Countermeasure for Landslides along the Pan-American Highway in the Metropolitan Area of El Salvador - Countermeasures for Problem Soils of Paleosol Overlaying Erodible Glassy Pyroclastic Flows which Occurred in the Fifth-sixth Centuries -

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INTRODUCTION

The landslide countermeasures were planned through the technical assistance project of the Japan International Cooperation Agency (JICA) for the Government of El Salvador.

A landslide blocked 2 of the four lanes of the Pan-American Highway bypass in the Metropolitan Area of El Salvador on 15th January 2009. After removing the soil from the carriageway, the highway had been operating with only 3.5 lanes, resulting in traffic jams.

During the May-October 2012 rainy season, the landslide was reactivated with a peak speed of about 8cm per day based on control point movement. The landslide are approximately 65m height, 140m length, 120m width, and 130 thousand m^3 volume. The main portion of the sliding surface was about 10m deep from the top using pipe strain gauge detection. The landslide had clear scape and cracks on flank and foot areas, so much so that the outline of the landslide was easily recognizable.

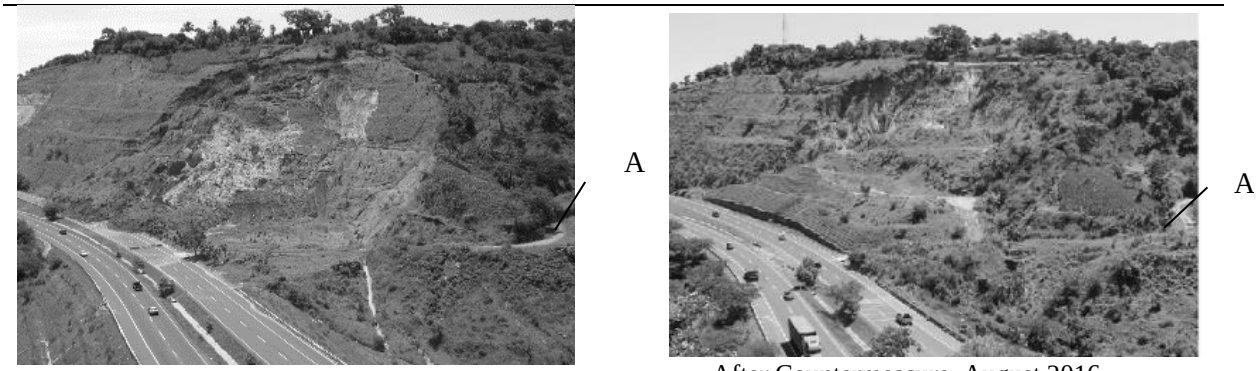

Fig. 1 Disaster Event and After the Completion of the Countermeasures

UNDERGROUND WATER DRAIN AND OTHER MEASURES TO STABILIZE SLIDING

Low cost general countermeasures were implemented in 2015 including earthworks (removal and filling), gabion retention walls with geocomposite drainage sheet and pipe drainage at the bottom of the gabion mountainside edge of road extension direction, concreting pavement of the community road on the landslide head, shotcrete works on the landslide scarp, drainage works (gutters),

underground drainage works (a total of 930m perforated plastic horizontal pipes, 10 drilling holes), and vetiver grass vegetation on the sliding mass surface for anti-erosion.

CONSIDERATION OF GEOLOGICAL CHARACTERISTICS

The paleosol (highly weathered pyroclastic flow) is underlying the white-colored erodible glassy pyroclastic flow called 'Tierra Blanca". The ground water exists in the Tierra Blanca supported by low-permeable paleosol, and the top of the paleosol is saturated, very weak and becomes the slip surface. The Tierra Blanca overlays the undulated paleo-mountainous topography. The boundaries of the paleosol and the Tierra Blanca are not easily recognizable. Therefore, a long horizontal drainage of on average, 93m were planned to successfully penetrate the boundary, and drain the groundwater from the Tierra Blanca.

The underground drainage works are installed at the foot of the slope with an elevation angle of 2.5 degrees, perpendicular to the road alignment of 60 -100m long. The drilling elevation angle of 2.5 degrees is gentler than normally practiced because the trial drainage drilling with 5 degrees or more was not successful. The groundwater level rises with a gentle angle of about 5 degrees in a direction perpendicular to the road extending to the mountainside from the roadside spring. During the study stage on April 2013, the most successful trial drainage drilling was a 2.5 degrees elevation angle and one at an angle of 35 degrees in the horizontal direction from the road alignment (because it was a requirement that there should be no traffic disturbance). This drained more than 500 liters per minute, decreasing to 30 liters in one hour, 1 liter in one month, and 0 liters in one year. This resulted in ground water level decreasing by about 1m at two observation wells. The drainage decreased by a maximum of 5cm per day during the 2012 rainy season (May-October) and less than 1cm per day during the 2013 rainy season.

The clogging of the drainage pipe was not identified including the gentle drilling elevation angle because both the paleosol and Tierra Blank have somewhat dispersive characteristics in the water and iron bacterium, which make mud of iron dioxide when mixed with oxygen, was not identified.

CONCLUSIONS

After the implementation of the countermeasures 1.5 years from October 2015, damage on the road has not occurred. The successful formulation of this type of low-cost countermeasure depends on investigation and monitoring during the study stage.

Roadside gabion retaining wall with geocomposite drainage is another effective countermeasure. The vetiver glass vegetation is successful for erosion protection of the erodible Tierra Blanca, even if the soil is low nutritious volcanic glass.

The geology of paleosol and the Tierra Blanca are well-known problem soils in El Salvador for slide-type geohazards and extensively developed in the Metropolitan Areas. The know-how on countermeasure works can be applied in similar geological conditions.

Keywords: Landslide, monitoring, Paleosol, problem soil, drainage drilling