Sensitive study of numerical simulation of wedge failure

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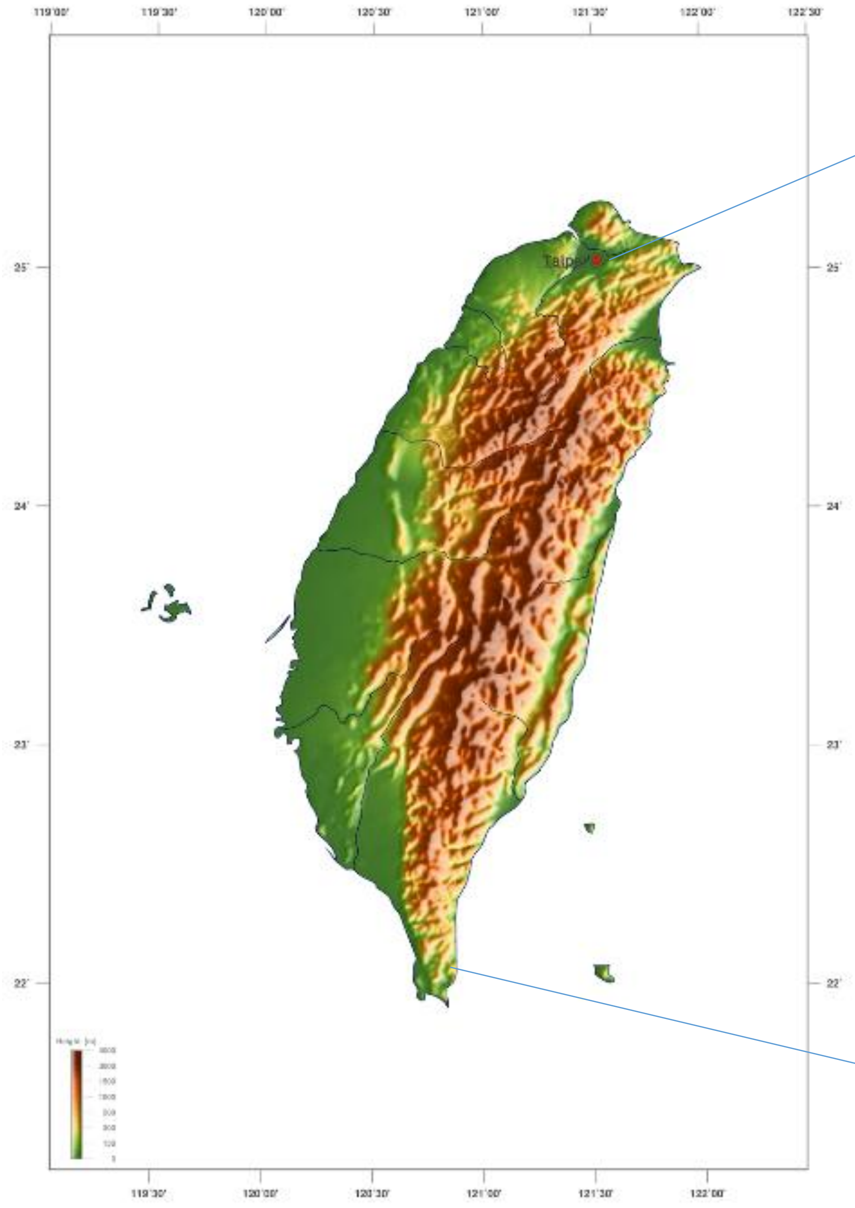
outline

1. Introduction
2. Motivation
3. Method
4. Preliminary Result
5. Preliminary Summary
6. Future work

Introduction

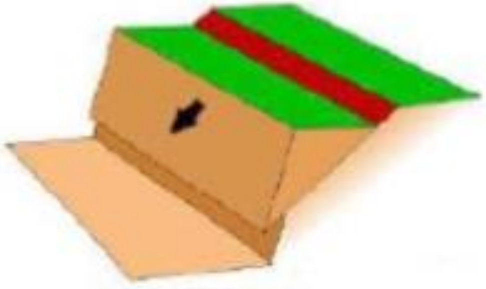


Plane
cover area
26.36%
in Taiwan

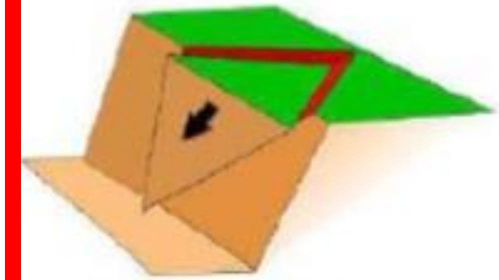
Hillside
cover area
26.91%
in Taiwan

High mountain
cover area is
46.73%
in Taiwan

Type of slope failure

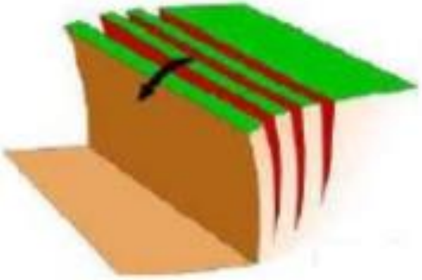


planner failure



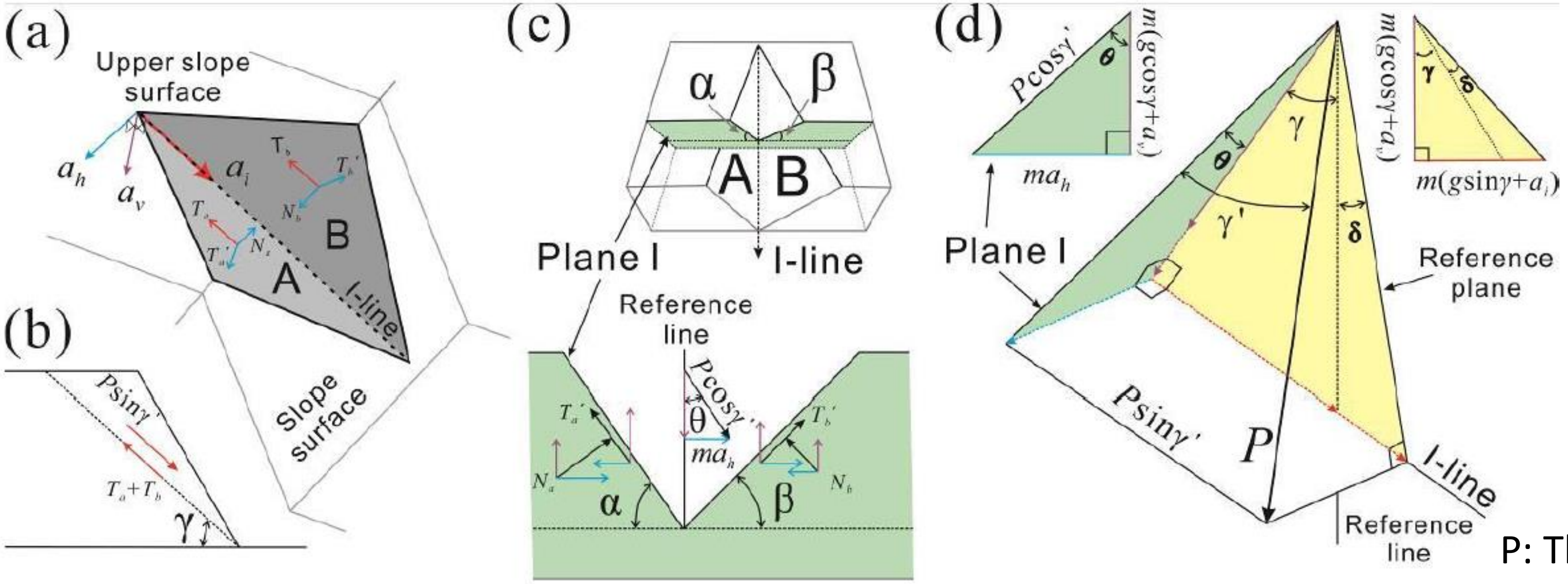
wedge failure

circular failure



topple failure

Introduction



Nguyen,2015(modified from Lee,1989)

P: The resultant force P

N_a/N_b: normal force of planeA/B

T'_a/T'_b: shear stress perpendicular to I-line on plane A/B

γ: the plunge of of I-line

θ:parameters used to define direction of vector force P

α: the plunge of intersection line with plane A on plane I

β: the plunge of intersection line with plane B

$$N_a sin\alpha + T'_a cos\alpha + T'_b cos\beta - N_b sin\beta = Pcos\gamma cos\theta$$
$$N_a cos\alpha + T'_a sin\alpha + T'_b cos\beta - N_b sin\beta = Pcos\gamma sin\theta$$

4 parameters are unknown, only 2 equation!!!

Introduction-Rigid wedge method (RWM)(Hoek and Bray,1974)

assumed the wedge is a rigid block and neglected the shear forces that perpendicular to I-line on two discontinuities Ta ‘ and Tb’
$T_a' = T_b' = 0$

$$N_a = \frac{W cos\gamma \sin(\beta+\theta)}{\sin(\alpha+\beta)}$$
$$N_b = \frac{W cos\gamma \sin(\alpha-\theta)}{\sin(\alpha+\beta)}$$

$$T_a' = C_a A_a + N_b tan\varphi' = 0$$
$$T_b' = C_b A_b + N_a tan\varphi' = 0$$

- $(\alpha-\theta)$ and $(\beta+\theta)$ are limited from 0° to 90°. otherwise it would be planar failure.
- $(\alpha+\beta)$ have to be restricted between 0° and 180°.
- $FS = \frac{resist\ force}{driving\ force} = \frac{T_a+T_b}{W sin\gamma}$

W: rock weight
N_a/N_b: normal force of planeA/B
T_a'/T_b': shear stress perpendicular to I-line on plane A/B
T_a/T_b: shear stress along I-line on plane A/B
γ: the plunge of of I-line
θ: parameters used to define direction of vector force P
α: the plunge of intersection line with plane A on plane I
β: the plunge of intersection line with plane B
φ': friction angle perpendicular to I-line on plane A/B

Introduction-Maximum shear stress method (MSSM)(Lee,1989)

$$T_a' = T_b' = \mathrm{T}_a = \mathrm{T}_b = \mathrm{T}_{max}$$

$$T_a{}' = C_a A_a + N_b tan\varphi'$$
$$T_b{}' = C_b A_b + N_a tan\varphi'$$

$$N_a = \frac{N_b D_3 + E_1 - E_3}{D1} \text{ , } N_b = \frac{D_1(E_5 - E_2 - E_4) - D_2(E_1 - E_2)}{D_1 D_4 + D_2 D_3}$$

$$D_1 = \sin(\alpha - \theta) - R_a tan\varphi \cos(\alpha - \theta)$$
$$D_2 = \cos(\alpha - \theta) + R_a tan\varphi \sin(\alpha - \theta)$$
$$D_3 = \sin(\beta + \theta) - R_b tan\varphi \cos(\beta + \theta)$$
$$D_4 = \cos(\beta + \theta) + R_b tan\varphi \sin(\beta + \theta)$$

$$E_1 = C_a A_a \cos(\alpha - \theta)$$
$$E_2 = C_a A_a \sin(\alpha - \theta)$$
$$E_3 = C_b A_b \cos(\beta + \theta)$$
$$E_4 = C_b A_b \sin(\beta + \theta)$$
$$E_5 = W cos\gamma$$

$$FS = \frac{resist\ force}{driving\ force} = \frac{C_a A_a + C_b A_b + N_a tan\varphi + N_b tan\varphi}{W sin\gamma}$$

W: rock weight
N_a/N_b: normal force of planeA/B
$\mathrm{T}_a'/\mathrm{T}_b'$: shear stress perpendicular to I-line on plane A/B
T_a/T_b: shear stress along I-line on plane A/B
γ: the plunge of of I-line
θ: parameters used to define direction of vector force P
α: the plunge of intersection line with plane A on plane I
β: the plunge of intersection line with plane B
φ': friction angle perpendicular to I-line on plane A/B
C_a/C_b: cohesion of material on plane A/B

Introduction(Nguyen,2018)

$$T' = RT_{max}$$ (R=0-1)

$$T_a{}' = R(C_aA_a + N_b tan\varphi')$$
$$T_b{}' = R(C_bA_b + N_a tan\varphi')$$

$$N_a = \frac{N_bD_3+E_1-E_3}{D1}\ ,\ N_b = \frac{D_1(E_5-E_2-E_4)-D_2(E_1-E_2)}{D_1D_4+D_2D_3}$$

$$D_1 = \sin(\alpha-\theta) - R_a tan\varphi \cos(\alpha-\theta)$$
$$D_2 = \cos(\alpha-\theta) + R_a tan\varphi \sin(\alpha-\theta)$$
$$D_3 = \sin(\beta+\theta) - R_b tan\varphi \cos(\beta+\theta)$$
$$D_4 = \cos(\beta+\theta) + R_b tan\varphi \sin(\beta+\theta)$$

$$E_1 = R_aC_aA_a\cos(\alpha-\theta)$$
$$E_2 = R_aC_aA_a\sin(\alpha-\theta)$$
$$E_3 = R_bC_bA_b\cos(\beta+\theta)$$
$$E_4 = R_bC_bA_b\sin(\beta+\theta)$$
$$E_5 = Wcos\gamma$$

$$FS = \frac{resist\ force}{driving\ force} = \frac{C_aA_a + C_bA_b + N_a tan\varphi + N_b tan\varphi}{Wsin\gamma}$$

W: rock weight
N_a/N_b: normal force of planeA/B
T'_a/T'_b: shear stress perpendicular to I-line on plane A/B
T_a/T_b: shear stress along I-line on plane A/B
γ: the plunge of of I-line
θ: parameters used to define direction of vector force P
α: the plunge of intersection line with plane A on plane I
β: the plunge of intersection line with plane B
φ’: friction angle perpendicular to I-line on plane A/B
C_a/C_b: cohesion of material on plane A/B

Motivation

- Because RWM and MSSM provide factor of safety upper and lower boundary, they show the lowest and highest shear stress which is perpendicular to I line. It also mean different deformable condition of wedge block. RWM regard the wedge block as rigid block and MSSM regard the wedge as the most deformable block. Therefore, this study want to know what kind of deformable condition is suitable for RWM and MSSM on different dihedral angle

Method-Flac 3D

- FLAC3D (Fast Lagrangian Analysis of Continua in 3 Dimensions)
- A numerical modeling code for advanced geotechnical analysis of soil, rock, and structural support in three dimensions
- Use **finite-difference methods (FDM)** to get solution **.**
- The calculation cycle repeats over-and-over until a steady-state solution has been achieved(i.e the maximum unbalanced force is small compared to the total applied forces)

Method-Flac3D

1. Generate grid, construct desire shape
2. Define material properties
3. Specify boundary and initial condition

Make initial stress balance

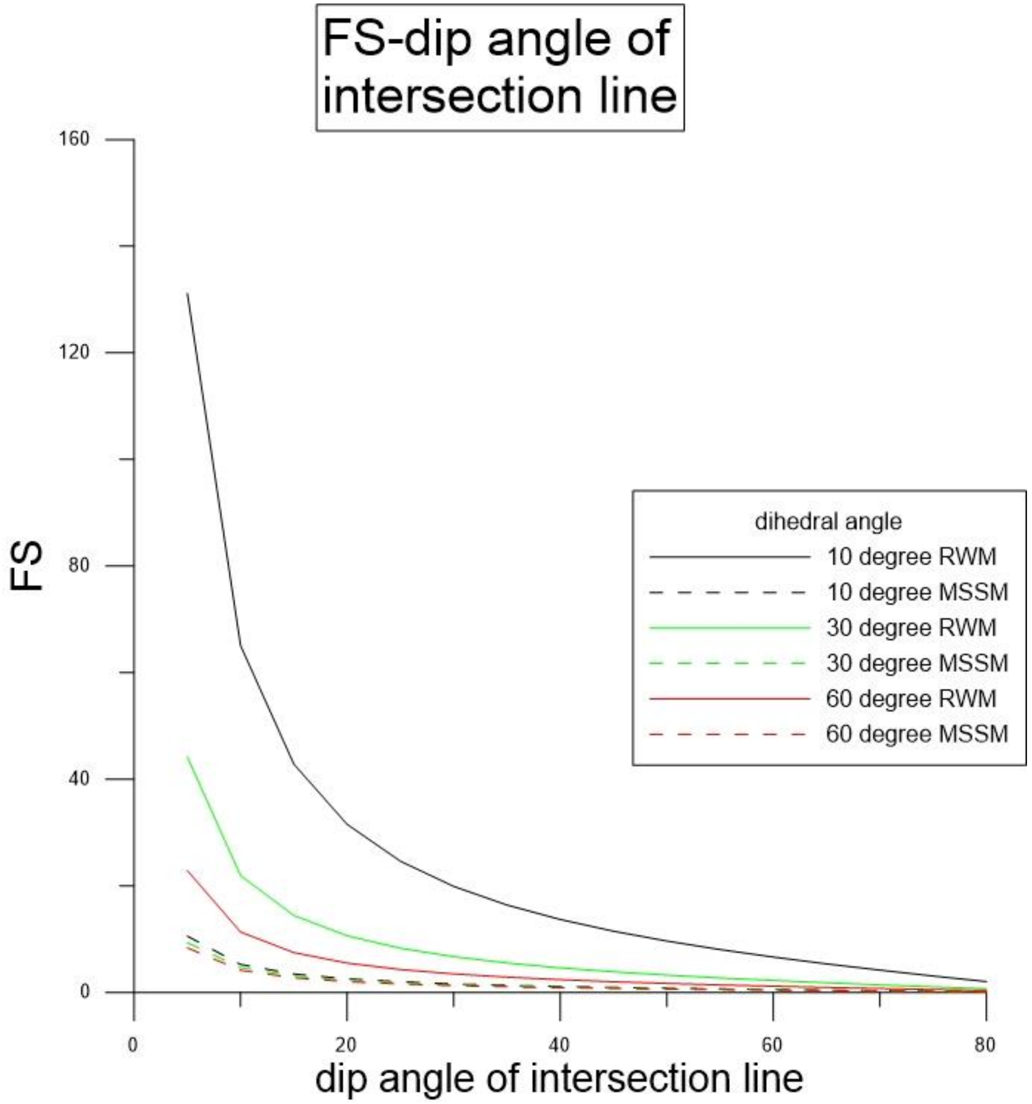
Set new condition which you want to simulate

solve

Construct analysis model

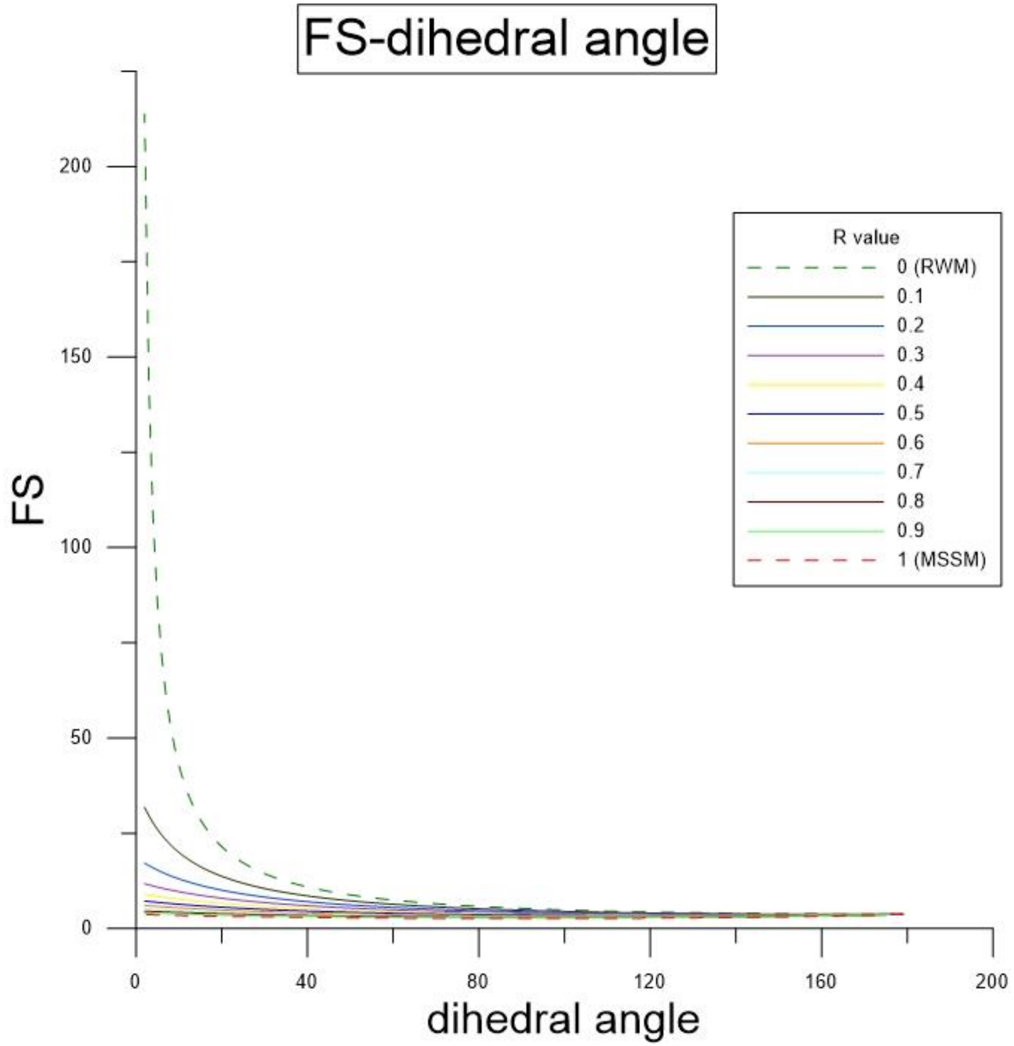
Simulate and get solution

Preliminary result



parameter	value
P=W	530 T
$C_a = C_b$	0
θ	0 degrees
$\varphi_a = \varphi_b$	45 degrees
Set $\alpha = \beta$ ，dihedral angle=180-$(\alpha + \beta)$	

Preliminary result



- $T' = RT_{max}$
- (R=0-1)

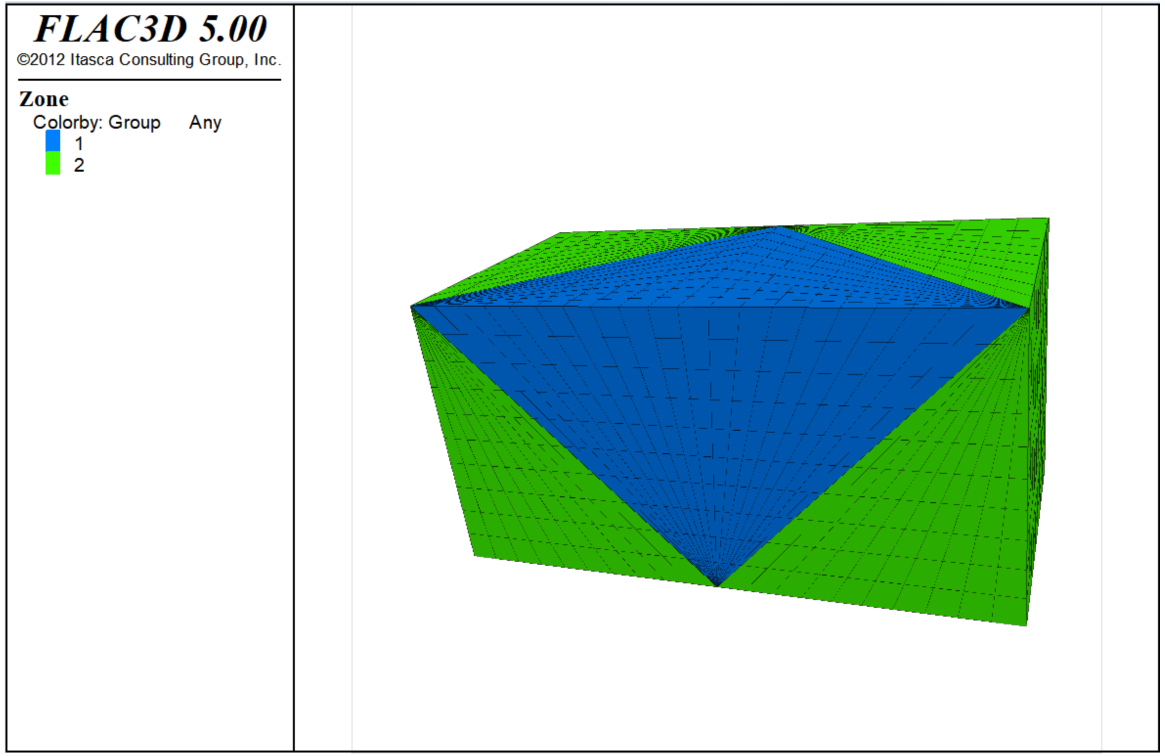
parameter	value
P=W	530 T
γ	15 degrees
$C_a = C_b$	0
θ	0 degrees
$\varphi_a = \varphi_b$	45 degrees
Set $\alpha = \beta$，dihedral angle=180-$(\alpha + \beta)$	

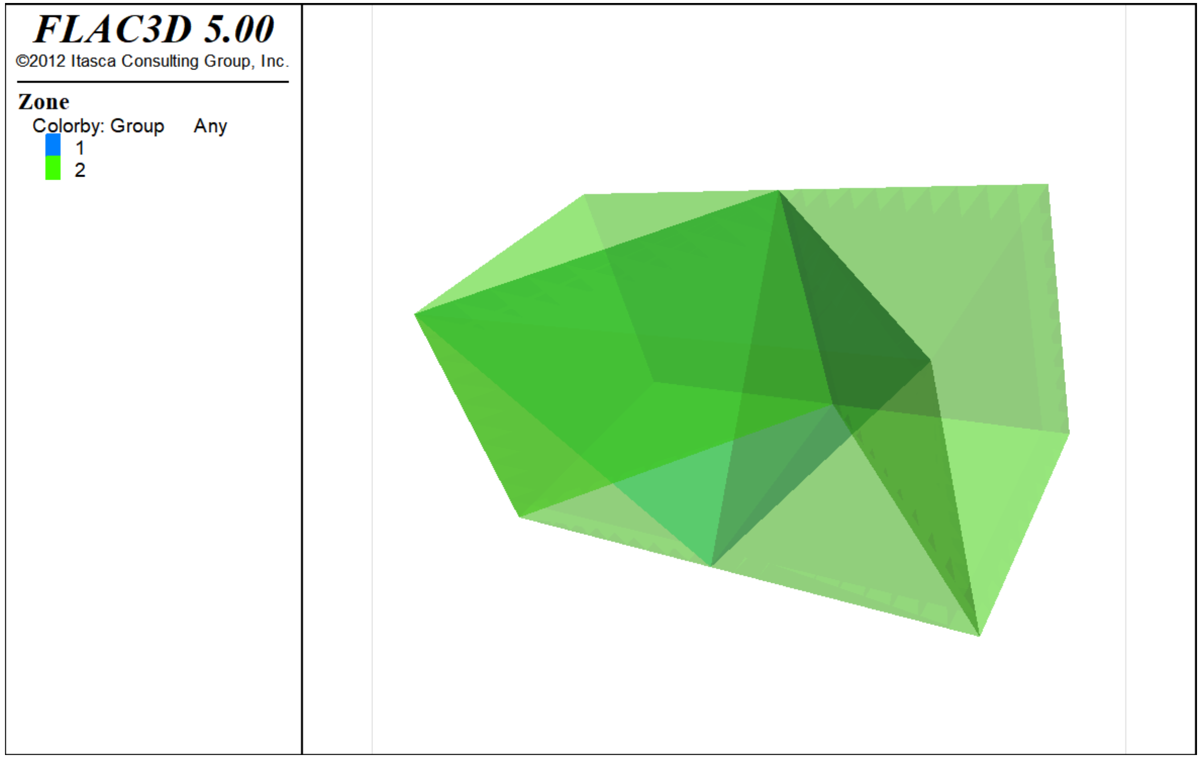
Preliminary summary

1. When plunge of sliding wedge is small, FS has larger difference between RWM and MSSM.
2. When plunge of sliding wedge is fixed and dihedral angle is small, if we increase shear stress which is perpendicular to I-line a little from zero, the influence is very significant.

Future work

- Construct model by using Flac3D.
- Set different deformation to get solution.





Thanks for listening