III-A 225

EFFECT OF THE CONFINING FORCE ON THE SAFETY FACTOR OF THE SLURRY TRENCHES CONSTRUCTED IN SANDY GROUND

群馬大学　正　于　玉貞　正　鵜飼恵三
東日本旅客鉄道　正　増田　達　正　相沢文也
日建設計　正　石井武司　正　斎藤邦夫

INTRODUCTION

One of the authors has presented a method for 3-D slope stability analysis(Ugai, 1986, Ugai et al, 1988) and it was employed to analyze the stability of slurry trenches constructed in sandy ground(Ugai et al, 1996). In this study, the effect of the confining force on the safety factor of the slurry trenches is discussed.

BASIC FORMULAS OF THE 3-D LIMIT EQUALIBRIUM METHOD(LEM)

The schematic of the slurry trench is shown in Fig.1. It is assumed that the difference between the mud pressure and the water pressure acts on the wall of the trench.

For three dimensional problem, the slide surface is assumed as two ellipse caps attached smoothly to a cylindrical surface, as shown in Fig.2. The forces acting on a typical column of the sliding body are shown in Fig.3 and their direction cosine are shown in Tab.1, where ΔW is the self-weight, ΔN and ΔT are the total normal force and the shear force acting on the base respectively; ΔH is the confining force in direction parallel to the y-axis and is expressed as $\kappa\Delta W|\tan\alpha_{yz}|$, where κ is a constant. Moreover, ΔQ is the resultant of the intercolumn forces acting on the sides. It is assumed that ΔQ has two components ΔQ_1 and ΔQ_2, where ΔQ_1 is on the xz-plane and parallel to the x-axis and ΔQ_2 is inclined to the xy-plane by $\tan^{-1}(\eta\alpha_{yz})$, where η is a constant. The plane composed of ΔQ_1 and ΔQ_2 is called the J-plane.

The failure condition, combining with the definition of the safety factor F, is expressed as

$$\Delta T = (cJ\Delta x\Delta y + \Delta N\tan\phi)/F \quad (1)$$

where c is the cohesion and ϕ is the angle of internal friction.

Based on these assumptions and the failure condition ΔN and ΔT can be derived from the equilibrium of the forces in the direction perpendicular to the J-plane.

Fs is defined by the simultaneous equations of vertical and horizontal force equilibrium for the sliding body as follows,

$$F_v = \sum(N_v/De)/\sum(\Delta W) \quad (2)$$

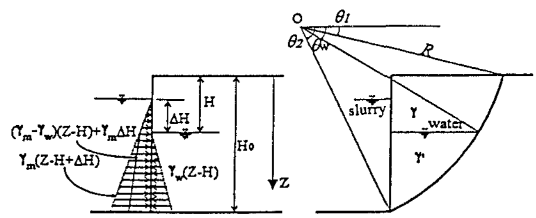

Fig.1 The schematic of the slurry trench

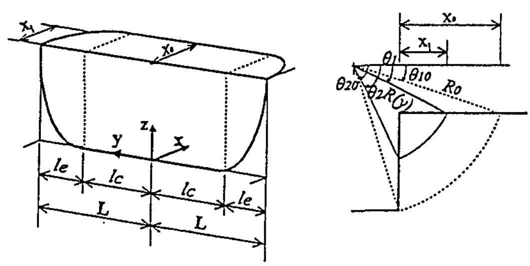
Fig.2 The shape of the 3D sliding body

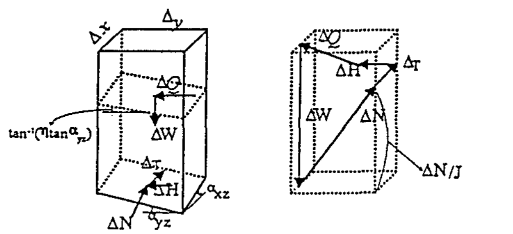
Fig.3 The forces acting on the column of the 3D sliding body

Tab.1 The forces acting on the column of the sliding body

$\vec{F}$	$\lvert\vec{F}\rvert$	$\vec{F}/\lvert\vec{F}\rvert$
$\overrightarrow{\Delta H}$	$\kappa\Delta W\lvert\tan\alpha_{yz}\rvert$	$(0,\ \tan\alpha_{yz}/\lvert\tan\alpha_{yz}\rvert,\ 0)$
$\overrightarrow{\Delta W}$	ΔW	$(0,\ 0,\ -1)$
$\overrightarrow{\Delta N}$	ΔN	$(-\tan\alpha_{xz}/J,\ -\tan\alpha_{yz}/J,\ 1/J)$
$\overrightarrow{\Delta T}$	ΔT	$(\cos\alpha_{xz},\ 0,\ \sin\alpha_{xz})$

$J = \sqrt{1+\tan^2\alpha_{xz}+\tan^2\alpha_{yz}}$

$$F_h = \sum (N_h / De) / (\sum (\Delta W \tan\alpha_{yz}) - U) \quad (3)$$

$$F_v = F_h = Fs \quad (4)$$

where $De = (1 + \eta \tan^2 \alpha_{yz}) / J + \sin\alpha_{xz} \tan\phi / F$

$$N_v = (F_v / J + \tan\phi \sin\alpha_{xz})(1 + \kappa\eta \tan^2 \alpha_{yz}) + c\eta \sin\alpha_{xz} \tan^2 \alpha_{yz} \Delta x \Delta y$$

$$N_h = F_h \Delta W \eta \tan^2 \alpha_{yz} \tan\alpha_{xz} (1 - \kappa) / J + [\Delta W \tan\phi (1 + \kappa\eta \tan^2 \alpha_{yz} \cos^2 \alpha_{xz}) + c\Delta x \Delta y (1 + \eta \tan^2 \alpha_{yz} \cos^2 \alpha_{xz})] / \cos\alpha_{xz}$$

Fs is determined by searching for its minimum value in the range of $0 \le \theta_1 \le \theta_2 < \pi / 2$.

EFFECT OF THE CONFINING FORCE ON THE SAFETY FACTOR

The value of κ has great effect on the safety factor. Obviously, it depends on the value of K_0. Furthermore, it is also dependent of the ratio of L and H_0. By fitting the predicted sliding surface and the safety factor with the test, κ may be expressed by the following equation,

$$\kappa = K_0 (L / H_0)^{0.138/K0} \quad (5)$$

where K_0 is the coefficient of earth pressure at rest which is calculated by $K_0 = 1 - \sin\phi'$. The calculated values of κ agree well with the observed ones in test S-2-1 and S-2-2.

RESULTS OF THE CALCULATION FOR THE CENTRIFUGE TESTS

The centrifuge tests have been carried out to study the stability of slurry trench(Higuchi et al, 1994, *Ishijima et al, 1996) . The basic data at failure are* shown in Tab.2. The calculated results by the proposed method using the above date are shown in Tab.3. $\theta_1 \approx 0$ means that the sliding surface is perpendicular to the ground surface. The comparison of the value of X_0 between calculation and test are shown in Fig.4. All the calculated results agree well with the tests. The calculated value of the safety factor are less than the test ones(=1), where the reason has yet to be studied.

Tab.2 The basic data for calculation

Cases	H_0 (m)	H (m)	ΔH (m)	L (m)	ϕ (°)	γ (T/m³)	γ' (T/m³)
S-2-1	14.88	0.28	0.80	3.0	39	1.53	0.876
S-2-2	14.88	0.28	0.40	1.5			
S-78T-21	5	0.20	0.20	4.5	42	1.57	0.93
S-78T-22	10	0.53	0.53				
S-78T-32	15	0.72	0.72				
S-78T-42	30	1.09	1.09				
S-78T-52	35	1.21	1.21				
S-77-21	5	0.08	0.08		47	1.49	0.82
S-77-22	15	0.35	0.35				
S-77-32	25	0.40	0.40				
S-77-42	30	0.44	0.44				
S-77-52	35	0.48	0.48				

Tab.3 The values of Fs calculated by LEM

Cases	θ_1	θ_2	X_0	le	κ	Fs
S-2-1	0.9	30.0	4.12	1.8	0.204	1.06
S-2-2	1.0	26.0	3.57	1.3	0.158	1.03
S-78T-21	1.3	45.5	2.17	4.5	0.317	0.82
S-78T-22	1.4	31.1	2.92	4.4	0.237	0.88
S-78T-32	0.8	26.2	3.61	4.5	0.200	0.89
S-78T-42	0.7	23.0	6.30	3.7	0.150	0.93
S-78T-52	0.5	22.7	7.19	3.6	0.141	0.95
S-77-21	1.5	41.5	1.97	4.5	0.254	0.78
S-77-22	0.5	22.2	3.01	4.5	0.145	0.82
S-77-32	0.7	19.1	4.37	3.9	0.111	0.80
S-77-42	0.5	19.0	5.16	3.4	0.101	0.81
S-77-52	1.0	18.2	5.90	3.3	0.094	0.82

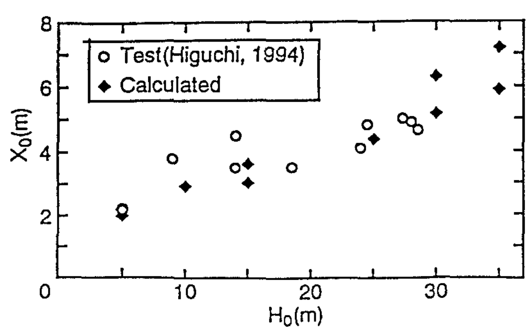

Fig.4 The relation between X_0 and H_0

CONCLUSIONS

An alternative method for the stability analysis of slurry trenches constructed in sandy ground is suggested and an equation is proposed to express the confining force. The calculated results by this method agree well with the test ones.

REFERENCE 1. 鵜飼ら(1986), 簡便分割法による斜面の三次元安定解析、土木学会論文集 Ⅲ－6。2. 鵜飼ら(1988), 簡易 Bishop 法, 簡易 Janbu 法および Spencer 法の三次元への拡張、土木学会論文集 Ⅲ－9。3. 鵜飼ら(1996), Stability analysis method for slurry trenches constructed in sandy ground, 第 31 回地盤工学研究会。4. 石島、増田ら(1996), 地下連続壁の泥水掘削溝壁の安定に関する研究, 第 31 回地盤工学研究会。5. 樋口ら(1994), 砂地盤に築造される泥水掘削溝壁の新しい安定計算方法, 土と基礎, Vol.42, No.3。