ADVANCED NUMERICAL MODELLING OF GEOGRID-REINFORCED ROCKFALL PROTECTION EMBANKMENTS

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Currently, empirical or simplified analytical methods are used to design such embankments. In order to assess behaviour of rockfall protection embankments in more detail, Opus carried out 3D numerical simulation using the finite element software ABAQUS. In the simulation process rock blocks were thrown onto a geogrid reinforced embankment at different impact angles. The effects of geogrid spacing, the presence of the steel facing mesh and impact angle have been investigated. The numerical simulation procedure can be used to develop and optimise the design of geogrid-reinforced rockfall protection embankments.

Keywords: rockfall protection, embankment, finite element modelling, geogrid.

Introduction

Rockfall can occur from natural sources, such as unmodified hillsides or relict sea cliffs, and man-made features including road cuttings and mines. These rockfalls can be instigated through a wide variety of triggers (e.g. weathering, frost-jacking, seismic activity and blasting). Away from the built environment and its supporting infrastructure, rockfall poses little more than an interesting study of natural process and its risk is generally accepted as part of the natural evolution of the environment. However, the interaction of rockfall with built elements at risk (e.g. residential settlements, businesses, highway infrastructure and rail corridors) frequently causes significant threats, typically in terms of structural damage, loss of life, financial cost and service disruption. As the availability of low-risk sites suitable for development become pressured, areas at greater risk from rockfall are increasingly considered as viable options. Geogrid-reinforced rockfall protection embankments provide effective mitigation against rockfall hazard. However, currently there are no commonly accepted design methods for the rockfall protection embankments. The most advance design technique involves the use of numerical modelling. Opus utilised 3D numerical modelling to investigate the behaviour of the rockfall protection embankments under the impact of rock blocks with high kinetic energies. The design methodology for rockfall protection embankments is described in this paper.

Recent rockfalls in Christchurch

The magnitude 7.1 Darfield Earthquake of 4 September 2010 was centred approximately 40 km west of Christchurch city centre at an approximate depth of 30 km and caused significant structural and land damage. Whilst some rockfalls were recorded as a result of the earthquake, these were generally confined to localised features and areas and their resulting damaging effects were limited, primarily due to the softer ground conditions (typically encountered at the end of the winter) limiting run-out paths. The magnitude 6.3 aftershock of 22 February 2011 generated far greater levels of rockfall. In the Port Hills to the south and east of Christchurch city centre, a total land area of about 65 km^2 was affected by rockfall, stretching from Mount Pleasant in the north, Lyttelton in the south, Godley Head in the east and to Governors Bay in the west. Examples of 22 February 2011 rockfall damage are shown on Fig. 1.

Increased levels of rockfall were largely attributable to the exceptionally high Peak Ground Accelerations (PGAs) in both the horizontal and vertical planes. PGAs of 2.1 g (horizontal) and 2.2 g (vertical) were recorded at Heathcote Valley, the approximate epicentre of the aftershock. In addition to the high PGAs, the dry ground conditions encountered at the time of year (late summer) will have further exacerbated the impact of triggered rockfalls resulting in unusually long run-out distances, especially when compared to those of the initial Darfield earthquake. Damage and disruption caused by the rockfalls was widespread. Transportation infrastructure, businesses and residential dwellings were all affected. For residential dwellings alone over 120 individual dwelling (or ancillary building) rockfall impacts were mapped. Many thousands of individual seismically triggered fallen boulders were mapped across the region, enabling the generation of a unique and comprehensive dataset. Mapped boulder sizes were widely varied. However, the average and the 95th % percentile boulder volume values have been reported as approximately 1.0 m^3 and 3.0 m^3 respectively.

Significant numbers of seismically triggered boulders coupled with their comparatively large volumes, high coefficients of restitution of the dry ground encountered along their run-out paths and mode of travel (significant angular rotation) culminated in a multitude of high total kinetic energy boulders, even over the lower sections of the Port Hills slopes. Resulting levels of damage to the built environment caused by individual rockfall boulders were in many cases localised but considerable.