Part I

Landslide Instrumentation and Monitoring

Introduction by Rajenda K. Bhandari[1], Leonardo Cascini[2], and Dario Peduto[2]

1) Centre for Disaster Mitigation and Management Vellore Institute of Technology University, India
2) Department of Civil Engineering, University of Salerno, Fisciano (Salerno) 84084, Italy

Session L07 of the Second World Landslide Forum was devoted to **"Landslide instrumentation and monitoring".**

This 4-day Session attracted several researchers with diverse backgrounds in different fields of science and technology spanning from landslide numerical modelling to in situ- and laboratory instrumentations and remote sensing monitoring techniques. The success of the Session was obvious from large audience (130 participants) and the lively multi-disciplinary discussions on 75 submitted full papers, 52 oral and 28 poster presentations

The present chapter is a compendium of all the papers and well documented case studies on landslide instrumentation and monitoring contributed by landslide experts from different parts of the world.

An overview of the session papers highlights that scientific studies of landslide phenomena derive their strength from thorough analyses of multitude of factors such as subsoil geology and minor geological details, predisposing and triggering factors, physical-mechanical and engineering properties of soil, groundwater regime and piezometric characteristics, and landslide kinetics including surface/deep displacements and displacement rates. Indeed, landslide investigations and instrumentations play a fundamental role for the comprehension of the landslide mechanics, for their monitoring and for exercising a check on the efficacy and effectiveness of landslide prevention and control works. Considering the differences in landslide features, the typology of these measurements often differs according to: the geo-environmental setting and catchment characteristics; the typology of the phenomena; the scale of the analysis; the parameter to be monitored (i.e. magnitude and rate of rainfall; slope displacements; piezometric variations, etc.). The above topics addressed in the papers are briefly summarized below.

Focus on landslide modelling is found in Del Fabbro et al.; Hassandi and Ghazali, etc., whereas aspects of either fast or slow-moving landslide monitoring are analysed by Vassallo et al.; Sarkar et al.; Chambers et al.; Bugnion and Wendeler; Passalacqua and Bovolenta. Some innovative field tests for the investigation of both mechanical (Ostric et al.) and hydraulic (Krzeminska et al.; Kapeller et al.) properties of the involved soils are also presented. As far as fast-moving landslides are concerned, several case studies dealing with rockfall are presented (Clerici et al., Arosio et al.) also furnishing general concepts and requirements for their monitoring (Blikra and Kristensen). In this regard, some Authors (Lenti et al.; Amoroso et al.; Walter et al.; Occhiena et al.) show a number of applications with seismic sensor networks.

Multi-parameter (i.e. temperature, groundwater levels, displacements, etc.) monitoring systems increasingly involve wireless sensor networks (Berti et al.; Koizumu et al.), fiber-optic sensing systems (Chu et al.; Kapeller et al.) and remote sensing data which can be less expensive and time-consuming than the conventional techniques.

Changes of geo-environmental features and related information (i.e. surfacial displacements, width of surfacial cracks, variations of vegetation cover, etc.) have been shown to be successfully detectable by optical (Debella-Gilo et al.; Wasowski et al.; Stumpf et al.; Travelletti et al.) image processing techniques over areas affected by different typologies of landslides.

With reference to deep/surfacial displacement monitoring, innovative techniques (i.e. Micro Electro-Mechanical System (MMES), Segalini et al.) as well as advanced procedures for the use of almost consolidated techniques such as GPS (Deprez et al.), total station (Manconi et al.) and LIDAR (Ventura et al.) are described.

The positive trend in the application of remote sensing data, especially when dealing with analyses over large areas, is testified in this chapter by the high number of contributions focusing on the use of synthetic aperture radar images—acquired from both spaceborne and ground-based platforms—processed via differential interferometric techniques (DInSAR). In particular, these data prove to be a valuable tool for superficial displacement monitoring over both large areas and single phenomena (Fornaro et al.; Singhroy et al.; Nutricato et al.; Moretti et al.; Antolini et al.; Tamburini et al.; Bonanno et al.; Kos et al.; Farina et al.; Norland and Gundersen; Agliardi et al.; Kristensen et al; Antronico et al.; Bozzano et al.; Tuan et al.; etc.)

Finally, some case studies reporting experiences in Europe, India and South-East Asia of either long-time working (Cardellini; Supper et al.) or recently built up (Sarkar et al., Kurosch et al.; Arnhardt et al.; Bednarczyk) early warning systems are also presented.

The overall impression gathered from the papers and poster presentations of the session has been heartening in terms of the high scientific value of the contributions made, rewarding in terms of the frontier of knowledge advanced and stimulating in terms of the limitations and problems uncovered for future research and development work. Then, referring to innovative ground-based and remote sensing techniques, a knowledge deepening appears necessary for their confident use considering that the results furnished up to now are very promising. To this end, a close cooperation among landslide experts, scientists and technologists involved in the development of advanced algorithms and instrumentations seems the most widely shared recipe to achieve more reliable data and, in turn, to foster the continuous updating of both processing algorithms and technologies.