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Review Article

ANALYTICAL RESULTS OF SLOPE FAILURE AND EFFECTIVE USE OF FLYCAM DATA: A CASE STUDY FROM KM 11 TO KM 13 ON THE 3B HIGHWAY, BACKAN PROVINCE OF VIETNAM

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ABSTRACT

This paper presents some analytical results of the physico-mechanical properties of typical three soil samples which are collected on the weathered layer surface and their relation to slope failure at the survey sites: M-02, M-03 and M-05, from km 11 to km 13 on the 3B highway, belong to Backan province of Vietnam. By using the Geoslope/W software, the analyses have determined the safety factor (Kmin) at three above survey sites to be 0.749, 0.660, 0.854. The topographic cross sections are used to calculate the safety factor using software to be flycam data. The obtained results from this paper have important significance for analyzing and predicting the slope failure on the other slope surface have similar properties.

Keywords: flycam, Geoslope/W, slope failure, safety factor, 3B highway

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INTRODUCTION

The 3B highway is a road which is connected among the three provinces of Lang Son - Bac Kan - Tuyen Quang with a length of over 200km. In the study area, the road cut through Backan province. The slope surface has high angle, in the rainy season it often happen failure, causing traffic congestion and affecting people and vehicles. Recently, on July 29, 2018, there are about tens of stone fell down from the slope surface to fill the road line. Especially, at about 20:00h on March 14, 2019 a large amount of the weathed layer from the slope surface suddenly fell down, buried about 1/3 area of the house's Mr. Hoang Van Viet, killed 02 sleeping grandchildren. This can be seen that the occurrence of slope failure is not only problem for the 3B highway in Backan province but also for all roads in the mountainous provinces of Vietnam.

The studies of slope failure in Vietnam has been carried out in recent years, based on the approaches and different methods. Some typical studies are: [3] suggested that the slope failure on the roads in mountainous areas of Quang Binh province are due to geological structure, topographic characteristics, weathering process, rainfall and slope cut. The studied results have emphasized the important role of rain in slope failure. [1] used the multipole measurement method to determine the failure blocks on the 4D highway, Mong Sen bridge area. [2] suggested that saturated soil was the cause of slope failure of weathered layer along the Ho Chi Minh highway, the section belong to Quang Binh - Thua Thien Hue province and it had a decisive role for the failure phenomenon was due to heavy rains in many days, causing the changes of physico-mechanical properties of weathered layers. Recently, [4] used GeoStudio software with SLOPE/W module to audit the slope stability from sections. The study results are the basis to propose the slope stability design to minimize the impact of landslides. [5] used Geostudio software to analyze the slope stability and indicated that the need to select a reasonable anti-slip coefficient.

In this paper, the we present some analytical results of slope failure along the 3B highway, the section from km 11 to km 13, belong to Backan province, according to the analytical results of physico-mechanical properties which obtained from three survey sites: M-01, M-02, M-05 and flycam data by using GeoSlope/W software.

MATERIALS

A. Field survey data

The field survey was carried out on the 3B highway, the section from km 11 to km 13, belong to Backan province, including: observation, description and sample collection where slope failure (Tab. 1).

Table 1. information of survey locations along the 3b highway, section from km 11 to km 13 belong to backan province

No	Survey site	Longitude	Latitude	Description
1	M-01	22°06'28.6''	105°58'38.2''	Sandy clay, yellow-brown, red-brown, blue- gray, stiff.
2	M-02	22°06'29.5''	105°58'34.7''	Sandy clay, yellow-brown, red-brown, blue- gray, with gravel, stiff.
3	M-03	22°06'29.5''	105°58'34.7''	Sandy clay, yellow-brown, red-brown, blue-gray, with gravel, very stiff.
4	M-04	22°06'29.9''	105°58'33.4''	Sandy clay, yellow-brown, red-brown, blue-gray, very stiff.
5	M-05	22°06'28.9''	105°58'31.5''	Sandy clay, yellow-brown, red-brown, blue-gray, very stiff.

The analytical samples is used in this paper, collected at the failure site in Figure 1.

Fig.1: (a) sampling site M-05; (b) sampling site M-02

B. Flycam data

In the study, we used flycam Inspire 1, which are equipped the high-precision of GPS, gimble anti-vibration for camera and high-definition cameras (Fig. 2).

Fig.2: Flycam Inspire 1

The image processing is carried out by using the automatic Agisoft Photoscan software, version 1.1.0 and Surpac software, version 6.5.1. The analytical results are shown in Figure 3.

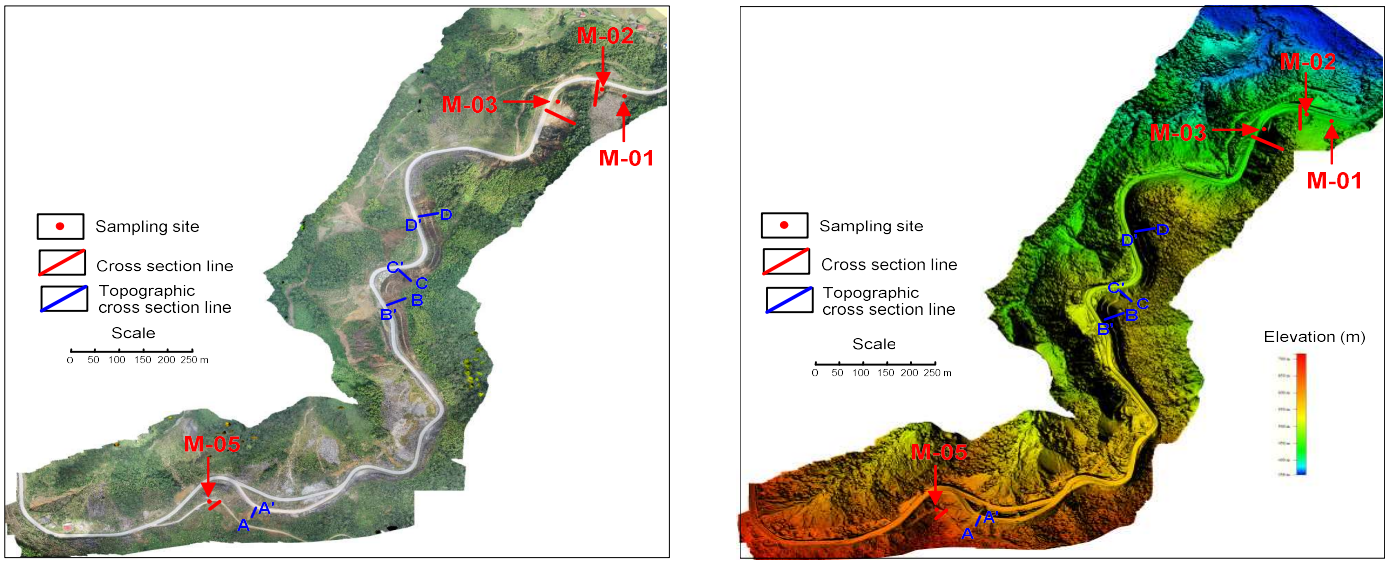


Fig.3: Photo of 3B highway, section from km 11 to km 13 belong to Backan province is taken by flycam and it's topographic 3D model

Topographic image obtained from analyzing flycam data in the study area has identified many slope failure points (5 failure points) at the elevation within 440 and 660m. The analytical results from flycam data are an important data source for building standard terrain cross section.

ANALYSIS RESULTS AND DISCUSSIONS

A. Analytical results

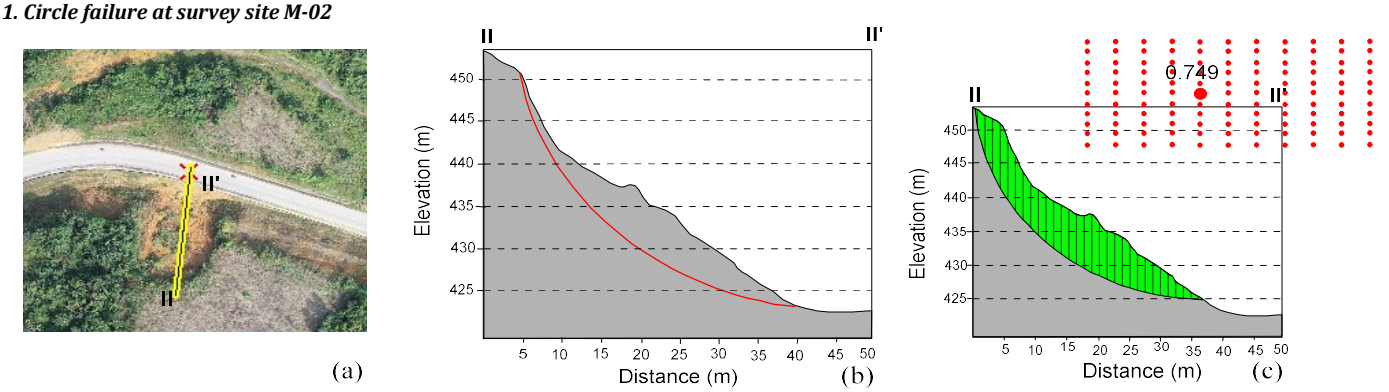
The analyses of physico-mechanical properties of each sample are carried out by using direct shear test from machine ZJ-2. The obtained results include the parameters: internal friction angle (phi), cohesion (c) and unit weight (γ) (Tab. 2).

Table 2: Analytical results of physico-mechanical properties

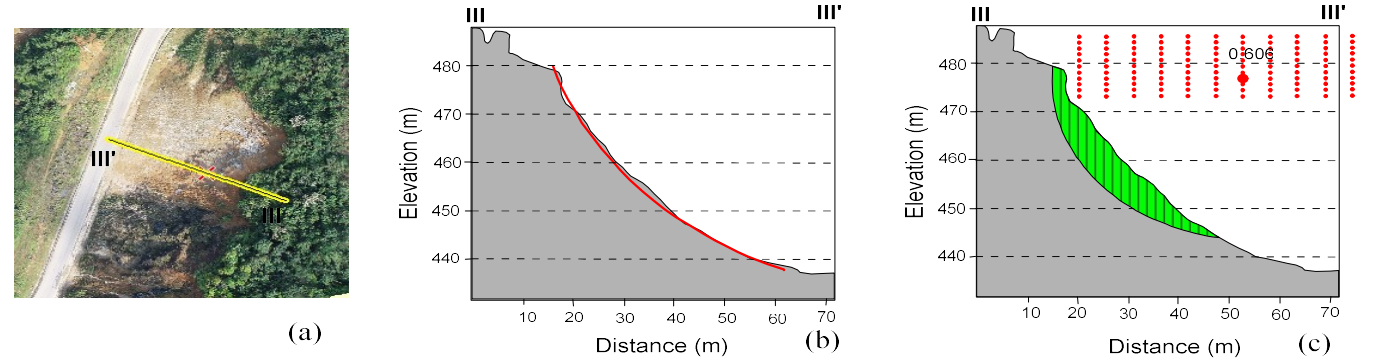
No	Survey site	Internal friction angle (phi) (degree)	Cohesion (c) (kPa)	Unit weight (γ) kN/m³	Factor of safety
1	M-01	11	25.5	16.5	
2	M-02	16	18.2	18.2	0.749
3	M-03	17	22.6	18.6	0.660
4	M-04	18	22.6	17.8	
5	M-05	13	30.4	18.9	0.854

The calculation of slope stability is conducted based on Geoslope/W software with input parameters, including: internal friction angle (phi), cohesion (c) and unit weight (γ) from Table 2. The calculated results of the safety factor (Kmin) of circle failures at survey sites: M-02, M-03 and M-05 are shown in Figure 4:

1. Circle failure at survey site M-02



2. Circle failure at survey site M-03



3. Circle failure at survey site M-05

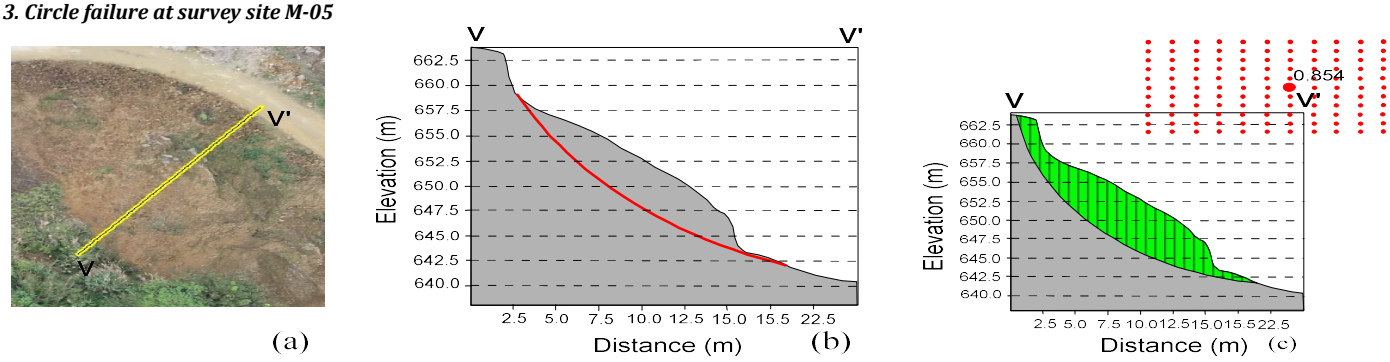


Figure 4. 1) Circle failure at survey site M-02; 2) Circle failure at survey site M-03; 3) Circle failure at survey site M-05

Figure 4 presents the typical cross sections of circle failure at three survey sites: M-02, M-03 and M05. In which, a) photo of the slope failure and the cross section line which perpendicular to the slope surface; b) current cross section which is drawn from flycam data; c) predicted model of the circle failure that can occur on the slope surface which is simulated from cross section of b).

B. Discussions

The 3B highway, the section from km 11 to km 13 cut through the sedimentary rocks of Na Quan formation ($D_{1\text{-}2}nq_1$), consist of shale interbeded with limestone. The rocks are strongly weathered with thickness varying from 2-3m to over ten meters. The composition of the weathered layer is mainly clay yellowish brown, reddish-brown, blue-gray, with gravel. In the rainy season, this area often happen failure.

On the 3B highway in the study area, the slope surface has slope angle that varies from 40^0 to over 50^0 (Figure 5). The experimental results: Internal friction angle (phi), Cohesion (c), Unit weight (γ) obtained from three above samples have shown that these slope surfaces have a high risk of landslides. Similarly, the predicted failure curve at each slope surface have also determined the value of the safety factor Kmin =0.867 (Fig. 6).

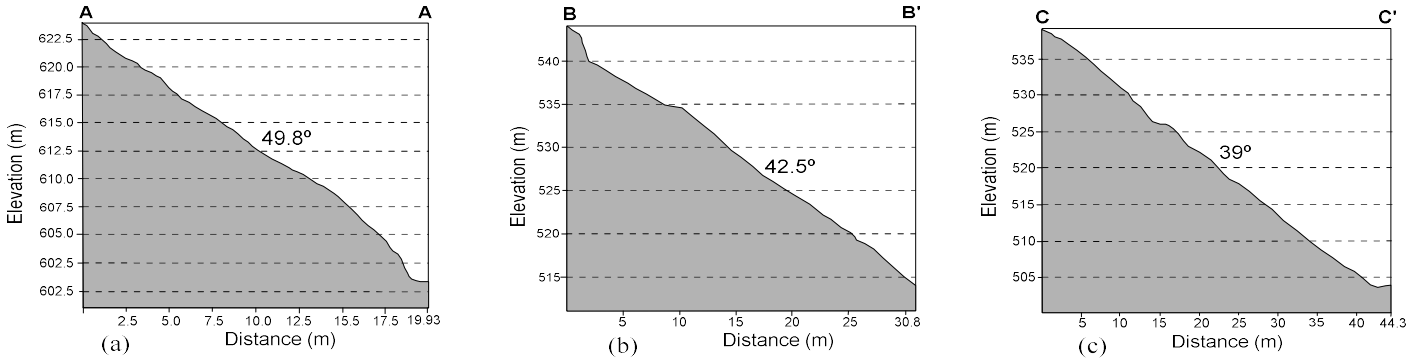


Fig.5: Topographic cross section at survey sites: A-A', B-B' and C-C'which are draw from flycam data, along 3B highway, from km11 to km13, belong to Backan province (Fig. 3)

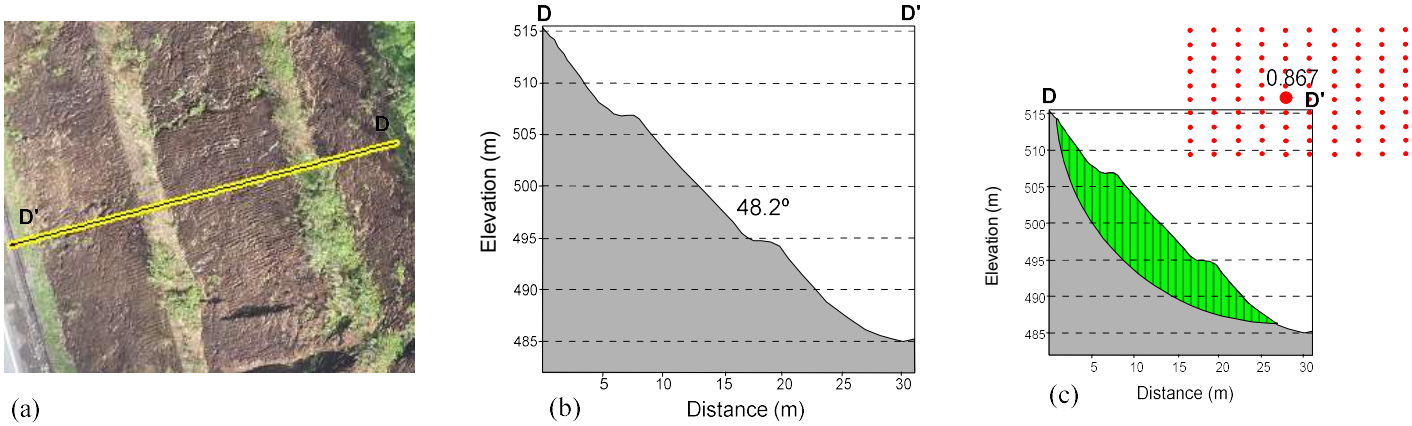


Fig.6: a) photo of the slope surface and the cross section line which perpendicular to the slope; b) current topographic cross section which is drawn from flycam data; c) predicted model of the circle failure according to internal friction angle (phi)= 17 (degree), cohesion (c)= 22.6 (kPa), unit weight (γ)= 18.6 (kN/m³) that can occur on the slope surface is simulated from the cross section of b).

CONCLUSIONS

The analytical results of physico-mechanical properties of soil on the weathered layer at three survey sites: M-02, M-03 và M-05, the section from km 11 to km 13 on the 3B highway belong to Backan province of Vietnam using Geoslope/W software with the input parameters including internal friction angle (phi), cohesion (c), unit weight (γ) have determined the safety factor (Kmin) of three survey sites to be 0.749, 0.660, 0.854. The safety factor (Kmin) values are almost below 1, belong to the threshold has high failure risk. Based on the flycam data and the experimental analysis results at three survey sites: M-02, M-03 and M-05, some circle failure predicted has been determined safety factor (Kmin) = 0.867. These results are the basis for managers to build reinforcement and slope protection plans.

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