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Observations of pre-failure behaviour of the shear zone during geotechnical simulation of rainfall-induced landslides using ring-shear apparatus

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It has been observed in field and in laboratory experiments that the failure of soils is preceded by time-dependent deformations related as creep. There can be detected three phases – primary with deceleration of the displacement, secondary with the rate being constant and tertiary where there is acceleration and is followed by the failure. The practice has shown that some of the failure prediction models based on the tertiary creep can be successfully applied in real cases and their reliability is very high. Fukuzono's (1985) proposed a simple graphical tool by plotting the inverse velocity of horizontal displacement to the elapsed time. When the curve of the inverse velocity reaches values close to zero, visually crossing or touching the abscissa, then the failure will occur. Fukuzono also described empirically the connection between the displacement and the elapsed time by the equation $d^2x/dt^2=A(dx/dt)^{\alpha}$ where x is the displacement, t is the time and A and α stand for constants.

In our research we conducted experiments on creep in soil triggered by gradual increase of the pore water pressure. The conditions of the tests correspond to the destabilization process in a slope under heavy rainfall and rise of the ground water level. The preliminary movements in the soil cause the formation of the sliding surface along which the failure will take place. The ring-shear apparatus DPRI-5, developed by Sassa et.al. (2003), has been used for conducting the tests as it could support partially drained conditions during the experiments and also it has predetermined shear zone.

We obtained the parameters A and α through velocity-acceleration analysis where we plotted the logarithm of velocity against the logarithm of acceleration for the tertiary phase of the creep. The relation was represented by a roughly straight line for the positive couples of data. We found the parameters are affected by the initial test condition – total normal stress, the initial shear stress, the stress history and the clay content.

The creep patterns shown in the tests could be grouped in two. The first group includes displacement patterns with only short tertiary creep preceding the failure. The time of failure was shorter than the tests from other group. The stress paths were smoothly reaching the failure line. The patterns from the second group had step-like features, the steps followed by full stop of the displacement or by much slower deformations. The time of failure has been delayed and the stress paths showed temporary peaks of mobilized shear resistance.

Observing the changes in the height of the sample in the shear box we detected that during the initiation of a more prominent creep displacement the soil dilates. Then with the further slower creep the height becomes less as the soil bears contraction. We suggest that the reason for the volume changes is particle rearrangement – overrunning at acceleration and jamming into tighter structure at slower creep. This rearrangement makes the soil denser with more stable structure and leads to delay of the time of failure as a bigger pore water pressure is needed to trigger shearing.