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Candlestick stalagmite's eigenfrequency characterisation with ambient seismic noise and 3D scan, a step to support seismic hazard assessment

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Intact speleothems can be used as indicators for an upper limit of the level of horizontal ground motions of past earthquakes which affected the cave. Candlestick stalagmites have eigenfrequencies well in the frequency-band of regional earthquake ground motions. An earthquake can therefore break such elongated structures if the ground movement is strong enough. In the study of the response of speleothems to earthquakes, eigenfrequencies are a fundamental parameter. A study was carried out at Han-sur-Lesse (Belgium Ardennes) to estimate these frequencies for the so called Minaret stalagmite, an imposing 4.5 m tall structure.

Three-component seismic sensors were used to record the ambient noise during a period of 22 days on the stalagmite, at its base on the cave floor, and at Earth's surface. This technique allows a precise determination of the first eigenfrequencies of the stalagmite (two firsts mode shapes) and the polarization of the motions associated with the frequencies. The use of three-component seismic sensors is a precondition to identifying these polarizations. Moreover, the horizontal motions recorded on the stalagmite show significant amplification (4 and 14 times depending on the orientation) compared to those recorded at the free surface outside the cave. The long recording period allows the measurement of transient events like earthquakes or quarry blasts.

In addition, a 3D laser scan of the stalagmite's shape has been used to construct numerical models. The dynamic behaviour of the models is in good agreement with the measured parameters. The use of the 3D scans clearly increased accordance between model and measurements compared to simply shaped approximations of the stalagmite. The combination of measured and modelled data clearly show that the shape of the stalagmite (elliptical cross-section and shape irregularities) influences the eigenfrequencies and the polarization of the modes while also causing a near-orthogonal split of the natural frequencies.

Knowing that the shape and the height of the stalagmites evolve over time, further steps in this study will be to date the candlestick stalagmites in order to have an approximation of their height

(and therefore their eigenfrequencies) during their history and to model their eigenfrequency evolution with time.