

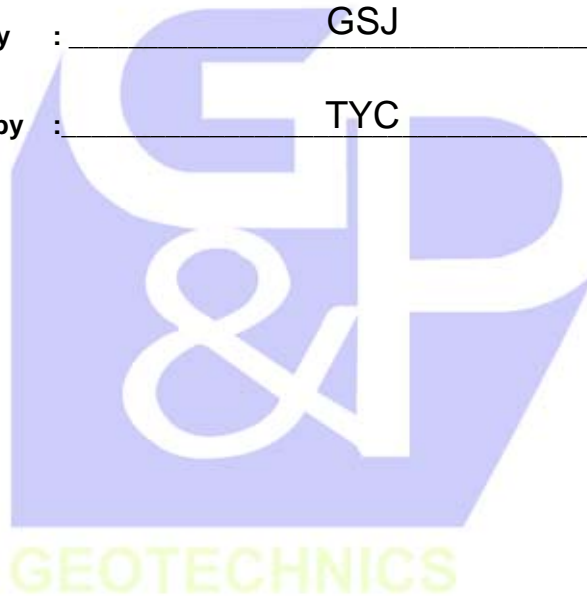


WORK INSTRUCTIONS FOR ENGINEERS

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**OP-022. PROCEDURE FOR ESTIMATION
OF TRAVEL DISTANCE ANGLE
FOR "RAPID" LANDSLIDES**

22.0 PROCEDURE FOR ESTIMATION OF TRAVEL DISTANCE ANGLE FOR "RAPID" LANDSLIDES

22.1 Definition

22.1.1 "Rapid" landslide is defined as a landslide with post failure velocity > 3m/min

22.1.2 Soil behaviour

Contractive on shearing – decrease in volume (drained condition); positive pore pressure (undrained condition)

Dilative on shearing – increase in volume (drained condition); negative pore pressure (undrained condition)

22.1.3 Landslide

Flow slide – occurs as a result of large loss in undrained shear strength due to static liquefaction on shearing

Debris flow – the slide mass retains its structure and fabric during travel

Debris slide – flowing of combination of water, air and debris; the slide mass does not retain its original structure or fabric

22.1.4 Degree of Confinement of the Travel Path

Confined

- The travel path is constrained by the relatively steep side slopes of a gully or small valley.

Unconfined

- The travel path is on open slopes

Partly confined

- The travel path is not clearly defined by the topographic depression

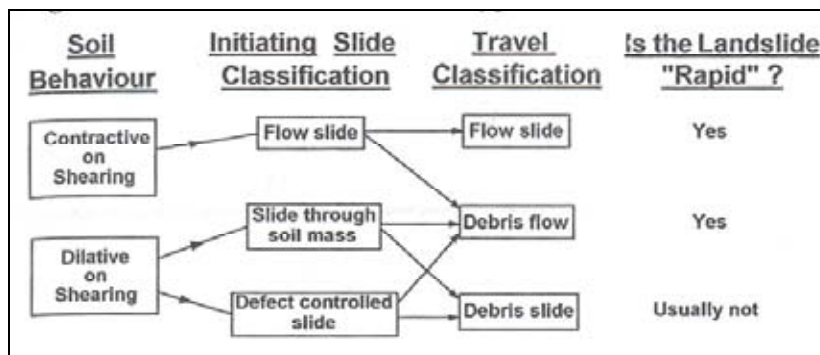


Fig. 1: Main classification of landslide

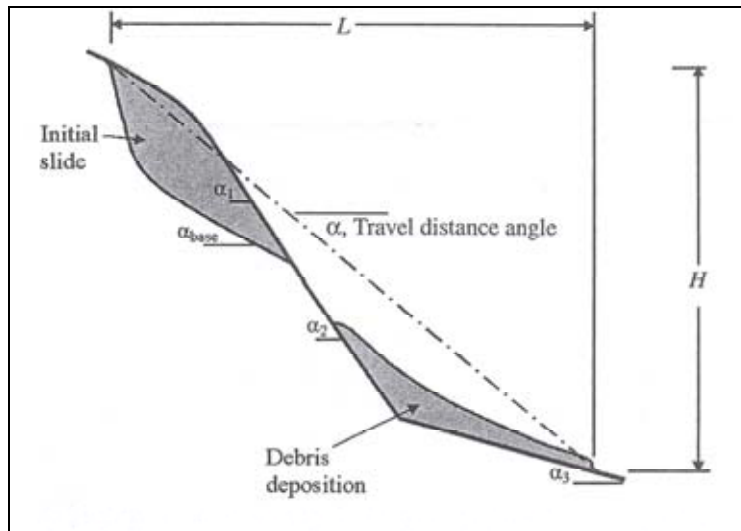


Fig. 2: Definition of travel distance, travel distance angle and slope geometry

22.2 Class of Slopes Susceptible to "Rapid" Landslide

1. Saturated (near-saturated) granular soil, eg. loose fill, mine tailing, hydraulic fill, submarine slope
2. Steep cut slope in residual soil, colluvium or weathered rock
3. Steep natural slope
4. Sensitive clay

22.3 Procedure for Estimation of Travel Distance Angle

1. Determine behaviour of soil on shearing (contractive/ dilative) for the slope concerned.
2. Establish the following parameters from the most critical slip plane established in the slope stability analysis:
 - Estimated slide volume (V)
 - $\alpha_1, \alpha_2, \alpha_3, \alpha_{base}$ (as defined in Fig. 2 & 3)
3. Based on class of slope and behaviour of soil, tangent of travel distance angle (H/L) is estimated according to:
 - Cl. 22.4 – Cut slope in dilative soil & weathered rock (with the slope below the cut slope is near horizontal)
 - Cl. 22.5 – Natural slope in dilative soil
 - Cl. 22.6 – Fill slope constructed with loose silty sand
4. Based on H/L ratio established in step (3), travel distance of a potential landslide is established and therefore the extent affected by the landslide can be determined.

22.4 Cut Slope in Dilative Soil & Weathered Rock

For slide volume $< 500\text{m}^3$,

$$H/L = 0.78 (\tan \alpha_{cut})^{0.5} \quad \text{Finlay, et. al. (1999)}$$

- The slope below the cut slope is near horizontal
- Applicable to soil/ weathered rock derived from granitic and volcanic rock

For slide volume < 20,000m³, use Figure 3 to obtain the tangent of travel distance angle (H/L):

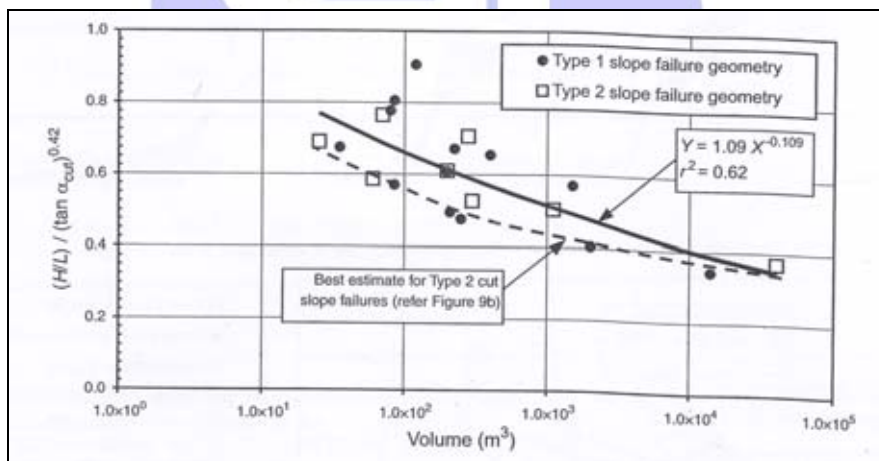
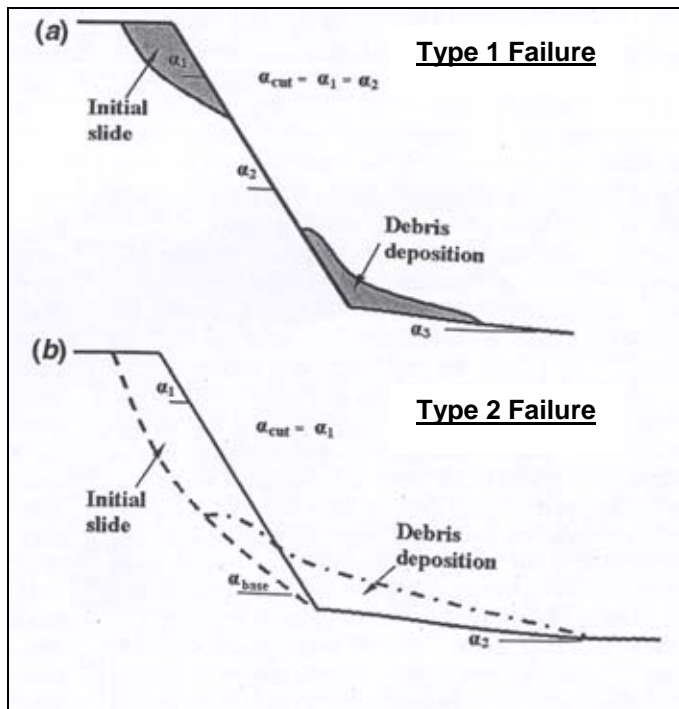


Fig. 3: H/L against α_{cut} versus volume for cut slope in Hong Kong

- $\alpha_{cut} - \alpha_3 > 20^\circ$ for type 1 failure ... Condition (1)
- $\alpha_{base} - \alpha_2 > 15 - 20^\circ$ for type 2 failure ... Condition (2)

For cut slope failure that does not comply with the two conditions, use approach for natural slope in dilative soil (Cl. 22.5).

22.5 Natural Slope in Dilative Soil

Step 1: Obtain preliminary estimate of mean travel distance angle from Table 1

Initial slide classification	Material & slope type	Travel path confinement	No. of slides	Volume range (m ³)	H/L properties				Comments
					Range	Mean	SD ^a	SD range ^b	
Flow slides in contractile soil	Coal mine waste spoil piles (sandy gravels) ^c	Confined; high mobility	7	110 000 - 5.6 x 10 ⁶	0.18-0.28	0.208	0.035	0.023-0.077	High mobility, as materials mantling downslope are liquefaction susceptible
		No confinement condition; normal mobility	47	3 000 - 8 x 10 ⁶	0.22-0.49	0.359	0.076	0.063-0.095	Similar mean and SD for all travel path types
	Loose silty and fills (Hong Kong)	All unconfined	16	20 - 10 400	0.28-0.60	0.405	0.094	0.070-0.146	
Failures in dilative soils ^d	Natural slopes, including Corominas (1996) debris flow data	Confined	19	50 - 13 000	0.22-0.67	0.426	0.110	0.083-0.162	For preliminary estimate of travel distance angle
		Partly confined	10	80 - 3000	0.28-0.62	0.470	0.114	0.078-0.207	
		Unconfined	52	20 - 140 000	0.22-0.75	0.547	0.137	0.115-0.170	

^aStandard deviation.

^bStatistical estimate of 95% confidence intervals of population based on case studies representing a sample of the population.

^cHigh-mobility events associated with confined travel path and liquefaction-susceptible materials mantling downslope travel path.

^dInclusive of defect-controlled slides, slides of debris, and slides through the soil mass.

Step 2: Estimate angle α_2 , in which the length for estimation of the travel distance should be at least 50% of the travel length beyond the toe of the landslide source area.

Step 3: Refine the prediction of travel distance angle by using the following equations:

$$H/L = 0.77 \tan \alpha_2 + 0.087 \quad (\text{unconfined})$$

$$H/L = 0.69 \tan \alpha_2 + 0.086 \quad (\text{partly confined})$$

$$H/L = 0.65 \tan \alpha_2 + 0.147 \quad (\text{confined})$$

22.6 Fill Slope Constructed with Loose Silty Sand

For slide volume between 50 and 500m³,
Use the mean and standard deviation from Table 1

For slide volume (V) between 500 and 10,000m³,
 $H/L = 0.67 V^{-0.882}$ for similar materials (ie. loose silty sand and sandy silt)