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Rockfall hazard assessment, risk quantification, and mitigation options for reef cove resort development, False Cape, Queensland, Australia

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GIS and 2-D rock fall simulations were used as the primary tools during a rock fall hazard assessment and analyses for a major resort and township development near Cairns, Queensland in Australia. The methods used included 1) the development of a digital elevation model (DEM); undertaking rock fall trajectory analyses to determine the end points of rockfalls, the distribution of kinetic energy for identified rock fall runout Zones, and 3) undertaking event tree analyses based on a synthesis of all data in order to establish Zones with the highest risk of fatalities.

This paper describes the methodology used and the results of this work. Recommendations to mitigate the hazard included having exclusions zones with no construction, scaling (including trim blasting), construction of berms and rockfall catch fences.

Keywords: GIS, rockfall simulation, rockfall runout Zones, mitigation options

INTRODUCTION

False Cape is located on the east side of the Trinity inlet near Cairns (Figure 1). Construction is underway for a multi-million dollar development close the beach front. The development will ultimately cover about 1.5 km of prime coast line. The granite slopes above the development are steep and are covered with a number of large, potentially unstable boulders.

Sheet jointing is present in the in-situ bedrock and these combined with other tectonic joint sets have provided a key mechanism for large side down slope on exposed bedrock. With each rock fall (evidence by boulders strew in gullies, over the lower parts of the slope, and on the beach) the failure mechanism migrates upslope.

In order for the Developer to proceed with construction he needs to mitigate the identified rock fall hazard. The method used to study the hazard and key finding are presented in this paper. Discussion is provided in the conclusion on mitigation options.

KEY METHODS USED TO STUDY THE HAZARD

In summary the methods used to study the hazard for the False Cape project include;

1. The development of a digital elevation model (DEM) used to delineate rock fall runout Zones [1] that included the spatial location of boulder fields mapped within Zones(Figure 2). A Zone is defined as an area above the development on steep sided slopes where falling rocks are channeled into gullies / and or are contained between topographic features such as ridges and spurs that extend down the mountainside. These natural barriers generally ensure that falling rocks do not fall or roll into adjacent Zones;
2. The use of 'Flow Path Tracing Tool' in Arc GIS spatial analyst to confirm typical descents of boulders in Zones. These were shown to correlated strongly with the endpoints of boulders observed within the development and major clusters of boulders on the beach front;
3. The use of 2-D rockfall trajectory analyses [2] using sections cut along typical 3-D trajectory paths mapped out in ARC GIS per Zone. Sections along typical paths in Zones simulated, to some degree, the 3-D affect or path of rocks as they bounce roll down slope (Figure 3);

4. The calibration of rockfall input parameters (coefficients of normal and tangential restitution, slope roughness, friction angle, etc.) using field identified endpoints and size of fallen rock and boulder; and
5. Undertaking risk evolutions in order to quantify the potential risk for each independent rockfall Zone.

KEY FINDINGS FROM THE STUDIES

The key findings from the study include;

1. Multiple potentially unstable in-situ boulders (some in excess of several thousand tonnes) are present above the development.
2. Similar geological structures (dykes, jointing, etc.) are present in the boulders on the beach front and within the development exposed in-situ bedrock located above the development. Measurement and comparison of the orientation of these geological structures present in boulders with that observed in the in-situ bedrock provided strong evidence that that the boulders have mitigated down slope.
3. Eight discrete Rockfall Runout Zones were identified using the digital elevation model set up in ARC GIS (Figure 4). The boundaries were field verified as far as possible. The identified Zones formed the basis of all subsequent work.
4. Once calibrated the rockfall trajectory modeling showed that only between 1% and in the worst case 28% of falling rocks (percentage of 1000 seeding events) per Zones would actually reach the development. While this indicated a reduced likelihood of an incident and hence the risk, the kinetic energy in the case of an impact in most Zones was so high (for the given design block size) that the consequence would be untenable without some form of mitigation.
5. An event tree analysis showed that five out of the eight Zones identified had risk profiles that fell above or very close to what was considered to be an acceptable annual probability of occurrence of a fatality or fatalities.

CONCLUSIONS

Each Zone has unique characteristics that influence the risk profile associated with the rock fall hazard to the development. Mitigation options and recommendations needed to be adjusted accordingly to fit the physical characteristics and assessed risk profile of each Zone. These included:

1. The possible implantation of exclusion zones (no build areas);
2. Scaling (including controlled blasting) to reduce the potential kinetic energy associated with identified potentially unstable boulders; and
3. The design and construction of Berms and rockfall catch fences.