FINAL REPORT ON RESEARCH PROJECT

Project No. 6UNI1/505

Modelling earthquake-induced bedrock landslides with a seismic wave tank – initial phase

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Abstract

Progress is reported in initiating a research project intended to utilise a small-scale laboratory model, dynamically-similar to large rock mountain edifices, to acquire data on the response of large rock slopes to seismic shaking. A small prototype seismic wave tank has been cast in concrete so that experimental techniques can be tested before committing to the design of a larger model. Fabrication and assembly of the vibration input device and of the accelerometer array are in progress. The choice of model material has been narrowed down to urethane; gelatine and silicone have both been eliminated for different reasons. Field inspection of the Acheron and Craigieburn rock avalanche source areas has yielded some interesting ideas, such as the relationship between coseismic rock avalanches and "Sackungen" or antiscarps. Map analysis of the source areas of the Whitehouse (1983) data set has demonstrated that there is considerable variation in morphology and setting, which requires further analysis using aerial photos. The project is on track for satisfactory completion in 2007.

Introduction

This project is the initial phase of a 3-year PhD study by Flo Buech. It commenced on October 2005, with EQC funding from 1 November 2004 to 30 May 2005 for start-up costs and student support.

The project is to investigate the role of seismic shaking in initiation of large, deep-seated bedrock slope failures in mountains. It is hypothesized that topographic modification of incident seismic waves, and the resonant response of the entire mountain edifice to the shaking, cause very low short-term factors of safety on deep-seated surfaces, with the result that these surfaces fail releasing large rock avalanches.

This hypothesis is to be tested by constructing small-scale laboratory mountain-shaped edifices of material that responds to incoming vibrations in a manner dynamically similar to that of field-scale rock mountains. The measured ground motions on the model edifice allow internal stresses to be calculated, and the location of likely failure surfaces identified. Initially the model material will behave elastically; at a later stage we intend to utilise a model material that is both sufficiently elastic to behave similarly to field-scale rock, and also sufficiently weak to fail in a manner similar to field-scale rock. Such materials are now becoming available (E. Bowman, Schofield Centre, Cambridge University, U.K., *pers comm* 2005).

Progress to date

1. Flo Buech has applied for, and been awarded, a University of Canterbury PhD Scholarship for 3 years. No further student support is required for this project.

2. Flo Buech has also submitted to the University, and received approval of, a Research Proposal on which his project will be based.

3. A considerable volume of literature on the research topic has been accessed and assimilated into the developing project concept.

4. A phased procedure has been developed for approaching the design of the model apparatus. This involves, as an initial step, fabricating a small version of the model to test the chosen materials, vibration input, reflection suppression and data acquisition techniques. The small model is now ready for this work, which will commence at the beginning of June. The detailed design of the final model, (which is complete in outline) can then be finalized.

5. A reconnaissance map study of the source areas of the 46 source area scars of the Whitehouse and Griffiths (1983) central Southern Alps rock avalanche data set has been completed. It is clear from this that some of these rock avalanches do not have prominent source area scars. There are a number of possible reasons for this:
    - The rock avalanches may have been aseismic (like the 1999 Mt Adams, 1991 Mt Cook and 1992 Mt Fletcher landslides) and therefore had an extensive, shallow source area rather than a deep bowl.

- The source area scars may have infilled subsequent to formation with products of subaerial weathering and denudation.
- The source areas may be poorly represented on the 1:50,000 contour map.

To investigate the latter possibility, an air photo survey of the poorly-defined source areas will be carried out, followed by field inspections in the 2005-6 and 2006-7 summers. It is also likely that specific flights will be undertaken to obtain good oblique imagery of selected source areas.

Similarly, there is no clear tendency apparent at this stage for large rock avalanches to fall from sites of particular geomorphic characteristics.

6. A considerable amount of investigation has been carried out with respect to selection of the most appropriate material for the model. The requirements are stringent: the material must
   - have an elastic modulus in the range 2 – 4 MPa and a density in the range 1-1.5 t m^{-3};
   - be non-toxic and stable over the long term at room temperature and humidity;
   - cost less than about $10/kg.

   Following rejection of gelatine (unstable and expensive) and silicone (very expensive), we have settled on urethane as the best material. It has the disadvantage that the large model must be fabricated off-site under factory conditions, but this is preferable to creating those conditions in the existing laboratory.

   Some initial testing will be done with silicone in the small model, where cost is much less of an issue and the convenience of on-site fabrication is useful.

7. The accelerometers, amplifiers and data logger required for ground motion measurement in the model have been acquired and are being commissioned.

8. The control apparatus and software required for programming time-varying three-dimensional vibrations into a mechanical output device has been acquired.

9. The output device design will be finalized following the small-scale preliminary tests. Initially a one-dimensional single-frequency input will be used, followed by the sequential introduction of realistic frequency ranges and further shaking directions. At this stage we are still considering the use of audio componentry for vibration input, though the use of piezoelectric linear actuators will have considerable advantages if the costs of these are within the project budget.

10. As a separate but possibly linked project, a study has commenced of the morphometric characteristics of cirques in Fiordland using GIS. It is intended to use the analytical techniques developed in that study on a selection of the Whitehouse and Griffiths (1983) source area scars, to see if there are any similarities with those of cirques (in which case it may be inferred that cirques can be ice-modified rock avalanche source areas).

11. A further linked project is a study of the initiation and development of antiscarps. The modelling results be utilised by that project in parallel with the present one.

Comments

Less has been accomplished than was anticipated at the start of the project, and than was expected in applying for the interim funding. This is because the experimental materials and techniques have become clarified as work has been done, and our state of understanding of the requirements of modelling has deepened. In particular, the decision to use a small preliminary model to assess seismic input, data acquisition and materials handling techniques has delayed the final design and construction of the final model; but there is no doubt that this is a sound step, since the final model reliability will be very much increased as a result.

The slower-than-expected progress at this stage of a major project is by no means unusual. The expectation of a complete outcome remains high, and is in fact increased by the greater thoroughness of preparation at this stage.

Further work

Further support has been requested from EQC for continuing this project as part of 2006 Biennial Research Funding. In outline, it is proposed to:

- Construct and commission seismic wave tank, 3-D computer-controlled seismic wave input device and data acquisition system; by December 2005.
- Carry out model tests on simple mountain shapes, starting with 2-D waves and topography. Compare results with numerical models; by June 2006.
- Extend tests to 3-D situations. Compare results with numerical models; by December 2006.
- Introduce non-homogeneous model materials in both 2-D and 3-D tests. Compare results with field data; by June 2007.

The outcome of the project will be a sound understanding of the failure mechanics of large coseismic bedrock landslides. This is a necessary precondition for prediction of the location and size of such landslides; once these can be predicted, the hazard zone of rock avalanches can be delineated from current understanding of the dynamics of runout processes (McSaveney and Davies, in press).

References

Davies, T.R. and McSaveney, M.J. (2005 *in press*). Rock-avalanche size and runout – implications for landslide dams. *In* Abdrakhmatov K., S.G. Evans, R. Hermanns, G. Scarascia Mugnozza and A.L.Strom (Eds) Security of Natural and Artificial Rockslide Dams. *Proceedings* of the NATO Advanced Research Workshop, Bishkek, Kyrgyzstan, June 2005.

Whitehouse, I.E. and Griffiths, G.A. (1983). Frequency and hazard of large rock avalanches in the central Southern Alps, New Zealand. *Geology*, 11: 331-334.