Safety distances from a speleothem cave for construction: Soreq cave Israel

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Introduction / Research Motivation

Soreq Cave (Fig.1) is a unique speleothem cave that is also a nature reserve in Israel. Its speleothems hold values both in an educational and research perspectives, as thousands of pupils and travelers venture inside. Future construction with heavy machinery adjacent to the cave, that includes building roads, bridge, and observations points – all aim to ease access for the general public. These infrastructure developments will cause vibrations and in turn ground accelerations that may rupture the speleothems. Hence, it is vital to take precautionary measures for the safety of these speleothems. We have designed a study before the commencement of these construction works to determine safety distances for the various instrument that will be used.

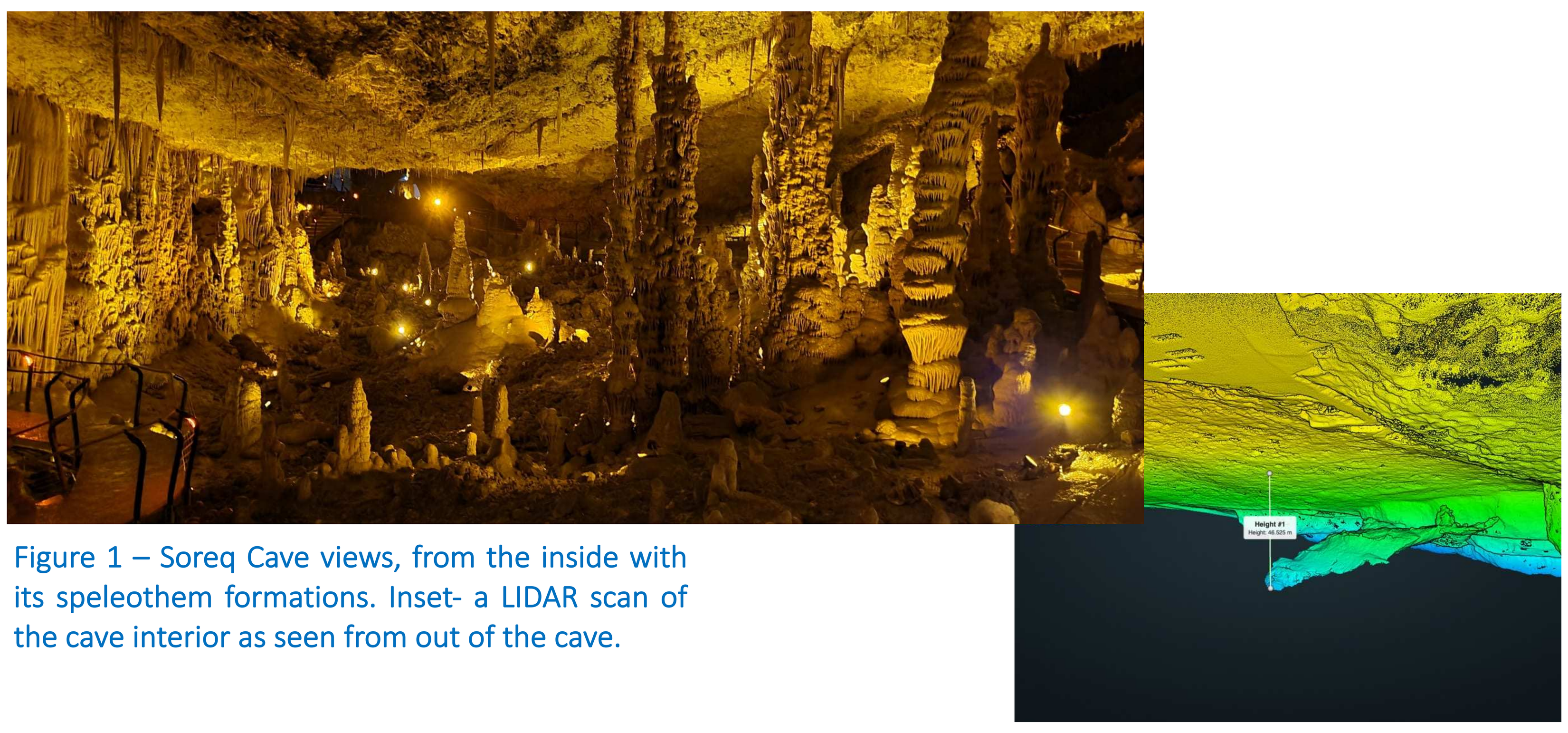


Figure 1 – Soreq Cave views, from the inside with its speleothem formations. Inset- a LIDAR scan of the cave interior as seen from out of the cave.

Materials and Methods

We had installed four 3-axial accelerometers at sensitive sites in the cave (Fig. 2). They had operated weeklong recording minute vibrations caused by the natural environment and by our purposed operations. The purposed operations had imitated future construction vibrations using a 2.7-ton press, a bagger with 4.75-ton hammer, as well as explosions from a nearby quarry (Fig 2b).

Figure 2a – Map of the Soreq Cave interior with locations of the four accelerometers.

Figure 2b – The three controlled vibrations experiments: a- press, b- bagger, and c- explosion. These vibrations are recorded in the accelerometers installed in the cave.

Results

The values of the accelerations recorded (Fig. 3a) were transformed to time series of (1) peak ground acceleration (Fig. 3b), (2) peak particle velocity, and (3) peak ground displacement. Additionally, the response spectrum was obtained from these time series (Fig. 4) – that describes the maximal acceleration of the more vulnerable speleothems (representing a simple oscillator) due to a given excitation that is manifested as our intentional mechanical vibrations.

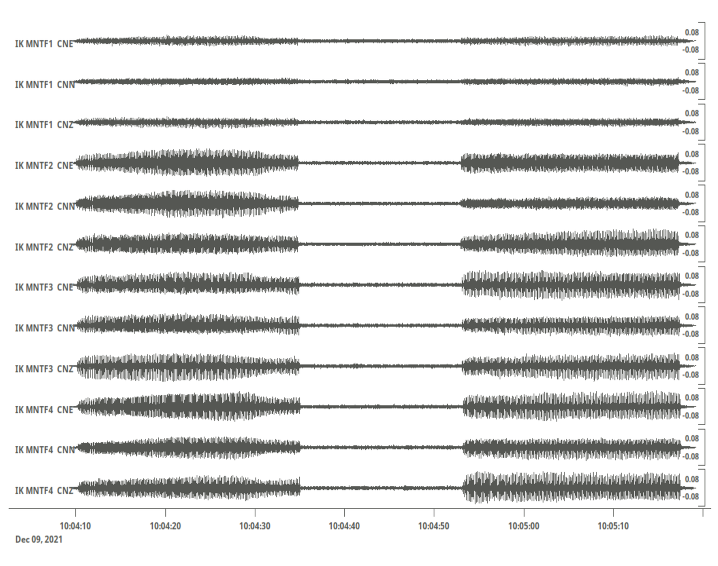


Figure 3a – The accelerations at x,y,z recorded in the four instruments for individual vibration event.

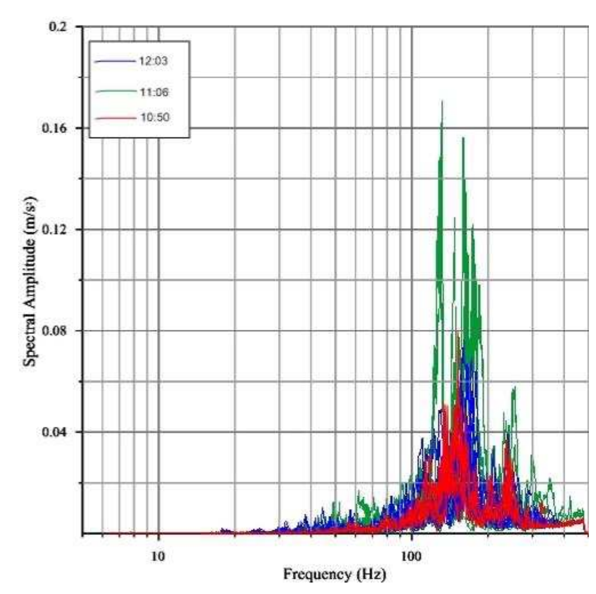


Figure 3b – Fourier transform analysis on the accelerations caused from bagger hammering at three different distances from the cave. The green curve was the closest.

Results

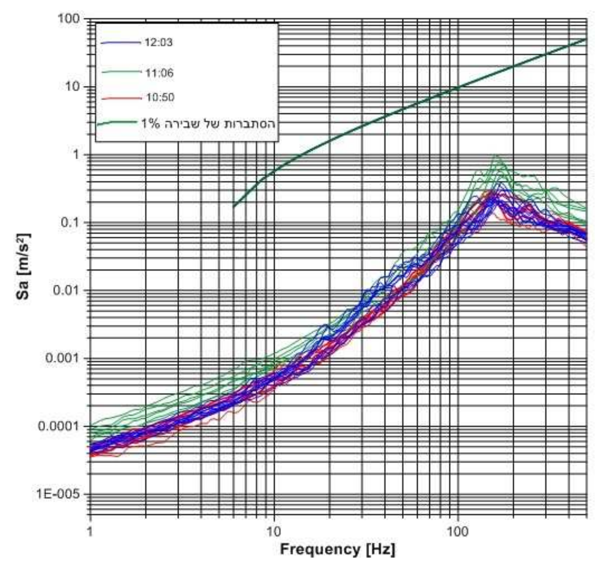


Figure 4a – Response spectrum during bagger hammering at three different distances from the cave. The green lines are the closest. Dark green above marks 1% probability of rapture in the speleothems.

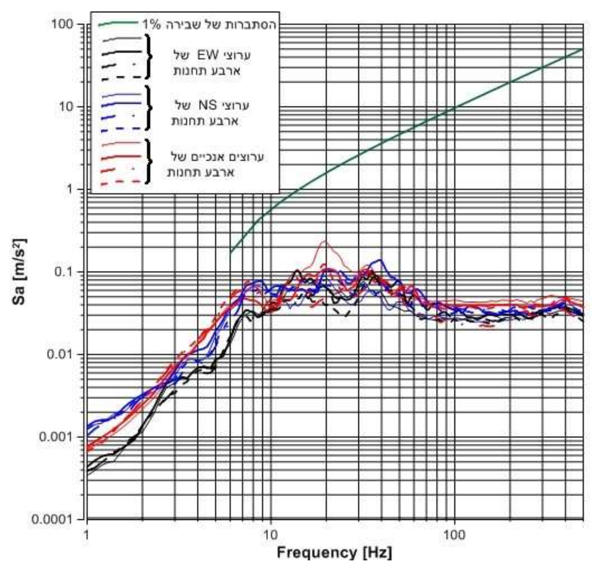


Figure 4b – Response spectrum at the x,y,z axis during quarry explosion. Dark green above marks 1% probability of rapture in the speleothems.

The response spectrum of bagger hammering events and of the explosions from the nearby quarry are plotted in figures 4a and 4b. Above them enveloping is the 1% probability of rupture in soda-straw speleothems that are the most vulnerable elements in the Soreq Cave. The results do not show danger to the speleothems from the activity we had conducted.

However, we calculate the safety distances for construction near the Soreq Cave. To evaluate these distances, we used a peak particle velocity of 2.4mm/s[1] as the velocity that may cause rupture in the speleothems. From the peak particles velocity results, we calculated equation (1) that describes the peak particle velocity (V) according to distance of excitation R.

$$(1)\ V = 1368 * R^{-2}$$

Depiction of this equation is given in figure 5 with the result that for bagger operations equipped with a 4.75-ton hammer, the minimal distance for operations from the cave is 25m (fig. 5)

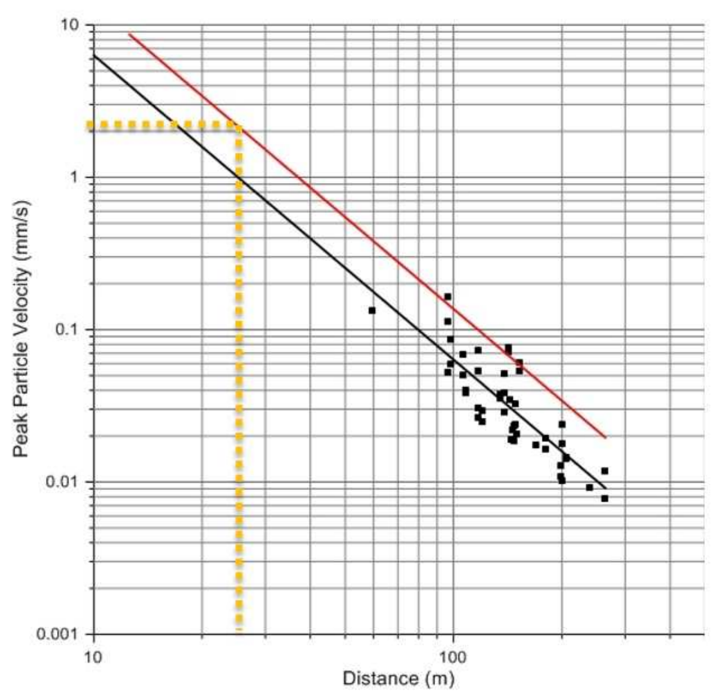
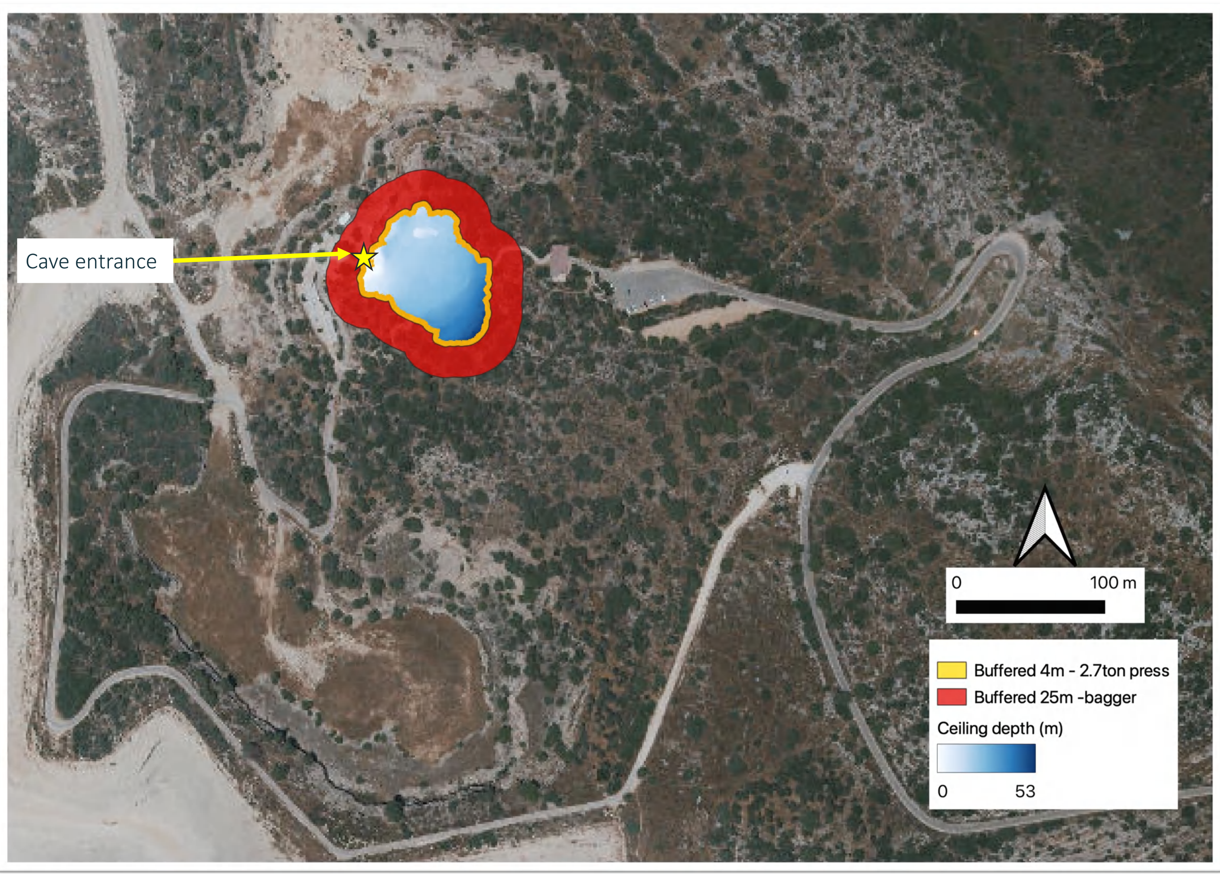


Figure 5 – Peak particle velocity caused by bagger operations at various distances from the cave. Black line and red line represent the correlation and 2σ. Dashed yellow line represents the minimum distance of bagger operations from the cave walls.

Conclusions

1. Accelerometers were positioned inside the *Soreq Cave nature reserve* to evaluate speleothems vulnerability in the face of future engineering development of the region.
2. Controlled vibrations conducted to mimic the operations that are about to take place using bagger, press, and explosions from a near by quarry.
3. The measured accelerations were converted to values that are used to set safety distances for mechanical engineering works around the cave:
- For 2.7 press machines the distance is 4m.
- For bagger equipped with 4.75-ton hammer the distance is 25m.
4. Explosions from the nearby quarry are close to the 1% probability of fracture and should be done carefully.



Acknowledgement

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