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암석 형상 효과를 고려한 무작위 토양-암반 혼합 경사면 안정성 평가

EVALUATION OF RANDOM SOIL-ROCK MIXTURE SLOPE STABILITY CONSIDERING ROCK SHAPE

카오반호아[1)], 고규현[*2)]

Van-Hoa Cao, Gyu-Hyun Go

[1)]금오공과대학교 토목공학과 박사과정, [*2)]금오공과대학교 토목공학과 부교수, 교신저자

Introduction

- The slope composed of a mixture of soil and rock (SRM) is prevalent in mountainous regions, exhibiting complex mechanical behavior. Consequently, investigating the stability of such soil-rock mixture slopes is crucial to improve our ability to predict and prevent landslide disasters.
- This study established a random Soil-Rock Mixture slope model based on random sequential addition (RSA). Besides, the strength reduction technique to calculate the safety factor of the soil-rock mixture slope using the finite element method in ABAQUS software was implemented. The influence of rock shape on slope stability and the complexity of the failure surface was discussed.

Methodology

- The strength reduction method is frequently employed in geotechnical engineering to determine the factor of safety (FOS) for slopes. The FOS value is the ratio of the initial shear strength parameters to those in the critical equilibrium state (Zheng et al., 2005). The FOS value can be calculated as

$$c_f = \frac{c}{FOS},\ \tan\phi_f = \frac{\tan\phi}{FOS} \quad (1)$$

where c and ϕ are the initial shear strength, c_f and ϕ_f are the strength parameters when a slope at the verge of failure.

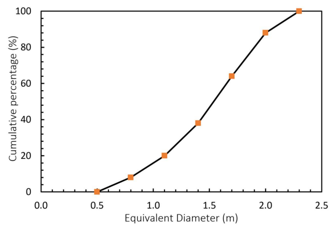
- To implement the strength reduction technique, a set of elastic-perfectly plastic parameters is computed with i-th shear strength parameters (c_i and ϕ_i) to calculate the *FOS* value

$$c_i = \frac{c}{FOS^i},\ \tan\phi_i = \frac{\tan\phi}{FOS^i} \quad (2)$$

here, FOS^i is the i-th shear strength reduction factor.

Random Soil-Rock Mixture Slope

- The random SRM slope modeling method was developed based on the RAS method proposed by Wang et al. (1999). The rock blocks are created with random, non-convex shapes, with the dimension lengths and widths defined as the aspect ratio (a/b) so that the area of the rock block is constant. The geometry of the SRM slope and the properties of materials were determined according to the research of Sun et al. (2019). The rock distribution curve is shown in Fig. 1. The influence of rock block shape on slope stability is considered according to aspect ratios (1, 1.5, 2, and 2.5) shown in Fig. 2.



Parameters	Unit	Soil	Rock
Density	(kg/m³)	2,000	2,410
Young' modulus	(MPa)	200	20,000
Poisson's ratio	-	0.35	0.2
Friction angle	(°)	20	42
Cohesion	(KPa)	12.38	900

Fig 1. Rock block size distribution and Parameters of material used in stability analysis

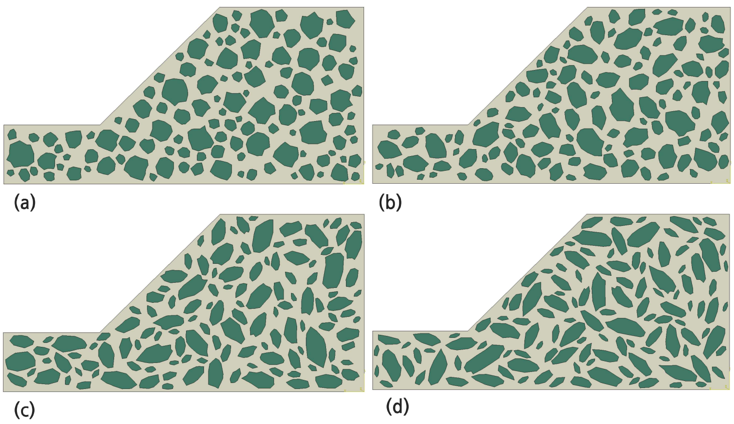


Fig 2. Soil-Rock Mixture slopes with different aspect ratios:
(a) 1.0; (b) 1.5; (c) 2.0; (d) 2.5

Results and discussions

- Ten SRM slopes are analyzed for each rock block shape with aspect ratios (1.0, 1.5, 2.0, 2.5), resulting in a total of 40 investigated SRM slopes. Figure 3 depicts one of these slopes, presenting equivalent plastic strain contours. The error bar diagram and box diagram can be found in Fig. 4.

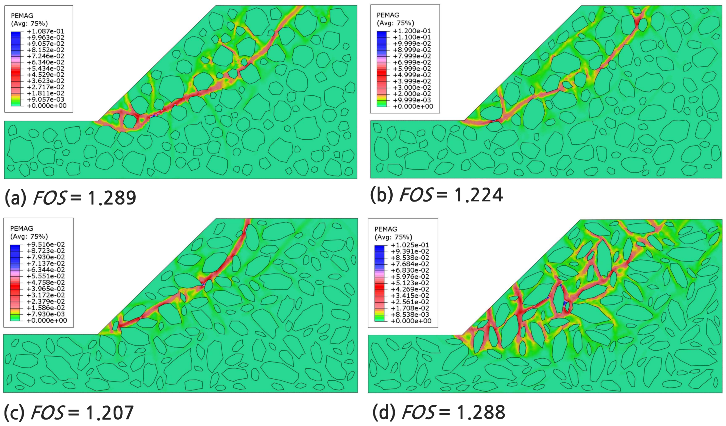


Fig. 3. Equivalent plastic strain contours of SRM slope with different aspect ratios:
(a) 1.0; (b) 1.5; (c) 2.0; (d) 2.5

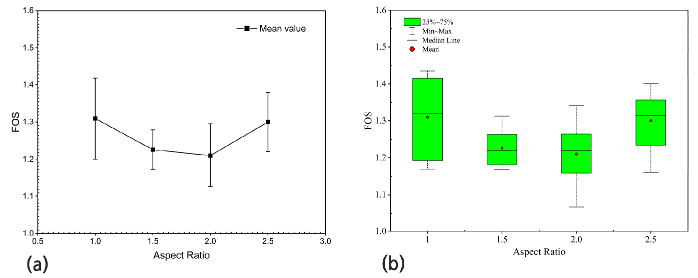


Fig. 4. Error bar (a) and box diagram (b) of FOS values of SRM slope with different aspect ratios

- The Factor of Safety (FOS) for SRM slopes tends to decrease as the aspect ratio of rock blocks increases from 1.0 to 2.0. The mean FOS value for the considered slopes decreased by approximately 6.4% with an aspect ratio of 1.5 and 7.6% with an aspect ratio of 2.0. However, when the aspect ratio increases to 2.5, the FOS value of the SRM slope increases, reaching an equivalent level to the FOS value when the aspect ratio is 1.0
- On the other hand, it is evident that the plastic zone in SRM slopes with an aspect ratio of rock blocks equal to 2.5 is more complex compared to other cases.

Conclusion

- The stability of an SRM slope can be significantly affected by the shape (aspect ratio) of rock blocks, especially within the aspect ratio range of 1.5 to 2.0. Surprisingly, as the aspect ratio of rock blocks reaches 2.5, the stability of the SRM slope matches the FOS value observed at an aspect ratio of 1.0. Moreover, the plastic zone becomes more intricate and fractured.

Acknowledgements

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