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Rate Assessment of Slope Soil Movement from Tree Trunk Distortion

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<http://dx.doi.org/10.5772/66813>

Abstract

The chapter presents the methods for determining the rate movement of the slope, which is based on an evaluation of a distortion of the tree trunk. The distortion develops during the growth period of the tree, and its conditions are trajectory and speed of material movement, which takes away the root system of a tree. The distortion of the tree trunk explains kinematics of the root system movement. The distortion curve is constructed from the results of measurements carried out on several horizontal levels of the tree trunk. The speed of movement of the slope is calculated from the age of the tree and the length of the path of movement of the tree, which is derived from the distortion curve of the tree trunk. The length of the track of tree movement is drawn from horizontal position of the gravity point of the curve corresponding with the longitudinal axis of the tree trunk. This method is documented in one example. The method is appropriate to quantify the movement of the latent long slope.

Keywords: landslides, latent movement, rate of movement

1. Introduction

Soil movement on slope is a common phenomenon that deserves attention in particular when on the slope there is an intention for an extensive development that brings about earthworks as its consequence. The soil movement can have many causes. Gravity and transport media as water, snow, ice, or wind are inherent and cannot be bypassed. Other causes are conditioned with anthropogenic activity and those can be only mitigated. The soil movement differs in many respects. Landslides are divided according to value of the speed of movement of slope materials into several categories (Abramson et al., 1996). Most usually attention is paid to the influence of vegetation on slope stability (Morgan and Rickson, 1995), but the idea that some kind of long growing plants, e.g., the trees in specific way depict as well soil movement that has not yet been

exploited. Determination of the rate of a slope soil material movement from trunk tree distortion growing on the slope is possible only for slow latent slope soil material movement. Latent movement escapes most observers and the slope is considered stable, although its degree of stability fluctuates around a value equal to the marginal state of equilibrium. Latent soil material movement can be exposed only over many years of continuous measurement, which is never done. This movement is typically indicated only with characteristic development of the trunk of tree. The distortion of a tree trunk can therefore be regarded as a direct form of continuous measurements of the slope soil material movement within an area that a root system of the tree develops in. With the age of the tree known the rate of a slope soil material movement can be set up.

2. Tree kinematics

The tree structure consists of two parts: underground root system that is manipulated by the creeping slope soil material and an above the ground part of tree trunk, a crown. Both the parts are linked together with stiff bond that transmits the principal compounds of soil movement, i.e., translation and rotation, on the above ground part of tree. The vital peak of a tree trunk executes a distortion of the tree trunk. It strives to keep the vertical direction of the growth of a tree and in this way it smooths out the tilt and shift of the root system of the tree being drifted through slope soil material. The tree trunk distortion determines type and size of the slope soil material movement. In general, there are two elementary shapes of the tree trunk distortion developments (see **Figure 1**):

- the vital peak and upper part of a tree trunk keep the vertical direction and distortion exhibits only the bottom irrespective of the middle tree trunk sections. This shape development refers to the latent soil material movement;
- excessive distortion of the entire tree trunk along and an apparent deviation of upper part of a tree trunk from the vertical direction refer to an advanced state of slope soil material movement.



Figure 1. Elementary shapes of the tree trunk distortion developments.

The apparent deviation of the upper part of a tree trunk from the vertical direction causes a load of a bending moment due to the weight of the above ground part of tree trunk a crown. This bending moment load opposes the root system together with soil environment. When the load exceeds a restrain capacity of the tree root system then the tree trunk inclines heavily

and finally tilts completely. This situation is inappropriate to set up the rate of a slope soil material movement, since for this situation it is not possible to separate which portion of the slope soil material movement belongs to the gravitation and to the soil ground yielding due to the bending moment.

The slope soil material movement describes exactly two vectors $\vec{u}_A(\vec{u}_{Ah}, \vec{u}_{Av})$ and $\vec{u}_B(\vec{u}_{Bh}, \vec{u}_{Bv})$, which state a displacement at two slope's points A and B. Both points are located in places where there are expected extreme values of displacements. They are located on the intersection line of a vertical plane of symmetry through the axis of the tree trunk with a slope's plane at antipodal points of tree root system extend (**Figure 2**).

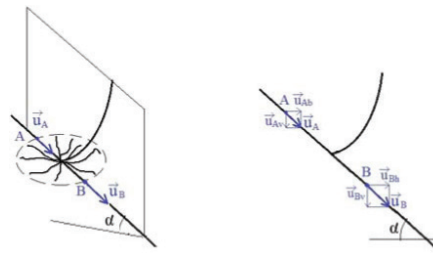


Figure 2. Kinematics of tree movement on slope.

Intersection line indicates the direction in which the maximum displacement occurs. Differentials of displacements between points A and B ($d_{uh} = \vec{u}_{Ah} - \vec{u}_{Bh}$; $d_{uv} = -\vec{u}_{Av} - \vec{u}_{Bv}$) induce simultaneous change of the distance length between A and B (Δs_{AB}) and change of inclination of slope section between points A and B ($\Delta \alpha_{AB}$). When the distance between A and B extends then the inclination becomes flatter and vice versa, and when the distance between A and B contracts then the inclination becomes steeper.

A distinctive distortion of the tree trunk arises due to incremental change of the inclination ($\Delta \alpha_{AB}$). **Figure 3** shows in sequence of the evolution for two forms of the tree trunk distortions one for the decreasing and second for increasing trend of inclination development of slope section.

In case when both the differentials d_{uh} and d_{uv} equal zero the change of inclination $\Delta \alpha_{AB}$ equals zero too and the tree root system does not rotate but translates so the tree trunk does not exhibit distortion. For this circumstance a rate movement of the slope soil material cannot be evaluated.

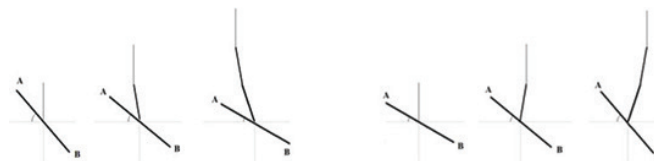


Figure 3. Phases of trunk distortion development of a growing tree during slope soil movement.

3. Evaluation of rate movement

The following assumptions are supposed to be taken into account:

- gravity is the only cause of material movement on slope;
- long term low rate of material movement on slope-latent movement;
- vital peak part of a tree trunk rectifies entirely the rotation of a tree root;
- soil yielding due a bending moment load from weight of the above ground part of tree is negligible and only moving slope materials drift the tree root system;
- the length of the path of the slope soil material movement corresponds to the trajectory of a tree trunk gravity point; consequently a horizontal distance between gravity point and heel point of the tree trunk (s) designates the value of the slope soil material movement in the horizontal direction for a tree lifetime (see **Figure 4**);
- tree lifetime is known (t);
- other factors affecting growth of the tree, such as climate and weather conditions, vegetation conditions, such as water and nutrients, site conditions like shading, or nearby standing objects are excluded.

For known values of the time of tree vegetation (t) and the value of the slope soil material movement in the horizontal direction (s) a simple calculation formula provides the value of average rate (v) of the slope soil material movement in the horizontal direction for the tree lifetime:

$$v = s/t \quad (1)$$

The value of the slope soil material movement in the horizontal direction (s) is solved analytically using approximation function that substitutes distortion line of tree trunk axis and a formula for calculating the position of gravity point of the distortion line. The analytic approximation of the distortion line of tree trunk axis is expressed as an exponential function with two coefficients:

$$y = a \times (1 - e^{-b \times x}) \quad (2)$$

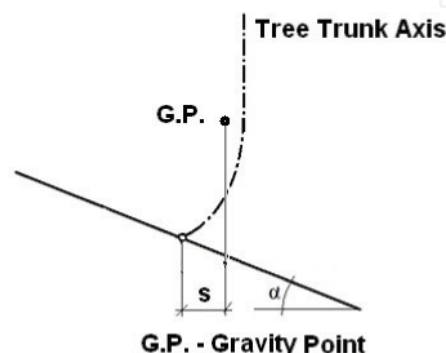


Figure 4. Scheme of tree trunk axis.

Determination of the coefficients " a " and " b " needs data from measurements made on the tree trunk. The measuring points are located along the vertical line on a peripheral surface of the tree trunk. This is necessary to localize four points minimally to implement the exponential function to state the distortion line of tree trunk axis satisfactory. The first point is placed at the lowest level over the terrain from which the shape of the peripheral surface of a tree trunk is not influenced by the development of the root system. The last is placed at the level from which the trunk is straight and vertical here above. Measured parameters are: the diameter of the tree trunk; vertical distance measured to the lowest point horizon; and horizontal distance measured to the highest point horizon. These parameters are worked out to set up the distortion line of tree trunk axis. The coefficients " a " and " b " are derived by applying the least square method from data that describe the distortion line of tree trunk axis. The horizontal coordinate of the gravity point of the distortion line of tree trunk axis is set up analytically. The tree lifetime can be established as sum of the tree herbaceous from core sample that was taken by Pressler's auger. Rough estimate of the tree's lifetime consists in measuring the girth and empirical formulas derived for the species of tree and geoclimatic conditions of the site that implement the measured girth. The second estimate is sufficient as the error of a few years does not matter in particular when the tree's lifetime is more than 50 years. In turn, the development of a tree root system influences the gravitational slope soil material movement too. The tree root system shore up the movement of slope materials and counteracts the effects of gravity. The rate of movement for slope covered with tree vegetation will not be constant. With the development of the root system the rate should decrease dependently on density and extension of the root system. The gradual decrease of the rate of slope movement can be set up under the following assumptions: a downward trend of the rate; sequencing calculation for several time periods; and determination of the age state for all points on horizons of measurement for the distortion geometry of the tree trunk. The last assumption requires to conduct the exact evaluation for particular section of the tree trunk.

4. Example

Documentation example shows determination of the rate of slope soil movement on the Flysch landslide area at Syrakov hill near Jasenna village in the Zlin region below the first class road number 69 (I / 69). The tree is located on coordinates 49.2743558N, 17.8982797E and is a beech, whose age is estimated at 32 years (see **Figure 5**).

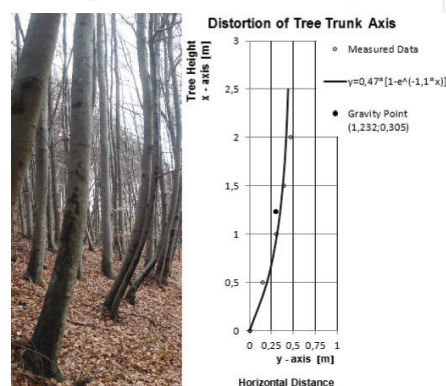


Figure 5. Illustrative example of evaluation of the rate of slope soil movement.

The graph in **Figure 5** displaces measured data, graph analytic function of the tree trunk axis, and the localization of the axis gravity point. The length of slope soil movement is to be about 9.5 mm per year ($s = 0.305$ m; $t = 32$ years).

5. Summary

Presented method allows easily with minimal instrumentation, costs, and only single measurement to determine the approximate value of the long-term rate of slope soil movement which other methods cannot ever achieve.

The method can be applied on all the sites that have not yet been investigated and which exhibit the latent slope soil movement.

The method can be applied in assessing the ground conditions for construction of many kind of engineering works such as roads, pipelines, power lines, as well as in foundations of civil engineering works on areas affected with long-term latent soil movement.

Acknowledgement

The chapter was prepared with the support of the Competence Centres of the Technology Agency of the Czech Republic (TAČR) within the project Centre for Effective and sustainable transport infrastructure (CESTI), project number TE01020168.

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