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A study on the quantification analysis of stereographic projection

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Abstract: The stereographic projection method accesses the stability of slope roughly, so it is difficult to apply its result in the technical designing of rock slopes. To solve this difficulty, using the limit analysis method, we quantified the stereographic projection with the safety level graded in the daylight envelope, which represents the failure possible area in the net.

1. Introduction

Large-scale slopes are needed to meet the demands of the huge building dams, and roads and railways are aligned to use them effectively. However, as the number and the size of slopes increase, the number of failure cases is increasing as well. Although many analytical techniques have been developed to predict and prevent slope failure and the new support systems have been applied to slopes, slopes still fail(Yu at al, 2000).

One of the widely-used methods to analyse the structural features of rock mass is stereographic projection. Stereographic projection, which can be applied to almost every slope, indicates the visible direction of discontinuities and handles the data effectively. However, since stereographic projection cannot be quantified, it is difficult to mechanically analyse rock slopes and thus difficult to design systemic excavation and slope supports. This research focuses on overcoming the limitations of stereographic projection by using limit equilibrium analysis and geometric characteristics of a slope and discontinuity. First, a safety factor for each discontinuity was calculated in daylight envelope, a means to assess the risk of plane failure of slopes. With this result, the potential danger of slope failure was evaluated by the different safety in the daylight envelope by the relative position of poles, which correspond to the dip and dip direction of each discontinuity.

2. Quantification process of Stereographic Projection

Fig. 1 is an example of a stability envelope diagram that shows the great circle, friction cone, and daylight and toppling envelope on the Schmidt net. In application, the diagram is drawn and assessed repeatedly on density distribution chart. The following is the assessment of stability on 5 randomly assumed areas. Area A is an unstable daylight area where the dip of discontinuity is bigger than the friction angle. B is a stable daylight area, where the dip of discontinuity is smaller than the friction angle. C is not in the daylight envelope but is stable, and the dip of discontinuity is smaller than the friction angle. In case of D, even if the dip of discontinuity is bigger than the friction angle, it is stable area because it is neither in daylight nor toppling envelope. E is the unstable area that has the potential of toppling failure. Daylight envelope means the possibility of plane failure, which indicates that discontinuity appears in the slope surface. In the analysis by stereographic projection, if poles were placed in the daylight envelope, the only result that plane failure can be occurred was shown. But, the possibility of slope failure may vary at each position in daylight envelope. This research examined the variation of failure risk in daylight envelope by using the limit equilibrium analyses, confirmed what influence these variations had on the total danger and assessed the different safety level in daylight envelope. Research procedure follows; standard to assess safety factor of each poles' position was established, safety level weight by the standard were given, and the safety level area was presented.

The relation of point P and L or R from Fig. 2 shows the difference of the dip direction of slope and discontinuity. If this angle goes beyond some limit, it means that plane failure is almost impossible(Kim, 1998).

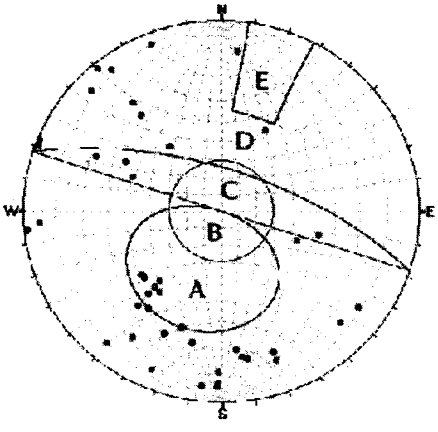


Fig. 1. Rock slope stability evaluation diagram.

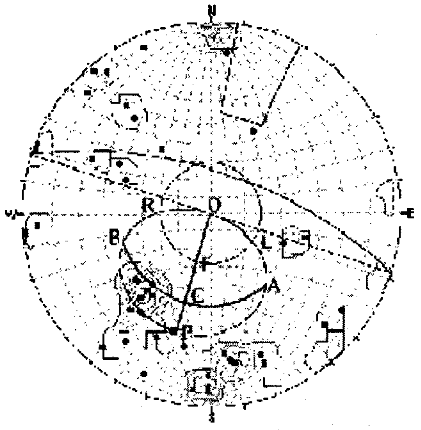
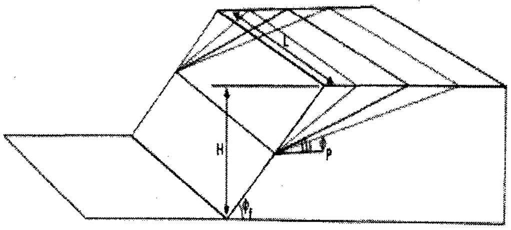


Fig. 2 Daylight envelope.

Safety factor by dip variation of discontinuity

Fig. 3 shows the variation of the discontinuity angle. This variation can be used to examine the effect dip variation of discontinuity on stability of slope. Fig. 4 shows the variation of safety factor by dip of discontinuity when dip of slope is 63° . The safety factor for each discontinuity was calculated by the limit equilibrium analysis. As the dip of discontinuity increases, the safety factor decreases and then increases, and when the dip of discontinuity is similar to that of slopes, the safety factor increases remarkably. The safety factor ranges between 0.86 and 2.93 when the dip of failure plane is between 30° and 62°, which is smaller than the dip of slope and bigger than the friction angle. This result proves that there is a problem with the existing stereographic projection analysis, which evaluates safety factor collectively regardless of the pole position corresponding to the dip and dip direction of each discontinuity in the daylight envelope, and the safety factor of discontinuity in daylight envelope depends greatly on dip of discontinuity.



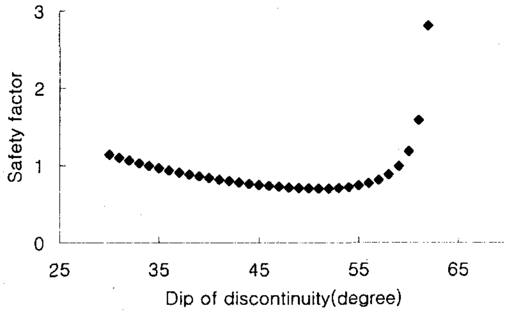


Fig. 3. Dip variation of discontinuity.

Fig. 4. Variation of safety factor by dip of discontinuity.

Safety factor by strike variation of discontinuity

The dip direction variation of discontinuity without any change in dip of slope and discontinuity is shown in Fig. 5. In this figure, the dip direction of discontinuity changes at the base of the centre. Fig. 6 shows the variation of the safety factor with the dip direction of discontinuity. As the angle, θ, between discontinuity and slope increases, the safety factor of slope decreases slightly.

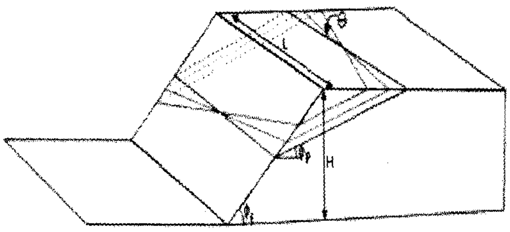


Fig. 5. Dip direction variation of discontinuity.

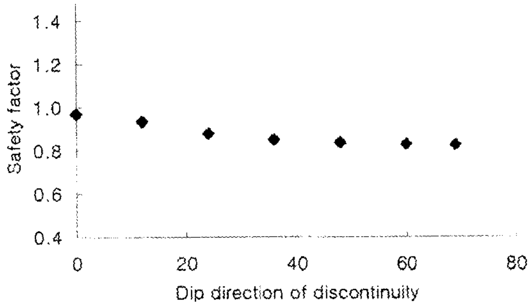


Fig. 6. Variation of safety factor by dip direction of Discontinuity.

Safety level distribution in daylight envelope

Safety factor by dip/dip direction for stereographic projection analysis is calculated, with geographical values such as width, height, and dip/dip direction of slopes, and physical properties of a rock such as cohesion, friction angle, and unit weight, fixed to find out the safety factor distribution by contouring similar safety level zone in daylight envelope. To fix the parameters of discontinuity mentioned above, typical values must be set. We analysed the data obtained from 52 rock slopes around South Korea from 2001 to 2002 investigated by KICT(Korea Institute of Construction Technology). Statistical analysis was performed on this data, and the most proper values were determined. Based on these analysed data, Table 1 shows the typical values of the slope parameters and provided basis for the values.

Table 1. Representative value of slope parameters.

Slope Parameters	Representative value	The basis of decision
Cohesion(t/m^2)	27	The highest frequency value
Friction angle(degree)	30	The highest frequency value
Unit weight(t/m^3)	2.50	The highest frequency value
Height(m)	20	Average/ The highest frequency value
Length(m)	100	The highest frequency value
Dip(degree)	63	Average/Standard value
Dip direction(degree)	0	Random value

Fig. 7 shows modelling of a total of 50 poles after dividing the dip and its correspondent dip direction equally to assess the safety factor in the daylight envelope. The assessed safety factors of the modelled poles are shown on Fig. 8, and the contour of same colour means the area of similar safety factors. From this result, safety factors that influence slope failure differ according to the position of poles that represent to the dip/dip direction of discontinuities in the daylight envelope. The safety factor area was divided into 5 areas in the daylight envelope, and the safety level was set in each area, so we can evaluate the safety of slope more concretely than before.

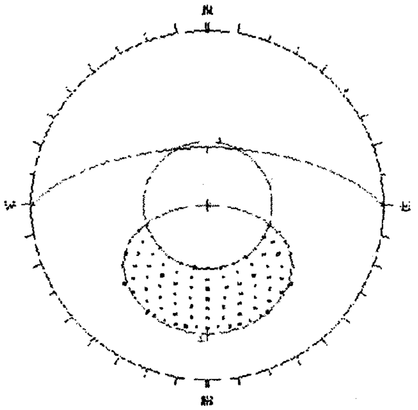


Fig. 7. Discontinuity modelling in the daylight envelope.

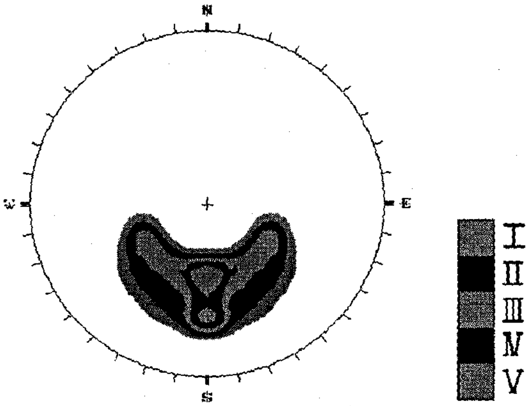


Fig. 8. Assessment of safety level in the daylight envelope.

3. Conclusion

In this research, stereographic projection was quantified by assessing the safety level in the daylight envelope by using limit equilibrium analysis. The safety factor calculation according to the dip of discontinuity in the daylight envelope by limit equilibrium equation showed a slight difference in the safety factor according to slope dip, but the safety factor was so sensitive to the dip variation of discontinuity in the daylight envelope. And also the lowest value of the safety factor decreased as the slope dip increased. Safety factor is varied slightly by dip direction variation of discontinuity in the daylight envelope. Typical values of slope and discontinuity parameters were determined through statistical analysis of rock slope investigation data. And poles of discontinuity were modelled as the dip/dip direction in the daylight envelope was varied at regular spaces. Calculating the safety factor of modelled discontinuity by limit equilibrium analysis, stereographic projection was quantified by assessing in 5 levels of safety by giving weight to each level.

Reference

Bieniawski Z. T., 1976, Rock Mass Classification in Rock Engineering, Proceedings of the Exploration for Rock Engineering, VI, pp 97-106.

George H. Davis, 1987, Structural Geology of Rocks and Regions, John Wiley & Sons, New York.

Hoek, E. and J.W. Bray, 1981, Rock Slope Engineering, Institute of Mining and Metallurgy, London.

KICT, 2001, 2002, Stability and measures of load cut slope III and IV. Annual report of Ministry of construction & transportation.

Kim, H. G., 1998, A study on the plane failure in daylight envelope, Master's Thesis, Chonnam national university, Gwangju, Korea.

Larbi S. and M. Megueddem, 1998, Stability Analysis of Jointed Rock Slope, Mechanics Research Communications, Vol. 25, No. 6, pp. 661-670.

Yu. B, Y. Hwang, G. Jeon and T. Kim, 2000, Distribution and failure characteristics of load cut slope near highway, Proceedings of KGS Annual Meeting, Seoul, Korea, 197-209.

Nawari O., R. Hartmann and R. Lackner, 1997, Stability Analysis of Rock Slopes with the Direct Sliding Blocks Method, Int. J. Rock Mech. Min. Sci., Vo. 34, Issues 3-4, 516p.

Sharma S., T. K. Raghuvanshi & Anbalagan, 1995, Plane failure analysis of rock slopes, Geotechnical & Geological Engineering, Vol 13, No. 2, 105-111.