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Rock mass characterization for shallow granite by integrating rock core indices and seismic velocity

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ABSTRACT

Mechanical and geophysical properties obviously vary between rocks and rock masses. In general, rock mass structures are seldom analyzed quantitatively based on geophysical information. In this paper, the authors combine data from 278 shallow boreholes and 12 CSNS engineering geo-exploration lines in a granitic area in South China and use the GOCAD software platform to establish a three-dimensional geological-geophysical model. A quantitative relationship between the rock mass structure and granitic RCI (rock core index) is then established. An empirical relationship between the RCI and the seismic velocity of the rock mass is also obtained, which is helpful for analyzing the features of the rock mass. This research improves the quantitative study of rock mass structures using geophysical parameters, which is helpful for the prevention of geological disasters along the highway in the granitic area.

1. Introduction

The validity of rock mass classification systems often depends on geological conditions. One such system is the Rock Quality Designation (*RQD*) system, which accounts for only the frequency of jointing within a rock mass. The Rock Mass Rating [1] and *Q* systems [2] used *RQD* as a measurable parameter and considered factors such as the intact rock strength, joint spacing, joint condition, field stress, joint sets and groundwater. The *GSI* [3,4] method assesses the lithology, structure and condition of discontinuity surfaces in the rock mass.

Many scholars [3,5,6] thought that geophysical methods, which are non-invasive and non-destructive methods to collect information on the heterogeneous subsurface, can be used as an initial assessment for engineering sites to optimize a site's investigation program. Seismic refraction can be used to assess the site's condition, rock mass structure, and so on. [7]

Empirical relationships between seismic properties and the mechanical behavior of rock masses have been studied by different researchers. [8,9] Barton 2 found that a corresponding relationship exists among seismic wave velocity, electrical resistivity and rock density (Fig. 1). Sjögren et al. [10] performed a comprehensive investigation, and summarized the correlations between the seismic velocities obtained from refraction surveys and the joints measured in drill cores. Combining geophysical data and geological drilling information can improve the methods that are used to characterize rock masses. [11] Choi et al. 12 derived some rock mechanical parameters, such as fracture frequency and rock quality designation (*RQD*), according to compressional wave velocity values (V_p). An average regression curve was generated for different rock types.

A total of 278 drill holes (with a total rock core length of 8968.7 m) and twelve geophysical survey lines (with a total length over 7000 m) were created as a part of geological investigation by the China Spallation Neutron Source (CSNS). During the designation of twelve geophysical survey lines, the main principle is that the geophysical lines are close to the drilling hole and to cover the main structural area (such as ZZK105, ZZK99, ZZK94, ZZK10 in the fracture zone) as more as possible, which makes that this paper can collect the better scientific data from field (Fig. 2).

A 3-D geological-geophysical model that is based on data from the cores and CSNS geophysical survey is constructed in this paper. The

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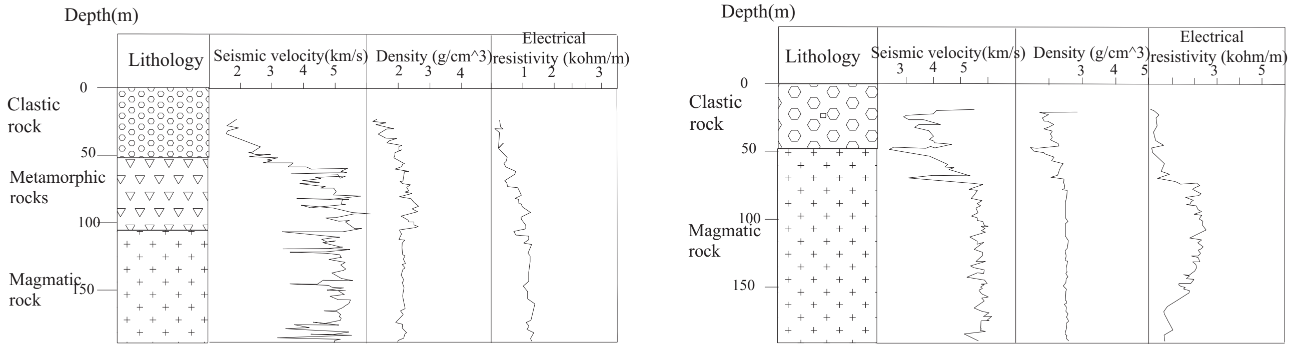

Fig. 1. Corresponding relationship among the seismic wave velocity, electrical resistivity and rock density (Barton, 2007).

RCI (rock core index) and seismic velocities are then assigned in every subdivided grid. An empirical relationship between the *RCI* and seismic velocity is analyzed and established in the grid. Different grid properties are matched in the GOCAD 3-D model based on these drilling core and geophysical data, and then the properties are analyzed and the empirical relationships are established.

This paper introduces a method to quantitatively analyze rock mass structures using geophysical parameters, which is helpful for the prevention of geological disasters along the highway in the granitic area.

2. Study on granitic rock mass structures

2.1. Engineering background of the case study

The CSNS is a major national science and technology infrastructure project, the laboratory foundation of which is located in an area with slightly weathered granite (Fig. 2). A total of 278 drill holes and twelve geophysics lines were created because of the high standard of the foundation (the annual differential settlement of the tunnel foundation should be less than 0.5 mm and the annual average settlement should be less than 1 mm).

The construction site is approximately 400 acres. Most of the drilling holes are approximately 15–90 m in depth (30–80 m in the main equipment area). A considerable amount of data from the rock mechanics and physical experiments were obtained. At the same time, many drilling holes are opened on the geophysics lines (such as ZZK104, ZZK105 et al.). In this study, the data from the drilling holes and geophysical investigation were combined to evaluate the features of the rock mass.

2.2. Evaluation of granitic rock mass quality based on the RCI

2.2.1. RQD and RCI

The most common characterization of rock mass structures is the rock quality designation (*RQD*), which is an intuitive feature and can be tested simply. However, recognizing rock structures in drilling cores becomes difficult at greater depths, which means that the *RQD* often cannot exactly describe the structural features of rock mass. For example, the *RQD* is 100 when the average length of the rock core is 120 cm or 45 cm according to Table 1 (ZZK2, ZZK41), but the cores have quite different properties, such as the depth, seismic velocity and *UCS*. The *RQD* varies sharply for different rock mass structures (from 100 to 0 in ZZK41 and ZZK14) with the same boundary of 10 cm.

To exactly illustrate underground information, this paper considers reported results [2,13,14] and defines the Rock Core Index (*RCI*) based on the core length with six grades (1–3 cm, 3–10 cm, 10–30 cm, 30–50 cm, 50–100 cm and longer than 100 cm) ration to the length unit (2.5 m for CSNS) of research, which can described as follows:

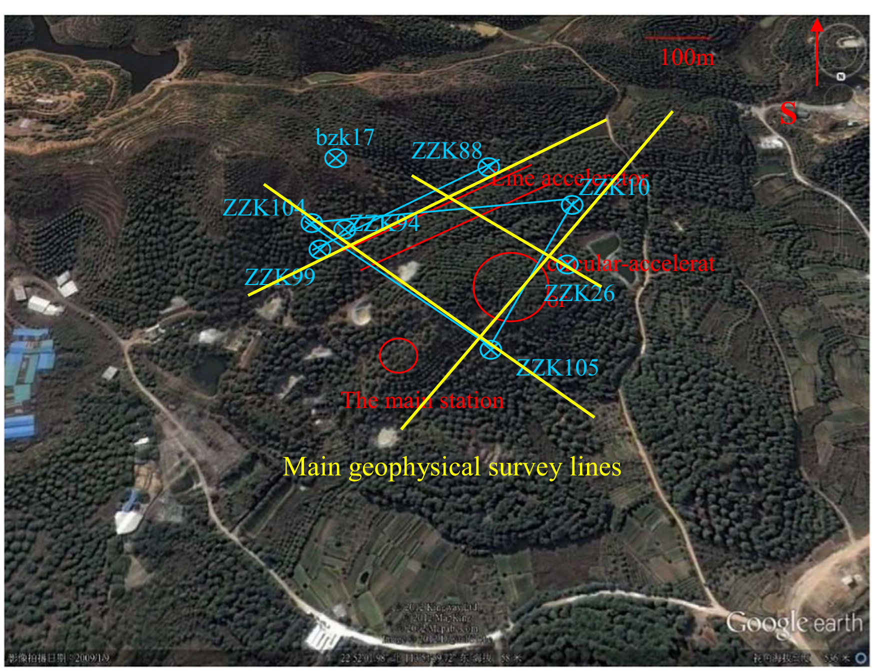

Fig. 2. Geomorphological map of the CSNS and key explored site.