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Evaluation of fissure formation processes caused by earthquakes using numerical simulations

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Throughout the world, major earthquakes cause significant changes to mountainous landscapes. Whilst landslides tend to be the most significant earthquake-induced hazards in most mountainous regions, numerous fissures (cracks) are regularly observed and often represent a significant hazard. These features may develop through many processes such as; incipient slope failure, surface fault rupture, dynamic compaction, liquefaction and lateral spreading, display different physical (e.g. shape, depth and displacement vectors), and site characteristics (e.g. the topographic setting, site specific soil/rock conditions) which may influence their failure mode and post-earthquake behavior. Identifying the dominant ground failure modes from fissure morphology, their displacement vectors, and their site characteristics is complex and requires site data from earthquakes where numerous fissures have developed, and their post- earthquake performance has been monitored. We investigated the formation mechanisms and post-earthquake performance of fissures caused by the 2010/11 Canterbury Earthquakes in New Zealand to test the hypothesis that their post-earthquake performance is strongly influenced by their formation processes.

We conducted Finite Element Method (FEM) modelling on one of the main fissured sites in the Port Hills of Christchurch, New Zealand, to show that the fissures developed through slumping of the soil masses, as a result of increases in pore-water pressure during the earthquakes. Displacement of the soil masses appears to have occurred via distributed shearing within a 2-3 m zone of saturated/partially saturated colluvial loess. Most of the fissures formed in response to the M_W6.2 22 February 2011 earthquake, but ongoing minor displacement of the soil masses were recorded by continuous GPS post this earthquake, which appear to correspond to decreasing pore-water pressures post-earthquake. These pore-water pressures and surface displacements took several months to attenuate. Displacement of the soil slumps also occurred during subsequent lower magnitude earthquakes, again in response to earthquake-induced increases in pore water pressures. No displacement of the slumps has been recorded during non-earthquake events such as rainfall-induced increases in pore water pressure, which during the monitoring period have been less than those pore-water pressure increases triggered by the monitored earthquakes. These results would suggest that such features are only activated by strong ground shaking.

We will now compare the morphology and site conditions of fissures associated with these slumping mechanisms with those generated by other earthquake-induced fissure development mechanisms recorded during the 2010/11 Canterbury Earthquakes and the 2016 Kumamoto Earthquakes, in Japan.