A SIMPLE MODEL OF A HAZARDOUS LANDSLIDE MODE ON THE INTERIOR PLAINS: THE SLIDING OF TWO INCLINED BLOCKS

K.W Soe Moe, University of Alberta, Edmonton, Alberta
D.M Cruden, University of Alberta, Edmonton, Alberta
C.D Martin, University of Alberta, Edmonton, Alberta

Since the beginning of the twentieth century, five documented landslides have damaged residences in the city of Edmonton. The 1999 Whitemud Road landslide illustrates their shared mode of failure, a translational movement along a bentonite layer. There are four kinematic stages.

1) The main scarp of the landslide develops behind the crest of a valley and cuts through Pleistocene deposits into the horizontally-bedded Cretaceous bedrock. The scarp may follow joints created by valley rebound.

2) Water pressure developed in the gaping main scarp pushes the displaced material along a seam of weak material whose resistance has been reduced to residual by rebound processes. Movement dilates the main scarp, cleft pore water pressures drop and the rate of movement drops, sometimes to zero.

3) The head of the displaced material of the landslide is unsupported. Over several months or more, an uphill-facing counter-scarp is formed which then separates a downward-tapering wedge, the active block.

4) Rapid downward movement of the active block is halted when its tip comes to rest on the weak seam that has allowed the displacement of the passive block. Further movements may then depend on erosion of displaced material from the toe of the passive block.

This four-stage landslide mode is modeled in two dimensions assuming both active and passive blocks are infinitely wide. Input data consist of material properties, slope and surface of rupture geometry and ground water levels. For the first stage, the strength properties of the displaced material and of the weak seam are required with an average total unit weight. Slope geometry is described by slope height and angle, the main scarp is characterized by its dip and distance back from the valley crest, and the weak seam or surface of rupture is assumed to be horizontal or with a dip. Depth to groundwater in the main scarp is specified. For the third stage, the dip of the counter scarp and the height of the active block are necessary, a groundwater level on the counter scarp can be independently specified.

The initial mode of movement is a single block mechanism, the main scarp is open but the displaced mass is still intact. Sliding occurs along the weak plane. The driving force is the pore pressure, whereas the resisting force is the shear resistance of the weak layer. After initial sliding along the weak layer, the head of the displaced material is unsupported and over a few months, a counter scarp develops which forms an active block. At this stage, the stability calculation can be divided into two parts. The first one is the determination of the resultant of the active block, which applies pressure on the passive block. Driving forces on the passive block include the resultant force of the active block and water pressures. The resisting force is the shear resistance of the weak layer.

Parametric analyses are performed by changing ground water level, size of active block, dip of main scarp and counter scarp, as well as the material properties of main block and weak plane. For the comparison, slope configurations and material properties from the Whitemud Road landslide are used in the analysis. Typical slope configurations at Whitemud Road are a slope height of 40m, slope angle of 30 degrees, distance from slope crest to the main scarp of 25m, dip of main scarp and counter scarp of 50 degrees and active block height of 30m. For the material properties, it is assumed that the sliding plane is pre-sheared due to valley rebound and unloading. Friction angle of 25 degrees for the main block and 10 degrees for the weak plane are used in the calculation.

In the single block analysis, a water table 30m above the sliding plane gave a Factor of Safety of 1. A 25% decrease in Factor of Safety follows the formation of the active block. It is assumed that the water level reduced after stage 2 and an active block is formed with time. At present the water level is 15m above the sliding plane at the site. This water level is used for the analysis of the active and passive blocks at stage 3. At the low water level, reduction in Factor of Safety due to the formation of active block is more pronounced. When the results are compared with SARMA and SLOPE-W, this two block model gives a slightly lower Factor of Safety.

These analyses, agree with the four-stage kinematic model of the translational sliding of two inclined blocks which have been observed at the landslide sites. The formation of the counter scarp, separating active and passive blocks, triggers an acceleration of slope movement.

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