Effect of In-situ Stress Condition on Stability of Slurry Trench

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1. Introduction

The deformation and stability of slurry trench wall depend mostly on the equilibrium between supporting slurry pressure and total lateral earth pressure, of which the value at static state is expressed as follows:

$\sigma_H = K_0 x \sigma'_H + u_0 + u_w$ (u_0: excess pore pressure; u_w: hydrostatic pore pressure)

When the wall displaces towards excavation side, the lateral pressure gradually decreases to a value between static state and active state. If the supporting slurry pressure is large enough and the wall has not deformed excessively, a stable state is usually established [1]. However, in case of under-consolidation clay ground, for example after reclamation, due to the existing of considerable large excess pore pressure, the equilibrium may not be satisfied and the wall displaces in form of failure. With in a numerical analysis, the measured data of pore pressure in the ground could be used to simulate the subsoil initial condition and the effect of excess pore pressure in the failure mechanism of trench wall could be clarified.

2. Experiment of trench excavation

Figure 1 shows the soil profile and basic data of the experimental trench excavation site. The pore water pressure measured just before excavation reveals the existing of excess pore pressure in soft clay layer, which had not completely dissipated under the overburden load of reclamation. The trench was excavated to GL. –20m in 5 days, using slurry of γ_f =11.3kN/m^3 maintained at GL. –0.3m. Even with this relatively large unit weight of the slurry the trench walls deformed excessively and finally touched each others (see Figure 2). Comparing with other experimental trench excavation sites in similar soil stratum, it may consider that one of the causes of this failure was the under-consolidation condition of soft clay layers.

3. Numerical analyses

Numerical analyses were performed by mean of the coupled analysis FEM program SAGECRISP 4.02. The analysis model is shown in Figure 3. Input parameters of soil models are summarized in Table 1. The parameter determination procedure of clay layers is as follows:

$\sin\phi' = 0.81 - 0.233 x Log(PI)$ *(Kenney, 1959)*

$K_0 = 0.95 - \sin\phi'$ (Brooker&Ireland, 1965)

$\nu = K_0/(1-K_0)$

$E_0 = 210 x C_U$ *(Takenaka, 1962)*

The initial stress was set up with two cases of normal consolidation (K_0-consolidation) and under-consolidation as shown in Figure 4. Elastic and Mohr-Coulomb elastic-perfectly-plastic soil models were used with each initial stress condition setting, resulting in 4 cases of analysis (Table 2).

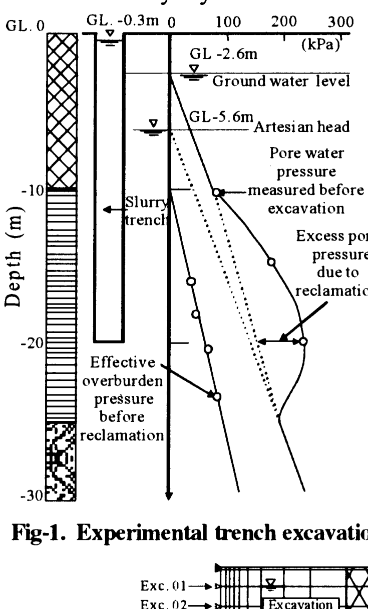

Fig-1. Experimental trench excavation

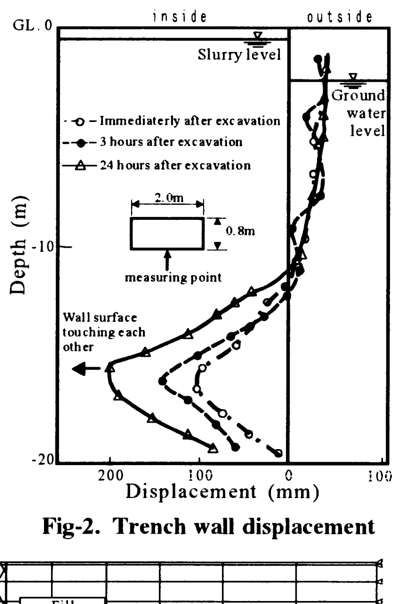

Fig-2. Trench wall displacement

Table-1. Soil properties

Layer	IP / N	γ	k	E_0	ν	K_0	C_u	ϕ'
		kN/m^3	m/sec	kN/m^2			kN/m^2	deg
Fill	10	18	1.0E-3	2.80E+4	0.300	0.426	0	35.0
Soft clay 1	59	16	5.0E-9	3.15E+3	0.356	0.553	15	23.4
Soft clay 2	67	16	5.0E-9	4.20E+3	0.361	0.565	20	22.6
Soft clay 3	70	16	5.0E-9	5.25E+3	0.363	0.570	25	22.3
Stiff sand	40	20	1.0E-3	5.60E+4	0.227	0.293	0	45.0

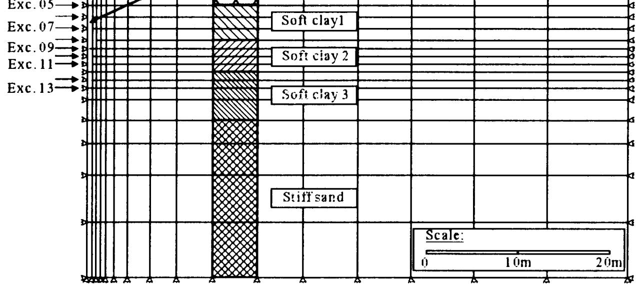

Fig-3. Analysis model

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Table-2. Analysis cases

		Case 1	Case 2	Case 3	Case 4
Soil model	Elastic	○	○		
	Mohr-Coulomb			○	○
Initial tress condition	Normal consolidation	○		○	
	Under consolidation		○		○

4. Results of Analyses

The results of the analyses are presented in Figures 5-7. Fig. 5 shows the displacement of slurry wall at 3 hours after finishing the excavation. Best agreement with experimental data was obtained in case 4. More over, only in this case, when the time effect was taken into account, the excessive deformation of the wall in form of failure was predicted. The plot of soil status (Fig. 6) reveals the spreading of a large yielding zone from the soft clay up to the filling layer. In case 3, on the contrary, the yielding zone has just started from the trench bottom. It's eliminated that the excess pore water pressure intensified the wall deformation not only by increasing the lateral pressure but also by flowing the soft clay layers into yielding.

Fig. 7 presents the variations of pressure constituents at GL.-14.5m and GL.-18.0m, one meter away from trench wall during excavation in case 4 of analysis. It is obsefved that in proportion to the increasing of wall displacement, the total pore pressure considerably decreases and the effective horizontal pressure slightly increases. The resulting total lateral pressure decreases during the excavation to a stable value at the end of the process. In this case, however, the slurry pressure is smaller than this value both at GL.-14.5m and GL.-18.0m. The equilibrium state could not be established and the wall destructively deformed. Besides, the pore water pressure has the tendency to recover to hydrostatic pressure when the elapsing time is large enough, due to which the lateral pressure will increase significantly. That is, in a long time analysis a higher slurry pressure is required to keep the wall stable.

5. Conclusions

The excess pore pressure has critical effect on the stability of slurry trench by increasing the water pressure acting on the wall and reducing the effective stress which leads to the yielding of soft clay layers when the wall undergoes excessively deformation.

Numerical analysis may yield good prediction with proper input soil parameters and appropriate setting of initial stress condition.

References

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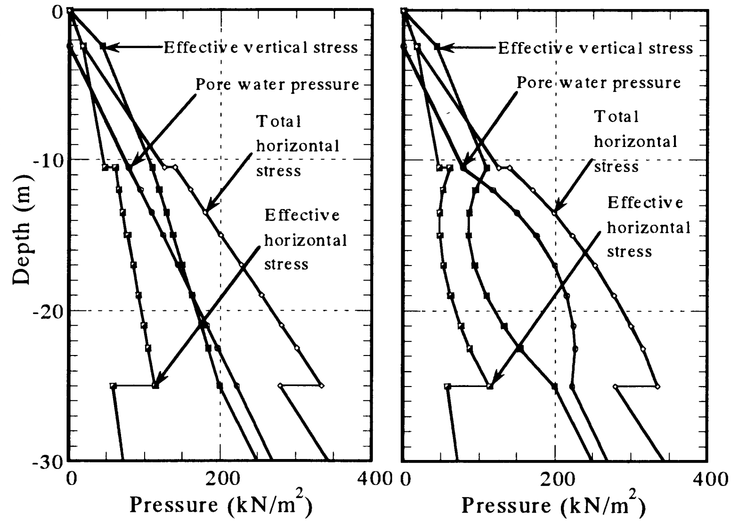
2. Woods, R. and Rahim, A. (1999): Sage-Crisp technical reference manual, SAGE Engineering Ltd..



(a) Normal consolidation (b) In-situ under consolidation

Fig-4. Initial stress condition.

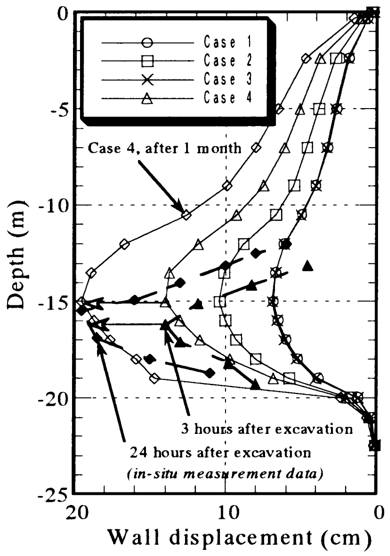


Fig-5. Wall displacement (3 hours after excavation)

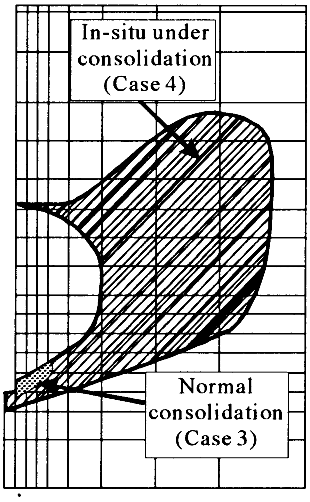


Fig-6. Yielding zone with different initial stress condition setting (Case 3 & Case 4)

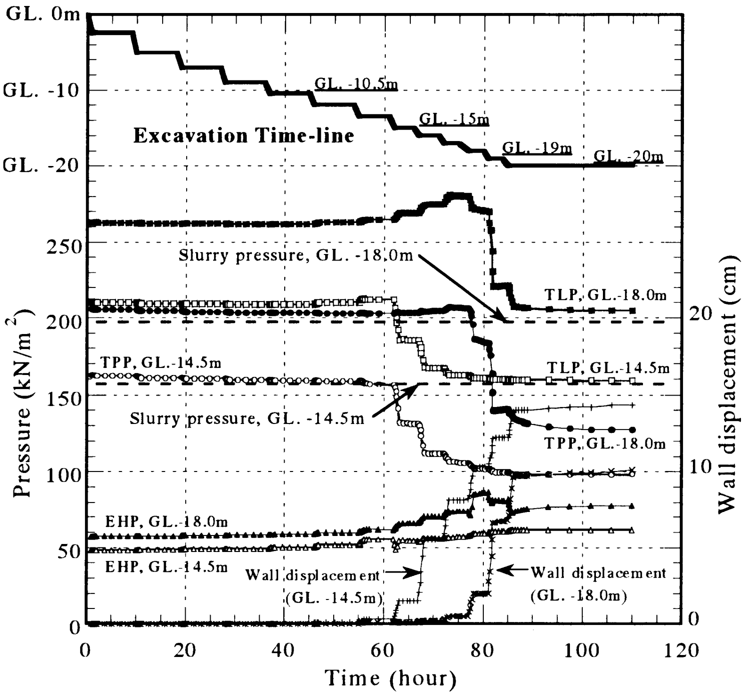


Fig-7. Variations of effective earth pressure (EHP), total pore water pressure (TPP), total lateral pressure (TLP) and wall displacement