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Fuzzified kinematic analysis of discontinuity-controlled rock slope instabilities

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Abstract

In this study, it is aimed to bring a different approach to kinematic analyses of discontinuity-controlled rock slope instabilities. For this purpose, the data of a detailed discontinuity survey carried out in Ankara, the capital city of Turkey, were updated and reevaluated. Serious discontinuity-controlled instability events were observed in the andesites covering large areas with dense population in the city. Instead of analyzing the effects of the planes belonging only to the major discontinuity sets on the stereographic projection net, all discontinuities were taken into consideration, and kinematic analyses were carried out for planar, wedge, and toppling type failures on pixel basis of the Digital Elevation Model (DEM) of the study area. By doing so, it could be possible to compensate for the deficiency created by neglecting the planes in the lower concentration zones of the stereographic projection. A computer program named FUDIKA (Fuzzified Digital Kinematic Analyses) was written to perform modular kinematic analyses and fuzzy operations, having four modules and operating in three stages. First, Potential Instability Index (PII) was introduced to define instability potential of the rock slopes based on the number of possible instability events for each failure type. Next, the PII values were normalized and fuzzified to obtain PII map of the area. It was seen that when tested on previously occurred instabilities in the area, the PII values obtained through the methodology proposed in the study showed quite a high performance.

Keywords: Ankara; Discontinuity; Fuzzy logic; Kinematic analysis; Rock slopes

1. Introduction

Almost all stability analyses of rock slopes containing discontinuities include kinematic checks before further limit equilibrium analyses in order to determine potentially unstable slopes. The so-called kinematic checks are extensively used in geotechnical engineering applications to pre-determine the discontinuity-controlled stability condition of rock slopes in different instability modes, namely planar, wedge, and toppling type failures.

General practice in kinematic analyses has long been in form of an assessment based on plotting all measured discontinuity planes on a stereographic projection net and evaluating the position (dip and dip orientation) of particular planes (major discontinuity sets) represented as the poles at the centers of the concentration zones. This evaluation with respect to the slope angle, slope aspect, and the friction angle (ϕ) of the discontinuity

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plane(s) in concern can be seen in Hoek and Bray (1981). The way of applying the kinematic analyses has then been adapted to the logic of geographic information system (GIS) in the way to compare the intersections, orientations and dips of the discontinuity planes, with the slope geometry from Digital Elevation Model (DEM). In fact, with the advances in computer technologies, it has become much easier to evaluate huge numbers of data on discontinuity records and perform analyses on very large areas in very short times.

The present study approaches the kinematic analysis of the rock slopes in the jointed andesites of Ankara city, Turkey, in a different way to evaluate all possible modes of discontinuity failures on pixel basis of the DEM of the area. Unlike in many previous similar works, in the present evaluation, for every pixel of the DEM, all of the recorded discontinuities were tested one by one in all possible combinations with each other for planar, wedge, and toppling types of failure. For this analysis, a computer program has been produced to fuzzify the kinematic analyses in a way to combine various databases used in the study. The application of this program will be given in detail later in the section to explain the methodology.

Another different approach in the present study is that, during the kinematic analyses at each pixel, the value of the friction angle (ϕ) is assigned as the value taken from the database, produced as a ϕ-map starting from the values obtained in laboratory shear tests, and interpolating these values for the whole area on pixel basis.

Kinematic analyses performed by using the computer program yield membership degree values for each failure type at each pixel, which will later be used in fuzzy mathematics to compare the normalized values of these membership degrees with actual slope geometry existing in the area. Eventually, an index value introduced in this study as the Potential Instability Index (PII) was produced by the calculation of the considered failure frequencies. The PII was defined as an index value, based on the normalized frequencies of potential instability event calculated for each failure mode at a pixel.

2. Problem statement

Kinematic analyses of discontinuity-controlled rock slope instabilities take into account the comparison of the orientation of discontinuity planes or their intersections with friction angles, slope geometry and slope orientation. When plotted on a stereographic projection net, poles of the discontinuity planes in most cases display a rather scattered picture, yet many of the poles may coincide with others if the number of poles plotted increases. As explained in Priest (1993), and shown in Fig. 1, which reflects the actual distribution of the discontinuities in the present study, these poles may become concentrated at certain zones in accordance with the number of planes measured and plotted on the stereo-net, represented by contour intervals.

It is obvious that certain zones have a higher concentration of poles while some others have lower ones,

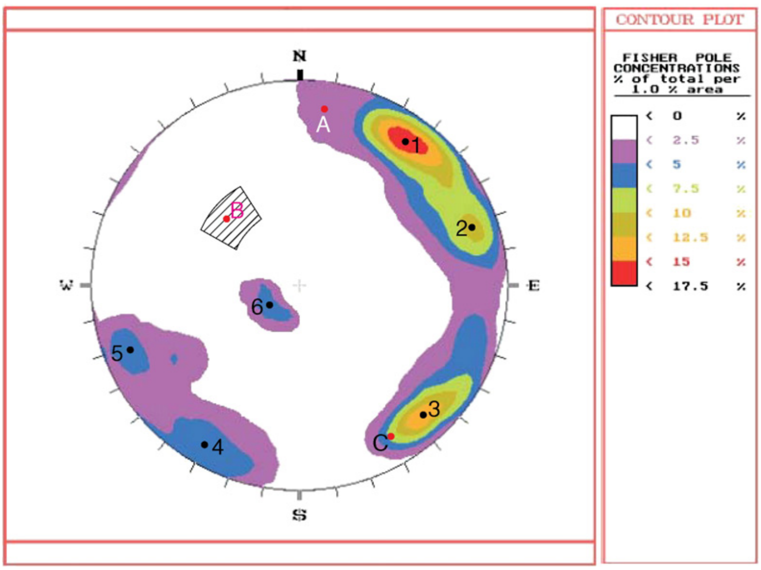

Fig. 1. Contour diagram of the measured discontinuities in the study area.