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A hypothesis of the earthquake and rain induced megaslide in Pakistan-based on the undrained dynamic loading ring shear tests and computer simulation

○Saima RIAZ, Kaoru TAKARA, Kyoji SASSA, Muhammad BASHARAT

INTRODUCTION

In Pakistan, during monsoon season majority of the landslides occur along the highways, built in the mountainous terrain. These landslides cause human and economic loss, disruption to traffic and reduce the tourist activities in these areas. Kashmir earthquake on Oct 8,2005 triggered thousands of mass movements in the affected region of Pakistan. The Panjgran landslide in the Neelum Valley area, close to the epicenter is one that obstructed the Neelum Valley communication system for many days even after the earthquake. This landslide travelled 650m in the direction of north towards the Neelum river and caused severe damage to the Neelum road. Some authors have worked on the study area but they made susceptibility maps or analyzed the area by empirical approach. Therefore, detailed field and laboratory methods were still indispensable and there was a dire need to model and study the landslides sub-surface structure and behaviour. The landslide disaster emphasis the necessity of a detailed geotechnical study for disaster risk preparedness which simulates initiation and motion. The field investigation and the undrained dynamic loading ring shear tests on the Panjgran landslide suggested that this landslide was triggered by the combined effect of pore water pressure due to rain and 2005 Kashmir earthquake. The application of LS-Rapid simulation model could well reproduce the initiation and motion of the Panjgran landslide.

METHODS

The study area is located in the Neelum Valley and lies in the NE of Muzaffarabad city, capital of the state of Azad Jammu and Kashmir, between the coordinates 34°21′ to 34°28′ N and 73°27′ to 73°41′ E. It is categorized as rugged topographic characteristics and steep slopes. Topographically, the study area is mountainous with valleys and stretches of plains and is very prone to landslides because of the long and persistent rainstorms and frequent earthquakes. It is the part of “Sub-Himalaya” a morpho-tectonostratigraphic division of Himalaya. Himalayan orogeny is the world's youngest active continental to continental collision. Two active faults Kashmir Boundary Thrust (KBT) and Kawai Fault (KF) are running through the area. KBT was responsible for the devastating 2005 Kashmir Earthquake. These interformational (KBT) and intraformational (KF) faults have affected the physical and mechanical properties of the rocks present in the immediate vicinity forming a 200m or sometimes thicker deformed zone. The rocks present in these fault zones are highly sheared, folded, weathered and in most parts, are badly crushed to fine material.

An engineering approach was adopted focusing on quantifiable outputs for physical aspects of Panjgran landslide. For this purpose, intensive field investigation was carried out and In-situ samples were collected. Digital elevation models and topographic sheets were collected from relevant authorities and photographs were taken. Ring shear tests were performed on the collected samples from the field by using landslide Ring shear simulator and the parameters obtained from laboratory testing will be used in LS-Rapid software to simulate the landslide initiation and motion.

RESULTS

Pore water pressure control test was the first basic test for this landslide to study landslide failure by increasing

only pore water pressure. At first, the sample was saturated (B_D value, 0.85), then consolidated to 1.2MPa normal stress and 0.7MPa shear stress in a drained condition. This preparatory stage was to reproduce the initial stress in the slope and is shown as a black line in Fig. 1. This initial stress corresponds to a slope or arctan (0.7/1.2) =30.1°. This is the slope of the landslide. Then in order to simulate the pore pressure induced landslide process, the pore water pressure was gradually increased at a rate of 1kPa/sec. Failure occurred at a pore water pressure of 0.375MPa (a pore water pressure ratio r_u = 0.375/1.2 = 0.3). This is the critical pore water pressure ratio which can trigger the landslide without earthquake. The friction angle at failure was 40°.

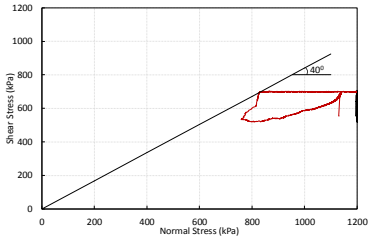

Fig.1: Pore pressure control test results

Undrained mono tonic stress control test can provide the appropriate shear stresses under rainfall,earthquake or undrained loading in the moving landslide mass to simulate the landslide phenomena. For test, normal stress was first loaded in the drained condition to close to the planned normal stress (1.2MPa). The shear box was then changed to the undrained condition, and shear stress was loaded gradually at a rate of $\Delta\tau$=1kPa/sec. When the effective stress path reached the failure line, it began to decrease due to pore pressure generation along the failure line (this is the phenomena of sliding surface liquefaction). Shearing was continued until 10m of shear displacement. The stress path and time series data for undrained stress control test are shown in Fig.2. Shear behaviour at 1200kPa normal stress was contractive and stress path at the normal stress reached the failure line (43.6 °) then went down until 250kPa shear stress and shows a dilative behaviour and increased to touch the failure line again. A positive pore pressure was generated until failure and then negative pore pressure was measured just before failure. After failure, the pore pressure decreased during shear displacement. Dilation of the sample near failure caused negative pore pressure and grain crushing occurred in the shear zone. The resulting volume reduction together with the accumulating post failure shear displacement, generated negative pore pressure in the sample.

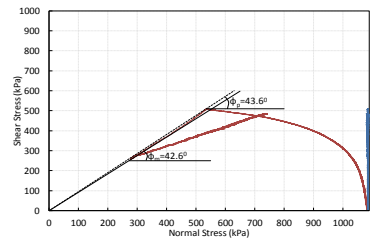

Fig.2: Undrained monotonic stress control test results

CONCLUSION

- The Panjgran landslide was first activated in 1988 and 1992 floods and was reactivated during the 2005 Kashmir earthquake in northern Pakistan causing many causalities and blocked the Neelum valley road for 60 days. The factors controlling the landside activity includes steep slope, presence of clayey material, construction of the Neelum road and river under cutting.
- The pore pressure control test for simulating the source area of the landslide suggested that a pore pressure ratio of 0.3 could have caused the landslide without an earthquake.
- This study can not only help in reducing the casualties but also in saving millions of dollars of nation by detailed analysis of the active landslide in landslide prone areas including geological, geotechnical, hydrological, and topographical data essential for the assessment of landslides. This research can provide a strong and practical base for the evaluation of risk and vulnerability assessment of the active landslides and slope failures in study area, and for the secured and cost-effective buildings and sustainable infrastructure in landslide prone areas.
- Seismic loading test results and simulation on LS-Rapid software are under study and their data will be published later.