(III－85) Determinations of area behind the slurry trench which needs the soil improvement.

Pavol Oblozinsky (PhD student) and **Keizo Ugai**
Department of Civil Engineering, Gunma University, Japan

Masaaki Katagiri, Kunio Saitoh and Takeshi Ishii
Nikken Sekkei Nakase Geotechnical Institute, Kawasaki, Japan

Shuji Tomita and Kiyoshi Kuwabara
East Japan Railway, Tokyo, Japan

Abstract: When we construct a deep trench excavation supported by slurry close to another existing structure, very often we need to improve the soil strength around the excavation in order to maintain the stability. This paper presents the method helpful for the determining of an area behind the excavation face which requires a soil improvement, based on the shear strength reduction FE analysis and the local safety factor concept. The presented method is a graphical trial and error method.

We can perform the analysis on the slurry trench stability with applied surcharge using the shear-strength reduction technique. As a common result of such analysis we obtain the global safety factor, *Fs*, of the excavation and shear strength distribution. If we introduce the local safety factor to the FEM procedures, we also can obtain the distribution of the safety factor over the modelled area at all Gaussian points. In the presented FEM analysis, the elasto-perfectly-plastic law was adopted, in which the failure criterion is governed by the Mohr-Coulomb equation:

$$f = \frac{1}{2}\left[3(1-\sin\phi)\cdot\sin\theta + \sqrt{3}(3+\sin\phi)\cdot\cos\theta\right]\cdot \sqrt{J_2} - I_1\sin\phi - 3c\cos\phi = 0 \qquad (1)$$

and the plastic potential obeys Drucker-Prager rule:

$$\Phi(I_1, J_2) = \sqrt{J_2} - \alpha I_1 \qquad (\alpha > 0) \qquad (2)$$

The Mohr-Coulomb equation (Eq. 1.) determines whether the soil fails at particular Gaussian point or not. When the element fails, the equation (1) is equal zero, and this may be only when its two components are equal to each other in the absolute magnitude. Thus we can define the local safety factor, *Fss*, as:

$$Fss = \frac{I_1\sin\phi - 3c\cos\phi}{\frac{1}{2}\left[3(1-\sin\phi)\cdot\sin\theta + \sqrt{3}(3+\sin\phi)\cdot\cos\theta\right]\cdot\sqrt{J_2}} \qquad (3)$$

We can also express the local safety factor by meaning of Figure 1, which shows the Mohr circle of the stress state at a particular Gaussian point, and the failure line which is governed by the equation:

$$\tau_F = c'/Fs + \sigma'\tan\phi'/Fs \qquad (4)$$

in which F means the global safety factor.

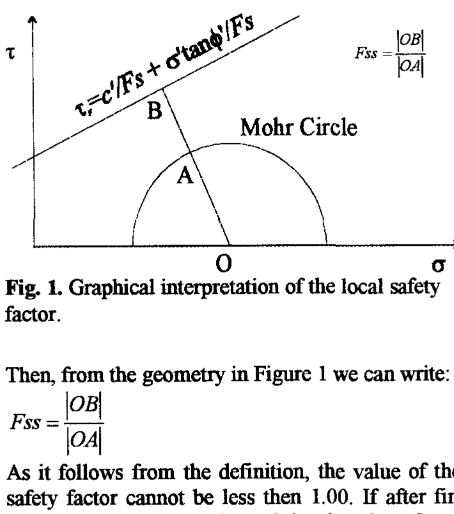

Fig. 1. Graphical interpretation of the local safety factor.

Then, from the geometry in Figure 1 we can write:

$$Fss = \frac{|OB|}{|OA|} \qquad (5)$$

As it follows from the definition, the value of the local safety factor cannot be less then 1.00. If after finishing the calculation the value of local safety factor was multiple by the global safety factor, *Fs*, we would obtain the distribution of the local safety factor with regard to the global safety factor. Based on the picture of the local safety factor distribution multiplied by the global minimal safety factor we can determine the area in which the safety factor is less then 1.00 and thus needs the increase in the soil strength.

2D FEM analysis on the slurry trench stability is demonstrated herein. The depth of the trench was 15 m, the surcharge of 230 kN/m^2 was applied over the strip 3.0 m long, placed 1 m apart from the edge of trench excavation. The supporting slurry (10.5 kN/m^3) was filled on the level +25 cm above the ground level. The soil properties were as follows: $\gamma'=8.7$ kN/m^3, $\varphi=\psi=39^\circ$,

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c=0 kN/m^2, E=20.000 kN/m^2, ν=0.3. The underground water level was put at the ground surface.

The calculated value of the safety factor for the above described condition was, Fs=0.55. Figure 2 shows the distribution of the local safety factor with regard to the global safety factor. Figure 3 shows the shear strength distribution before the failure. With the help of those two pictures we can suggest the shape of the area which requires the soil improvement. For demonstration purpose two areas were chosen, column-like area next to the excavation face (D 15m x L 4m) and rectangular area under the surcharge (D 6m x L 9m). The soil was improved into following parameters: c=100 kN/m^2 and φ=ψ=0°. The column-like improvement increased the global safety factor from 0.55 to 1.08, the safety factor distribution is shown in Figure 4. The rectangular-like improvement under the surcharge improved the safety factor from 0.55 to 1.21 and safety factor distribution is in Figure 5. In both cases the Fs is greater then 1.00, which indicates the stable conditions, however rectangular-like improvement (Fig. 5) seems to be more effective. The scale of the safety factor distribution is in the range from 0.55 to 1.5 in all Figures (Fig. 2. 4. 5.) in order to visualise and compare the change in the safety factor distribution due to the soil improvement. The values over 1.5 are not shown and the corresponding colour is white.

Conclusions: The picture of the safety factor distribution is a helpful tool for the design of the to-be-improved area behind the face of the excavation. The method is a trial and error method, allowing to take into consideration another stabilising factors, like the height of the slurry filling, slurry density, shape and strength of improved area and then chose the most suitable combination for the design.

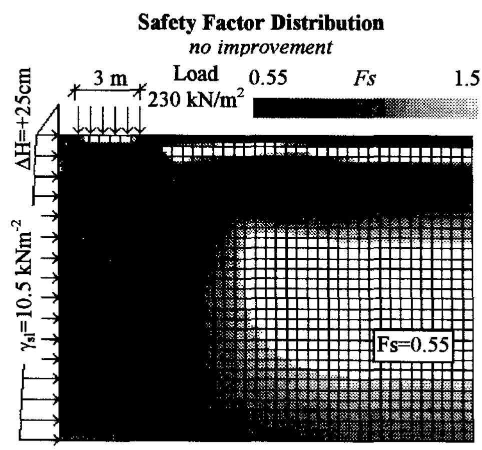

Fig. 2. Distribution of *Fs*, no improvement

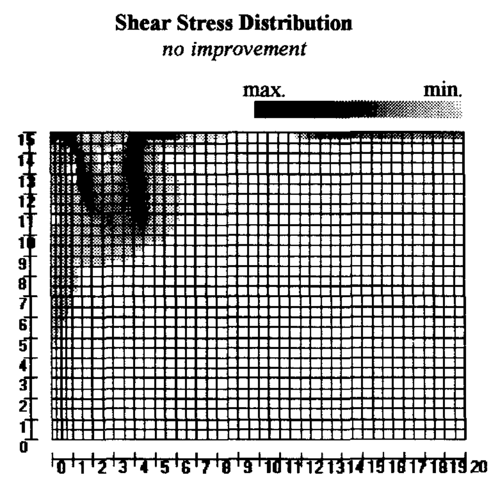

Fig.3. Shear strength distribution

Safety Factor Distribution

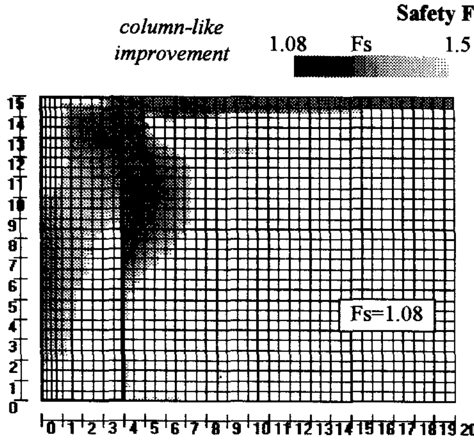

Fig. 4. Safety factor distribution, column-like shaped improvement

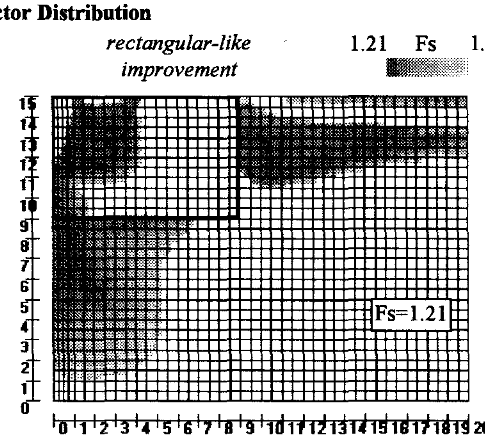

Fig. 5. Safety factor distribution, rectangular-like shaped improvement