DELINEATION OF STRUCTURAL DOMAINS BY USING FRACTURE ORIENTATIONS AND ANALYZING SLOPE FAILURE

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ABSTRACT

The sliding of rock blocks on the slope is closely related to it's internal structures. Therefore, in the slope stability analysis, the structural domains should be identified together with analyzing failure modes and mechanism of failure model.

About 450 fracture measurements obtained from 9 boreholes on a slope in Okcheon area,Chungbuk, South Korea used to caculate correlation coefficient among boreholes for delineating structural domains on slope. The calculation is carried out by comparing the frequencies of fracture poles between two stereonet windows from each pair of adjacent boreholes. The structural domain boundaries are assumed that wherever the correlation values among them are considerably low.

The analytical results at Okcheon slope determined three structural domains inside the rockmass corresponding to three different failure modes on the slope.

KEYWORDS: Structural domain, Fracture correlation, Stereonet windows, Failure mode, Slope stability

1. INTRODUCTION

A structural domain shows a volume of rock mass and is characterized by a distinct fracture pattern distribution of the intensity, orientation, spacing, size and shape. However, the determining structural domain normaly only use the number of fractures (intensity) and their orientation distribution.

The identification of structural domain considered from many past decades by Miller (1983), Kulatilake et al. (1990), Martin et al. (2004) because of its close relationship to potential failure of rock blocks on the slope. Recently, Nguyen et al. (2012) also used correlation coefficient method to analyze fracture frequency along a tunnel and determine structural domain boundaries. The above studies provided helpful tools for determining fracture patterns inside the rockmass and identifying structural domain boundaries.

In this study, we continue extending the correlation method for identifying structural domains and analyzing failure modes from the data of 9 boreholes on a slope in Okcheon area, Chungbuk, South Korea.

2. METHODOLOGY

The methodology used in this study is to calculate correlation coefficient of fracture orientation frequency between two stereonet windows of two adjacent boreholes. The calculation is carried out based on the number of fracture poles in each cell of stereonet, plotted on the lower hemisphere projection (Fig. 1).

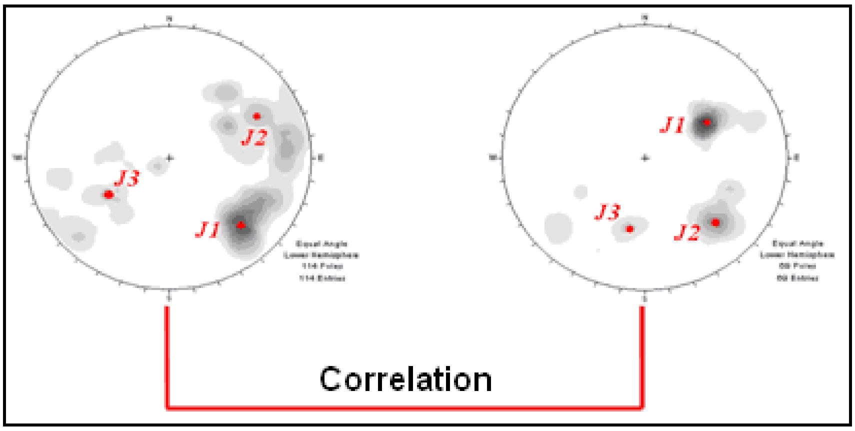

Figure 1. Stereonet pole plot of two adjacent boreholes

Figure 1 shows the fracture frequencies on each stereonet window. After plotting fracture orientations of each borehole on the stereonet window in Figure 1, the calculation of fracture correlation coefficient between two stereonet windows is carried out by using Equation 1.

$$Correl(x,y) = \frac{\sum (x-\overline{X})(y-\overline{Y})}{\sqrt{\sum (x-\overline{X})^2}\sqrt{\sum (y-\overline{Y})^2}} \qquad (1)$$

Where: x and y are number of fractures in each cell of two stereonet windows; $\overline{X}$ and $\overline{Y}$ are the average values of fracture number of two stereonet windows.

The correlation coefficient expresses the strength of the association between the two variables from two stereonet windows. These values always lie within (-1, 1) and they are independent of the magnitude of the variables. If the correlation coefficient is -1, it means perfect negative correlation; if the correlation coefficient is 0, it means no correlation and if the correlation coefficient is 1, it means perfect positive correlation.

3. APPLICATION

Application of this study is carried out at a slope, located at coordinate of about $36^0$16'49" and $127^0$31'48", belong to Okcheon area, Chungbuk, South Korea (Fig. 2).

The size of this slope is about 160m long and 133m high. The dip direction and dip angle of the slope is $290^0/45^0$. The study area lies in metamophic rocks of triassic age. The exposed rocks on the slope surface are mostly shales and calcareous shales, weathered and heavily broken.

3.1. Calculation of fracture correlation coefficient

The correlation analyses are carried out from data of Borehole Image Processing System (BIPS) of 9 boreholes on the slope (Fig. 2). The analytical process is conducted by comparing in each pair of boreholes' data.

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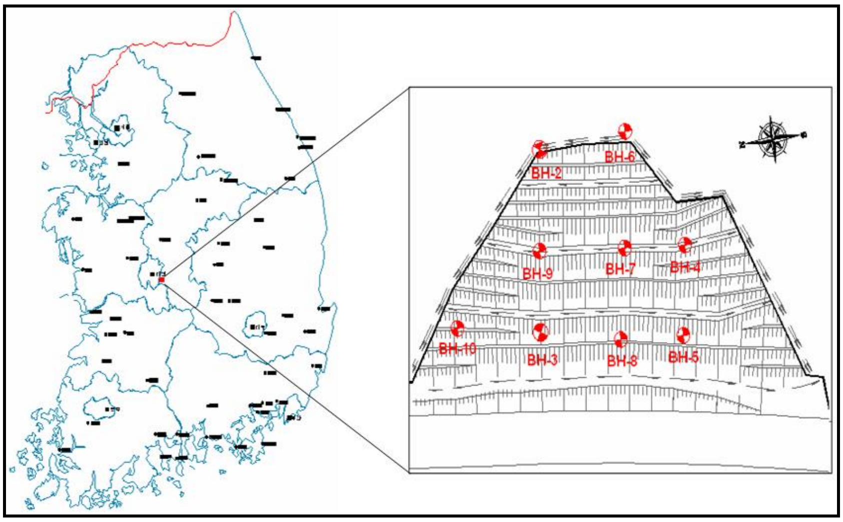
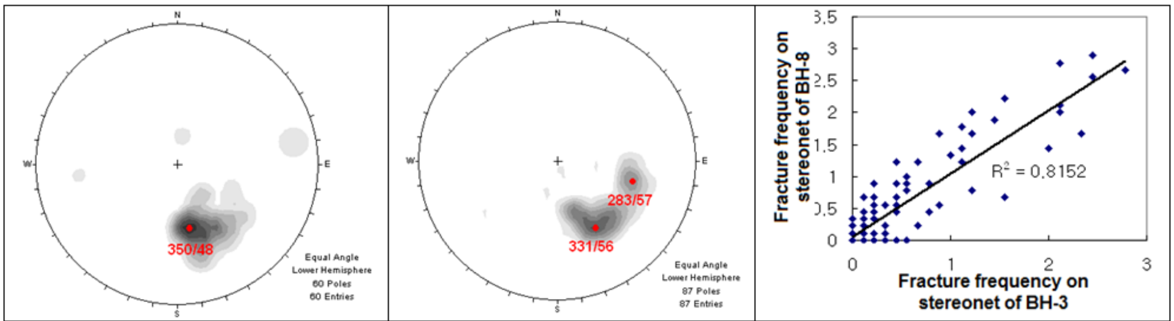


Figure 2. Location map of study area belong to Okcheon area, Chungbuk, South Korea

Table 1. Number of fractures and depth of boreholes on the slope, belong to Okcheon area, Chungbuk, South Korea

Borehole number	Thickness of fracture data	Fracture numner	Borehole number	Thickness of fracture data	Fracture numner
BH-2	16.6-28.5 (m)	42	BH-7	4.3-34.7 (m)	47
BH-3	6.5-24.3 (m)	87	BH-8	5.5-37.5 (m)	60
BH-4	2.2-35.0 (m)	51	BH-9	15.7-25.2 (m)	30
BH-5	6.4-34.4 (m)	53	BH-10	12.6-24.6 (m)	34
BH-6	8.9-34.1 (m)	42			

The calculation results of fracture correlation coefficient based on the distribution of fracture orientations in a pair of borehole between two stereonet windows are shown as Figure 3, Table 2 and 3.



BH-8	BH-3	Fracture correlation coefficient

Figure 3. Distribution of fracture contour poles of boreholes BH-3 and BH-8 and it's correlation coefficient

Table 2. The results of fracture correlation comparison between each pair of borehole in normal lines (Fig. 4a)

Number	Pair of boreholes	Correlation values	Number	Pair of boreholes	Correlation values
1	BH-2 and BH-6	0.45	7	BH-7 and BH-4	0.51
2	BH-2 and BH-9	0.51	8	BH-7 and BH-8	0.74
3	BH-9 and BH-7	0.65	9	BH-8 and BH-5	0.11
4	BH-9 and BH-3	0.69	10	BH-8 and BH-3	0.82
5	BH-3 and BH-10	0.66	11	BH-5 and BH-4	0.63
6	BH-6 and BH-7	0.69			

From the calculation results of Table 2 for the case of checking normal lines, the slope can be delineated three structural domains and determined the borehole BH-2 belong to structural domain **I;** the boreholes BH-3, BH-6, BH-7, BH-8, BH-9 and BH-10 belong to structural domain **II;** the boreholes BH-4 and BH-5 belong to structural domain **III** (Fig. 4a).

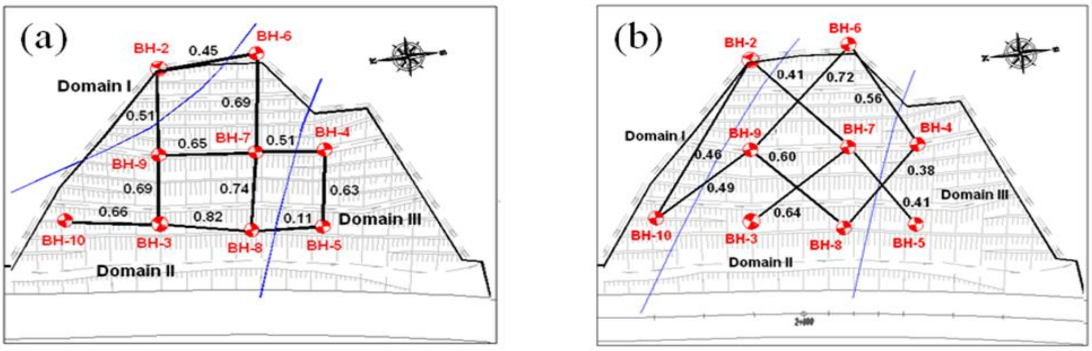


Figure 4. The structural domains on the slope are divided from fracture correlation coefficients among adjacent boreholes in normal lines (a); in cross lines (b)

Similarly for the case of examining cross lines, the fracture correlation coefficients among adjacent boreholes are summarized in Table 3 and the structural domains are delineated in Figure 4b.

Table 3. The results of fracture correlation comparison between each pair of boreholes in cross lines (Fig. 4b)

Number	Pair of boreholes	Correlation values	Number	Pair of boreholes	Correlation values
1	BH-2 and BH-10	0.46	6	BH-3 and BH-7	0.64
2	BH-10 and BH-9	0.49	7	BH-6 and BH-4	0.56
3	BH-2 and BH-7	0.41	8	BH-7 and BH-5	0.41
4	BH-9 and BH-6	0.72	9	BH-8 and BH-4	0.38
5	BH-9 and BH-8	0.60			

The three structural domains delineated in the Figure 4 by using fracture correlation coefficient reflected clearly the difference among these regions with fracture orientation distribution (Fig. 5).

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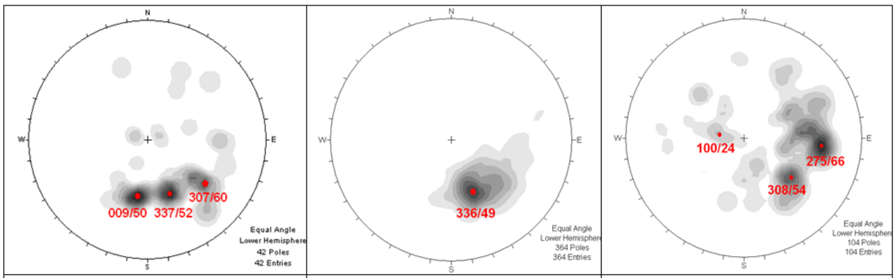


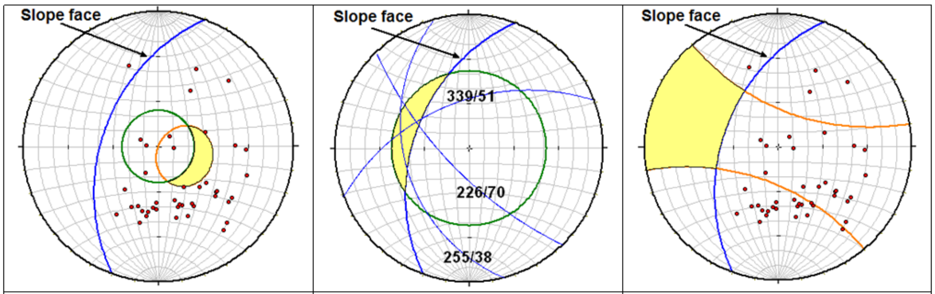
Distribution of fracture contour poles of BH-2 (Domain I) (a)	Distribution of fracture contour poles of BH-3, 6, 7, 8, 9, 10 (Domain II) (b)	Distribution of fracture contour poles of BH-4, 5 (Domain III) (c)

Figure 5. Distribution of fracture contour poles of three structural domains on the slope

3.2. Analyses of slope stability

The analyses of slope stability are carried out by examining three potential failure modes of plane failure, wedge failure and toppling failure with friction angle 30^0 based on the distribution of boreholes' data from three structural domains, separately (Figs. 6-8).

3.2.1. Structural domain I

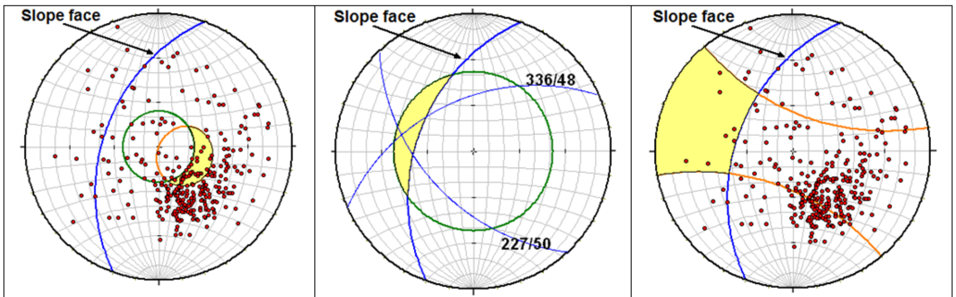


Plane failure (a)	Wedge failure (b)	Toppling failure (c)

Figure 6. Three diagrams of failure analyses for Domain I

In the Domain I, the fracture orientations do not focus in a set. Their poles do not fall into the area of potential failure for the case of plane and toppling failure. This mean that these fractures hardly cause plane and toppling failure in this area. However, it can occur wedge failure due to having conjugate fractures which can form wedge failure blocks (Fig. 6b).

3.2.2. Structural domain II



Plane failure (a)	Wedge failure (b)	Toppling failure (c)

Figure 7. Three diagrams of failure analyses for Domain II

In the Domain II, the analytical results showed that the fracture orientations focus according to main set 336/49 and can occur three types of failure, especially strong for the case of plane failure.

3.2.3. Structural domain III

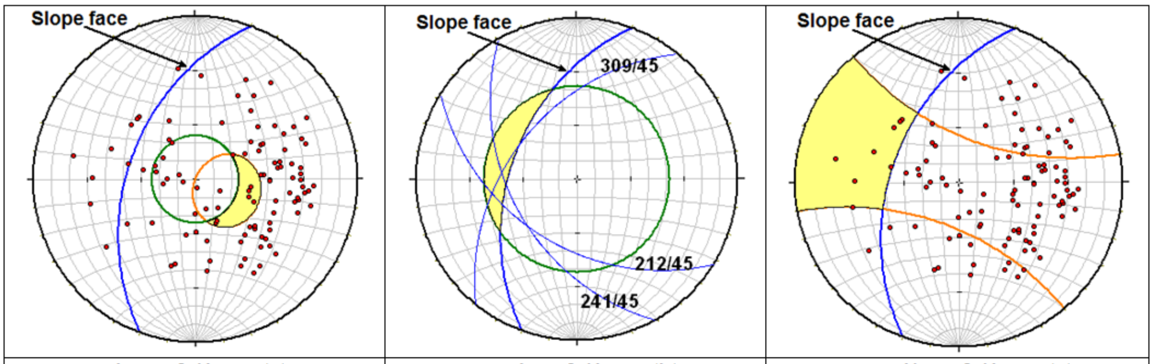


Figure 8. Three diagrams of failure analyses for structural domain III

Siminlar, the analytical results in the Domain III also showed that this area can occur three types of failure. However, the wedge failure potential is highest.

4. CONCLUSIONS

The experimental results obtained by calculating fracture correlation coefficient between two stereonet windows according to each pair of adjacent boreholes from 9 boreholes on the slope in Okcheon area, Chungbuk, South Korea clearly reflected the relationship between spatial fracture patterns inside rockmass and structural domains. On the slope established three structural domains according to the borehole's data. The fracture patterns in three structural domains are quite different. Besides, the result of failure analyses from three structural domains on the slope using fracture orientations also showed clearly the difference of failure modes on these structural domains.

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