Invited Paper

IDENTIFATION OF LANSLIDE DIMENSION BASED ON SEISMIC REFRACTION SURVEY IN TENGKILK VILLAGE, KARANGANYAR, CENTRAL JAVA

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Abstract

A seismic refraction survey was conducted at a landslide site, which had destroyed a road and several houses in Tengklik Village, Karanganyar, Central Java, Indonesia. The survey provided insight into the slope stratigraphy, as well as the dimensions of sliding area and depths of the slope failure planes. Field observations and drill-hole data were used to verify the accuracy of seismic refraction data. The seismic velocity measured in the top - sliding layer of sandy silt was less than 900 m/sec, while that in the underlying layer of silty sandstone ranged from 2400 to 900 m/sec. The stable bedrock of andesite breccia underneath the sliding soil layers was about 2500 m/sec. It was apparent that the failure surface was irregular, varies in depth. This failure plane exists at the contact of the andesitic breccia (bedrock) and the sliding layer of silty sandstone. The thickness of the sandy silt ranged from 3 to 5 m at lower part of sliding mass, while at the upper part ranged from 4 to 8 m. The estimated depth of the failure surface ranged from 12 to 24 m. The volume of mass movement is estimated about 111.386 m^3. It was also found that the presence of mountain block at the bedrock of andesitic breccia may resist the movement.

Keywords: Seismic refraction, Sliding surface

Introduction

Tengklik village is located in Karanganyar Regency of Central Java Province. This village is sited in the west slope of Lawu Volcano. The topography is predominated by hilly area with high fertility and thick soil. In addition, this area also has high rainfall intensity causing the area to become susceptible to landslide. Landslide mapping conducted by Geological Engineering of Universitas Gadjah Mada in 2006 showed that Karanganyar area can be divided into several zones of landslide susceptibility, from low to high susceptibility. The research area, Tengklik village, falls into the high susceptibility category.

On February 2009, a considerably large landslide occurred in Tengklik village. The movement was initiated by the development of a 30 cm deep and 2 meter long tensional crack. Since then, the number and geometry of tensional crack increased inducing a 450 cm deep

downward land movement. As a result, ten houses were damaged and ten families had to be relocated. The landslide type was apparently developed as a progressive soil creep, with the potential risk for human life and property damage in the downstream area. To mitigate the landslide therefore, it is necessary to know the dimension of vertical and horizontal movement of this creeping. One of the methods to identify the subsurface dimension is by using geophysical survey such as seismic refraction, which is also calibrated with two drilling holes.
This paper addresses the implementation of seismic refraction to support the analysis for estimating landslide geometry and movement, as a part of the mitigation of landslide risk in this area.

Methodology

The research was conducted by field investigation and seismic refraction survey. Seismic refraction is a technique that has been used to investigate landslides since the early 1960's. Refraction surveys have been used to estimate depths to the failure surfaces and the lateral extent of landslides [1]. The basis of the interpretations is the difference in the physical properties of the sliding materials and the underlying undisturbed sediments or bedrock that result in different seismic velocities [2]. Some advantages of refraction surveys in landslide investigations over other methods are the environment is not disturbed, the equipment is portable, and the technique is relatively in-expensive [3]. Intercept-time and reciprocal methods of interpreting refraction data can be used to model velocity structures of some landslides. These methods are most applicable to sites where subsurface layer dip less than approximately 20° and have nearly uniform velocities. These methods assume a layered model and continuity of refractor surfaces across a profile. However, the velocity structures of landslides can be complex, making them difficult to accurately model using intercept-time and reciprocal methods. Lateral and vertical changes in velocity, steeply dipping and discontinuous refractors, and also diffractions from blocks within the landslide mass, are the features commonly observed in refraction surveys of landslides.

The seismic survey, which was conducted to determine the subsurface conditions, employed PASI^{tm} seismic data logger with a 24 channel, geophone equipments and GPS. Seismic refraction measurements in the research area were carried out for a total line of 600 meters which was divided into 6 measurement channels, as shown in Figure 1. The seismic refraction measurements used several geophones which were configured in one straight line. Directions of the seismic lines were determined based on the geological conditions of the research area. It aims to obtain a combination of engineering geological investigations with seismic refraction data for determining the subsurface conditions at the project site. The lines and directions of the seismic survey are shown in Figure 1. Acquisition parameters used in the seismic survey are listed in Table 1. Figure 2 shows activities during the seismic survey.
A result of the seismic survey was verified with the field investigation which involved data collection of geomorphology, lithology, geological structure and two drilling log data from this area.

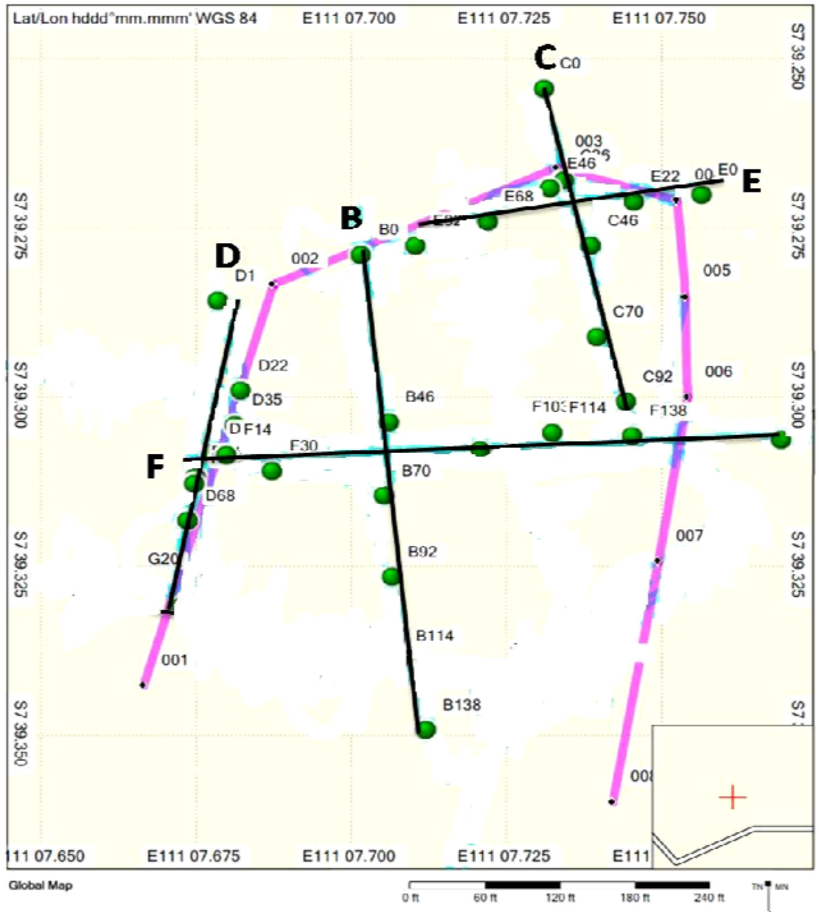

Figure 1. Seismic Lines at Tengklik Village

(B70 means Line B at pack number 70m; Purple Line shows the route for surface landslide and black line indicates the survey line)

Table 1. Acquisition Parameters

Parameter		Value
Array	:	In Line Spread
Num Geophones	:	24 (0 – 46) meter
Geophone Spacing	:	2 meter
Shot per spread	:	7 shot
Shot position	:	-11, 0, 11, 23, 35, 46, 57 m
Overlap per spread	:	1 geophone
Gain	:	Automatic
Sampling time	:	250 microseconds
Recorded per shot	:	2048 data
Source	:	Hammer 10kg

Figure 2. Seismic refraction survey
(a) PASI^{tm} seismic data logger; (b) Geophone (yellow equipment); (c) Seismic line; (d) Hammer to make a source of vibration.

Result and Discussion

The engineering geological map of research area is shown in Figure 3 consists of three soil/rock units, i.e. sandy silt, silty sandstone, and andesite breccia units [4]. According to the two drilling log data in Figure 4 shows the youngest unit is the 4 – 7.5 meter thick of sandy silt. The sandy silt unit has an intermediately weathered up to residual soil condition [5]. The second unit is the 3 – 5.5 meter thick silty sandstone. It has highly weathered condition, intermediate – rather loose compactness's and intermediate hardness. In this rock unit, andesite fragments are found in 7.5 meter – 12.5 meter depth. Andesite breccia is the oldest rock unit which has thickness of more than 7 meter. Fragments of this unit are andesites having pebble to gravel sizes and volcanic sand matrix. From drilling log correlation in Figure 4 also shows that a thickness of sandy silt is become thinner to the down slope.

Surface investigations of the crack structures in the research area showed that most cracks had an N100^{o}E orientation, which was relatively parallel to the mountain, as shown in Figure 3. The cracks ranged from 3 to 5-meter long or larger and up to 5-15 cm wide. Every 10-meter distance, 2 to 5 cracks were found. The numbers of the cracks were larger at the landslide crown.

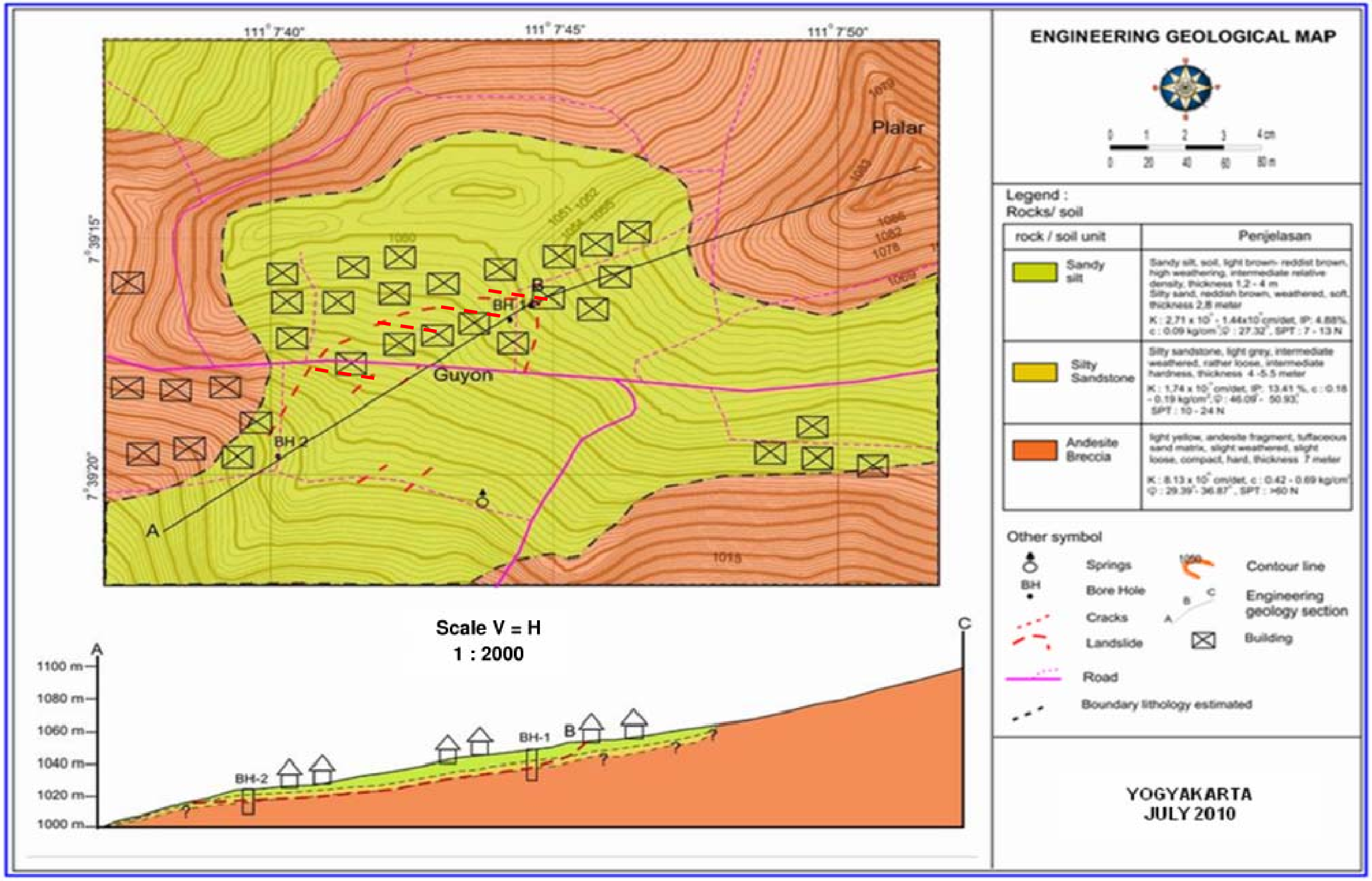

Figure 3. Engineering Geology Map[4]

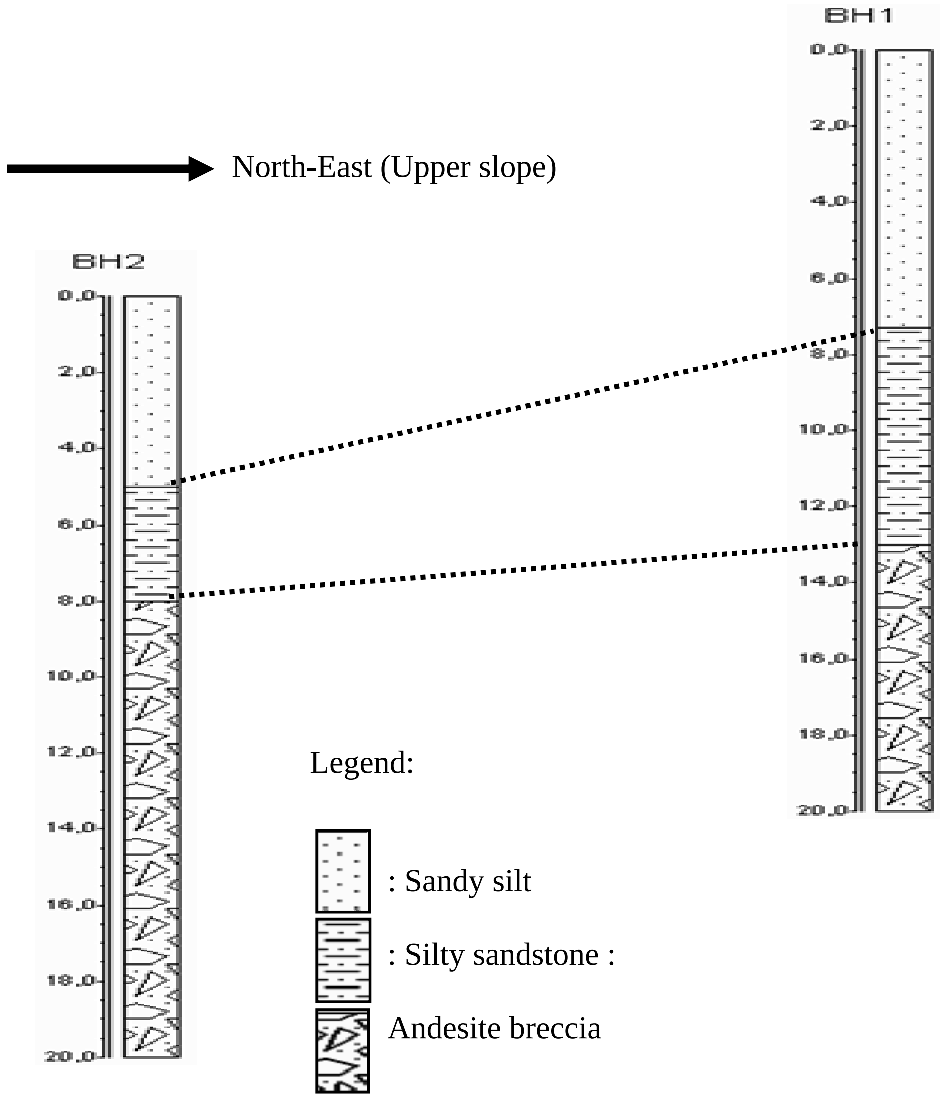

Figure 4. Correlation of drilling log data

Figure 5 shows the graph of travel time velocity versus distance obtained from the seismic survey that can be used to interpret the sub-surface condition. Based on the patterns of the travel time (blue, green-yellow, and red-pink colors), it can be identified that there are at least three different rock units in the research area, as follows:

a. Rock unit with a travel time velocity more than 2400 m/s (blue color) is interpreted as bedrock with a depth varies between 10-40 m from the ground surface. This unit consists of andesite breccia of low weathered to fresh.
b. Rock unit with a time travel velocity 900 - <2400 m/s (green – yellow color) is located above the bedrock and has a thickness varies from 5-20 m, with an average thickness of 15 m. This unit consists of silty sandstone, which is a product of light weathering of andesite breccia.
c. Rock unit with a travel time velocity less than 900 m/s (red- pink color) is started at a depth of 0 - 17 m, with an average thickness of 10 m. This unit consists of sandy silt, which is a weathering product of andesite breccia.

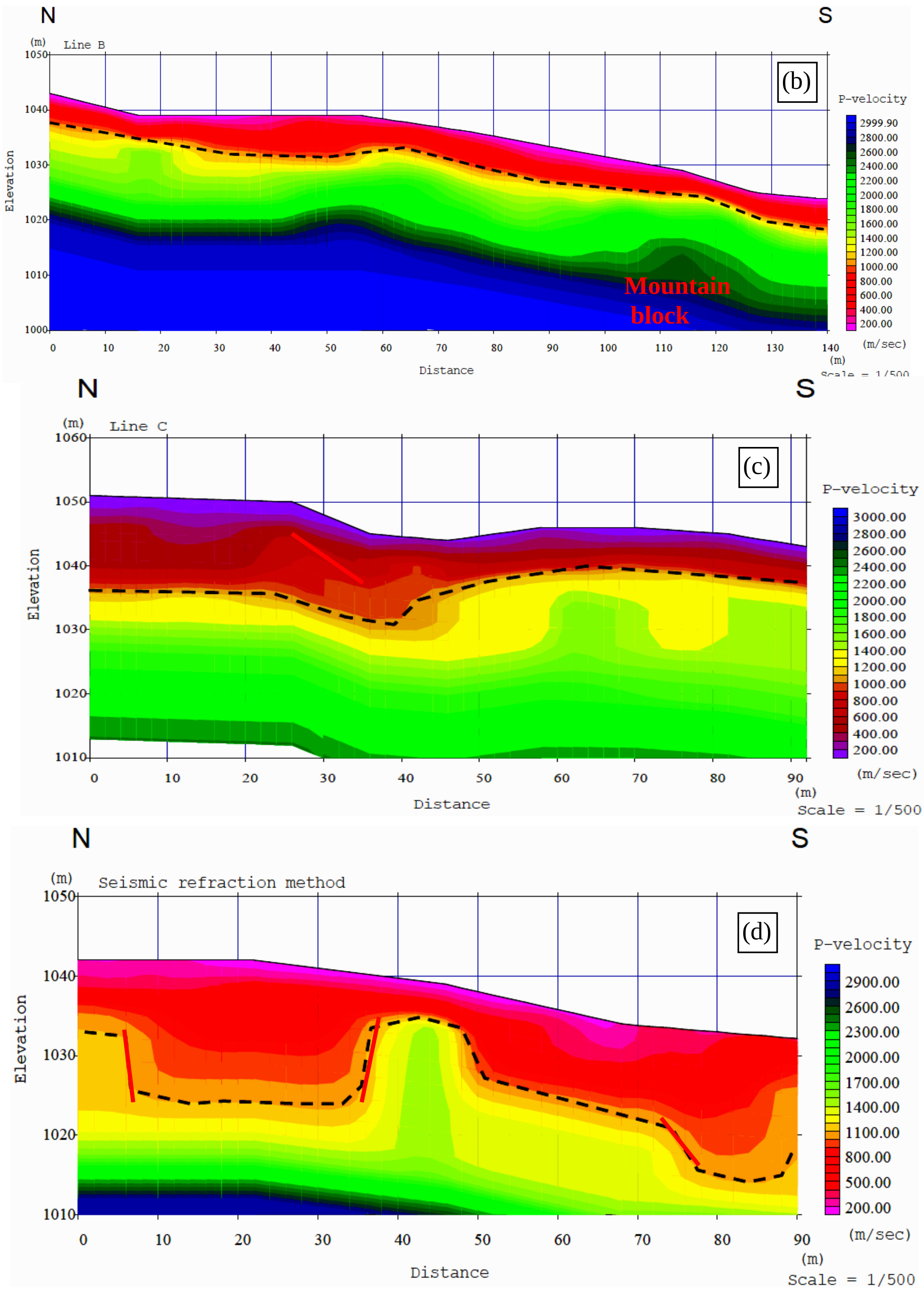

Figure 5. Cross section based on the seismic analysis
(Black dashed line: sliding surface; red line: fault/crack)

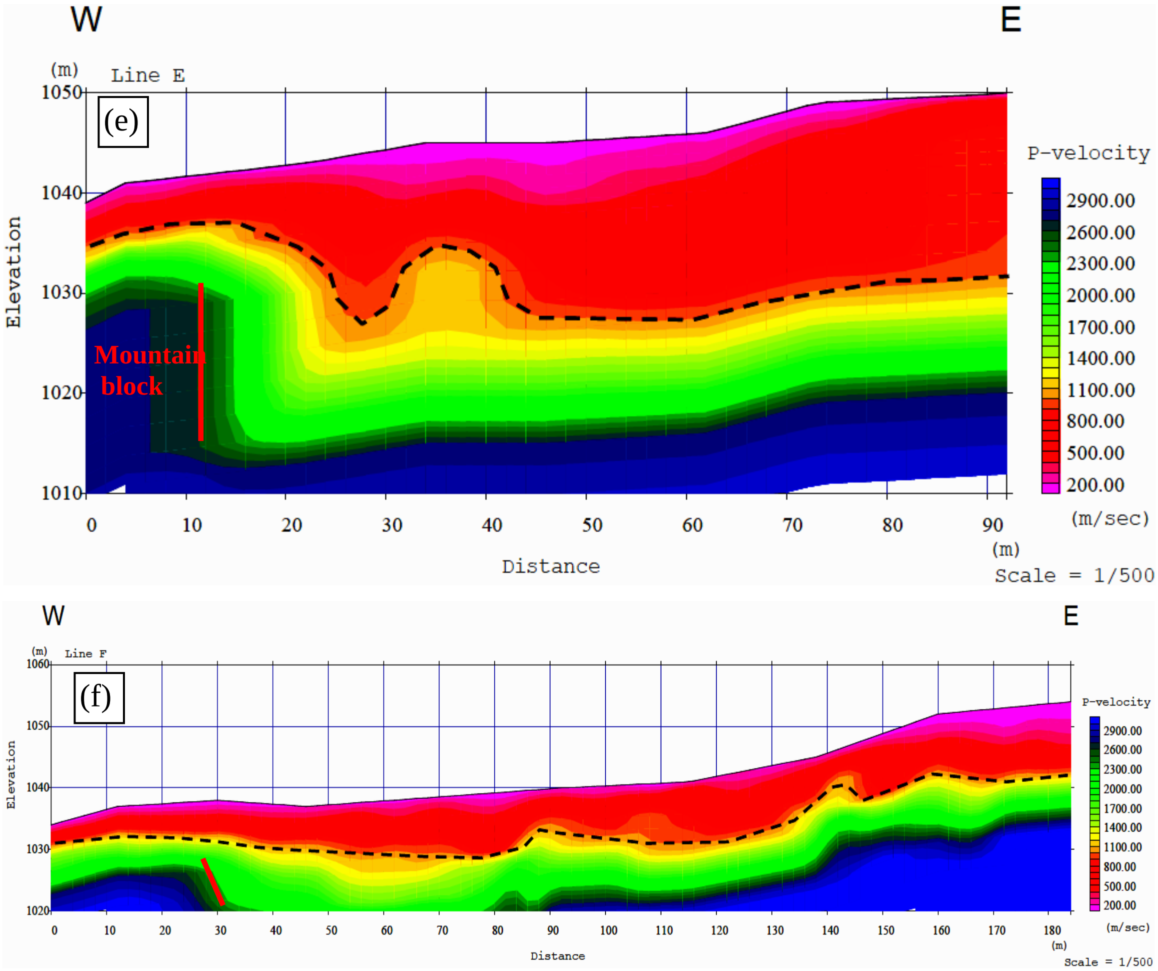

Figure 5 (Continued)

Black dashed line: sliding surface; red line: fault/crack

Figure 5 shows that the sandy silt is thinner in the down slope area. It also shows that the subsurface of the down slope area contains a mountain block of bedrock (Figure 5b, 5c, and 5d). This condition may resist the land movement, does not continuously occur in the down slope area, as recognized from site investigation.

The presence of cracks or faults in the sub-surface can also be interpreted from the seismic refraction data. Cracks or faults (red line) are interpreted from the discontinuity of travel time velocity or a suddenly change travel time velocity from six measurement lines of seismic, as shown in Figures 5c, 5d, 5e and 5f .

The dimension of the land movement in the research area identified from the surface mapping and seismic analysis. It shows the relatively large creep crown with wide of land movement 120 meters and length 135 meter. The volume of soil movement is 111.386 m^3. The land movement at the research area is progressing because (1) the increasing burden due to construction road and (2) the increased load due to the accumulation of a mass influx of groundwater in the moving soil and vehicle on the road. The more dominant factor is the increased groundwater volume entering the soil caused by the poor drainage system, especially in the upper area.

Conclusions

Soil mass movement in the research area compriesed of 20 m thick of soil / rock mass in average, controlled by the presence of large fractures (identified as faults or discontinuities) and the existence of mountain blocks at the bedrock. Based on the field observation and seismic data, the soil movement is still active although it occurs slowly as the creeping, with a bulk volume of 111.386 m^3 soil mass. However, this movement does not reach down slope due to the presence of mountain block at the bedrock. Therefore, it is consider that the risk of landslide movement downslope to the south in the community settlement, may not yet critical. Based on the progress of creep conditions, it is recommended to reduce the risk of landsliding by minimizing the movement through the application of drainage system to avoid water flow and seepage into the landslide area, and through the load and vibration control for any vehicles passing the road at the sliding area.

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