

LANDSLIDE MANAGEMENT IN THE MOUNTAIN AREAS OF CHINA



Li Tianchi

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1. Debris flow from the watershed temporarily blocked the Xiao River (immediate foreground). View looking westwards of large landslide above Xiabeini Ravine on hillside; alluvial fan of debris flow (centre).

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Foreword

Natural hazards are inherent in mountain environments. Of these, landslides probably constitute the most common and dreaded hazard for mountain people everywhere. This is particularly true for the mountainous regions of the Hindu Kush-Himalayas where the mountains rise suddenly from near sea level to close to tropospheric heights within a span of 200 km or less. Such a high energy environment with very steep slopes is the home of millions of people and loss of life and property due to landslides is almost an integral feature of life in these mountains.

Landslides are estimated to cost more than US \$ 1 billion in economic losses and to cause more than 200 deaths each year (30 per cent of the world total of such fatalities) in the Himalayan Region. Large-scale deforestation, unplanned urban growth, and badly engineered mountain roads have been major contributing factors more recently. Nearly every country in the Region is prone to serious damage from landslides. In China alone, the annual loss due to landslides is estimated at 0.5 billion U.S. dollars, and the number of landslide-related deaths per year is estimated to exceed 140.

Although it could be said that the occurrence or non-occurrence of landslides depend mainly on natural causes and factors, such as the geological and geohydrological characteristics of any locality (or region), exogeneous factors such as intense precipitation over a short time interval and earthquakes also trigger and accelerate landslides. Similarly, growing human and animal populations in the mountainous regions of the Hindu Kush-Himalayas have also created other imbalances such as deforestation and encroachment on to steep slopes. More recently, construction and mining activities have also increased as have the factors that cause landslides. Hence, the complexity of these causes has increased, due to natural and human factors, and along with these the human and economic consequences of such incidents have also become more damaging, adding to the miseries of people who are already in the grip of poverty. It is in this context that a proper understanding of the physical processes, as well as human interventions, that lead to increased incidences of landslides along with the methods and techniques of managing and monitoring landslides, to minimise loss of life and property, is a priority for all concerned with the well being and development of the mountain people.

ICIMOD's primary concern being the sustained and balanced development of the people of the Hindu Kush-Himalayas, one of its major concerns is the minimisation and mitigation of hazards - whether natural or man-made. Considering that, for rapid development, human interventions in the mountains will increase, ICIMOD considers it important to have a better understanding of the geophysical and man-made processes that cause landslides as well as of the enhanced ability to provide technical solutions to such problems.

The Mountain Environmental Management Programme of ICIMOD is endeavouring to respond to some of these challenges facing the mountain environment in this Region. To examine these and other major issues concerned with environmental management in the mountains an **International Symposium on Mountain Environmental Management in the Hindu Kush-Himalayan Region** was organised by ICIMOD under this programme from 11 to 14 April, 1989. This paper was prepared within the framework of ICIMOD's ongoing programme on Mountain Environmental Management and was also presented at the Symposium as one of the theme papers along with others dealing with major issues of the mountain environment.

Professor Li Tianchi, who, until recently, was associated with ICIMOD as Head of the Mountain Environmental Management Division, has a great deal of experience in Landslide Monitoring and Management in China. As he has pointed out in his paper, China has made significant achievements in the management of landslides and has developed new methods of predicting, mapping, and preparing inventories of landslides. It was therefore felt that much could be learnt from China's rich experience in this field by the publication of this work in an occasional paper. It is hoped that this will highlight the diverse issues related to landslides in the Hindu Kush-Himalayas and contribute to enhancing the capability of reducing the disastrous consequences of landslides within the limits of technological innovations and human ingenuity vis-a-vis unalterable natural causes and factors. Although the emphasis is on the Hindu Kush-Himalayan Region, it is also hoped that this publication will be of interest to all who are involved and concerned with landslides in mountain environments elsewhere.

Dr. E. F. Tacke
Director

Abstract

Located on the east coast of the largest continent (Eurasia) and on the western margin of the largest ocean (the Pacific), China has a land area of about 9.6 million km² and a population of more than one billion. In China, 66.5 per cent of the total land area is mountainous, and contains 33 per cent of the total population and 40 per cent of the total cultivated land. Landslides are of critical significance, especially in the Hengduan Mountain Areas of Southwestern China, the Loess Plateau Area, and Taiwan Island; including the Provinces of Sichuan, Yunnan, Guizhou, Hubei Xizang, Gansu, Shaanxi, Shanxi, and Taiwan.

Landslides are the result of a complex interaction of geologic and geographical environments, and have a variety of causes: heavy rains, melting snow or ice, earthquakes, volcanoes, deforestation, and human activities. Among these, earthquakes and heavy rainstorms constitute two of the most important landslide-inducing agents in the mountain areas of China. In addition, landslides are also triggered by road construction, deforestation, overgrazing, and exploitation of mineral resources. Increased population and construction in mountain terrains expose more people to the landslide problem and the economic consequences can often be quite serious.

Landslides destroy or damage residential and industrial developments, agricultural and forest land, and railways and highways. They also have a negative impact on the quality of water in rivers and streams. In China, landslides caused at least US \$ 0.5 billion in economic losses per year during the period from 1951 to 1987. Damages to transportation facilities, mainly railways and highways, constitute a significant part of total landslide costs.

Apart from the substantial loss of property, landslides killed an average of 140-150 people annually during the period from 1951 to 1987. Mortality figures due to landslides exceeded 257,000 during the period from B.C. 186 to A.D. 1987. The large number of

landslide deaths in China is related to earthquakes, very heavy rainfall, and flooding due to the destruction of landslide dams.

Since the 1960s, a great deal of effort has gone into the reduction of landslide hazards. Many mitigative techniques, such as regional landslide studies and mapping, monitoring and warning systems, and landslide control works, have been developed.

Regional landslide studies and mapping are considered to be the first step in coping with landslide disasters on a regional basis. During the last ten years, regional landslide investigations at various levels, from the provincial to the small local watershed areas, have been carried out. Consequently, it has been possible for various government organizations to publish landslide distribution and susceptibility maps on different scales by using a variety of parameters.

Since the 1970s, a number of landslide and debris flow observation and monitoring stations have been established. The most common methods of monitoring include field observation and surface measurement; and, in addition, the use of inclinometers, extensometers, tiltmeters, and pipe strain gauges. A monitoring system for Xintan Landslide, Western Hubei, composed of four collimation lines, was set up at the end of 1977, and eight monitoring survey points and a triangulation network were added in July 1984. Based on the monitoring data, a landslide of 20 million m³ on the upper slopes of Xintan Town, which occurred on June 12, 1985, was accurately predicted. The 1,371 local inhabitants of Xintan Town were safely evacuated.

The relationship between antecedent precipitation and rainfall intensity has been established to predict debris flow by the Dongchuan Debris Flow Observation Station of the Chinese Academy of Sciences. The accuracy of debris flow forecasting is as high as 85 per cent. Debris flow and landslide warning systems have also been installed in some ravines that are susceptible to

debris flow and in potential landslide areas along the railway lines from Chengdu to Kunming and from Tianshui to Baoji. When the specified safety conditions are exceeded, the railways are closed.

The control of landslides in China is undertaken as follows:

- by avoidance: by relocating, bridging, tunnelling;
- by surface drainage: channelling or ditching, preventing water leakages;
- by sub-surface drainage: tunnelling, deep seated counterfort drains, vertical and horizontal drilling of drainage holes;
- by support structures: retaining walls, anchoring of retaining walls, crib work, gabion stabilizing trenches, piling works;
- by excavation: removing, flattening, and benching;
- by river structure work: damming for erosion control and consolidation: consolidation of dams; revetment bolts, vaulting, and construction of spur dikes; and
- by other methods: planting vegetation, blasting, and hardening.

Physical landslide control measures actually carried out in the landslide areas are based on certain concepts. Priority is given to preventing the loss of human life; followed by the preservation of public structures, buildings, and roads. Flooding control measures are undertaken in areas where slides are likely to dam rivers. The best methods of preventing landslides in watershed areas are the reforestation of slopes and construction of check dams in the valleys.

China has a natural disaster insurance programme that covers losses from landslides. This programme assists those whose dwellings and farmlands have been damaged by landslides or other natural hazards.

In recent years, losses from landslides have increased. This is largely due to the fact that residential and industrial developments have expanded on to steeply sloping terrain, and these areas are prone to landslides. Although the recent progress in landslide control techniques has made it possible to solve some landslide problems, there remains a great deal to be done in order to reduce landslide hazards in mountain areas.

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