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Technical note

A method for assessing discontinuity poles for potential wedge sliding

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ABSTRACT

Conventional assessment of the potential sliding of wedge blocks involves identification of the lines of intersection of the two planes on a stereograph. The stereographic envelope for kinematically feasible wedge intersections exists between the plane of the slope face and a friction circle. An alternative method of stereographic analysis is presented involving fitting great circles to a pair of poles representing the planes of the wedge. If the great circle passes through the polar daylight envelope for the slope face, without passing through the friction circle, wedge sliding on the pair of discontinuities is kinematically feasible. This method is advantageous as 1) the distribution of discontinuity poles on a stereograph can be interpreted directly without showing the individual planes as great circles, 2) only pairs of discontinuities from opposing orientations are included, 3) geometric attributes of the potential wedges, such as symmetry and shape, can be assessed directly on the stereograph and 4) reduction of data to sets is not required prior to kinematic assessment.

1. Introduction

The potential for tetrahedral wedge-shaped blocks of rock to slide on two discontinuity planes is a well-known problem in rock slope engineering (Goodman, 1980; Brown, 1981; Hoek and Bray, 1981; Park and West, 2001; Lisle and Leyshon, 2004). The problem is typically addressed in two stages. Firstly, the potential or feasibility of the block's movement or kinematics is assessed. This kinematic assessment is typically conducted on a stereograph (Hoek and Bray, 1981). Demonstrated kinematic feasibility indicates that the second stage, stability analysis, may be warranted. Only the first stage, kinematic assessment, is considered in this paper.

The lateral transition between planar sliding and wedge sliding is also not considered in this paper. This transition is complex as tetrahedral wedges which typically slide on both planar surfaces in the direction of the intersection line, can slide on one of the planes in its down-dip direction (Markland, 1972; Hocking, 1976; Lucas, 1980). The lateral limit of planar sliding has been selected by some authors as $\pm 20°$, however, this limt has been defined by small circles (Wyllie and Mah, 2004, Fig. 1A) or as vertical planes (Hudson and Harrison, 2000, Fig. 1B).

An important concept in kinematic assessment of any sliding mechanism on a stereograph is the daylight envelope which defines the range of poles which have their dip vectors on or outside the slope plane (Wyllie and Mah, 2004). Wyllie and Mah (2004, p. 38) label the entire daylight envelope as the 'daylight envelope for wedges' with an overprinted pattern for the planar sliding part of the envelope. Wyllie and Mah (2004, p. 39) also label the daylight envelope as the 'envelope of potential instability: wedges' (Fig. 1 C&D). This statement is incompatible with examples of wedge sliding that clearly have poles outside the daylight envelope. An example of a kinematically feasible pair of discontinuities (Wyllie and Mah, 2004, p. 45), when compared to the daylight envelope, readily shows that the poles to the wedge sliding planes do not lie in the daylight envelope (Fig. 1 E).

Current practice for kinematic assessment of potential sliding wedges emphasises identifying the lines of intersection (e.g. Hudson and Harrison, 2000, p. 316) however, the distribution of the poles forming the wedges should also be included in a kinematic assessment to confirm that the intersection occurs from discontinuities with opposing dip directions relative to the slope direction.

It has been previously recognised that the great circle (otherwise known as a cyclographic trace) passing through a pair of discontinuity poles has as its pole the line of intersection of the two planes (Hoek and Bray, 1981, p. 58, Fig. 1F). It is this relationship between discontinuity poles and kinematic feasibility which is further explored in this paper.

2. Potential for a single pole to be part of a wedge sliding pair

If the daylight envelope does not limit the range of poles capable of forming sliding wedges (as demonstrated in Fig. 1), then it is necessary to determine what the limits are. The condition that two planes intersect within the intersection envelope (between the slope face and the friction circle measured from the stereograph perimeter) has the precondition that both planes must pass through the intersection envelope. Therefore for a single plane to have the potential to contribute to a pair of wedge sliding planes, it must itself pass through the intersection envelope. It can be readily found that a great many planar orientations pass through the intersection envelope. The exceptions are those planes which dip too gently and those which dip too steeply. There are five

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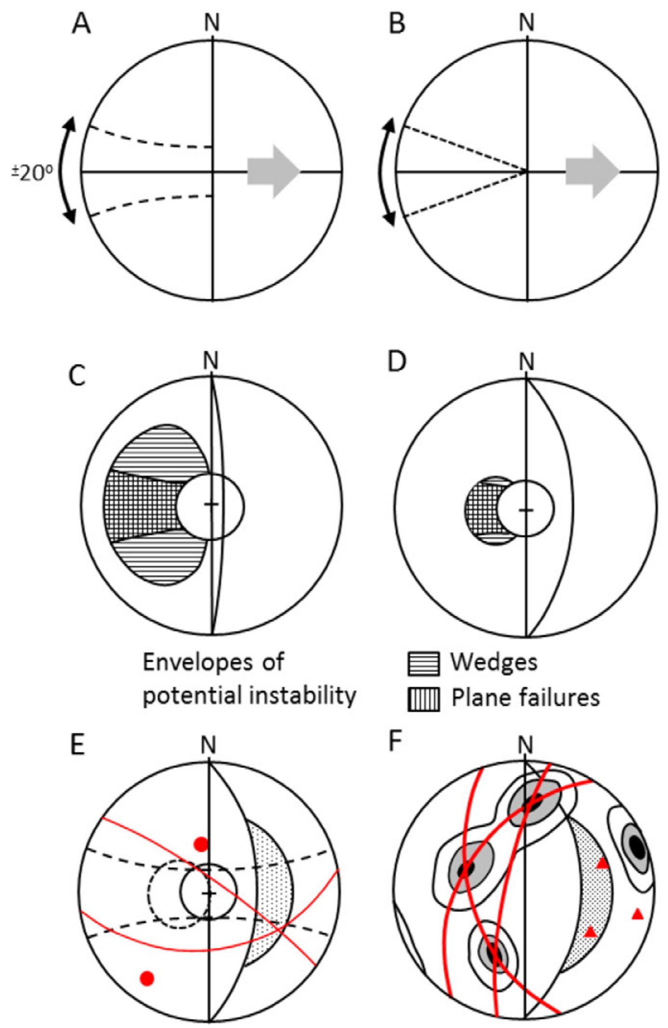

Fig. 1. (A) Lateral limit between planar and wedge sliding based on a small circle. (B) Lateral limit between planar and wedge sliding based on vertical planes. (C) Daylight envelope applied to wedge stability for an 80° dipping slope and (D) a 50° dipping slope (with the annotations from Wyllie and Mah (2004), p. 39). (E) Potential wedge sliding on two discontinuities not in the daylight envelope (Wyllie and Mah, 2004, p. 45, rotated to an east dipping slope for comparison). (F) Stereograph of contoured discontinuity data (Hoek and Bray, 1981 p. 58, rotated to an east dipping slope for comparison). (A–E) Equal angle stereographs. (F) Equal area stereograph.

features which limit the range of poles which may form one part of a pair of wedge sliding discontinuities (Table 1). The boundary which has not previously been identified is the plane with its pole at the end of the intersection envelope (Fig. 2A, star). Planes with poles steeper than that great circle do not pass through the intersection envelope. Any pole within the defined range (Fig. 2, shaded) passes through the intersection envelope and dips outward from the face.

When applied to stereographs for a range of face slope angles, it can be seen that a large part of each quadrant opposite the slope face allows for the potential for poles to represent planes which pass through the intersection envelope and therefore have the potential to form part of a pair of wedge sliding planes (Fig. 2). Any pole lying outside this range can be excluded from consideration as a potential contributor to wedge sliding for the given face orientation, slope face angle and frictional conditions of the discontinuities. The range of planar sliding poles (not shown in Fig. 2) effectively separates the potential wedge forming polar envelopes into two zones with opposing dip directions relative to the slope face. Potential sliding wedges are formed by a pair of poles, one from each of these zones.

Table 1
Features marking the range of poles which may form one part of a pair of wedge sliding discontinuities.

Stereographic feature	Explanation
Primitive circle (perimeter of stereograph, horizontal plane)	Beyond this limit the plane would dip steeply toward the slope face.
Vertical plane parallel to slope face	Beyond this limit the plane would dip toward the slope face (kinematically feasible wedges can include a plane dipping into the face but this is not considered significant in this study).
Lateral limit from parallel to slope face	A boundary between planar and wedge sliding planes (not specified in this study). For example slope direction ±20°. may be bounded by vertical planes or small circles.
Friction circle	Beyond this limit sliding on the plane is mechanically infeasible.
Planes perpendicular to each end of the intersection envelope	Beyond this limit the plane does not pass through the intersection envelope.

3. Combinations of two poles to form a wedge sliding pair

Although the range of pole orientations which can form one part of a wedge sliding pair has been defined above, it does not follow that every pair of such planes will form a potential sliding wedge. In conventional

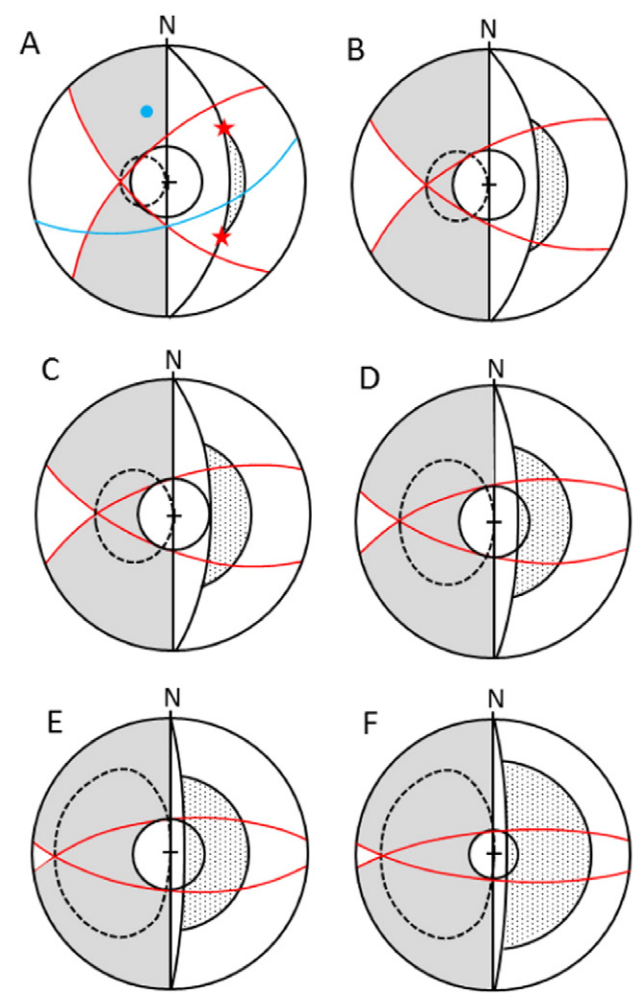

Fig. 2. (A) Envelope (shaded) for poles to discontinuity great circles which pass through the intersection envelope (stippled) and dip out of the face, for a slope face dipping 40° toward the east. The great circle perpendicular to the point at each end of the intersection envelope (stars) forms part of the pole envelope boundary. An example of a plane meeting the criteria is shown (circle). (B–E) Envelopes for slope faces dipping 50°, 60°, 70° and 80°, respectively. Polar daylight envelope is dashed. Friction angle (A–E) is 30°. (F) Envelope for slope face dipping 80° with friction angle of 20°. Equal angle stereographs.