Statistical Analysis of Rock Mass Fracturing

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Over the past 10 years considerable empirical work has been reported on the stochastic description of rock mass fracturing, and on the statistical design of joint surveys. This has led to consistent conclusions on the distributional properties of such discontinuities, and is beginning to lead to improved survey designs. Two of the strongest conclusions appear to be the exponentiality of the distribution of spacings between discontinuities when measured by their intersections with sampling lines, and the lognormality of discontinuity trace lengths as observed in outcrops. Consistent conclusions on the form of orientation distributions appear more elusive. Sampling biases in joint surveys now seem more pervasive than was earlier thought. In addition to the well-known orientation bias in sampling from two-dimensional outcrops, proportional length bias in which larger discontinuities are sampled with increased probability, and censoring biases in which larger discontinuities are often only partially observed, complicate statistical inferences. These results are reviewed against a recent study involving some 15,000 data.

KEY WORDS: joints, trace lengths, truncation bias, censoring bias.

INTRODUCTION

Joint surveys are an integral component of site characterization studies in rock engineering because the strength, deformation, and flow behavior of rock masses are strongly influenced by the geometry and engineering properties of rock mass discontinuities. For many decades the collection of geometric data on rock mass jointing has been recognized as a problem of statistical sampling, and beginning in the mid-1960s many workers have devoted their efforts to developing sound survey procedures and to interpreting the empirical data base.

This paper summarizes empirical results, with special reference to work at MIT (Einstein, Baecher, and Veneziano, 1978) and discusses the influence of present concepts of joining geometry on sampling procedures.


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GEOMETRY OF JOINTING

In this section the geometric properties of jointing observable in common surveys are described. While these geometric properties seem to fall naturally into distinct geometric classes, in reality they are only facets of other, more fundamental ways of describing joint geometry. It is, therefore, important, when interpreting the implications of survey results for predicting aggregate rock mass behavior, that these observed geometric properties be viewed as strongly interdependent.

In joint surveys, three geometric properties are commonly of interest: density (e.g., spacing, frequency), size (e.g., trace length, area), and orientation (e.g., strike and dip of an approximating plane, direction cosines of the pole). The measures adopted here are spacing, trace length, and polar direction cosines. Spacing is measured by the separation of the intersections of adjacent joint traces with a sampling line, either for individual sets of sub-parallel joints or for all joints (Fig. 1). Trace length is typically measured as the linear distance between the end points of the intersection of a joint with an exposed surface. For joints that are strongly nonplanar, other measures are sometimes used. If both ends of a trace are not observable, the length recorded is a censored length.

![Fig. 1. Typical chalk sampling line on an outcrop, showing definitions of joint spacing (A) and trace length (L).](image)