4.2.18. DETECTION OF SUBTLE CHANGES IN MATERIALS BY CODA WAVE INTERFEROMETRY

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Ultrasonic velocity measurements are an established tool in material science to detect structural information and changes in lab samples. Difficulties arise, when small changes in velocity have to be detected or the wavelength of the ultrasonic signals is in the order of magnitude of the internal structure of the samples.

Coda Wave Interferometry (CWI) is currently mainly used to detect slight velocity changes on one side in the earth’s crust due to seismic effects, mining influence or seasonal variations and on rock samples on the other. The coda of seismic or ultrasonic signals before during and after events or loads is evaluated to detect time shifts.

A preliminary experiment on two concrete cubes ($15\times15\times15$ cm^3) has been conducted at BAM to evaluate the potential of CWI and to support a field study at the University of Leipzig. Two ultrasonic setups, normally used for time of flight measurements, were used to generate and receive signals in transmission mode (fig. 1). Similar and more sophisticated experiments have been published e.g., by Larose et al (2009).

In a first step the ultrasonic transmission data (fig. 2 top) was evaluated by evaluating the time of flight (TOF). Due to the high noise level caused by the load frame we had to stack 32 measurements. The Akaike information criterion (AIC) as proposed by Tronicke (2007) was used to pick most of the arrival times.

Compression wave velocities were calculated from TOF and CWI and plotted vs. load cycles (fig. 3). The slight velocity change expected at small to medium loads (“acoustoelastic effect”) is not visible in TOF data due to the up to 5 % scatter caused by noise and sample interval. The first arrival times are almost identical (fig. 2 middle). The irreversible velocity drop during high loads (caused by microcracking) is about 10 %.

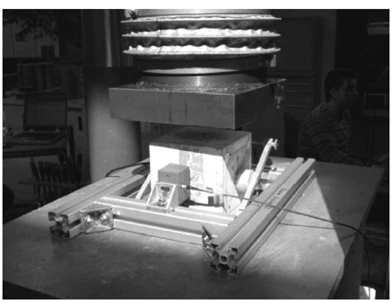

Fig. 1. Experimental setup: Concrete cube under 1 MN load frame, equipped with 125 kHz point contact (red, front/back) and 250 kHz conventional piezo transducers (silver, left/right)

Contrary the coda wave shows significant phase shifts even for small load changes (fig.2 bottom). The time series were evaluated by the method proposed by Sens-Schonfelder & Wegler (2006). Fig. 4 shows a linear relationship between stress an velocity change as expected (acoustoelastic effect / expansion).

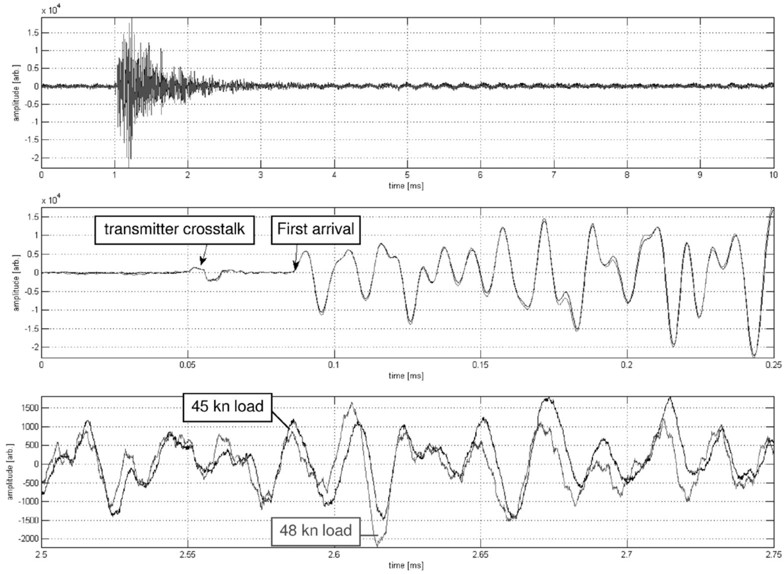

Fig. 2. Typical time series (point contact transducers, 32 stacks, 1 ms pre-trigger, 10 ms sampling time, 10 MHz sampling frequency) at 45 (blue) and 48 kN load (red). Top: Entire signal. Middle: Detail near first arrival Bottom: Detail of coda wave. Significant phase shift visible

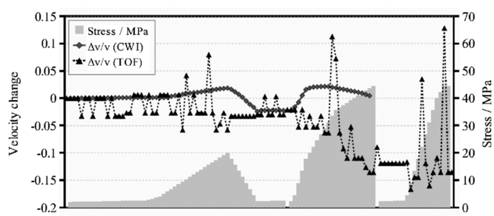

Fig. 3. Comparison of Wave velocity change estimations from TOF and CWI in dependence of load cycles. CWI suitable for detecting small velocity changes but problematic for larger ones. For TOF the velocity drop after high load is visible, velocity increase at small loads is not

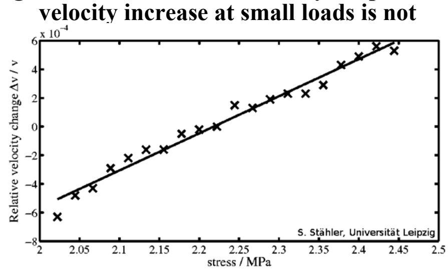

Fig. 4. Velocity changes at small stress levels evaluated by CWI. Corresponds to load step 1 to 21 of fig. 3