Effect of soil loading/unloading on its acoustic behavior

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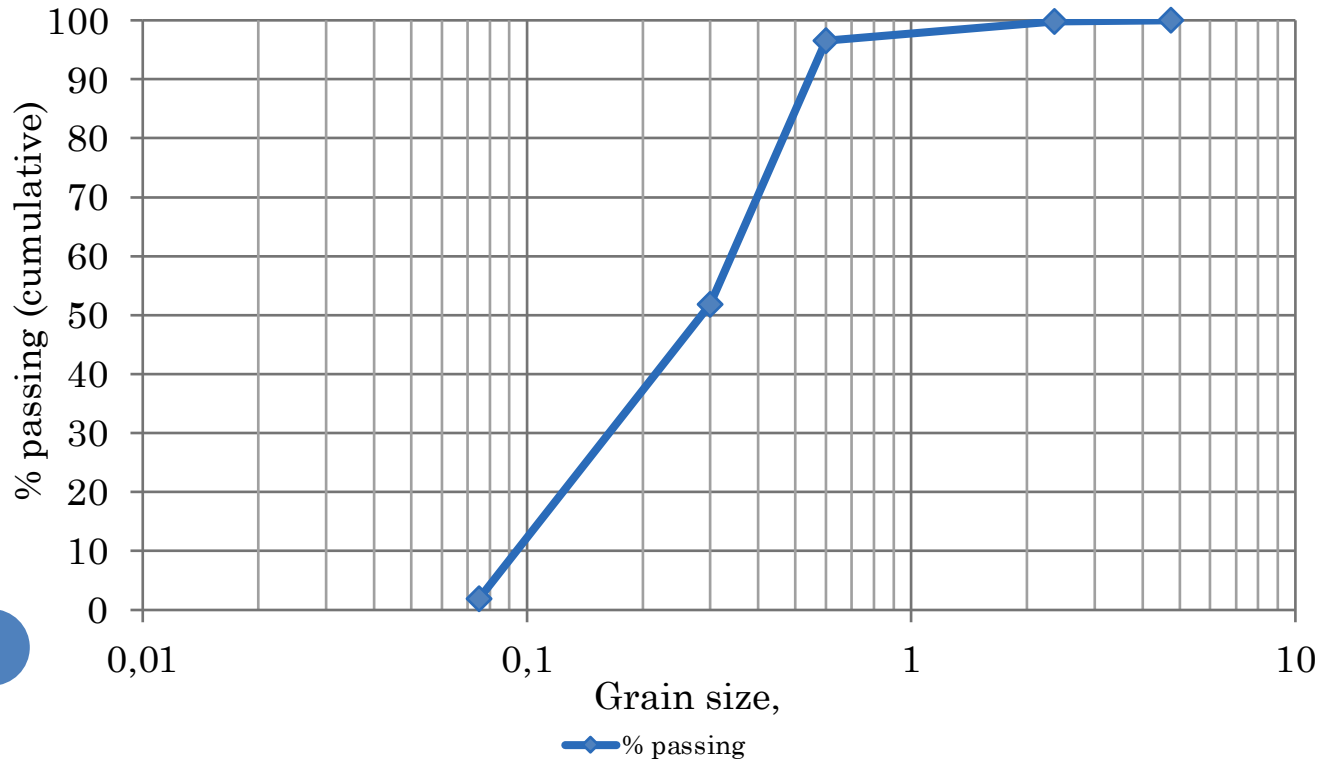
The aim -to understand the changes of ultrasound-wave speed (US) and acoustic emission (AE) as a result of soil loading/unloading.

Location: Dune sand from the Ashdod beach (Southern Israel) was selected for the experiments.

Sand type: the sand is categorized as "SP" based on the Unified Soil Classification System (USCS).



The experiments were carried out using four types of dry samples as follows:

- natural dune sand

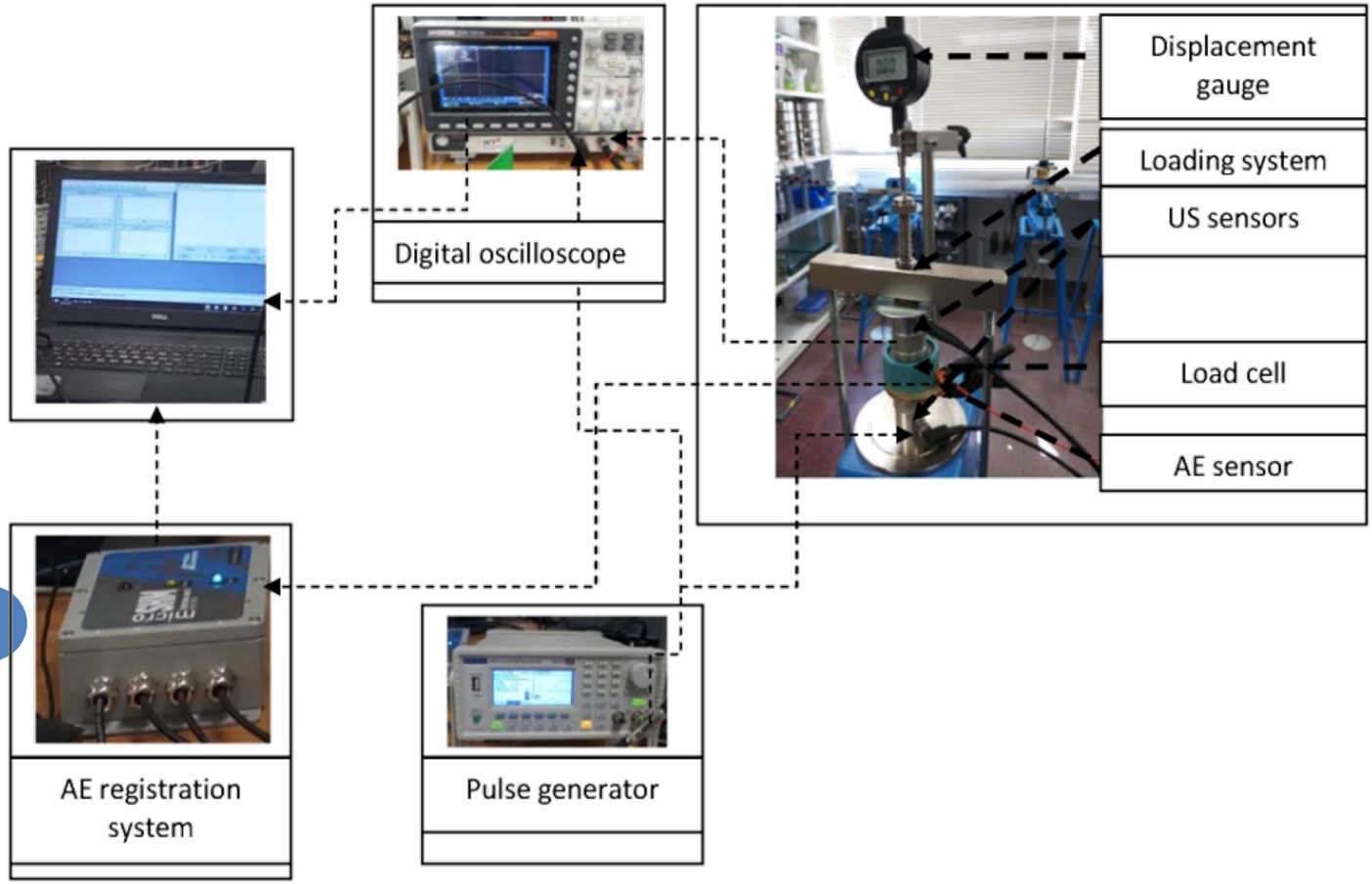
and

its three extracted fractions:

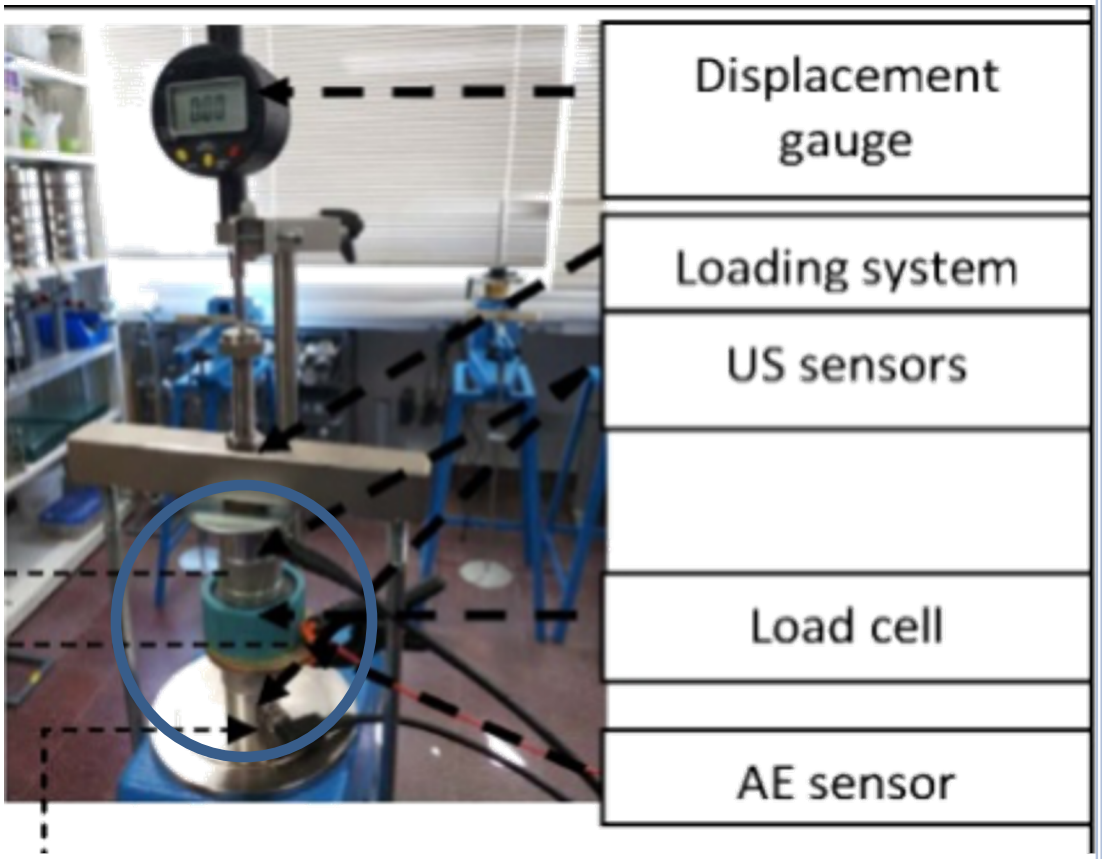
- 2.36-0.6mm,
- 0.6-0.3mm,
- 0.3-0.075 mm.

The average value of beginning density for all samples was 1.67±0.03 gr/cm^3.

THE EXPERIMENTAL SYSTEM USING AN OEDOMETER INSTRUMENT (THE MATEST INC.)

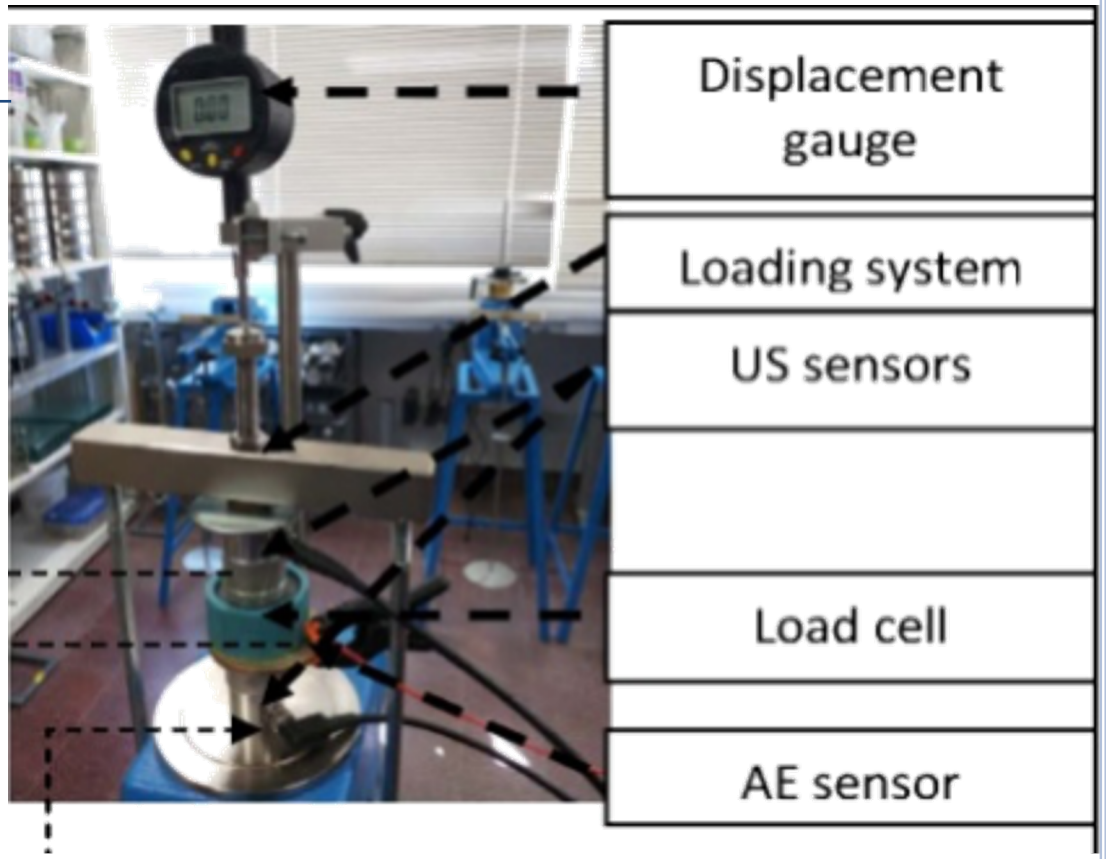


Load cell



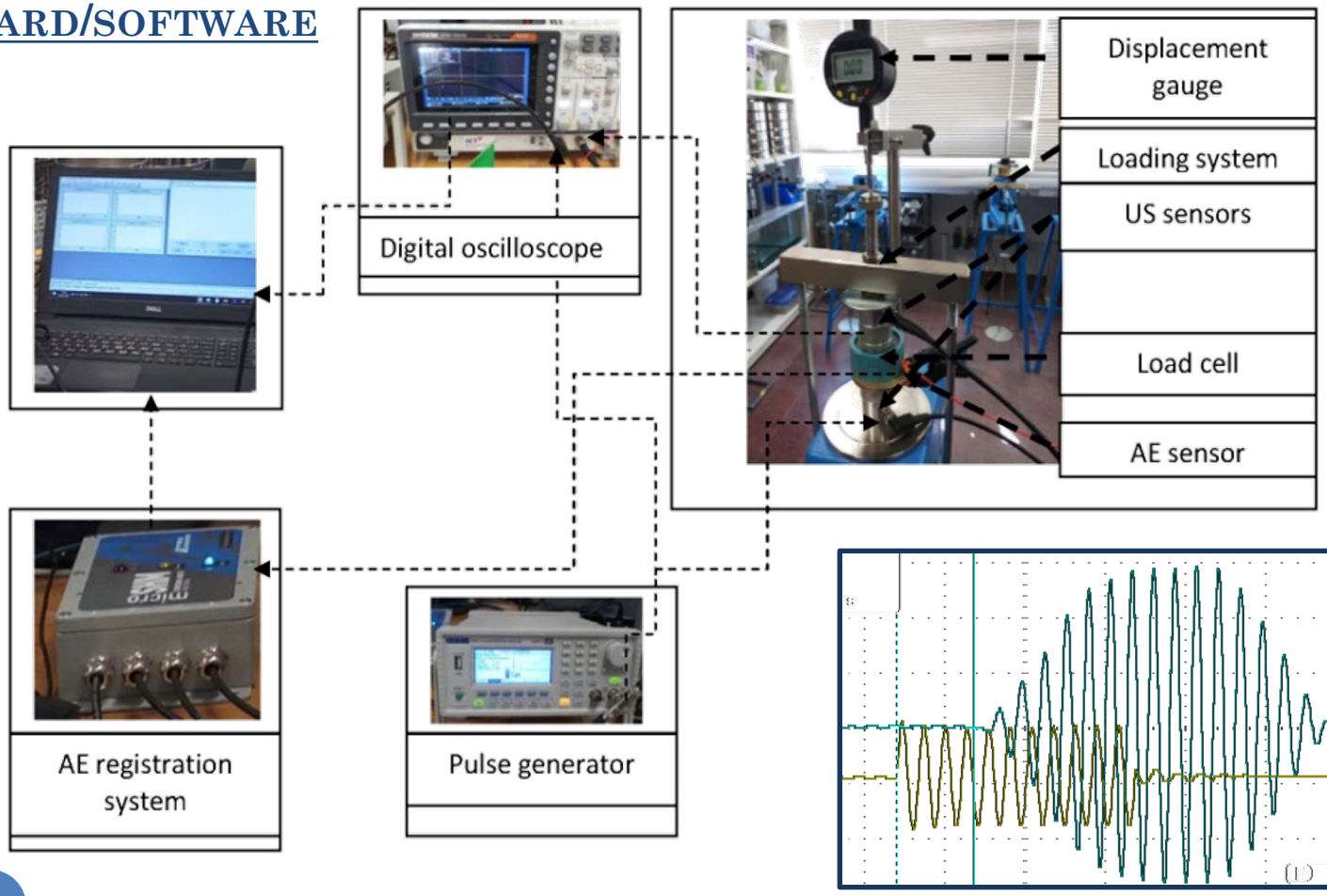
For the experiments the samples were prepared in the fiberglass load cell (blue ring in Figure) with an internal diameter of 51.6 mm and height of 31.5 mm.

Loading procedure



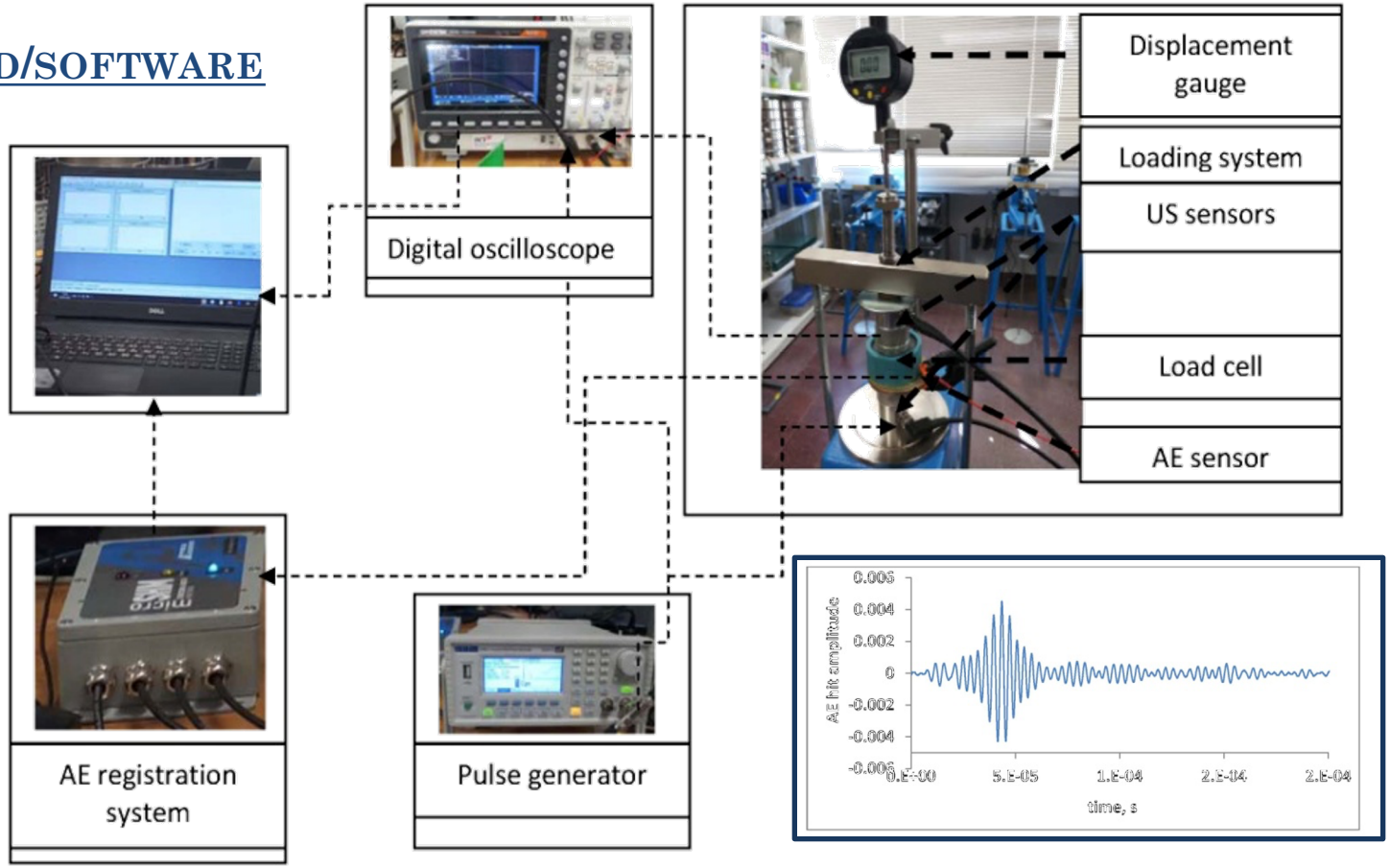
- The load increment was 5 kg.
- The maximal load applied to the samples was 30 kg that corresponds to the maximal applied stress level – 143.5 kPa.
- At each increment of loading the final deformation value was measured using a displacement gauge

US HARD/SOFTWARE



- Two ultrasonic sensors were located at both ends of the soil samples.
- US sensors were connected to the pulse generator (TG5011A) and the digital oscilloscope (GDS1054B), respectively.
- The Open Wave software was used for the data recording to a PC. The US wave speed was measured using the first arrivals method.

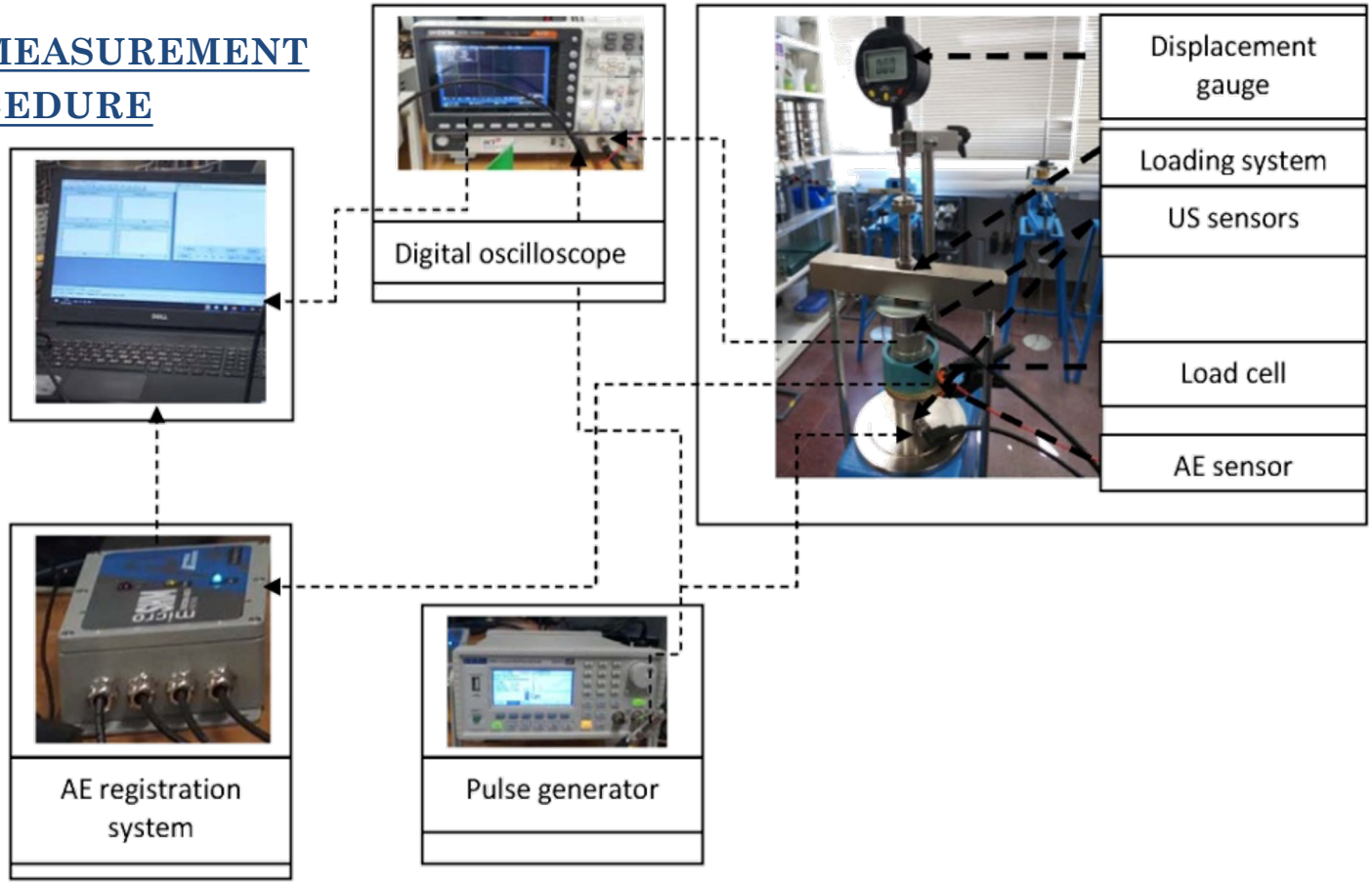
AE HARD/SOFTWARE



The AE sensor located at the fixed bottom end of the load cell was connected to the "Micro SHM" monitoring system (Mistras/Physical Acoustic Inc.).

The "AE win" for Micro SHM software was used for data recording to the PC.

US vs. AE measurement procedure

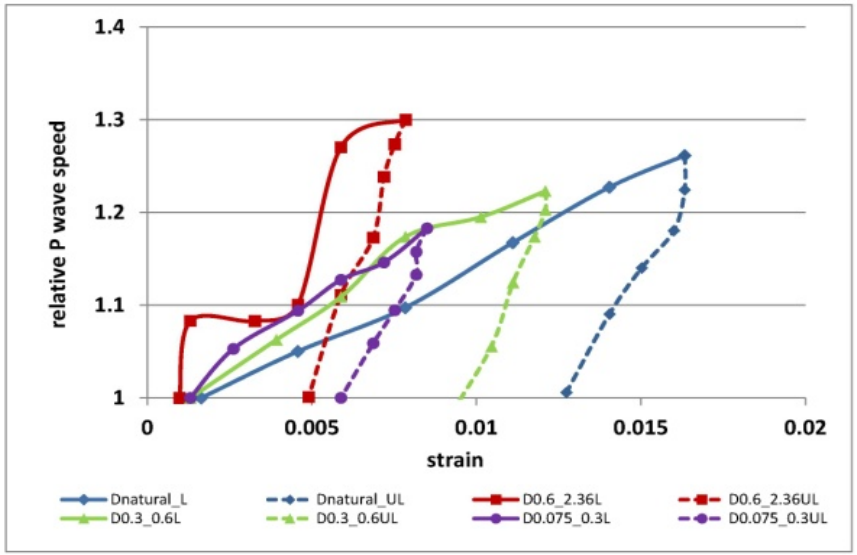


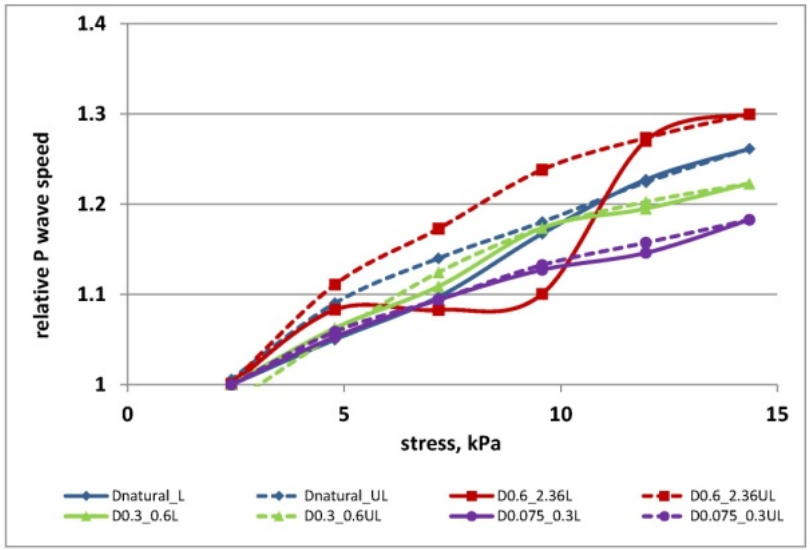
The AE measurements were performed continuously at each loading stage from the moment of load application (US generator in switched off position) till cessation of AE hits.

Just after the AE cessation, the record of AE was stopped and the US generator was switched on for US measurements.

After the completion of US measurements the US generator was switched off again and the procedure of sample loading with simultaneous AE measurements was repeated.

THE RESULTS OF US MEASUREMENTS





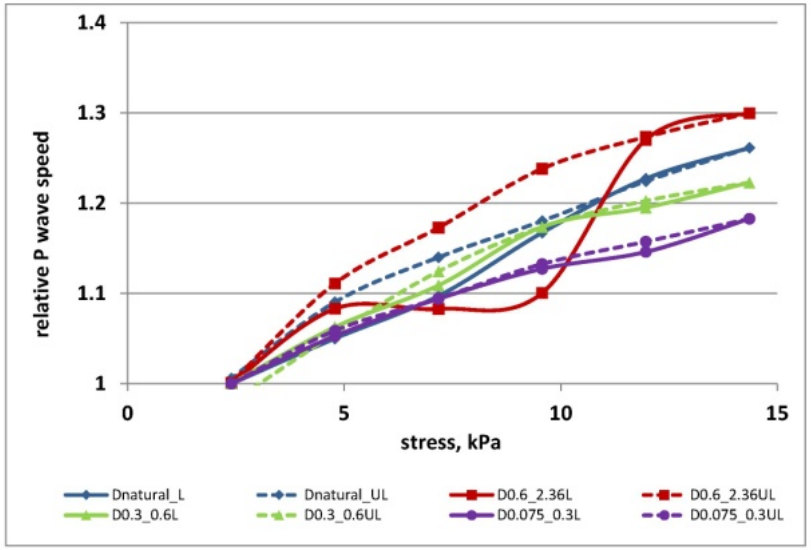
Left: The changes of relative US wave speed vs. strain variation for four used soil samples.

Right: The changes of relative US wave speed vs. applied stress variation for four used soil samples.

"Dnatural", "D0.6-2.36", "D0.3-0.6" and D0.075-0.3 in the (b) and (c) figures' key to symbols stand for natural dune sand, fractions 0.6-2.36 mm, 0.3-0.6 mm and 0.075-0.3 mm, respectively

'L' and 'UL' keys mean the loading (full line) and unloading (dashed line) branches, respectively.

THE RESULTS OF US MEASUREMENTS



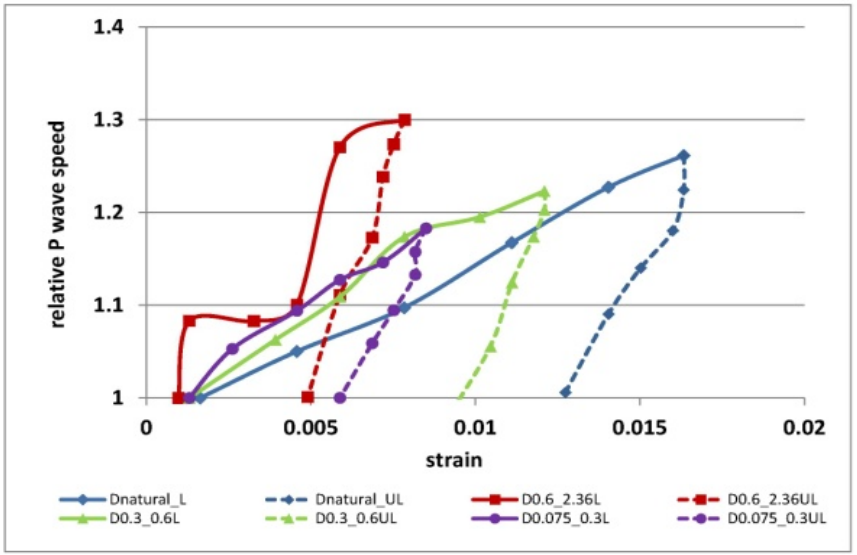
The experimental results show

- that the increase of stress level causes the rise of p-wave speed in the range of 480-640 m/s for all studied samples.

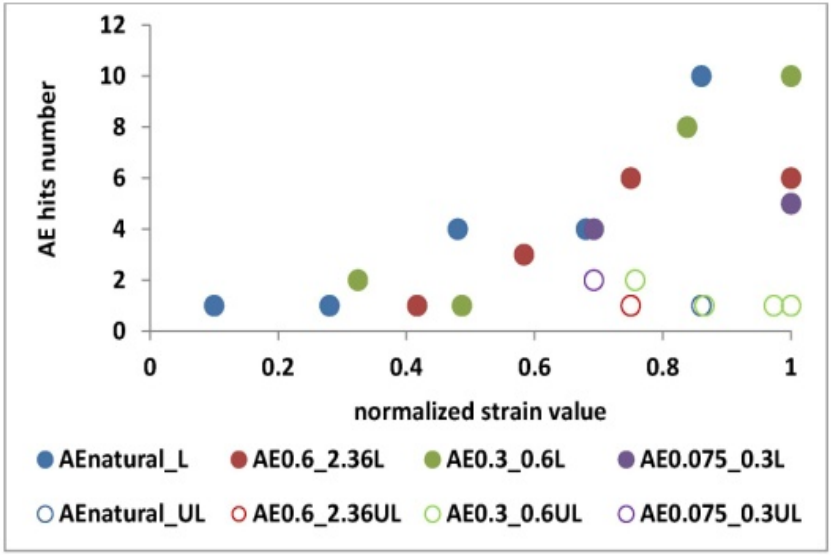
- the difference between the values of the US wave speed during loading and unloading (dashed lines) the samples: the maximal difference is for the coarsest fraction, the difference for the natural dune sample is also essential, the difference in US wave speed values between loading and unloading branches for two fine fractions is insignificant.

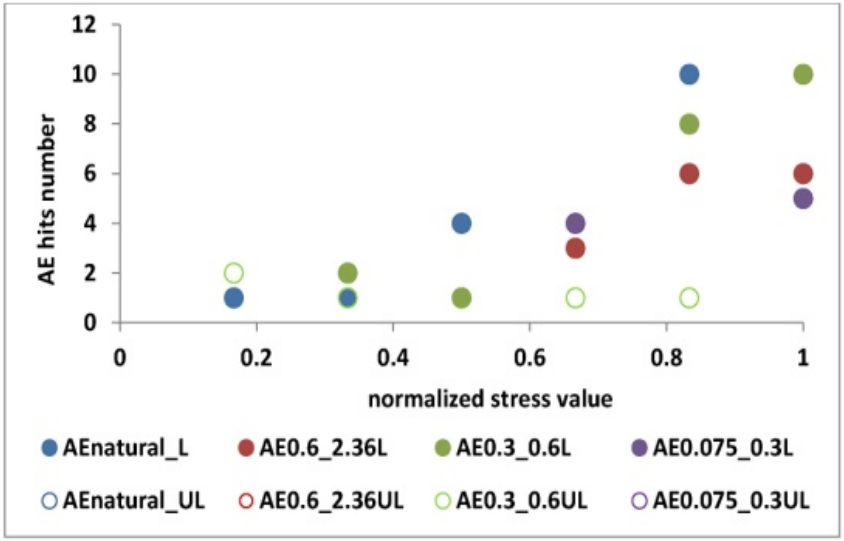
It can be seen a significant difference between the changes in the US speed during sample loading and unloading (dashed lines).

The values of the US wave speed gradually increase with increasing strain and sharply drops when the strain decrease (unloading branch).



The results of AE measurements





Left: The normalized strain value (calculated as the ratio of the value of strain at loading increment to the maximum strain value) vs. AE hits number per loading (full circles) /unloading (empty circles) increment stage.

Right: The normalized stress value (calculated as the ratio of the value of stress at loading increment to the maximum stress) vs. AE hits number per loading (full circles) /unloading (empty circles) increment stage.

“AEnatural”, “AE0.6-2.36”, “AE0.3-0.6” and AE0.075-0.3 in the figures’ key to symbols stand for natural dune sand, fractions 0.6-2.36 mm, 0.3-0.6 mm and 0.075-0.3 mm, respectively

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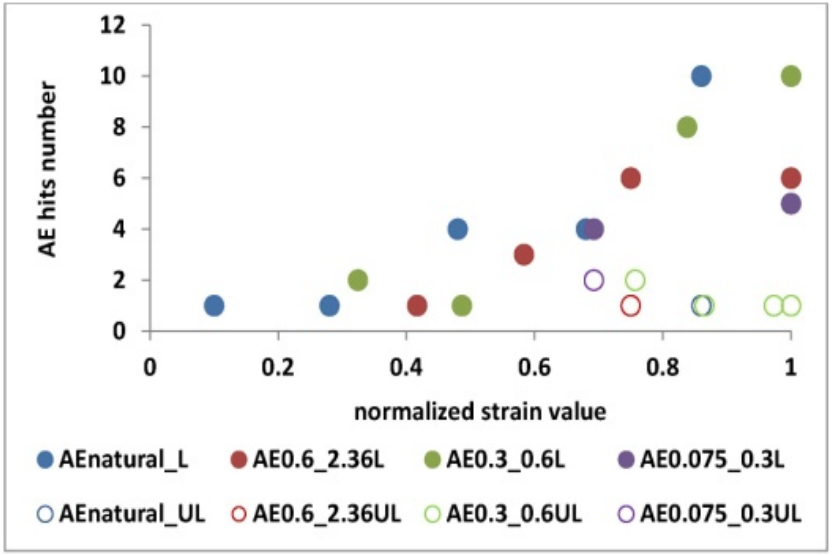
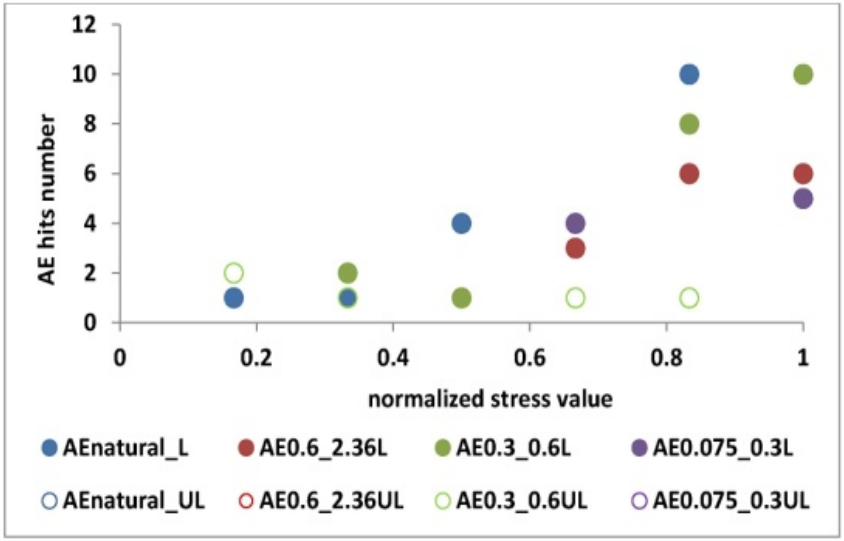
The results of AE measurements





Analysis of both figures portrays that an essential increase of the number of AE hits (AE events) begins at the range 0.65-0.7 of maximum normalized stress/strain level.

Maximum measured values of AE hits were measured at the range 0.8-1 of maximum relative stress/strain. These two observations concern the loading branch of the samples (full circles).

During the samples unloading (empty circles) only single AE hits were recorded.

Summarizing, the analysis of AE behavior indicates gradual increase of the AE activity with increase of stress and strain levels for all studied samples, while a minor AE activity during all soil types unloading is observed.

Conclusions:

One can see the difference in the behavior of the two studied phenomena – US wave speed and AE:

In the stress increase branch: gradual increase in US-wave speed and sharp excitation of AE activity.

In the stress relaxation branch: abrupt decrease in US -wave speed and minor excitation of AE signals.

Thank you