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Evaluation of Slope Stability by the In Situ Monitoring Data Combined with the Finite-Discrete Element Method

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Abstract

We examine the stability of an ancient slope located at Jietai Temple in western Beijing of China, by using the remote monitoring system of sliding force combined with the combined finite-discrete element method (FDEM) as well as the field surveys. Potential pre-existing joints in the slope were firstly determined by the in situ study and rock mass mechanical properties were then estimated to be taken as input parameters in the numerical modelling, for understanding the instability mechanism of the slope. Results from this synthetic assessment together with the monitoring data suggest that current protection measures in the slope may not be sufficient so that the local authorities should define hazard zones and work out further development plans for the Jietai temple.

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Keywords: the combined finite-discrete element method (FDEM); remote monitoring system; landslides; early warning

1. Introduction

Limit equilibrium method and numerical modelling techniques are the most commonly used methods in the evaluation of slope stability. To complex rock and soil slopes, numerical approaches such as finite element and finite difference methods may be more suitable due to their flexibility when applied to simulate in situ stresses, loading condition, and multi-field interactions. Even though numerical modelling of rock slopes is commonly implemented by continuum approaches [1–4], features such as fracture, fragmentation, and crack propagation within

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rock mass extended to a computer code is very much appreciated to better describe the unstable process characteristics of rock slopes. The underlying geological data including fault, joint, foliated structure, and underground water table are required to be as the input parameters in the model to determine and calibrate the mechanical properties of rock masses in the numerical modelling of rock slopes. These in situ data together with monitoring information can further help to improve numerical modelling for providing the more reasonable prediction of the failure behaviours of rock slopes [5–7].

In the present report, we examine the stability of an ancient slope located at Jietai temple in western Beijing of China (Fig. 1) by using the field investigation, the monitoring technologies, and the combined finite-discrete element method (FDEM) [8]. Our work aims to help local authorities to define potential hazard zones of the region where Jietai temple locates and develop available plans for the reinforcement and early warning systems of the slope stability.

2. Site overview and geological setting

Jietai temple is situated on the Saddle Mountain north of northwest 35 km far from Beijing and has been with history dating back over 1400 years (Fig. 1). It is on an ancient slope of the approximate N-S trending Mountain Ridge, at an approximate elevation of 400 m above the Mountain floor. The slope is composed by four level plateaus whose elevation is progressively reduced from south to north and overall slope angle is about 20–40 degrees.

The ancient landslide that holds an integrity structure has a relative single lithology, where shale with extremely poor ductility represents that of the majority, with less structure planes (usually less than 3 sets) and slightly tectonic deformation. Additionally its structure closure is dominant and there is almost with little infilling or with a little inclusion in the rock masses, which are distributed on the surface below 30 m. Secondly, the broken rock structure that is mainly made of sandy shale and shale is with the characters of strongly broken rock masses and various structure planes developed, which are cut off and infilled each other, due to human beings activity and underground mining. The patterns of the structure planes are rather different and the smoothness is also varied. Such rock masses are mainly situated on the surface below the range of 5–30 m. Thirdly, the very loose rock masses that are also known as the loose slope deposition are with the characters of extensively developed joints and cleavages, which are at the state of mud mixed with small rock blocks due to the strength softening of sandy shale and shale induced by rainfall precipitation, sunlight, and weathering. Such rock masses are mainly distributed on the surface below the range of 0–5 m uniformly. Fig. 2 shows that the simplified concept model of the slope is based on Fig. 1, in which the geological settings and geological strength index (GSI) [14] are presented. The latter is well known as one of the classifications of rock mass quality. Generally, the intact rock masses are typically with GSI≥60, but the jointed rock masses or soil-like materials are with GSI≤30. However, some of the rock mass quality in terms of GSI is between 30 and 60.

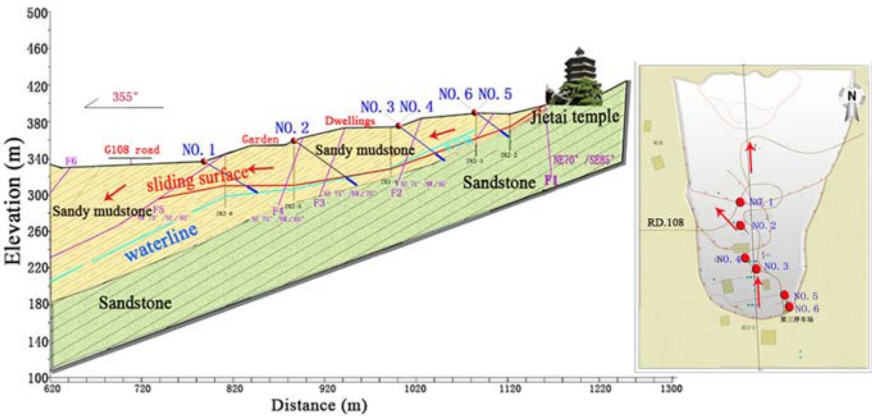

Fig. 1. Location of the study site of Jietai temple on an ancient slope (the left side is the model section and the right indicates the location map).