Assessing the vulnerability of roof collapse in response to loading from volcanic ash with relevance to Ascension Island.

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Rationale

The loading that results from ash fall following volcanic eruptions can pose a significant problem to the structural integrity of buildings (Figure 1). Damage to buildings due to volcanic ash fall is frequently reported yet poorly studied. This is largely because damage data needs to be collected as soon after an eruption as possible before clean-up and repair, or erosion by wind and rain. This involves entering areas where there is a danger of further eruptions, and there are often sensitivities with local communities, science agencies and disaster emergency managers. As a result, there is a need for focused experimental studies on the impacts of ash loading on buildings and given that over 800 million people are now estimated to live near active volcanoes, the evaluation of the vulnerability of buildings to ash loading is also essential for disaster risk reduction.

Figure 1. Partial roof collapse of a school in a village which has experienced heavy ash fall from Sinabung volcano, Indonesia, Jan 2014. Image taken by Dr Richard Roscoe and available on www.photovolcanica.com

The ability to assess the risk to buildings from loading caused by air fall deposits is a routine procedure within the fields of structural engineering, and such procedures are outlined in codes of practice or standards such as the Structural Eurocodes: a set of ten standards that govern the design of building and civil engineering works. However, these codes deal almost explicitly with snow and there is no consideration of ash loading as a potential problem. There are significant differences between snow and ash ranging from the physical properties to the way in which it is produced and distributed which mean that assessing ash fall hazard is not as simple as adopting the current procedures for snow. Developing the Eurocode guidance on snow loading, this project will develop a methodology for assessing the ash loading on roofs and the hazard posed.

Objectives

Roof collapse is the result of a complex interaction involving the loading caused by the ash, the design and condition of the structure and the weather. As such there are three main objectives in this project.

1. Defining a “characteristic” amount of ash

2. Defining the relevant seasonal properties of the ash

3. Evaluating the vulnerability of buildings and the hazard posed.

Project Summary

The project objectives will be achieved through a combination of desk-, laboratory- and field-work. Attempting to undertake these objectives on a global scale is not possible, so this project will be using Ascension Island as a case study. Ascension Island is a remote volcanic island that lies ca. 90 km east of the Mid Atlantic Ridge in the South Atlantic (Figure 2). It rises 4 km from the seafloor to a height of 859 m above sea level (a.s.l.), and has an area of approximately 91 km^2. It forms part of the UK Overseas Territory of St Helena, Ascension and Tristan da Cunha, and has a population of approximately 800 including the UK Royal Air Force and US Air Force. The island is volcanically active, with recent research revealing that the youngest lava flows are just a few hundred years old. Past volcanic activity on Ascension Island was dominated by mafic lava flows with felsic pyroclastic deposits and scoria. The explosive eruptive history is confined to vents on the central mountainous region of the island and recent research has revealed at least 74 pumice-producing eruptions were identified within the last 1 Myr.

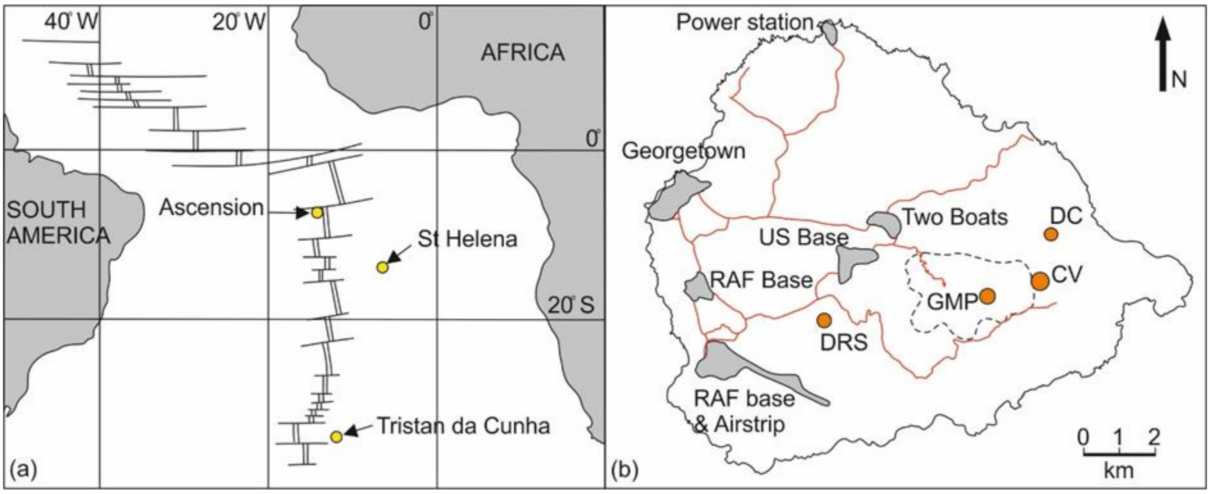

Figure 2. (a) Ascension Island location map and (b) map of Ascension Island showing the main residential areas (grey areas) and the principle vent locations of Devil's Cauldron (DC), Cricket Valley (CV), Green Mountain Peak (GMP) and Devil's Riding School (DRS). The red lines are roads and the dashed line outlines the central mountainous region, Green Mountain.

This first stage of the project will be defining a "characteristic" value for the amount of ash. A characteristic value, in the concept of loading from ash fall, can be thought of as an upper value with an intended probability of not being exceeded. While this may be straight forward to define for activities such as snowfall, where there is access to decades of weather data. For ash fall, where eruptions can be separated by centuries, often with no written record, determining such a value is extremely challenging. In such situations, a scenario-based approach will be used. Eruptions scenarios of specified magnitude are developed based on the geological record. Multiple simulations are run for each scenario using a tephra dispersion model (e.g. Tephra2; Connor and Connor 2006). For Ascension Island, explosive eruption scenarios have been developed and simulated based on two months of wind data. The resultant ash thickness maps have been used as a basis for an initial ash fall hazard assessment on Ascension Island at the BGS. This project will expand on this work through tephra dispersion modelling of a ten-year Reanalysis wind database to develop an ash loading characteristic value. This will be led by Dr Crummy at BGS Edinburgh, supported by colleagues at the School of Earth and Environment in Leeds.

The second stage will involve characterising the ash and its interaction with the structures. After determining a characteristic value for the amount of ash (which can be simplistically thought of as the thickness of an ash deposit for a given situation), to calculate the true load imposed on a roof there are many aspects that need to be considered. These include properties of the ash such as composition (density) and shape (related to the eruption style), whether the ash is dry or wet (which changes the density), or how the ash will have accumulated on the roof (e.g. drifting), which is determined by the shape of the roof and the material the roof is made from. This latter point is usually dealt with by shape coefficients, which can be thought of as a simple constant derived for the shape of a roof that modifies the applied load. For example for a flat roof you would not expect the shape of the roof to alter the amount of material that falls on it, but if the roof had a pitch, the steeper the pitch the greater the amount of material you would expect to slide off, reducing the load. This is another example of where there is copious data relating to materials such as snow, but an almost a complete lack of information on the shape coefficients relevant to ash. Volcanic ash acts in a very different manner to snow, and has vastly different properties in a dry and wet state, so deriving appropriate shape coefficients is a crucial step. Through laboratory work at the University of Leeds conducted on real and synthetic ash, this project will define the required properties of the ash and relevant shape coefficients to combine with the characteristic loading values needed to accurately characterise the loading caused by ash fall.

Following the full probabilistic characterisation of the ash load, the third stage will involve incorporating these data into a vulnerability/hazard assessment for Ascension Island led by Dr Crummy at BGS Edinburgh.

Training, Funding and Field Work Opportunities

The student will be a member of an active and enthusiastic cohort of PhD researchers at the University of Leeds and will become part of both the Volcanology and Rock Mechanics, Engineering Geology and Hydrology research groups. The successful candidate will receive training in research methodology, scientific writing, tephra dispersion modelling, geotechnical characterisation of materials and conduction of vulnerability/hazard assessments. There will be significant time spent working closely with the BGS in Edinburgh and the potential for field campaigns on Ascension Island, which will be extremely beneficial in gathering gather data on the buildings on Ascension; information to be used in both the characterisation of the ash load and the vulnerability assessment. There will be the opportunity to present research findings at national and international conferences and workshops as well as internal seminars.

This project will benefit from extra funding and support from the BGS University Funding Initiative (BUFI). The additional funding (up to £11k) will help cover field work and any additional lab costs. BUFI supports around 100 PhD students across the UK, therefore the student will benefit from being part of a wide network of PhD students as well as access to BGS facilities and training.

This project will also benefit from close working relationships between BGS and New Zealand and Earth Observatory Singapore researchers who are leaders in the field of vulnerability and impacts of ash fall on critical infrastructure

Suggested Reading

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Keywords

Fieldwork; Geoengineering; Hazard and Risk; Laboratory; Volcanoes