**PROJECT**

**Road-Landslide Interaction: Monitoring and Inverse Stability Analysis (VSS2005/502)**

*Interaktion Strasse-Hangstabilität: Monitoring und Rückwärtsrechnung*

**Funding:** National (Switzerland)

**Duration:** Nov 2010 - Dec 2014

**Status:** Complete with results

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**Background & policy context:**

The most reliable approach to the long-term displacement and stability analysis of the large creeping landslides is based on the back-calculation (inverse analysis) of soil parameters from observed displacements and measured earth and water pressures in the sliding layer.

In addition to the conventional geodetic measurements, it is suggested to monitor the deformations of a road intersecting a landslide using a novel fiber-optics strain measurement technology. This could serve a double purpose: to monitor the health of the road structure and to provide a unique data for the inverse analysis of the landslide stability and displacements. A novel Inclino-Deformometer (IDM) will allow for the first time to measure reliably the earth pressures in the sliding layer contributing more unique data for the inverse analysis. Novel approach to chemical treatment of clayey soils will help to increase the soil permeability allowing for improved drainage in the sliding layer.

Novel approach to biological treatment of soil will help to remediate effects of the chemicals on the environment and to increase the shear strength of soil due to the bio-mineralisation. Results of the research will be used for prediction of the road and landslide behavior and for planning of the stabilisation measures.

**Objectives:**

The goal of the project is to develop a state-of-the-art procedure for analysis of long and short term effects of different environmental factors (including the road and railway construction and operation) on landslide evolution and stability. This procedure will be based on the inverse analysis of the monitored landslide displacements with the landslide being used as a gigantic “strain gauge” to interpret its displacements for mapping the shear and normal stresses on the slip surface and in the sliding body.

**Methodology:**

Following activities will be part of the project:

- “Further development of the IDM“ will be divided into the following subtasks:
  - Improvement of accuracy
  - New analytical and numerical approaches to back-calculation of pressures
  - Time dependency of measurements
  - Effects of grout
- “Further development of the FO landslide monitoring techniques“ will be divided into the following subtasks:
  - Design of cables and micro anchors
  - Full scale shear zone simulation
  - Further monitoring of the instrumented landslides approaches to back-calculation
  - Improvement of interpretation techniques
- “Development of chemical and biological stabilisation techniques“ will be divided into the following subtasks:
  - Chemically enhanced drainage
  - Bioremediation of the negative effects of the chemicals
  - Strength increase via bio-mineralisation
- “Study of a naturally constrained landslide (Brattas, St. Moritz)” will be divided into the following subtasks:
Related Projects:
Research organisation: Swiss Federal Roads Office; Research Roads-Bridges-Tunnels
Project number VSS2005/502
Project title Interaktion Strasse-Hangstabilität: Monitoring und Rückwärtsrechnung Project title (in English) Road-Landslide Interaction: Monitoring and Inverse Stability Analysis

Parent Programmes:
ARAMIS - ARAMIS information system

Institute type: Public institution
Institute name: Swiss Government: State Secretariat for Education and Research
Funding type: Public (national/regional/local)

Partners:
Switzerland
Swiss Federal Roads Office
ETH Zürich Institut für Geotechnik

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Key Results:
This pilot project had an objective to identify the methods and to collect the necessary data for investigation of the long term stability of a number of Swiss creeping landslides and their effects on road infrastructure. The main achievements of the project are listed below.

- A novel inverse analysis approach to the long term stability of artificially or naturally constrained landslides has been developed and successfully applied to the St Moritz and Combe Chopin landslides.

- An extensive geodetical measurements program allowed for identifying the true length and velocity field for the St Moritz landslide to be used in the inverse analysis of its stability.

- For the first time, both the Cambridge and Marcchetti Dilatometers have been successfully applied in such difficult soil conditions to determine the stiffness of the sliding layer in the St Moritz landslide.

- A novel ring shear apparatus, with significantly reduced friction and advanced measurement of forces has been developed and applied to determine the residual shear strength on the sliding surface in the Braunwald landslide.

- A novel inclinofeformometer (IDM) device for back-calculating the earth pressure changes in the sliding layer (by measuring the change in size and shape of an inclinometer pipe cross-section) has been developed and calibrated. Its first applications are for the St Moritz and Ganter landslides.

- A novel technique for determining the landslide boundaries using distributed fiber optic strain measurements (BOTDA) have been applied in the St Moritz landslide. For the first time the fiber optic cable was successfully integrated into an asphalt road, which allows for the road to be used as a gigantic strain gauge for monitoring the landslide deformation, at the same time providing information on the health of the road pavement.

- The same BOTDA technique used by grouting a fiber optic sensor cable into an old inclinometer pipe in the St Moritz landslide allows for the displacements on the sliding surface to be monitored long after the pipe was sheared.

- Preliminary recommendations for analysis, monitoring and stabilization of the constrained creeping landslides have been formulated. As is seen, the main focus of this pilot project had to be shifted towards development of the novel tools for analysis, monitoring and laboratory and field testing techniques, in order to be able to collect the missing information for the
Other results

Prediction of the road and landslide behavior for planning of the stabilization measures.

Documents:
21276_1270_Inhalt.pdf (Final report)

STRIA Roadmaps: Vehicle design and manufacturing, Infrastructure
Transport mode: Multimodal transport
Transport sectors: Passenger transport, Freight transport
Transport policies: Environmental/Emissions aspects
Geo-spatial type: Other