CHRACTERISTICS OF LANDSLIDE OCCURRED IN LOPARE, BOSNIA AND HERZEGOVINA

Jun Sugawara¹ and Takao Aizawa²
¹ WorleyParsons, Australia
² Suncoh Consultants, Japan

ABSTRACT

This paper presents results of detailed site walkover inspections carried out in June and September 2015 at the landslide site in Lopare Municipality, Bosnia and Herzegovina (BiH). The works took place as a part of the 2015 – 2016 Geoscientists without Borders (GwB) project of “Assessment of flood-damaged infrastructures in Bosnia and Herzegovina and Serbia”.

From the site inspection, the slip surface is estimated at a shallow depth about 10m or less, and the landslide site is considered prone to reactivation even with a minor triggering event. Some economical remedies are suggested to the condition of the Lopera site.

1. INTRODUCTION

This paper presents results of site walkover inspections undertaken for the landslide occurred in Lopare Municipality, Bosnia and Herzegovina (BiH).

The works were carried out as a part of the 2015 – 2016 Geoscientists without Borders (GwB) project of “Assessment of flood-damaged infrastructures in Bosnia and Herzegovina and Serbia”.

The nature and significance of damage sustained by this area is described, along with the landslide mechanism and the potential mitigation measures which may be employed for future landslide mitigation.

2. BACKGROUND

2.1 Geography

Lopare is located where Mount Majevica transitions into the plans of Semberiji and Posavina. An average altitude of Lopare is approximately 235m above sea level. A number of small water flows are developed in this region.

According to relevant geological map [1], this region comprises Neogene (Middle to Later Miocene) age sandstone and conglomerate, with clay and sand.

2.2 Flood Events in 2014

A torrential rainfall (cyclones Tamara and Yvette) in the Balkan region in May 2014 caused extensive landslides and flood damages in BiH. A quarter of the BiH territory and approximately one million people, which is equivalent to 27% of the country's population, were affected by this disaster.

In the Lopare landslide site, however, the landslide was initiated during approximately 10 days’ rainfall and snowfall events in March 2015 according to the local residents.

Fig. 1 Location of Lopare in BiH (after [2])

3. SITE WALKOVER INSPECTIONS

Detailed site walkover inspections were carried out on 13 June 2015 and between 12 and 13 September 2015 at the location shown on Fig. 2. Geophysical investigations were also carried out separately at the time of site walkover inspection in September 2015.

Based on the observations at the site walkover inspections, authors note the following:

- The site is generally sloping to the southeast. Depending on location on the site, the slope angle varies from approximately 10 degrees to up to 30 degrees above horizontal.
- The size of the landslide is approximately 100m wide and 300m to 400m long. The toe of the landslide was unclear at the time of investigation.
- In general, the site predominantly comprises a
very soft to soft high plasticity Silty Clay layer, which overlies very low to low strength Siltstone and Mudstone. Silty Sand layers and rounded and semi-angular gravel sized fragments are also found in a matrix of silty clay / silty sand near the crest.

- Multiple scarps up to approximately 8m high are present at near the crest (Photo 1).
- A number of tension cracks near the left side of the crest are noticeable. The typical width of the tension cracks is up to 300mm or less. Some of them appear to be deeper than 1m deep and are near-vertical. There appears to be a drop of elevation on downslope site of some cracks (Photo 2).
- A number of damaged houses are present within the site. The direction of tilting of the houses varies significantly indicating the site comprises multiple landslides (Photo 3).
- Deformations were present along the road in the middle section of the landslide. This road runs approximately perpendicular to the direction of the landslide movement (Photo 3).
- Groundwater seepage and ponding of water are observed at multiple locations (Photo 4).
- Based on communications with local residents, authors understand several surface drains were installed by residents after the landslide event.

**4. ENGINEERING ASSESSMENTS**

**4.1 Classification of Landslide**

Based on the results of site walkover inspections, this landslide site is considered to be consisting of thin layers of top soil and residual soils overlying weathered rocks (sandstone, siltstone and conglomerate). According to Varnes’ classification...
this landslide can be classified into “multiple rotational slide” (upper part of the slope) and “earth slide” (lower part of the slope). Also based on another landslide classification system [5], this landslide can be classified into “clayey soil slide”.

It is noted that this landslide is one of the most common types in BiH. In many cases, landslides in BiH are shallow and are observed on the relatively gentle slope which often consists of thin layers of top soil and residual soils overlying weathered rocks.

Fig. 3 Shape of typical landslides in BiH: multiple hill terrain type (left) and concave hill type (right) (after [5])

4.2 Mechanism of landslide
Based on the communication with local residents, we understand that this landslide was triggered by the long rainfall and snowfall events in March 2015. During the landslide, one of residents witnessed overflow of the water from the well located between the crest and the middle section of the slope, indicating the significant rise of groundwater during the landslide (Photo 5).

In addition, it is deduced that the current shape of the upper slope was formed after multiple rotational failures in the past. Based on the topography of the site, the original angle of the upper slope section could be up to approximately 25 degrees above horizontal.

The causes of the past instabilities are unknown, however, one of the plausible explanation for the past instability may be by the deforestation and conversion of grass land to arable land, roads, buildings, etc. Vegetation dries out the surface layers. Plant roots can also help stabilise slopes by anchoring a weak soil mass to fractures in bedrock by crossing zones of weakness to more stable soil, and by providing long fibrous binders within a weak soil mass [6]. Landslides in these areas could be reactivated easily, even with relatively minor triggering events.

4.3 Surface Water and Groundwater
The surface drain located along the road above the right side of the crest seems to be small and was partially blocked at the time of inspection. Based on the topography of this area, authors consider that a large quantity of overflowed surface water was diverted towards the right side of the crest prior to / during the landslide (Photo 6).

In addition, a number of water ponding areas were evident across the site. Abundant seepage from the overburden soil can be also anticipated in the wet condition. It is considered that, the rise of groundwater could be significant following long intensive rainfall events even if the groundwater level is not high during the dry season. Therefore control of surface water and groundwater is the key to mitigation of this landslide.

4.4 Landslide Slip Surface
No borehole or test pit investigation was carried out at this location. Based on the site conditions observed and authors’ experience with similar landslides, the potential slip surface is likely to be
located at the contact between overburden soils and weathered rocks. The depth to the slip surface could be up to approximately 10m in the upper section and up to 2 to 3m in the lower section. This is supported by the fact that the existing well located in the lower section of the slope was sheared approximately 2m below the ground surface (Photo 7).

Residual strength of the material along the slip surface could be smaller than $C' = 12kPa$ and $\phi' = 25$ degrees depending of the location of the slip surface.

The current factor of safety (FOS) against instability of the site and the upslope property is likely to be close to or slightly above 1.0. Landslides in this area could be reactivated even with relatively minor triggering events.

### 4.5 Possible Mitigation Measures

- Clearance of accumulated debris from drainage channels, repair of cracked or damaged drainage channels and their regular maintenance.
- Temporary protection of damaged slope surface with polyethylene sheeting or tarp.
- Surface protection of the slope located downslope of the existing road with gabion walls.
- Re-alignment of surface drainage path using sandbags.
- Mechanical pumping or siphoning of groundwater from existing wells.

It should be noted that these mitigation measures are effective in reducing movement, but unlikely to increase FOS to the commonly accepted minimum FOS (e.g., FOS $> 1.5$ for long term stability).

### 5. CONCLUSION

Detailed site walkover inspections were undertaken as a part of the 2015 – 2016 GwB project of “Assessment of flood-damaged infrastructures in Bosnia and Herzegovina and Serbia”.

Results of site walkover inspections and recommendations were provided to Lopare Municipality in September 2015.

In the next stage, various geophysical investigation results will be incorporated for more detailed characterisation and comprehensive interpretation leading to effective mitigation methods of this landslide.

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