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DETERMINATION OF RELATIONSHIP BETWEEN UNIAXIAL COMPRESSIVE STRENGTH (UCS) AND ROCK DENSITIES USING FRACTAL MODELLING IN KAROUN-4 DAM, SW IRAN

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ABSTRACT

The aim of this study is to identify different populations for rock characteristics based on uniaxial compressive strength (UCS) and density within limestones of Karoun-4 Dam, SW Iran. The results from a Number-Size (N-S) fractal model log-log plots for UCS and rocks' densities reveal that there are four populations for the studied variables. The last populations for UCS and density commence from 87 MPa and 2.65 t/m^3, respectively. Finally, a log-ratio matrix is applied to validate and determine the overlaps between the N-S fractal model for UCS and density values within the main rock type. The overall accuracy (OA) is 85% which shows that there are positive correlations between UCS and rock density in the Karoun-4 Dam.

Keywords: *number size fractal modelling; uniaxial compressive strength (UCS); logratio matrix; karoun-4*

1. Introduction

Outlining of host rock characterisation in terms of uniaxial compressive strength (UCS) and density is one of the fundamental aspects in a reservoir dam planning and design. Main host rocks of Iranian dams are carbonate rocks especially limestones and dolomites. Numerical models specifically based on geostatistics and fractal have been utilised to define various phenomena for better interpretation of the parameters' variability for rock mass characteristics in rock mechanics [1, 2, 3, 4].
Fractal/multifractal modelling, established by Mandelbrot (1983), has been used for delineation and classification of various parameters in mining engineering and geomechanical modelling such as ore grades, geophysical parameters and rock characteristics since the 1980s [5]. Consequently, several fractal models have been proposed and developed for a wide application from rock 1980s to mineral exploration [5, 6, 7, 8].
The purpose of this study is to recognise different populations for rock characteristics with respect to UCS and density within limestones as the main lithological unit of Karoun-4 dam, SW Iran according to the Number-Size (N-S) fractal modelling proposed by Mandelbrot (1983) [5]. Furthermore, a log-ratio matrix is used to determine the intersections between the N-S fractal model for UCS and density values within the limestones.

2. Studied area characteristics

The Karun 4 reservoir dam is an arch dam on the Karun River located in Charmahal and Bakhtyari Province, SW Iran (Fig. 1). Marginal part of Zagros orogeny has a high amounts of carbonate rocks especially limestones and dolomites. Main rock type of the studied area is limestones and minor lithological units are sandstones, marls and shales.

3. Methodology

In this study, 70 rock samples were collected from limestones in different situations within the dam

area and also, their UCS and density values were measured. Moreover, the main parts of the limestones were determined using N-S fractal modelling in terms of the above-mentioned variables. Finally, the main populations for these parameters were correlated and compared by the logratio matrix as proposed by Carranza (2011) [9].

Fig. 1: The location of Karoun-4 dam in Iran

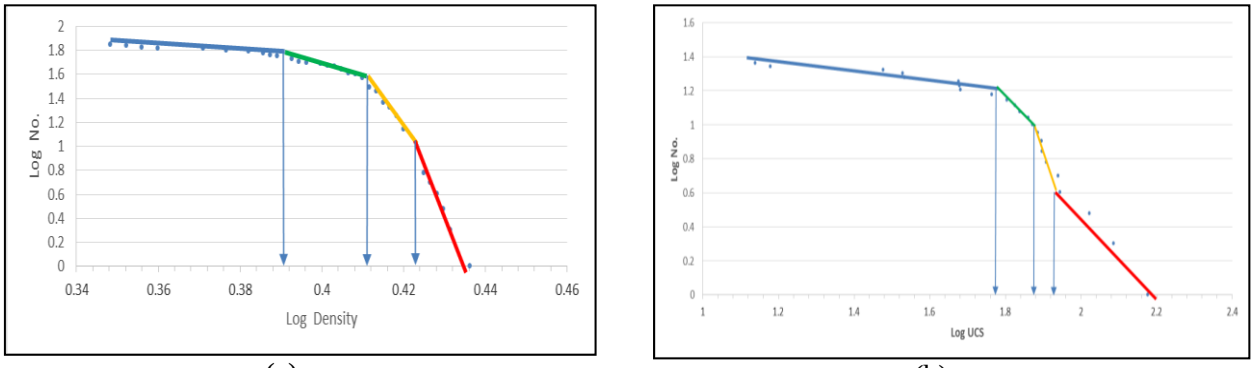
4. N-S Fractal Modelling

The N–S fractal model can be utilised to describe the distribution of geomechanical populations without pre-processing of data. The N-S log–log plot describes the power law relationship according to the frequency distribution of size, which is UCS and density values in this study, and cumulative number of samples [5, 10]. This model is expressed by following equation [2, 5, 10]:

$$N(\geq\rho) = F\ \rho^{-D} \qquad (1)$$

Which in this equation ρ and N(≥ρ) denote elemental values (UCS and density) and samples cumulative number with values greater than or equal to ρ respectively, F is a constant and also, D is fractal dimension. The N-S log-log plots show straight lines segments, with different slopes (-D) corresponding to different intervals [10].

There are four populations based on the N-S log-log plot which indicate that the main UCS and density populations have the USC and density values higher than 87 MPa and 2.65 t/m^3, respectively (last populations: Fig. 2). The background parts for USC and density values are lower than 60 MPa and 2.45 t/m^3, respectively, as depicted in Table 1.



(a) (b)

Fig. 2: The N-S log-log plots for (a) Density for (b) UCS

Table 1: The UCS and density thresholds derived via the fractal modelling

UCS(MPa)	Density (g/cm3)
60	2.45
76	2.57
87	2.65

5. Correlation between the UCS and density

Based on the N-S fractal modelling, the main populations of UCS and density for limestones were compared and correlated by the logratio matrix proposed by Carranza (2011) [9]. An intersection operation between major parts of UCS and density derived via the fractal modelling was performed to obtain the number of samples according to each of the four classes, as indicated in Table 2. Overall accuracy (OA) of the populations was calculated which shows that the OA is 0.85. This reveals that there is a direct relationship between high intensity populations of UCS and density within limestones.

Table 2: The correlation between main UCS and density populations

		Main density population (> 2.65 t/m^3)	
		Inside zone	Outside zone
Main UCS population I(> 87 MPa)	Inside zone	True positive (A) = 2	False positive (B) = 8
	Outside zone	False negative (C) = 4	True negative (D) = 68
		Overall accuracy = (A+D)/(A+B+C+D) = 0.85	

6. Conclusions

Results obtained by the N-S fractal modelling show that there is a positive and direct relationship between two important parameters of rock characteristics including UCS and density in the Karoun-4 dam, SW Iran. The major populations of these characteristics obtained by fractal modelling have a good correlation based on the high value for OA resulted via the logratio matrix. As a result, the limestones contain high density with large values of UCS.

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