Progress in investigation of vulnerable stalagmites vibration, numerical and analogue modeling

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Recently, it has been argued that natural intact stalagmites in caves give important constraints on seismic hazard since they have survived all earthquakes over their (rather long) life span. This suggests that the pattern of oscillation should be fully understood, including the splitting of eigenfrequencies that has occurred in recent cave observations. In the present study, we simulate the oscillation of a given stalagmite by setting up four simplified models of the stalagmite. The dimensions of the intact stalagmite were measured in-situ, and the geo-mechanical and elastic parameters of broken stalagmite samples, determined in geo-mechanical laboratory, have been taken into account. The eigenfrequencies of the stalagmite are then calculated numerically, by the finite element method, and compared with the measured in-situ values. The latter have shown splitting of eigenfrequencies, which we were able to reproduce by the numerical model calculations taking into account the asymmetric shape of the stalagmite.

In order to determine the critical value of horizontal ground acceleration, that would have made them failed at different stages of their growth, we need to understand the failure process of these intact and vulnerable stalagmites. More detail information of the vulnerable stalagmites' rupture is required, and we have to know how much it depends on the shape and substance of the investigated stalagmite. Predicting stalagmite failure limits using numerical modeling is faced with a number of approximations, e.g. from generating a manageable digital model. Thus it seems reasonable to investigate the problem by analogue modeling as well. The advantage of analogue modeling among other things is that nearly real circumstances can be produced by simple and quick laboratory methods. The stalagmite model sample bodies were made from gypsum. These bodies were reduced-scale with similar shape as the original, investigated stalagmite. During the measurements, we could change both the shape and the material and the time series of acting horizontal acceleration. Comparing the results from analogue to numerical modeling could improve the accuracy of long-term seismic hazard assessment.