

**Supervisors:**  
 Prof Stefan Kaczmarczyk  
 Prof Nick Petford  
 Dr Eiman Elbanhawey

## Abstract

This study aims at exploring the effects of both static and dynamic loading of volcanic ash on a building roof, by proposing a revision of the building regulations with the objective of making existing and future European buildings more resilient to volcanic ash loading on the buildings in the prone areas. Preliminary results show that there is a direct proportionality between deformations of the roof and the load due to weight of the impacting ash as demonstrated through simulation tests using a finite element method.

## Previous Studies

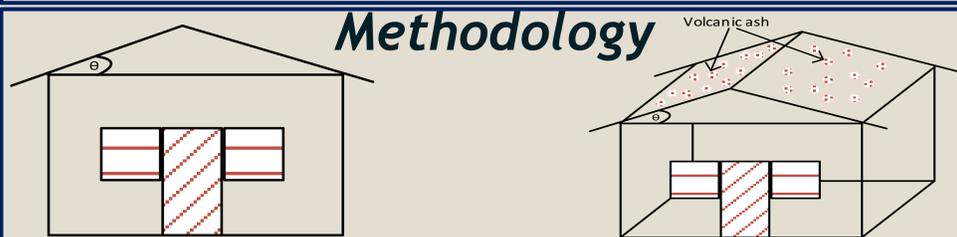
Density & load comparison, 100 mm (4 in) of snow and 100 mm (4 in) volcanic ash (Johnston, 1997)

Description	Density kg/m <sup>3</sup>	Load kPa
New snow	50-70	0.05-0.07
Damp new snow	100-200	0.1-0.2
Settled snow	200-300	0.2-0.3
Dry uncompacted ash	500-1,300	0.5-1.3
Wet compacted ash	1,000-2,000	1.0-2.0



There have been a number of research projects carried out concerning the roofs of buildings in Europe, such as the effect of roof covering on the thermal performance of highly insulation roof, others explored roof exposure to tephra around the Vesuvius in Italy and also an experiment on the volcanic ash fall accumulation and loading on gutters and pitch roofs from laboratory empirical experiment. (D'Orezio et al., 2010, Spence et al., 2005, Spence et al., 2005).

## Methodology



The diagrams illustrate the modelling part in more detail, which will be carried out in both 2D and 3D. The research follows a multi-method approach. Numerical modelling using the Finite Element Method (FEM) models and the Discrete Element Method (DEM) modelling tool is deployed to interrogate the volcanic ash effects loadings on a concrete flat roof within the current EN1991 code.

## EN1991 Code

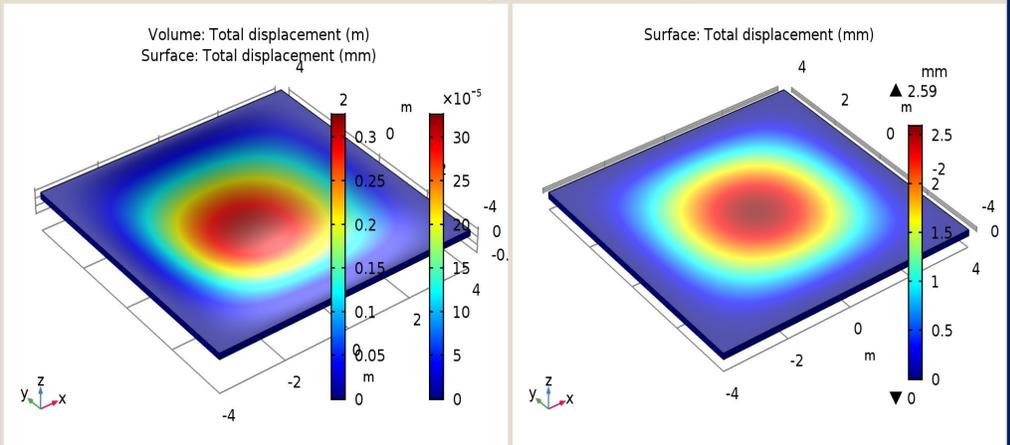
<b>EN 1991-1-1:2002</b>	<b>Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings.</b>
<b>EN 1991-1-3:2003</b>	<b>Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads</b>
<b>EN 1991-1-4:2005</b>	<b>Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions</b>



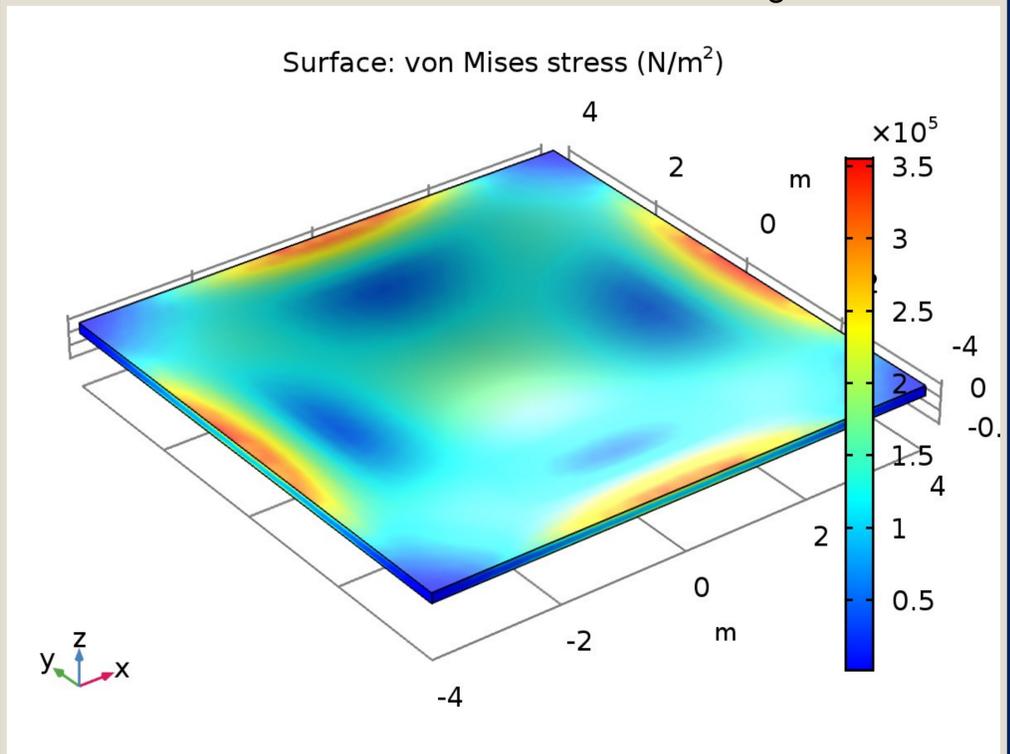
## Results

A simulation test which has been conducted with a pressure of volcanic ash layer on a concrete flat roof shows deflection is inversely proportional to the thickness of the roof and its moment of inertia. For example, a pressure of 0.5 kN/m<sup>2</sup>, 1.0 kN/m<sup>2</sup>, 2.0 kN/m<sup>2</sup> on a flat concrete roof shows a deflection of 0.34 mm, 0.69 mm and 1.38 mm for 0.154 m thick concrete roof respectively.

### Effect of volcanic ash loading on buildings



Results of applying a pressure of 500N/m<sup>2</sup> Results of applying a pressure of 500N/m<sup>2</sup> (due to the ash load) combined with the roof self-weight.



The overall stress distribution on the roof

## Summary

Further work will assess the effects of volcanic ash of changing density on various roofing materials to:

- Determine the stress levels
- Determine Maximum deflections
- Determine the nature of failure of the roof due to volcanic ash pressure

## References

- D'Orazio, M., Di Perna, C. and Di Giuseppe, E., 2010. The effects of roof covering on the thermal performance of highly insulated roofs in Mediterranean climates. *Energy and Buildings*, 42(10), .1619-1627.
- Formichi, P., 2008, February. EN 1991-Eurocode 1: Actions on structures. Part 1-3 General actions-Snow Loads. In presentation at Workshop "Eurocodes. Background and Applications (18-20).
- Hampton, S.J., Cole, J.W., Wilson, G., Wilson, T.M. and Broom, S., 2015. Volcanic ash fall accumulation and loading on gutters and pitched roofs from laboratory empirical experiments: Implications for risk assessment. *Journal of Volcanology and Geothermal Research*, 304, .237-252.
- Johnston, D.M., 1997. The impact of recent falls of volcanic ash on public utilities in two communities in the United States of America. Institute of Geological & Nuclear Sciences Limited
- Luckett, R., Baptle, B. and Neuberg, J., 200. The relationship between degassing and rock fall signals at Soufriere Hills Volcano, Montserrat. *Geological Society, London, Memoirs*, 21(1), .595-602.
- Spence, R.J.S., Kelman, I., Baxter, P.J., Zuccaro, G. and Petrazzuoli, S., 2005. Residential building and occupant vulnerability to tephra fall. *Natural Hazards and Earth System Science*, 5(4), .477-494
- Westergaard, H.M. (1943) Stress Concentrations in Plates Loaded over Small Areas. *Transactions ASCE*, 108, 831-856