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Measurement of displacement for open pit to underground mining transition using digital photogrammetry

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A B S T R A C T :
The newest digital photogrammetric technology is applied to investigate the deformation characteristics of rock mass when it changes from open pit to underground mining. First, the calculation formulas of pixel deformation and instrumental error were derived. Based on this, the calculation of digital camera calibration were obtained and used to calibrate the physical model for rock mass undergoing the changing mining process. Finally, the deformation characteristics of rock mass were revealed based on a geotechnical engineering of Daye iron mine and the monitored results of digital photogrammetry were compared with the dial indicators. It was found that the surface deformations measured by digital photogrammetric technique are similar to the results using dial indicators. The maximum error between these two was less than 0.02 mm. These tests demonstrate the efficacy of digital photogrammetry as a powerful technique for deformation measurement in the geotechnical model tests.

Keywords:
Open-pit to underground transition, Deformation characteristics, Measurement technique, photogrammetry, Model test

NOMENCLATURE			
E	Elasticity modulus（Mpa）	σ_t	*Tensile strength（Mpa）*
C	*Cohesion（Mpa）*	σ_c	*Compressive strength（Mpa）*
R	*Similarity ratio*	*X,Y,Z*	*Coordinates of a point in the object space coordinate system*
Xs,Ys,Zs	*Coordinates of a perspective center in object space coordinate system*	*x,y,z*	*Coordinates of a point in the spatial coordinate system*
φ，ω，ξ	*Angle between light beam toward centre points and the coordinate axis*	S_0	*Distance of centre points between the photo object and focal plane of camera*
Greek Symbols			
φ	Internal friction angle	γ	Specific weight（KN/m^3）
ε	Strain modulus（Mpa）		

1. INTRODUCTION

In recent years, more and more high-steep slopes were formed through years of open-pit mining around the world. Open pit to underground mining transition is normally resulted from exhausting of shallow resources [1, 2, 3, 29]. This is quite dangerous as it may threaten the stability of high-steep slopes [49]. In order to ensure safety production of those mines, many research methods were adopted to investigate the stability of high-steep slopes influenced by underground mining. Examples include limited equilibrium method [4, 5], block theory [6], fuzzy mathematics [6,12], neural network theory [7], finite element method [8, 42,45], neural networks [10], as well as finite difference method [11, 40] in evaluating the stability and failure of high slopes induced by mining.

Despite all the applied techniques, the model test is usually an appropriate procedure that is required in engineering practices. Reliable model test can accurately simulate the real strata movement influenced by engineering activities and therefore provide adequate engineering suggestions [13, 30, 43, 48]. It should be noted the precision and accuracy of model test largely relies on measurement and experimental technology. However, common measurement equipment [14, 15, 16, 41] such as dial indicators and undersurface displacement meter can hardly measure the real-time deformation changes of high-steep slopes during the model testing. As a new non-contact

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