A Lecture on Landslides: Physical and Numerical Modelling of Large Ground Movements

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PROF. Kenichi Soga of Cambridge University, United Kingdom recently delivered a two-hour lecture to about 90 participants on "Landslides: Physical and Numerical Modelling of Large Ground Movements" at the Malakoff Auditorium, Wisma IEM in Petaling Jaya. The event was organised by CESIG, IEM and supported by UTM, GETD, TUSTD, ICE, SEAGS and AGSSEA.

Prof. Soga began the lecture by showing the debris flow of Colorado in 1997 and the submarine landslide in Hawaii in 2003. He then proceeded to show how the debris flow and submarine landslide could be modelled using centrifuge and numerical methods.

Landslides are known to cause loss of lives and property. It is also known that these landslides can move rapidly (such as in debris flow) and travel long distances. The traditional way of evaluating the risk of landslide is by slope stability analysis and determining its Factor of Safety. However, this method does not assess the extent and speed of ground movements. Prof. Soga, using advanced computational and physical modelling, demonstrated how the initial state of the soil influences the movement of landslides.

Initially, Prof. Soga presented some animations of large-scale model tests on sand embankment that failed from seepage in two different manners. The sand levee that was initially wet or damp failed rather abruptly and more extensive as compared to the dry embankment where gradual failure occurred near its toe. Submarine landslide is known to move massive volumes and can travel at distances of up to 400km with a surface gradient of only 0.1 degree. Such landslide can cause significant damage to the marine environment and facilities (e.g. seabed pipelines). The key question in understanding submarine landslide impact is how to model the mass velocity and travelling distance correctly.

To further elaborate on this, Prof. Soga presented the latest research work at Cambridge, using a mini-drum centrifuge to model the submarine landslide flows. Actual flow velocity in the field can be predicted and factored using suitable gravitational scaling laws. It should be noted that submarine landslides are more complicated to model due to the fact that the flow is also affected by water entrainment, frontal shear and hydroplaning, basal shear, flow thickness and water viscosity.

Advances in numerical methods to solve continuum problems were introduced in the second half of the lecture. While many audiences may be accustomed to the commercially available programmes such as Finite Element Method (FEM) or Finite Difference Method (FDM) which are all mesh-based techniques, conventional methods have limitations in simulating very large ground deformation. Particle or mesh-free methods, or in this case called Material Point Method (MPM) can be used to model large ground deformation and simulate landslide flow. Complex MPM consolidation formulation was developed to couple the effect of multi-phase soil and water movements. The model can also include partially saturated ground conditions.

Prof. Soga delivering his lecture

Prof. Soga with organising members

An intriguing note was made concerning experiments on levee failure, where the mode of failure is not only influenced by the shear strength properties of the soil, but is also sensitive to the angle of dilation. Remarkably, the MPM method is able to replicate various types of landslide movements, that is, from gradual retrogressive sliding to a more catastrophic failure (larger mass movements).

In the case of modelling submarine landslides, water entrainment that affects the flow viscosity was included in the constitutive model. Prof. Soga also highlighted some examples of new opportunities of slope monitoring technique using distributed optical fibre strain sensing. The sensor is known as Brillouin Optical Time Domain Reflectometry (BOTDR) and is said to be capable of measuring continuous strain profile (e.g. every 10 cm) along a standard 10km long telecommunication optical cable.

Apart from that, some field instrumentation readings conducted by Cambridge Geotechnical Research Group on slopes near a coastal area in the UK were also presented. An interesting point to note is that the fibre optics can be configured into various types of sensors depending on its applications. For example, for slope monitoring purposes, it can be used to monitor lateral displacements similar to an inclinometer, measure axial strain in soil nails and detect subsurface shallow movement of an embankment. Surprisingly, the subject of field instrumentation using BOTDR drew the largest interest among the audience during the question and answer session. Indeed, this lecture has greatly benefited all the participants. ■