Assessment of Performance of Engineering Measures for Mitigation of Sediment Disasters after Typhoon Morakot

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Abstract—Landslides and debris flows are frequent sediment disaster events in Taiwan. Recent catastrophic event, Xiao-lin Landslide in Chishan, Kaohsiung County, Taiwan is a fresh reminder of the possible devastating destruction and tragedy caused by large landsides and debris flows. Thus, a cost-effective engineering measure to mitigate the occurrence of disaster and to reduce the disaster-induced losses is urgently needed. In this paper, we present a framework for assessing the performance of an engineering measure to mitigate the landslide hazards and demonstrate it with 18 cases of engineering remedial work. The cost-benefit analysis is employed to assess the performance of a given engineering measure. This framework consists of three parts: (1) an estimate of the engineering completeness rate, (2) a procedure for estimating the disaster-induced losses, and (3) a procedure for assessing the performance of an engineering measure. The results of the case study show that the proposed methodology is an effective approach for mitigation of landslides and debris flows. Use of the proposed methodology for assessing the cost-benefit of an engineering mitigation work is also presented.

Keywords— sediment disaster, cost-benefit analysis, loss, mitigation

I. INTRODUCTION

Attributed to the crushing geology and steep topography in Taiwan, landslides and debris flows can easily be induced by the event of typhoons and heavy rainfalls, which often cause great destruction and losses in this densely populated island. Table 1 shows statistics of typhoons and heavy rainfalls and the associated losses during the period of 1999 to 2011 in Taiwan. More than two catastrophic events occurred every year. Over the past 13 years, there were 1171 people killed, 293 people lost, 3450 people injured, 2353 structures collapsed, 4437 structures partially collapsed and the total landuse loss of 47,055 million NT dollars ($1.56 billion US dollars), as shown in Table I. Among these events, Typhoon Morakot, which occurred during the period of 8-10 August 2009, recorded a precipitation of 2,361 mm in 48 hours (which is very close to the world record of 2,467 mm in the 7-9 April 1958 rainfall at Aurere, La Reunion). Typhoon Morakot was the triggering event for Xiao-lin Landslide in Chishan, Kaohsiung County, one of the most catastrophic landslides in Taiwan, which buried 474 people and more than 100 buildings abruptly.

Naturally, there is a national effort to develop strategies to mitigate landslide and debris flows disasters in Taiwan (note: in local practice, the disaster related to landslides and debris flows is often termed “sediment disaster”). Generally, these strategies to prevent and mitigate sediment disasters (landslides and debris flows) can be divided into engineering and non-engineering categories. The engineering strategies may include retaining facilities, sabo dams, and so on. The non-engineering strategies include planning the suitable land use, strengthening the structures, building the early warning system, evacuating and relocating the residents, and so on. Because of limited government resources, it is essential to assess the expected performance of an engineering measure for sediment disaster mitigation. It is equally important to assess the quality of the decision on mitigation work by various authorities. To this end, the cost-benefit analysis is often adopted to measure the decision quality of such mitigation work.

The cost-benefit analysis is often to determine the ratio of benefit (B) over cost (C). In practice, an engineering measure is considered efficient if this ratio of benefit over cost is greater than 1. On the other hand, an engineering measure is considered inefficient if this ratio is less than 1. In this paper, the cost-benefit analysis is used to assess the performance of a given engineering measure. We develop a simple framework for assessing the performance of a given engineering measure, and use it to examine the engineering mitigation measures at 18 major disaster areas identified after the event of Typhoon Morakot. These engineering measures were implemented by the Soil and Water Conservation Bureau, Taiwan as part of the post-event mitigation effort. Results of the investigation of these 18 cases show that the proposed framework is an effective approach for assessing sediment-disaster mitigation work.

II. DEFINITION OF HAZARD RISK

Natural hazard risk (R) is the total loss of life, property, economic activities and environment induced by a given hazard event (Fell, 1994):

$$R = \sum (E \times p \times V),$$

where $p$ is the occurrence probability of disaster in a given period (say, one year); $E$ is the elements at risk including life, property, economic activities, and public facilities in the impact range (for convenience, the currency unit is often used to measure the elements at risk); $V$ is the vulnerability in the...