Comprehensive investigation of intact, vulnerable stalagmites standing in Hungarian, Bulgarian, Slovakian and Austrian caves in order to estimate of an upper limit on prehistoric peak ground horizontal acceleration

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Abstract

Non-intrusive in situ measurements were carried out in caves in Hungary, Bulgaria, Slovakia and Austria in order to determine the fundamental frequencies and horizontal peak ground accelerations resulting in failure of intact, slim, vulnerable stalagmites.

The main steps of investigation are:
---The density, the Young’s modulus and the tensile failure stress of the samples originating from broken stalagmites (lying on the ground of an investigated cave) have been measured in a mechanical laboratory.
---The natural frequency of intact stalagmites were determined by in situ observation.
---The value of horizontal ground acceleration resulting in failure and the natural frequency of stalagmite were assessed by theoretical calculations.

Our investigations show that the upper limit for horizontal peak ground acceleration, $a_g$, for slim stalagmites from theoretical calculations, can arise even for moderate-sized earthquakes. The natural frequency of the investigated stalagmites is low, about 1 - 2 Hz. Since this low value is in the frequency range of nearby earthquakes, resonance effects can occur, which may reduce the failure acceleration even further.

Core samples were taken from the investigated stalagmites to estimate ages by ICP-MS analyses. Stalagmite ages constrain the time period, assuming that the stalagmite shape has not changed. Therefore, one can infer that the geological structures close to the investigated caves did not excite paleoearthquakes in the determined time period, corresponding to horizontal ground accelerations larger than the determined $a_g$ values.

Keywords: natural frequency; PGA; prehistoric-earthquake; seismic hazard; stalagmite