

# ROCK DISCONTINUITY SPACING STATISTICS: LOG-NORMAL DISTRIBUTION VERSUS EXPONENTIAL

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## 1. INTRODUCTION

The load - deformation behaviour and seepage characteristics of a rock mass are directly related to the geometric characteristics of its discontinuities (spacing, trace length and orientation). In order to take account of the distributive character of these properties and to allow for the fact that field sampling is a statistical problem, it is essential to use statistical descriptions of these properties.

## 2. DISCONTINUITY SURVEY METHOD

Different techniques have been used to survey discontinuity characteristics. The most common and generally accepted method involves the use of a series of scanlines (e.g. Piteau 1970, Attewell et al. 1976, ISRM 1981).

The scanline technique which is used on rock surface exposures involves extending a measuring tape along the face of an exposure and measuring all discontinuity spacings, lengths and orientations along the tape. Discontinuity spacing can also be determined from analysis of drill cores.

Biases in discontinuity spacing and length are numerous. These have been described by Attewell & Farmer (1976), Priest & Hudson (1981), and, Rouleau & Gale (1985), for example.

## 3. DISCONTINUITY SPACING DISTRIBUTION

Different statistical techniques have been recommended for analysing and describing discontinuity survey data (e.g. Bridges 1975; Priest & Hudson 1976; Baecher, Lanney & Einstein 1977; Meritt & Baecher 1981; ISRM 1981 and Rouleau & Gale 1985). However, the statistical distributions of discontinuity spacing, length and orientation fitted to the results obtained by these and other investigators are not strictly consistent. For example, both exponential and log-normal distributions have frequently been fitted for discontinuity spacing. Analysis of field results obtained from scanline measurements carried out on a mudstone, a sandstone and two chalks, by Priest and Hudson (1976 and 1981), have indicated that a negative exponential distribution of discontinuity spacing values is a good approximation to the true distribution pattern. On the other hand Sen & Kazi (1984), in a discontinuity spacing study on a schist, using scanline measurements, have concluded that, "The log-normal probability density function provides flexibility in the sense that, in addition

to the average discontinuity spacing value, the variance of the discontinuity spacings is also taken into consideration in any scanline evaluations. Increase in the standard deviation gives rise to greater errors in estimations". It should be noted that in an exponential form of distribution, standard deviation and mean are equal.

Similarly, Rouleau and Gale (1985), analysing an extensive fracture data base, collected from drill cores of granite, indicated that the exponential distribution did not fit their data at all but the log-normal distribution fitted their data very well. They evaluated the goodness-of-fit of three statistical models, exponential, log-normal and Weibull, with quantile plots, and their results showed, quite clearly, that the log-normal distribution fitted the data very well. However, it is interesting to note that all the data points which did not fit the exponential distribution had spacing values about one metre or larger.

The discontinuity spacing distributions reported by Priest & Hudson (1976) show good agreement with exponential distributions for three different discontinuity sets and for each set the value of the mean spacing is approximately equal to the standard deviation (this is a characteristic of the exponential distribution). However, their results show that, for all scanlines taken together, their spacing values are smaller than one metre.

Similarly, deviation of actual spacing values from the exponential distribution, when some of the spacing values are larger than one metre, can be seen in results reported by other workers (e.g. Bridges 1976, Baecher & Lanney 1977, Wallis & King 1980 and Sen & Kazi 1984). This could be an indication that the distribution of spacing values may be assumed to be either exponential or log-normal, depending on the rock type and spacing range (between the maximum and minimum values). Apparently the spacing distribution patterns of sedimentary rocks are different from those of igneous and metamorphic rocks. It appears that spacings are randomly distributed in sedimentary rocks, but they are not randomly distributed in crystalline rocks. Furthermore, it appears that discontinuities with spacing values larger than about one metre are not randomly distributed along the scanline or borehole.

## 4. CONCLUSIONS

The distribution of spacing values may be assumed to be either exponential or log-normal, depending on the rock type and the range of spacing size (between the maximum and minimum). It appears that discontinuities with spacing values larger than about one metre are not randomly distributed.

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As a consequence of this investigation, the writer makes the following suggestions:

- (i) Discontinuities could be classified as finely-spaced if less than 10 per cent of the spacing values are larger than one metre and as coarsely-spaced if 10 per cent or more of the spacing values are larger than one metre;
- (ii) Exponential and log-normal distributions could be fitted for finely-spaced and coarsely-spaced discontinuities respectively;
- (iii) To estimate RQD, from field discontinuity spacing measurements, Priest & Hudson's equations (Priest & Hudson 1976) and Sen & Kazi's curves (Sen & Kazi 1984) could be used for finely-spaced and coarsely-spaced discontinuities, respectively.

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