of the tension cracks can be estimated theoretically and then using engineering judgment it is decided the depth in stability analysis.

Other causes for cracks in clay are weathering, wind, freezing and melting, movements etc. It is notable that in Scandinavia there were so called Little Ice Age from 14th century to 19th century, when there were several cold periods.

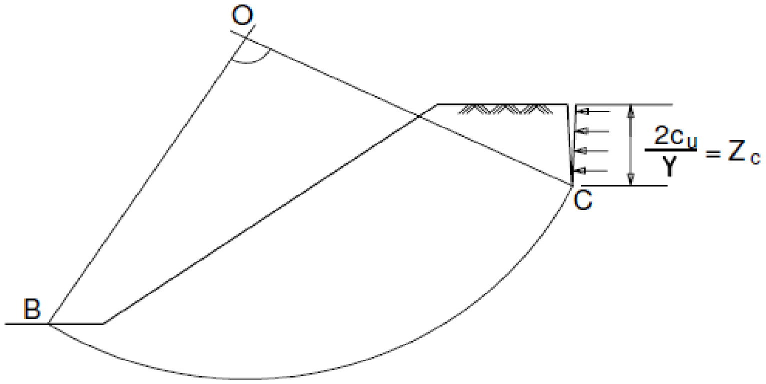

Figure 3. Tension cracks, existing slope.

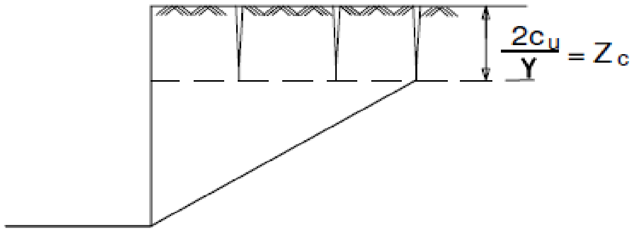

Figure 4. Tension cracks, new trench.

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UNBRACED PIPE TRENCH

In Europe different countries have their own regulations or codes concerning human risks, risk-to-life categories in unbraced pipe trenches. The codes - just as the Finnish Code - usually give only average “references or guidelines” , such as height of trench, soil-material, slope angle, distance of excavator from upper slope rand, workload of excavator, the type of excavator and weight of stored material near the rand slope etc.

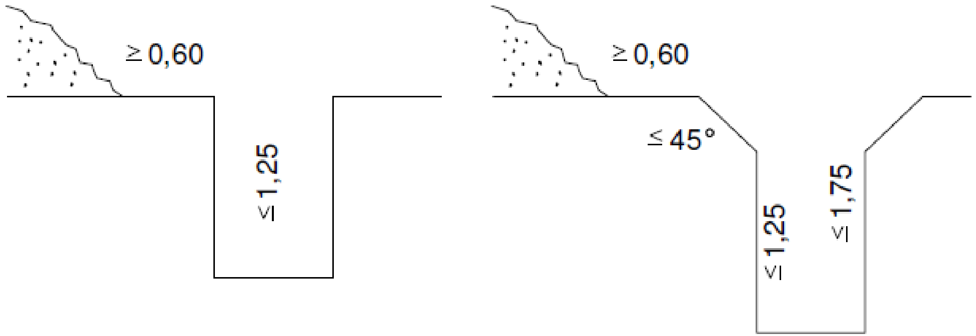

Figure 5. Examples from German code DIN 4124.

One of the most useful codes is the German DIN 4124, where most of the above mentioned parameters are clarified in a practical way. In Germany, if undrained shear strength is > 25 kPa, then the maximum height of the unbraced trench is 1.75 m .

Finland

Table 16200;T2. Unbraced, temporary trench. Maximum depth and slope angle.
Su =undrained shearstrength

earth basis		slope angle					
		5:1	3:1	2:1	1:1	1:2	1:3
		maximum depth m					
IV	Very soft clay (Su=7...<10kPa)	-	-	-	1,7	1,9	2,1
V	Soft clay (Su=10...<20kPa)	1,6	1,7	1,9	2,3	2,5	2,7
VI	Stiff clay (Su=7...≥20kPa)	2,0	2,5	3,0	3,2	3,7	4,0

Trench has to be predesigned if there is any risk of collapse and always when the depth is >2,0m.

Figure 6. Table 16200;T2. InfraRYL 2010, Finnish Code Of Building practice, Infrastructure.

In Finland, regulations concerning risks in trenches state that every trench with height > 2.0 m must be “braced”, but the bracing system can consist of slopes and berms (Fig. 6)

The trench must be designed by a geotechnical engineer. If there are workers in the trench, then the overall safety factor must be more than 1.5.

NEW CRACKS DUE TO EXCAVATION

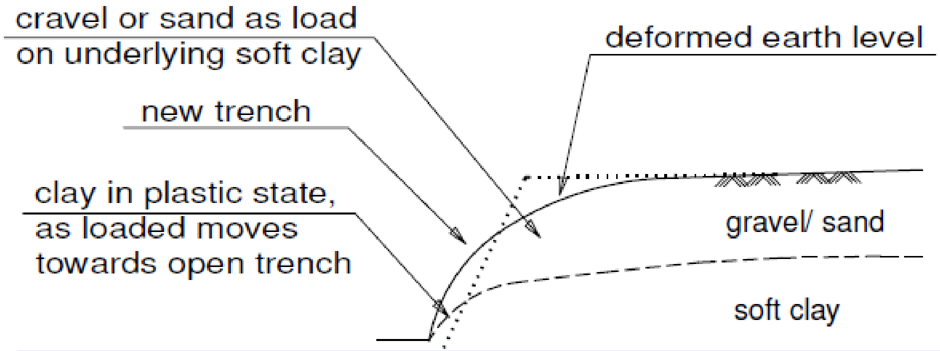

Figure 7. Visual demonstration, overlying material gravel or sand. No cracking due to excavation.

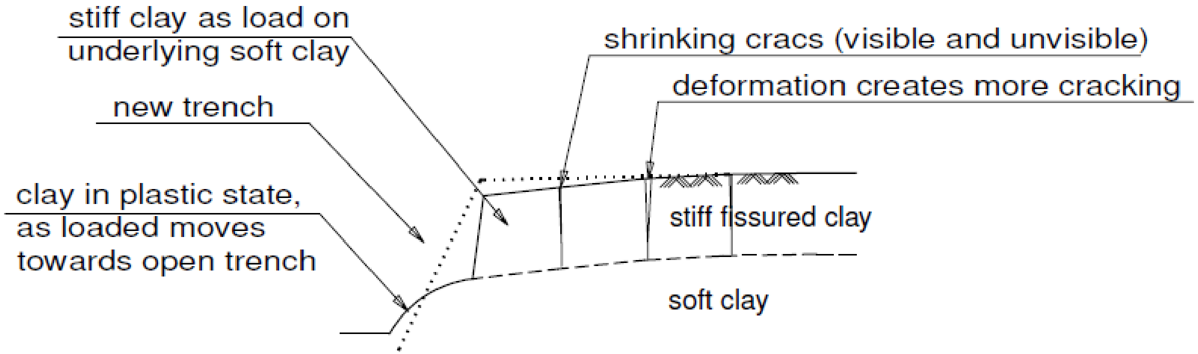

Figure 8. Visual demonstration, overlying material stiff clay. New cracs due to excavation.

The mechanism of new cracks due to excavation are shown in Fig 7 and 8.

Layer of stiff fissured clay is loading underlying soft clay.

Case in southern Finland, crossing pipe trenches. Failure due to tension crack in stiff clay. Collapsed edge 4 m x 2,3 m (L x H).

Figure 10. Unbraced test trench. Underlying soft clay is flowed towards the trench

CASE IN SOUTHERN FINLAND

The project consisted of 2 200 meters pipe trench of which 1 500 m unbraced and 700 m braced by standard-box V.B. 100 [Euro Verbau].

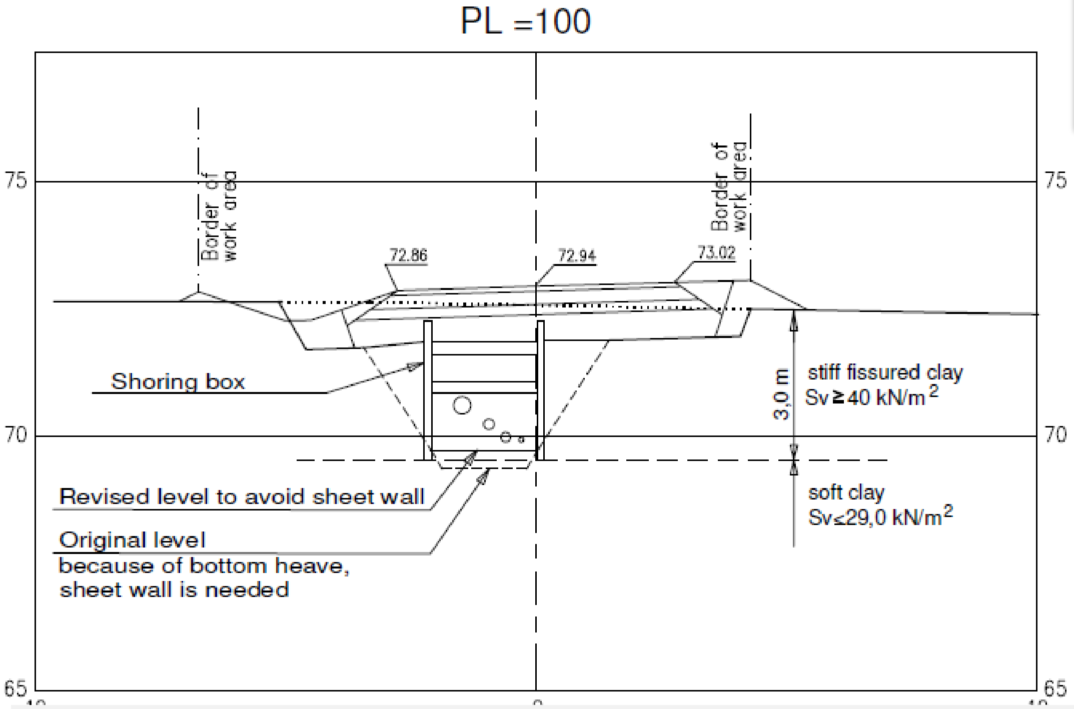

Figure 11. Street section and trench. Undrained shear strengths.

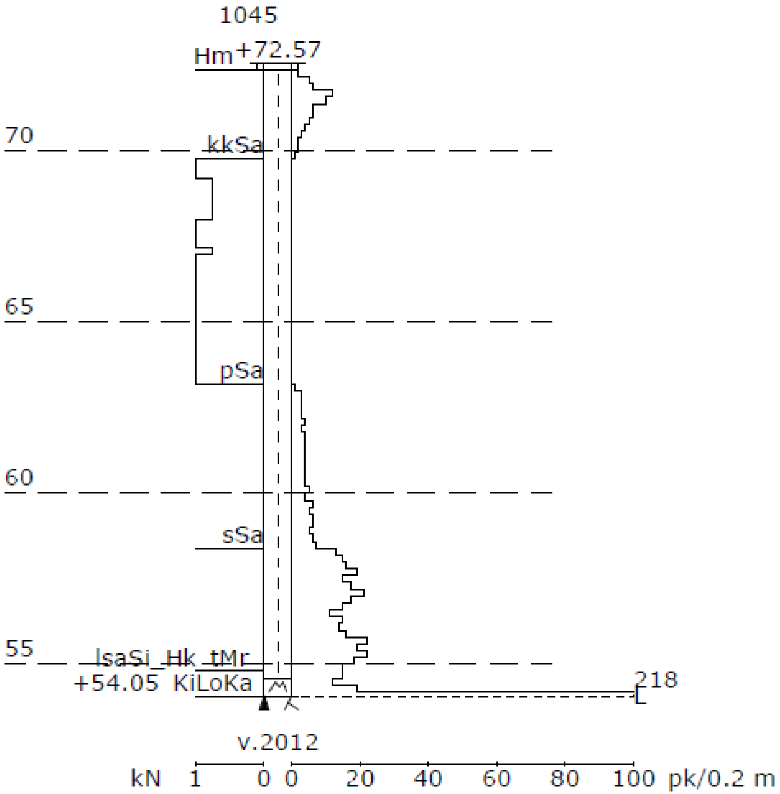

Figure 12. Swedish Weight Sounding

Figure 13. Vane Test. Undrained shear strengths.

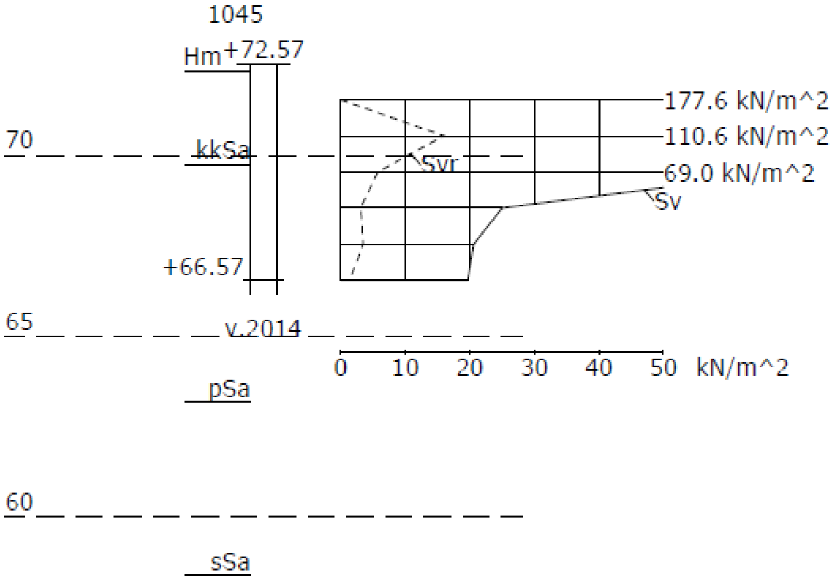

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Figure 14. Test trench, depth of visible crack apr. 1,8m from surface.

Figure 15. Detail picture of the crack.

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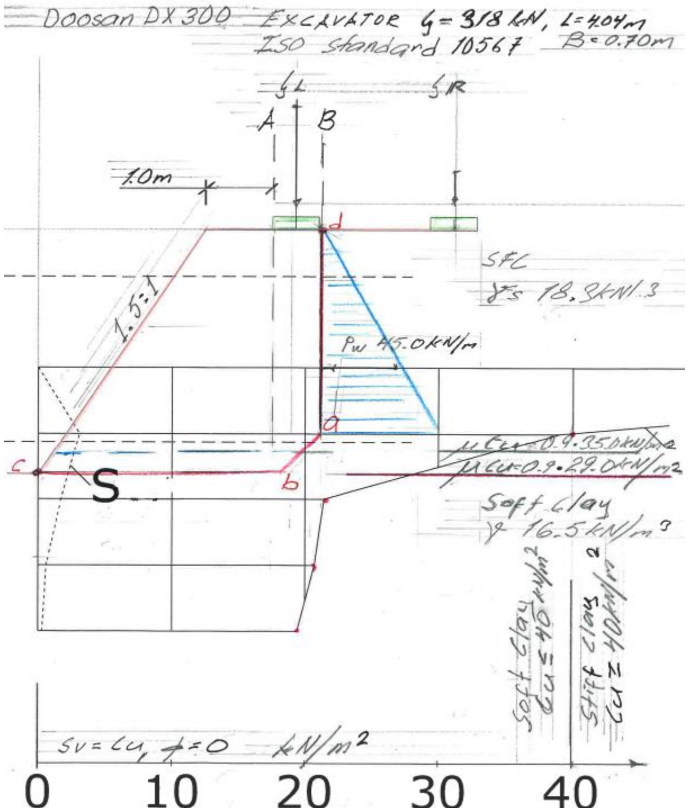
CALCULATIONS



SIMPLE WEDGE ANALYSIS (SWA), only one "wedge"

Actions

Crack Zc

$Z_C = \frac{2 \cdot 97.4\,kN/m^2}{18.3\,kN/m^3} = 10.6\,m$

limiting up Sv 40.0 kN/m² = Cu

$Z_C = 3.0\,m$,

Water

$p_w = 30.0\,kN/m^2$

$P_w = 45.0\,kN/m$

Excavator

G 318 kN, L 4.04 m

GL 59.0 kN/m, ISO 10567

GR 19.7 kN/m

Slideline a-b, B 0.7 m

GL 59.0 kN/m

Gs 44.0 kN/m

Fc 0.9 m · 35 kN/m² · 0.9 = 28.4 kN/m

Ebc = 36.0 kN/m

Σ E Ebc + Pw = 81.0 kN/m

Resistances

Fc already in slideline a-b

Horizontal slidesurface b-c

RCu 3.8 m · 1.0 · (0.9 · 29.0 kN/m²) = 99.2 kN/m

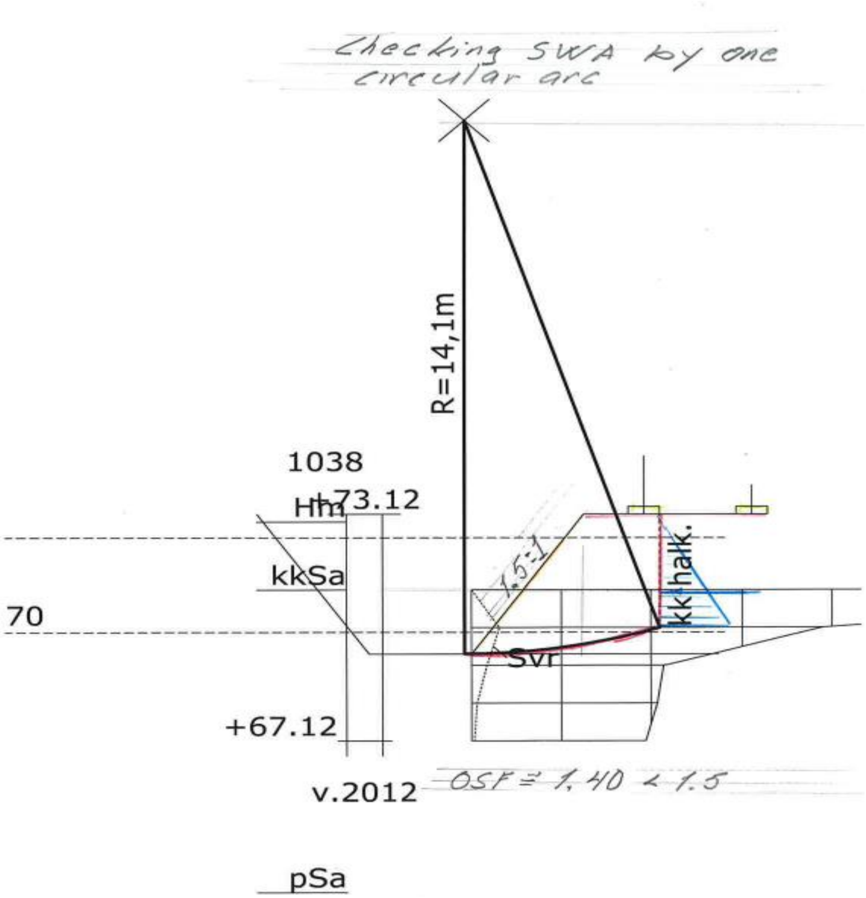
Overall safety factor

OSF 99.2 kN/m / 81.0 kN/m = 1.22 < 1.5

Steel boxes are needed

Note: This calculation is approx. calc.:
ground crossing trenches, no
rand effect is taken in calc.

CALCULATIONS

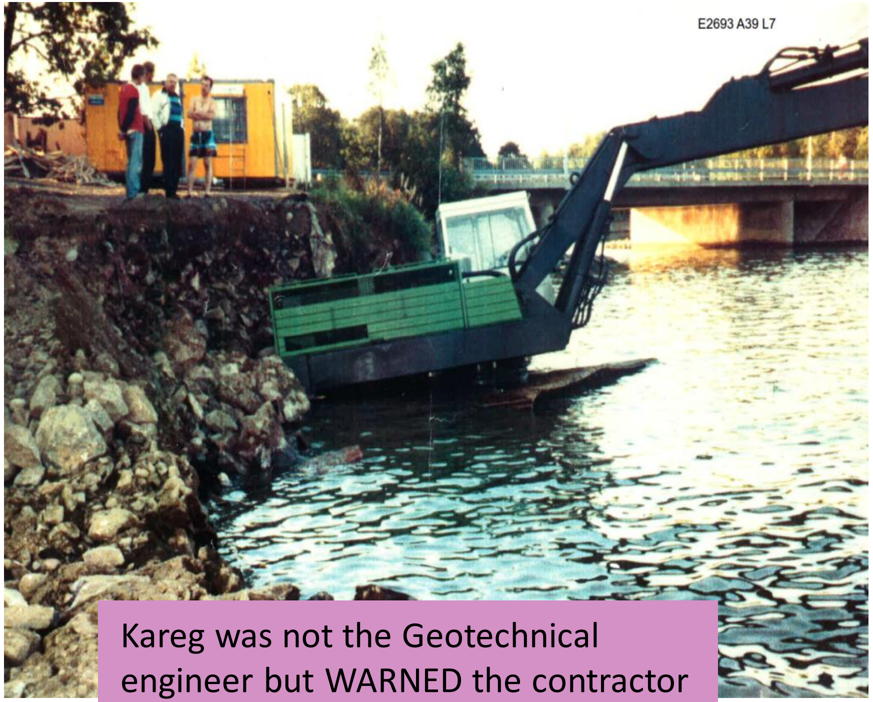


CONCLUSIONS

It is well known that clay as material is more complicated than pure mechanical geological material. A lot of new information is available by using SEM-technology and now the development of knowledge of the clay minerals, their atomic structures, chemical connections etc. is growing. New findings may help understand why the cracks in stiff clay are seldom visible by the eye ($w \leq 0.1$ mm) and mostly invisible before excavation of trenches.

The shown calculation is according my opinion on the safe side also in the corner of trenches, where there can not be real influence of arching or 3-dimensional stability.

There is no exact method to predict the safety factor for a pipe trench when a layer of stiff fissured clay lies on soft clay.



Kareg was not the Geotechnical engineer but WARNED the contractor and client.

Thank you for your attention