General Report for Session 4C – Natural hazard mitigation

Rapport général pour la Session 4C – Réduction de risque des dangers naturels

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ABSTRACT

The human impacts of natural hazards and their economic consequences have had an increasing trend in recent decades. The post-disaster effects can be especially severe in a vast, densely-populated area. Many of the world's fastest growing cities are located on coastal land or rivers where climate variability and extreme weather events pose increasing risks of disaster. Geotechnical engineers play a major role in designing and implementing risk mitigation measures against landslides, floods, earthquakes and other natural hazards. Thirteen papers were submitted to Session 4C of the 17th ICSMGE: Natural Hazard Mitigation. The papers are grouped into 4 different categories: risk assessment, early warning systems, active countermeasures (including slope stabilisation), and landslides and slopes. This General Report provides an overview and summary of the thirteen papers in Session 4C.

RÉSUMÉ

Les conséquences humanitaires et économiques associées aux désastres naturels n'ont cessé d'augmenter ces dernières décennies. L'impact suivant les désastres est souvent de dimensions immenses, surtout dans les vastes régions densément peuplées. La majorité des cités au développement des plus rapides sont situées dans des régions côtières ou près de rivières, où la variation du clima et l'occurrence d'événements extrêmes posent un risque de catastrophe. L'ingénieur géotechnicien a un rôle important à jouer dans le domaine des risques naturels, tant au plan dimensionnemnet qu'au plan implémentation de mesures de mitigation pour parer aux glissements, inondations, tremblements de terre et autres désastres naturels. Treize articles ont été soumis à la session 4C du 17ème congrès SIMSFG, Mitigation des risques naturels. Les articles sont groupés en quatre catégories: évaluation du risque, systèmes d'alerte, mesures de protection, y compris la stabilistion des terrains, ainsi que glissements et pentes. Ce rapport général présente une vue d'ensemble et un résumé des 13 contributions de la session 4C.

Keywords : natural hazards, risk mitigation, early warning system, risk assessment, landslide, slope stabilization.

1 INTRODUCTION

The human impacts of natural hazards, as well as their economic consequences have had a dramatic increasing trend since the 1950s (UNISDR, 2009). Some of the reasons for this increase are obvious, others less so. The post-disaster effects can be especially severe in a vast, densely-populated area where sewers fail and disease spreads. Slums spring up in disaster-prone areas such as steep slopes, which are prone to landslides or particularly severe damage in an earthquake. Many of the world's fastest growing cities are located on coastal land or rivers where climate variability and extreme weather events, from cyclones to heat waves to droughts, pose increasing risks of disaster.

Several recent studies, for example the UNISDR Global Assessment Report for Disaster Risk Reduction (2009) and the report by IFRC (2001) clearly show that developing countries are more severely affected by natural disasters than developed countries, especially in terms of lives lost. Table 1 shows the data compiled by IFRC (2001) for the decade 1991-2000. Of the total number of persons killed by natural disasters in this period, the highly developed countries accounted for only 5% of the casualties. In absolute numbers, the material damage and economic loss due to natural hazards in highly developed countries by far exceed those in developing nations. However, this reflects the grossly disproportionate values of fixed assets, rather than real economic vulnerability.

Table 1. Natural disasters in the period 1991-2000 (IFRC 2001).

Country classification	No. of disasters	No. of lives lost
Low and medium developed countries	1,838	649,400
Highly developed countries	719	16,200

Mitigation and prevention of the risk posed by natural hazards have not attracted widespread and effective public support in the past. However, the situation has changed dramatically during the past decade, and it is now generally accepted that a proactive approach to risk management is required to reduce significantly loss of lives and material damage associated with natural hazards. The wide media attention on major natural disasters during the last decade has clearly changed people's mind in terms of acknowledging risk management as an alternative to emergency management. A milestone in recognition of the need for natural disaster risk reduction was the approval of the "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters" (UNISDR 2005). This document, which was approved by 164 UN countries during the World Conference on Disaster Reduction in Kobe, January 2005, clarifies international working modes, responsibilities and priority actions for the coming 10 years.

Thirteen papers were submitted to this session of the 17th ICSMGE. The papers address various issues in risk assessment and risk mitigation for natural hazards. They are grouped into 4 different categories: Risk assessment, Early warning systems, Active countermeasures (including Slope stabilisation) and

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Landslides and slopes. One paper was misplaced in this session, but it is a very interesting paper and is duly reviewed.

2 EARLY WARNING SYSTEMS

R. Cleave, F. Myrvoll and R. Nålsund from Norway are authors of the paper "Microseismic monitoring and early warning of geohazards along railway lines in Norway". The paper presents the case study of a section of Norway's northern railway network that has been used as a pilot site for a microseismic monitoring and early warning system for the last four years (Figure 1). The 500 metre long section is vulnerable to ice and rock falls, and the early warning system has been designed to distinguish between passing trains, maintenance vehicles, low energy rock falls, electrical noise, and ice and rock falls of different categories. These categories correlate with the mass and position of the slide, based on data from both controlled and natural events. If a high energy ice or rock fall is recognised the train operator is warned. Cleave et al. examine several techniques that have been applied in recognising potentially harmful rock falls. These techniques include among others Page-Hinkley stopping rules, velocity mapping and time shifting, and analysis of spectral signatures. The practical challenges involved in implementing and maintaining such an early warning system are also discussed. The techniques examined are assessed in terms of their applicability to other sites and other natural hazards.

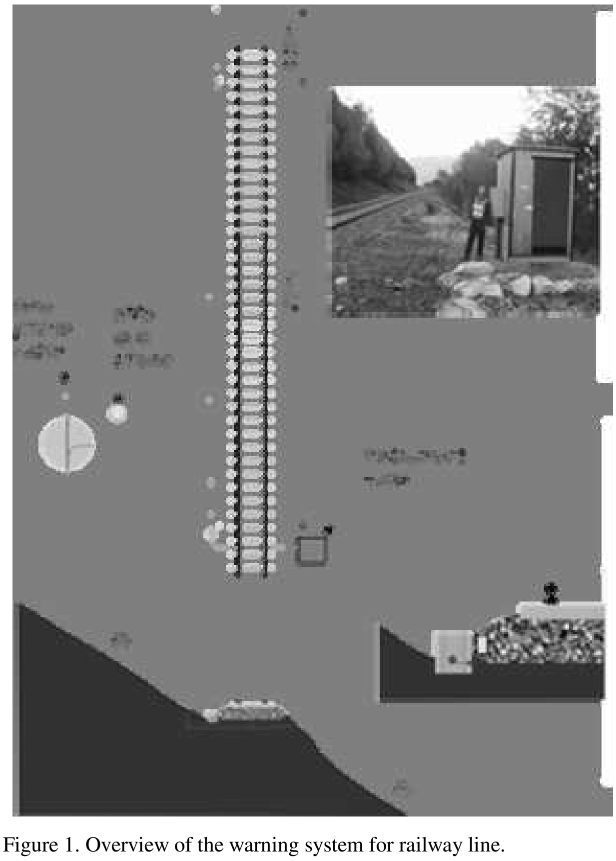


Figure 1. Overview of the warning system for railway line.

M.L. Lin, T.C. Kao and T.C. Chen from Taiwan are authors of the paper "A probability based early warning system for rain-induced landslides – A case study of Taipei City". On September 15, 2001, Typhoon Nari struck Taiwan with heavy rainfall inducing more than 400 landslides in Taipei City. An early warning system is a useful tool for reducing the landslide risk. To develop the warning criteria, the landslide events caused by Typhoon Nari along with events occurred in 2004 were used. Field investigations and documentation of the occurring time of each event were conducted carefully to validate the data. By cross-comparisons of the rainfall records from different rain gauge stations, Taipei City was divided into three subzones taking into account the geomorphological condition, distribution of the geological formations, and characteristics of rainfall pattern. Methods for determining the representative and effective rainfall parameters at the landslide sites were determined based on the rainfall records of the rain gauge stations. The probability-based early warning criteria were established using the rainfall intensity and effective cumulative rainfall at the time of occurrence of the events as the key parameters. Figure 2 shows the criteria developed for the three subzones of Taipei City. The criteria were verified by simulating the landslide event induced by typhoon Crosa on October 7th, 2007, and proved to be effective and feasible with satisfactory results. The resulting early warning system for landslide in Taipei City can be used to support decision-making during the emergency response and for hazard mitigation of rainfall induced landslide.

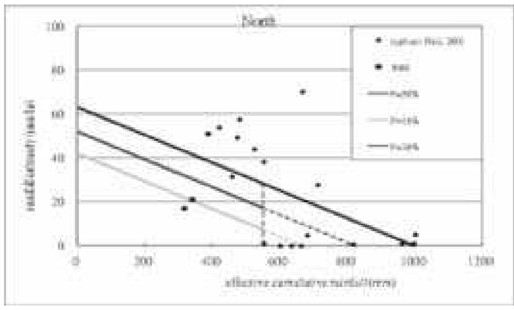


Figure 2. Early warning criteria for the north region of Taipei City.

3 ACTIVE COUNTERMEASURES AND SLOPE STABILISATION

G. Heerten, M. Heibaum, R. Haselsteiner and K. Werth from Germany are authors of the paper "Danger of flooding - New safety measures in dike construction by using geosynthetics". The risk of dyke failure is mainly given in cases of critical water saturation (due to non effective sealing or drainage zone) and dyke crest overtopping (due to undervalued crest height, settlements or higher design water levels than expected). Safe cross-sections according to state of the art are characterized by the successful use of geosynthetic clay liners as alternative dike sealing element (e.g. Figure 3). After several years of service as sealing element at dikes in Germany, geosynthetic clay liners (GCLs) have been exhumed and examined. The results of these in-service GCL analyses confirm their effectiveness. As an alternative to conventional construction designs for dike crest overflow, an enhanced geosynthetic application of soil reinforcement is taken into account. Different construction methods for the design of overflow dikes are presented. Some of the presented constructions were tested within a research project at Institute of Hydraulic and Water Resources Engineering of the Technische Universitaet Muenchen. The results of these tests are briefly summarised in the paper by Heerten et al.

E. Falk from Austria is the author of the paper "Innovative high capacity anchors to secure a motorway in Austria". More than twenty years after the completion, the motorway A2 from Vienna to Graz still has to be monitored due to possible landslides in a mountainous area (Figure 4). Existing anchors were overloaded and the required additional anchor force could hardly be transferred to the non homogeneous rock within a drilling length of 100 m. The limited space between existing anchors determined very sharp criteria regarding borehole deviation. Works had to be executed on a very steep slope considering the existing concrete beams. Single bore multiple anchors allowed to reduce the number of anchors and their length. They could be tested successfully up to a single anchor load of 5700 kN.

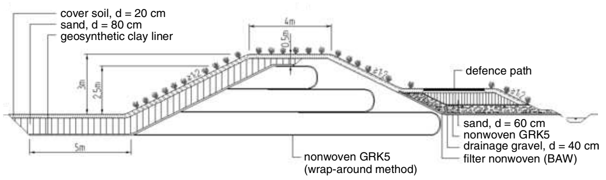


Figure 3. Cross-section of a rehabilitated dike along Poland's Oder River.

Figure 4. Actual view of the site at motorway A2 from Vienna to Graz.

Ž. Arbanas, Č. Benac and M. Grošić from Croatia are authors of the paper "Remedial works on landslide in complex geological conditions". During the construction of the Adriatic Highway section near Rijeka, Croatia, a landslide occurred on the slope alongside a highway cut. The affected section of the highway route lies on a flysch slope, in a flysch synclinal valley narrowed by limestone rock mass from the Cretaceous Period. Through lateral expansion, the landslide also affected the partly finished highway cut. The landslide occurred on the site formed in layers of Paleogene flysch, a very complex geological material. Complex geotechnical investigation works were carried out as part of a landslide remediation project. Based on the results of additional investigation works, a landslide remediation project and a new highway cut construction project were made. The basic rock reinforced structure was replaced by an anchored boring pile-wall structure in the toe of the landslide body (Figure 5). The landslide remediation was based on observational methods. The observational methods monitor the behavior of designed geotechnical structures and allow for potential corrections. This is especially useful in complex geological conditions where site investigation works are not enough to determine the condition of all site features.

A.L. Gotman and M.A. Suvorov from Russia are authors of the paper "Behaviour of many row pile landslide protection structure under deep shear". The paper present the results of investigation of landslide protection structures comprised of many pile many rows. Experimental investigations of the behaviour of many row pile landslide protection structures are carried out on models in trays with the sandy soil under the lateral landslide soil pressure (Figure 6). Based on results of the experimental investigations, the method of analysis of many row pile landslide protection structure is validated and their design scheme is improved.

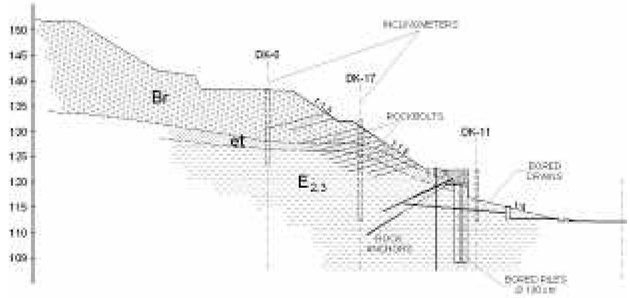


Figure 5. Cross-section of landslide with anchored pile-wall solution.

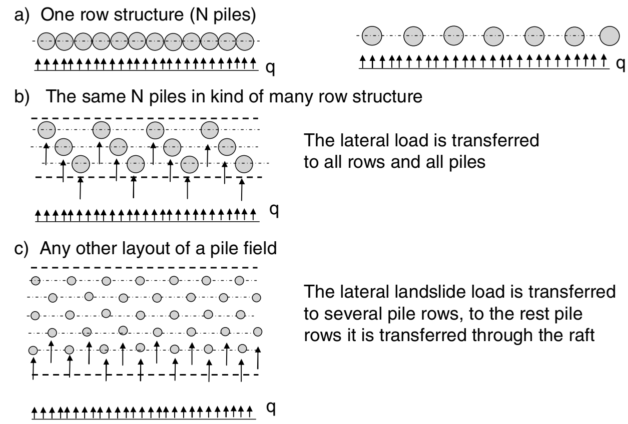


Figure 6. Constructive scheme of landslide protection structures.

D. T. Bergado, N. Phienwej, P. Jamsawang, G.V. Ramana, S.S. Lin and H.M. Abuel-Naga from Thailand are authors of the paper "Settlement characteristics of full scale test embankment on soft Bangkok clay improved with Thermo-PVD and stiffened deep cement mixing piles". Although their paper does not directly address a problem related to risk mitigation of natural hazards, the ground improvement techniques described in the paper could potentially be used for improving the stability of earth slopes. The full scale test embankments were constructed on improved soft Bangkok clay in Thailand. The ground improvement methods consisted of thermal treatment with drainage (Thermo-PVD, see Figure 7) and reinforced deep cement mixing (SDCM). The study compares the reduction of settlements among those aforementioned full-scale test embankments. The observed settlements data in field situation also discussed by means of rate and magnitude of the settlements. The Thermo-PVD treated embankment foundation indicated both higher rate and magnitude of settlements (the rate of settlement of Thermo-PVD was 3 times faster than PVD only). The SDCM reduced the settlement magnitude by 40% compared to the DCM improvement. These innovative soft ground improvement techniques are recommended as viable techniques for future applications in geotechnical construction projects.

4 LANDSLIDES AND SLOPES

F.A.J.P. Franch and M.M. Futai of Brazil are authors of the paper "Influence of surface coverage on non-saturated flows". Data were collected during an 8 month continuous measurement of rainfall, groundwater level and pore-water pressure for two portions of an unsaturated slope, in São Paulo, Brazil, under two types of surface cover: vegetation and mortar (Figure 8). The data were analyzed to evaluate the magnitude and time-dependent behaviour of pore water pressure (suction). Laboratory and in situ tests were performed to obtain physical, geotechnical and hydraulic characterization of the two geological/geotechnical horizons found on the slope. The ground smoothing caused by concrete application to the experimental slope reduced rainwater infiltration into the soil, increasing the run-off and keeping active the suction during rainy periods. During the drought periods, the evapotranspiration promoted significant reductions in pore water pressure in the vegetation-covered portion of the slope, but not in the concrete-covered portion.

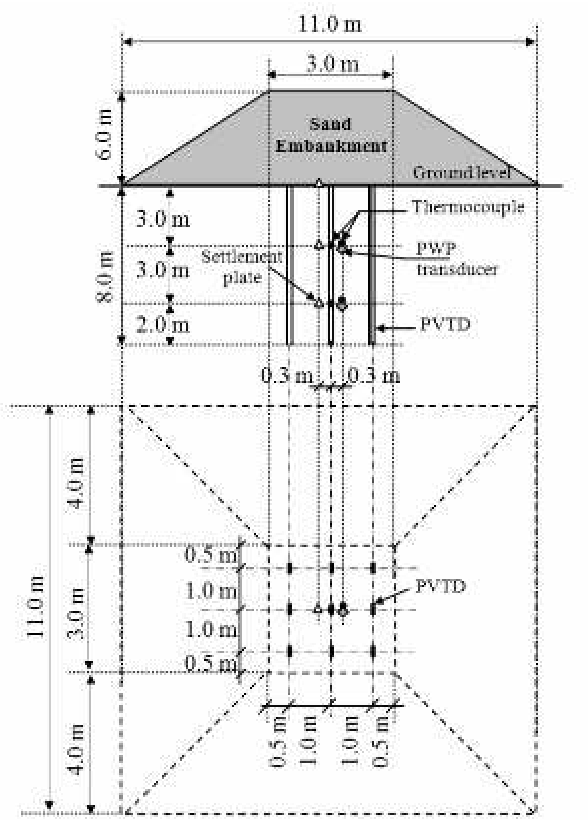


Figure 7. Layout of full-scale thermo-PVD embankment.

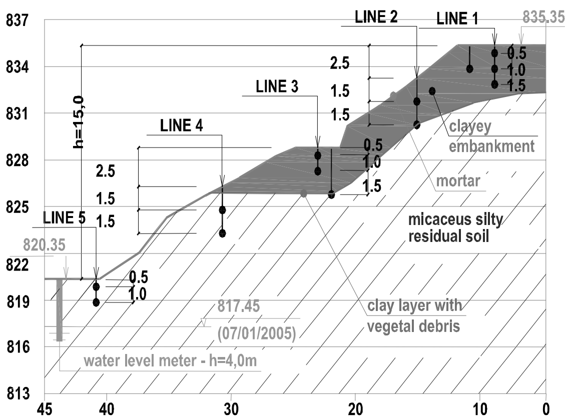


Figure 8. Geological-geotechnical profile and instrumentation used at the slope section coated with mortar: tensiometers and water level meter.

M.P. Doubrovsky, M.B. Poizner and G.N. Meshcheriakov from Ukraine are authors of the paper "Improvement of monitoring, design and constructing of piled structures located at the base of soil slopes". In coastal and harbour construction practice there are many piled structures (quays, shore protections, etc.) located at the base of landslide slope. In many cases to withstand landslide pressure, special landslide protection structures are used. The peculiarities of the complex "piled structure – landslide protection – soil slope" system, based on data from many years of special instrumental geodetic investigations, are considered in the paper. As a case study, the complex system functioning at the sea Port of Yuzhny (Ukraine) is studied. Method to analyze piled structures considering the degree of physical deterioration of their main bearing elements (e.g. Figure 9) is presented in the paper. In order to provide stability of landslide slopes during construction the modular piling system was developed. Pile monitoring data confirmed by Static Load Testing allows prediction of static bearing capacity of the piles, providing the quality assurance of the piled foundation and allowing an interactive design procedure.

Figure 9. Reinforced concrete piles of the quay after significant physical wear.

N. J. Yoo, C. J. Lee, Y. J. Choi & H. S. Lee of Korea are authors of the paper "A Study on Disaster and Restoration of Debris Flow Landslides at Inje, Kangwon Province, Korea". A series of site investigations were carried out to study the characteristics of debris flows and losses occurring during heavy rainfall in the summer of 2006 at Inje, Kangwon Province, Korea (e.g. Figure 10). It was found that major losses are caused by discharge of soil and rock fragments from debris flow landslides. During the record-high rainfall, precipitation of 113.5 mm/hour and 355 mm/day was recorded, which might occur at intervals of 80-500 years. It was also found that occurrence of the landslides is directly related to heavy rainfall by comparing the record of rainfall with the time of the landslides. At present, several debris barriers have been built in valleys and natural slopes have been protected by the seed spray method (Figure 11).

Figure 10. Overview of debris flow affecting a rural community.

a) A slit-type debris barrier

b) A shell-type debris barrier

c) A slope protected by the seed spray method

Figure 11. Debris barriers and slope protection in Korea.

S.P.R. Wardani and M. Irsyam from Indonesia are authors of the paper "Alternative Solution for the Failure of Sheet Pile Structure at Barito River in Marabahan, Indonesia". A sheet pile structure that was reinforced with concrete spun piles was constructed in 2005 in order to act as a road widening and riverbank protection for Barito river. The structure is comprises of 12 m long concrete sheet pile combined with concrete pile having a diameter of 60 cm and length of 36 m. During the early filling for the road widening, however, a landslide occurred and the structure collapsed (Figure 12). An alternative solution was therefore required. Soil profile at the site consists of very soft to soft clay having a thickness of 25 – 28 m. This layer is under laid by medium clay and dense sand up to 35m below the ground surface. Finite Element analysis was performed by modeling soil as the Mohr-Coulomb elastic-plastic material and by modeling concrete sheet pile and pile as elastic-plastic beam elements. Calculation results showed that safety factor for existing condition before filling was 1.1. Filling for the road widening reduced safety factor to less than 1.0 and resulted in instability of river slope and failure of the structure. It was decided that the combination of concrete sheet pile and slab-on-pile structure was the optimum solution. With this solution, safety factor of the river slope was then increased to more than 1.25, satisfying the minimum requirement.

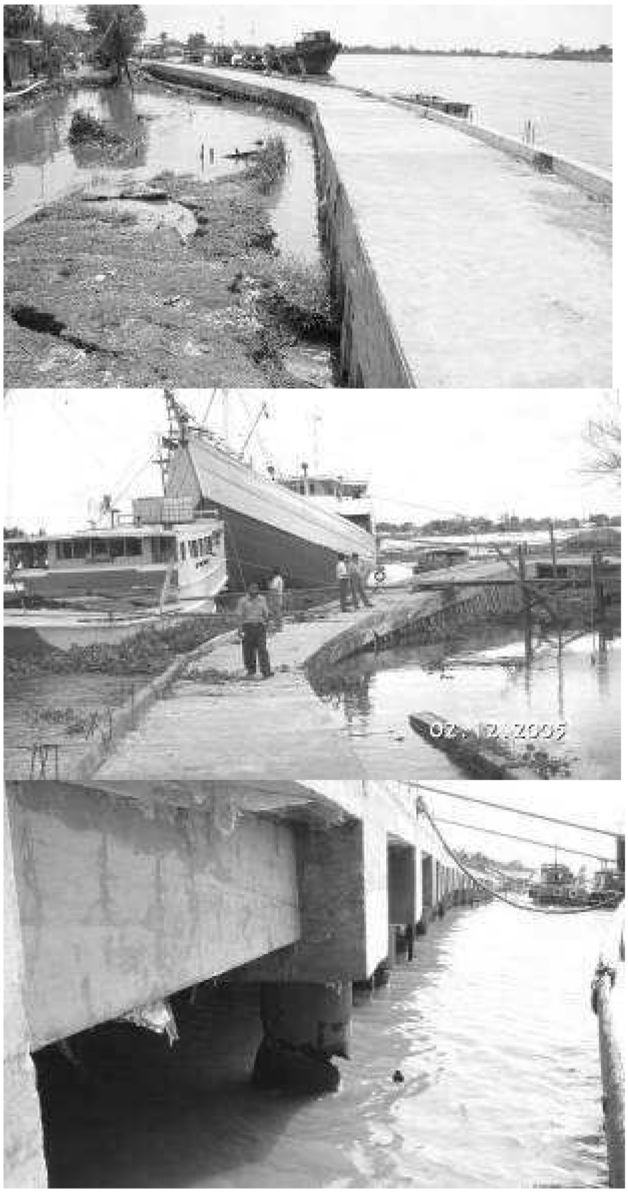
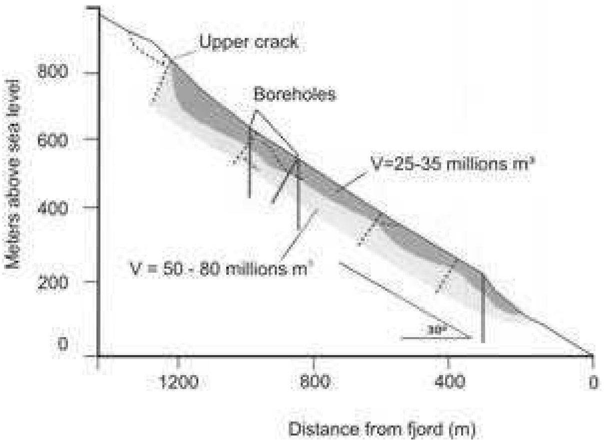


Figure 12. Landslide of riverbank followed by collapse of the structure consists along the riverbank of Barito river.

5 RISK ASSESSMENT

U. Eidsvig, S. Lacasse and F. Nadim from Norway are authors of the paper "Event tree analysis of the Åknes rock slope". A massive rockslide at Åknes in the Stranda municipality in western Norway (Figure 13) would have dramatic consequences, as the tsunami triggered by the slide would endanger several communities around Storfjorden. Site investigations, offensive monitoring and a warning system for the potentially unstable rock slopes were implemented to reduce hazard and consequences. As part of hazard and risk assessment, event trees were constructed by pooling the opinion of engineers, scientists and stakeholders. The objective was to reach consensus on the hazard, vulnerability and elements at risk (consequences) associated with a rockslide and tsunami, quantify the hazard (probability of a rockslide and tsunami occurring) and the potential losses (human life and material and environmental damage). The probability of occurrence and the risk were obtained through a consolidation of all the branches of the event trees. The event tree analysis results in a map of the risk for the residents for the municipalities close to Åknes. Eidsvig et al. present the event tree analysis process and some of the preliminary results achieved on the hazard associated with the failure of the Åknes rock slope.



Area I: Slide volume 10-15 mill. m^3, displ. = 6-10 cm/yr
Area II: Slide volume 25-80 mill. m^3, displ. = 2-4 cm/yr

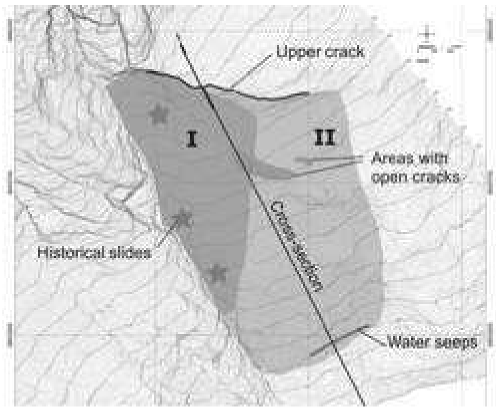


Figure 13. Sliding volume scenarios: surficial area (top) and cross-section (bottom).

6 MISPLACED PAPER

G. Almeida, I.M. Almeida, M.C.R. Silva, F.T. Jeremias, C. Pinto and M. Muñoz from Portugal are authors of the paper "Engineering geological role on cemetery planning – Lisbon Carnide's Cemetery Case Study". This paper seems to be misplaced in Session 4C as it does not address an issue related to natural hazards. However, it does address an unusual problem in geotechnical engineering and engineering geology. In the last quarter of the 20th century the estimation of available space for interment in Lisbon indicated a critical situation; the six municipal cemeteries were close to exhaustion and without capacity for expansion. The site of the new cemetery at Carnide was selected between three hypotheses as meeting the main prerequisites. However in the initial opinion it was already recognized that the topography was too rough and the composition of local soil and relatively high groundwater levels should be considered as less favourable conditions. The engineering geological characterization of the Carnide's cemetery site was based on a site investigation program carried out in 1983. As the groundwater level may reach the elevations of the burials, the design studies proposed to elevate the burial areas over the natural terrain. With this purpose a terrace modelling of the terrain was proposed, using selected materials to construct the burials prisms, and designed a deep drainage systems as well as surface system. The Carnide's New Cemetery was opened in 1996 and after a period of 12 years there were a total of about 10000 burials. According to a preliminary analysis of the first 5 years of activity (1996-2000) it seems that a timescale of 5 to 10 years as design criterion for corpse decomposition failed leading to studies with the aim of determining the causes and possible solutions for that problem. The cemetery management practice of Lisbon Council requires that decomposition of corpses takes place during a timescale of 5 to 10 years. Taking the Carnide's Cemetery as case study the problem of non-decomposition of corpses in the specified period is discussed by Almeida et al.

7 CONCLUDING REMARKS

This General Report presented an overview of the papers submitted to Session 4C of the 17th ICSMGE: Natural Hazard Mitigation. The papers covered various issues related to risk mitigation for natural hazards such as risk assessment, active countermeasures, early warning systems and slope stabilisation. The wide variety of topics presented in these papers clearly highlights the important role of geotechnical engineers in disaster risk reduction.

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