International Journal of Rock Mechanics & Mining Sciences 75 (2015) 33–43

Contents lists available at ScienceDirect

International Journal of Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Ground characterization using breaking-action-based zoning analysis of rotary-percussive instrumented drilling

J. Chen [a,*], Z.Q. Yue [b]

[a] China Harbour Engineering Company, Beijing, China

[b] Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, China

ARTICLE INFO

Article history:
Received 14 March 2014
Received in revised form
24 November 2014
Accepted 28 November 2014

Keywords:
Ground characterization
Rotary-percussive drilling process
Breaking action
Zoning
Drilling process monitoring
Independent parallel drillhole logging

ABSTRACT

In this article, we conducted in-situ rotary-percussive instrumented drilling monitoring and associated data analysis in parallel to determine weathering grades of rock mass and their corresponding spatial distribution. The influence of the mechanism of percussive drilling on the variations of drilling parameters is discussed. Three kinds of breaking actions in percussive drilling were summarized based on over 600 monitored soil nail holes. On the basis of breaking action identification, we propose a new breaking-action-based zoning analysis to remove the variations of drilling parameters caused by percussive drilling itself, only leaving the rock-dependent variations. In a case study, we verified the ground characterization results using this methodology with two sets of parallel drillhole loggings. The comparison results showed that this methodology offers great potential in ground characterization.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Many researchers have practiced recording and analyzing drilling parameters in the oil, gas, mining and tunneling industries for a long time [1–8]. These existing technologies in monitoring drilling parameters provide some assistance in zoning soil and rock strata during construction with reduced cost by estimating rock strength [9] and detecting cavities in rocks [10]. The concept of monitoring drilling parameters was introduced into civil industry for ground investigation in the 1970s. Therefore, many researchers and engineers have tried to characterize the rock mass conditions through the measurement of drilling parameters.

A device named the Enpasol recorder was invented for vibro-percussive drill and rotary hydraulic drill. The drilling parameters including penetration rate, rotation speed, thrust and torque as well as others were monitored by this device at a given penetration depth interval during drilling. Researchers employed this device for soil/rock identification at dredging sites [11], soil improvement projects [12,13] and subsurface investigations in London [14,15].

Peck and Vynne [2] reviewed some drill monitoring systems used in Canadian mining industries. Their original system was termed as a drilling efficiency indicator (DEI). It was subsequently improved and renamed as Stratalogger II and Stratalogger Plus. These systems were used to monitor blasthole drills and to identify soft coal seams from surrounding hard waste rocks.

Fortunati and Pellegrino [16] introduced the so-called Papero system to monitor drilling parameters in ground investigation. The system was applied to continuous non-coring rigs for soil grouting treatment and rock mass characterization for fast construction. Garassino and Schinelli [17] used a similar system for monitoring of a number of tricone drillholes to detect cavities in a power plant project in Italy. They adopted an optimized drilling rig pressures and kept them as constant as possible during drilling.

Suzuki et al. [18] in Japan developed a soil survey system vehicle for seismic cone penetration test in combination with a rotary percussion drill without coring. A measurement-while-drilling logging device was equipped in the vehicle for measuring the soil resistance to the high-speed rotary percussion drill [19]. Zhou et al. [20] conducted automated rock recognition research to determine rock type and strength with the data collected from the blast hole drill performance. Ghosh et al. [21] applied this system to characterize the rock mass in Boliden Minerals Aitik Mine. Drilling rate and specific energy were used to describe how subsequent benches (upper and lower) were inter-related.

Although above devices were developed for different purposes and working conditions, they were all composed of three major parts: a graphical plotter, a micro-computer and an electronic control box and sensor systems for parameter monitoring. With the recording systems, the drilling parameters, such as drilling rate, torque pressure and thrust were monitored at pre-selected depth advancement increments. For example, the pre-selected

* Corresponding author. Tel.: +86 10 64174417; fax: +86 10 64174490.
E-mail address: jchen@chec.bj.cn (J. Chen).

http://dx.doi.org/10.1016/j.ijrmms.2014.11.008
1365-1609/© 2015 Elsevier Ltd. All rights reserved.

depth advancement increments were 5 mm in [11–15], 10 mm in [16,17], 25 mm in [18,19], 50 mm in [2], and 100 mm in [22].

The development of these depth based instrumented drilling devices needed some corresponding data treatment methods. But the results were not satisfactory. Cheetham and Inett [23] designed an experimental drilling rig for testing the performance of percussive drilling machines and for investigating the factors affecting percussive drilling of rocks, such as lubrication of a rock drill and effect of cuttings flush. They also summarized the relations between drilling parameters such as thrust, rotation and drill speed. This provided an idea to normalize the in-situ drilling data.

Pfister [12] described the recorded shapes of curves for silly surface deposits, clay layers, alluvium, empty cavity, unfilled fracture, plain massive limestone and fractured zone filled with clay and summarized three steps to analyze the raw data obtained from Enpasol recorder. He tried to characterize different rock and soil structures with drilling parameters. However, because the data were recorded by depth increments, the variations of drilling parameters resulting from percussive drilling could not be separated. The accuracy of this characterization was reduced.

Scoble et al. [24] discussed and summarized the characterization of dill performance parameters: thrust, rotary speed, circulating fluid flow rate, operating pressure, penetrating rate, torque and drilling fluid pressure. They also combined the laboratory study with the in-situ study to estimate drilling rate. They applied drilling rate log to detect shale bands. Upon comparison with the fractures logged from core, 60% of these were also indicated by a corresponding drilling rate peak. Because the drilling rate was estimated by a pre-selected depth advancement increment, different pre-selected increments could result in different drilling rate variations with depth for the same ground geological conditions. This undermined the application of this system to rock mass characterization.

Schunnesson [22] discussed and summarized the relation between pressures and drilling rate in percussive drilling and described the affection of hole depth to drilling parameters. He also suggested a data analysis method for separating rock dependent variation from other influences on the monitoring drilling parameters. It was based on a step-wise normalization of raw data, where hole length dependent variation initially was removed, followed by a normalization of the thrust dependent variation, and finally, by removing the influence of penetration rate on torque pressure. Furthermore, he separated the drill response into two independent signals, one representing the hardness of the rock and the other representing the inhomogeneity (fracturing) of the rock. These research efforts supplied a new idea for analyzing the variations of parameters. But the relations between drill parameters behaved differently at different weathered degree zones of rocks. This would cause errors in the data analysis. Different sources of errors such as wearing of bits or geological variations related to the different test sites in the mine would affect the component values by a change in levels. Such errors could be fatal to the possibility of a direct classification of rock type.

Despite these obvious efforts and achievements in the field of drill monitoring hardware and analysis method over the last two decades, instrumented percussive drilling has not become a standard method for ground characterization. One of the major reasons can be that the past studies apply the depth-sampling based instrumented drilling devices to estimate the drilling rate from the total time that is used for a pre-selected depth advancement increment. This would cause random variations in the measured drilling rates, because the drilling process during the drilling of the pre-selected depth advancement increment is not known.

2. Drilling process monitoring system

The research group of The University of Hong Kong (HKU) has placed great efforts on in-situ techniques for automatic monitoring [25–27] since 1998. In 1998, HKU launched a project to develop an automatic monitoring system to measure soil nail drilling process. Since then, an automatic digital drilling process monitoring (DPM) methodology have been developed and verified to quickly characterize rock mass in the ground. The DPM methodology includes a hardware system for in-situ automatic monitoring and recording of drilling parameters in real time sequence (see Fig. 1) and a software package for analyzing and presenting the digital data in time series.

Up to date, we have monitored the full drilling processes in time sequence for more than 600 production holes of soil nailing during the construction in weathered rock slopes in Hong Kong. Based on the analysis to monitoring data, many progresses have been made in this field. To locate soil and rock boundaries, Yue and Lee et al. [25] developed preliminary correlation between weathering grades of

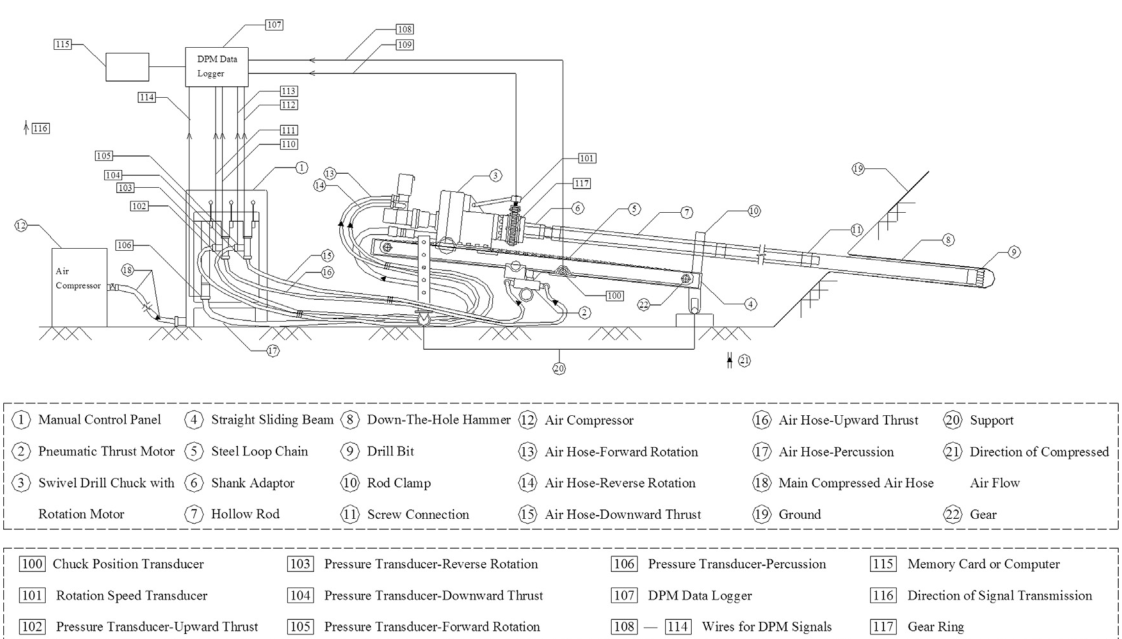

Fig. 1. DPM integrated data logging system and pneumatic rotary-percussive drilling machine.

Download English Version:

https://daneshyari.com/en/article/7206586

Download Persian Version:

https://daneshyari.com/article/7206586

Daneshyari.com