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Characterization of rock slopes through slope mass rating using 3D point clouds

Adrián J. Riquelme [a,*], Roberto Tomás [a], Antonio Abellán [b]

[a] Departamento de Ingeniera Civil, Universidad de Alicante, Alicante, Spain
[b] Risk Analysis Group, Institut des sciences de la Terre (ISTE), Facult des Gosciences et de l'Environnement, Universit de Lausanne, Unil-Mouline, Geopolis, 1015 Lausanne, Switzerland

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ABSTRACT

Rock mass classification systems are widely used tools for assessing the stability of rock slopes. Their calculation requires the prior quantification of several parameters during conventional fieldwork campaigns, such as the orientation of the discontinuity sets, the main properties of the existing discontinuities and the geo-mechanical characterization of the intact rock mass, which can be time-consuming and an often risky task. Conversely, the use of relatively new remote sensing data for modelling the rock mass surface by means of 3D point clouds is changing the current investigation strategies in different rock slope engineering applications. In this paper, the main practical issues affecting the application of Slope Mass Rating (SMR) for the characterization of rock slopes from 3D point clouds are reviewed, using three case studies from an end-user point of view. To this end, the SMR adjustment factors, which were calculated from different sources of information and processes, using the different softwares, are compared with those calculated using conventional fieldwork data. In the presented analysis, special attention is paid to the differences between the SMR indexes derived from the 3D point cloud and conventional field work approaches, the main factors that determine the quality of the data and some recognized practical issues. Finally, the reliability of Slope Mass Rating for the characterization of rocky slopes is highlighted.

1. Introduction

Rock mass classification systems are well-known tools which are useful for characterizing rock mass properties, in order to assign an 'index of quality' for stability purposes. These tools are used worldwide by geo-mechanical engineers in the design or pre-design stages of civil or mining projects. Existing classification systems analyse the most significant parameters responsible for influencing the behaviour of a given rock mass and providing a quantitative rating from qualitative observations. The main advantage of these classification systems is the use of straightforward (even simplistic), arithmetic algorithms for quantifying the rock mass quality. Since they have been widely applied in the past through a plethora of case studies, the use of rock mass classification systems constitute an effective way of representing the quality of the rock mass [1].

Rock Mass Rating (RMR) [2,3] along with *Q* [4] is one of the most widely used rock mass classification systems [5]. This classification was initially developed for tunnels. Although the RMR index has been applied to rock slopes and foundations, its application is hard, as there is no exhaustive definition for the selection of the correction factors [6]. Based on this, Slope Mass Rating (SMR) provides comprehensive adjustment factors to RMR system [7,8]. These adjustment factors depend on the geometrical relationship between the rock mass discontinuities and the slope, as well as the excavation method.

The parameters required for rock mass characterization are usually acquired through time-consuming field investigation techniques: geological compass for obtaining discontinuity orientations, tape measurements for discontinuity spacings or persistence and roughness analysis by local examinations. Sometimes, fieldwork campaigns can be affected by several restrictions, being well-known examples, such as, safety issues in active rockfall areas, possible access limitations and intensive work requirements in highly fractured rock masses. More recently, several attempts have been made to determine the rock mass quality using remote sensing data [9,10] or

* Corresponding author.
E-mail addresses: adririquelme@ua.es (A.J. Riquelme), roberto.tomas@ua.es (R. Tomás), antonio.abellanfernandez@unil.ch (A. Abellán).
URLS: http://personal.ua.es/en/ariquelme (A.J. Riquelme), http://personal.ua.es/en/roberto-tomas (R. Tomás), http://www.3d-landslide.com (A. Abellán).

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digital pictures [11]. The use of remote techniques (for example, 3D laser scanner and digital photogrammetry) allows for the acquisition of three dimensional information of the terrain with high accuracy and high spatial resolution. Three-dimensional datasets coming from both techniques are widely used for landslide investigations [12,13]. Moreover, the scientific community is showing an exponentially growing interest in the study of the extraction of several parameters influencing rock slope stability, including rock mass discontinuity orientations [14–23] and other rock mass parameters: spacing between discontinuities [24,14,25], discontinuity persistence [26,18,27] and roughness [28,26,29,11].

In this work, the practical issues for the characterization of rock slopes by means of the SMR index are reviewed, using three case studies. The sources of information being used are 3DPC datasets combined with information acquired through traditional methods. Basic RMR index is calculated, using the fieldwork data. The main aim of this work is the analysis of SMR adjustment factors, and how the use of the different sources of information affects SMR index, and thus, the slope of characterization. To achieve this, an open source tool has been developed. It is programmed in MATLAB, and is able to calculate the SMR adjustment factors, including the auxiliary angles and their graphical interpretation.

This paper, has been organized in the following way: (a) An explanation of the methodology used, which is included in Section 2; (b) a description of the three case studies in which the method is applied in Section 3; (c) an application of the three case studies is presented in Section 4; and finally, (d) a summary of the results along with a discussion of the developed approach is presented in Sections 5 and 6, respectively.

2. Proposed methodology approach

2.1. General overview

The methodology presented in Fig. 1 uses 3D point clouds (which would be subsequently called 3DPC in this work), which is acquired, by remote imaging techniques (that is 3D laser scanner or digital photogrammetry) and the basic RMR parameters, obtained by means of conventional field surveys as input data. The calculation of SMR is performed following three main steps: (a) 3D data acquisition, (b) extraction of geometrical information, and (c) computation of SMR value, as explained below:

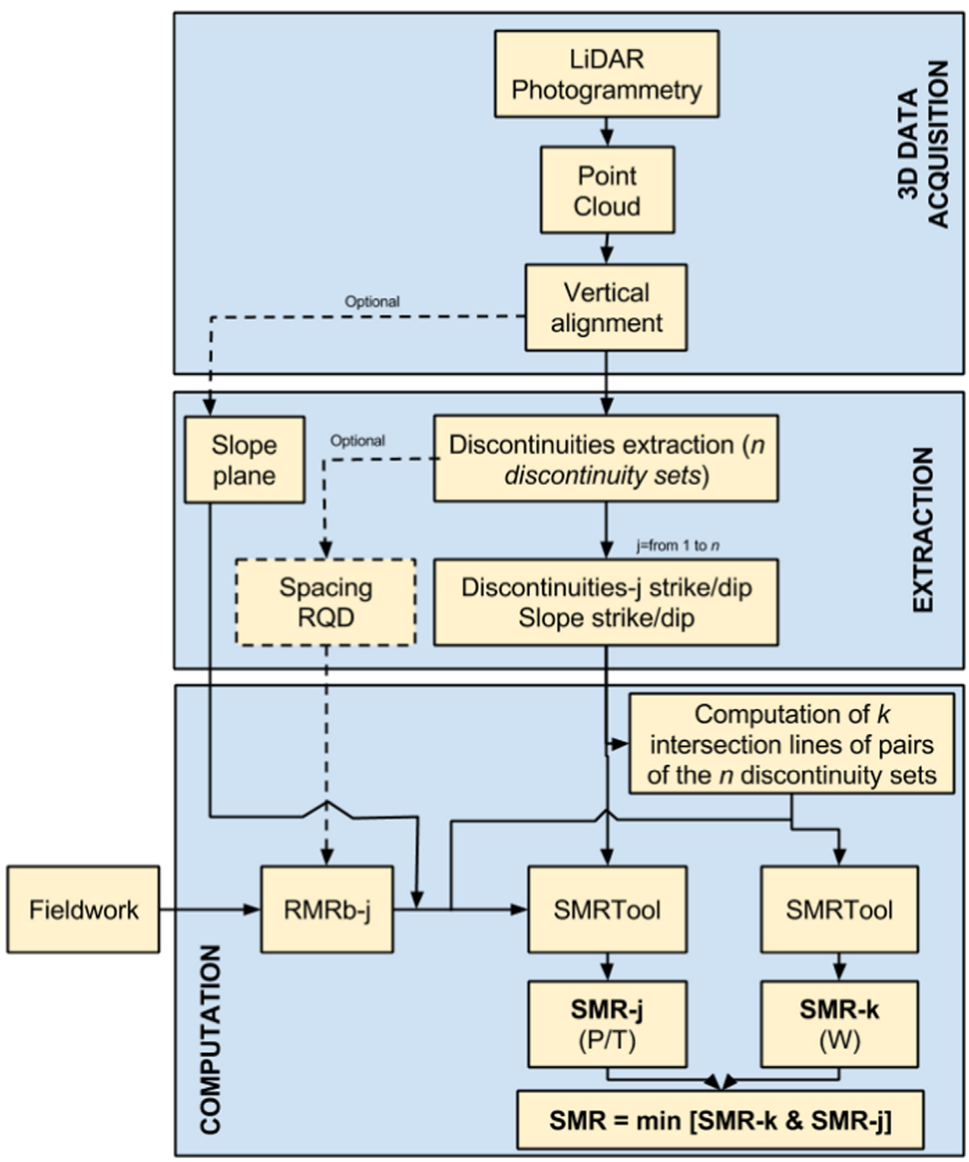

Fig. 1. Flowchart of the methodology used. P: planar failure; T: Toppling failure; and W: wedge failure.