Monitoring Reinforced Concrete Structures with Coda Waves

The Influence of Temperature on Ultrasound Velocity Changes calculated with Coda Wave Interferometry

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Background

Less than 20 % of Germanys Bridges are in good or very good condition (Source: BMVI)

- Permanent monitoring of bridges can extend their service life
- Condition-based maintenance saves costs
- Sustainable building management requires frequently updated structural models

Aim

- Monitoring with embedded ultrasound (US) transducers
- Application of Coda Wave Interferometry for detection of (velocity) changes in reinforced concrete structures
- Discrimination of environmental and structural changes
- Development of strategy of removal of environmental influences

Experiment

To determine the influence of daily and seasonal temperature variations on the Ultrasound signal we embedded several US-transducers and Temperature sensors into a large reinforced concrete model at a BAM test site in Horstwalde close to Berlin (details see [1]).

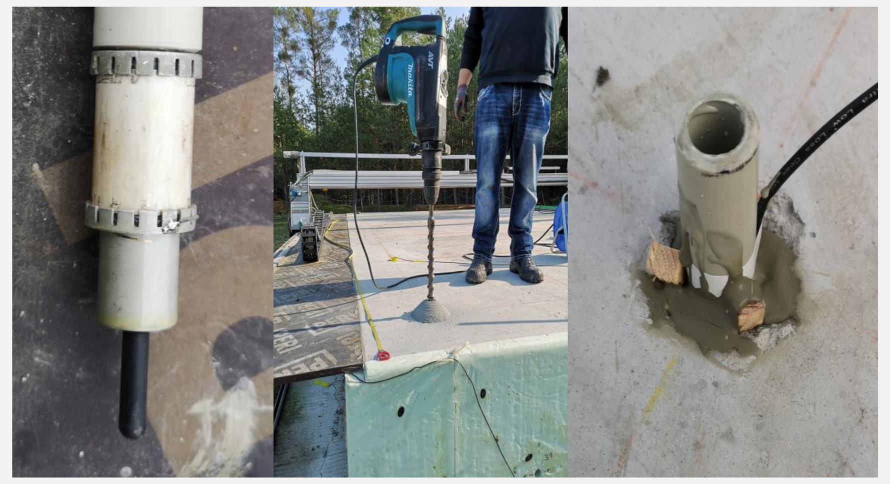

Fig. 1: Embedding of US-transducers and temperature sensors in a large concrete model

Methodology

Coda Wave Interferometry:

CWI velocity change ϵ=dv/dt calculation by maximization of correlation coefficient (CC) for two signals u_u and u_{pt}:

$$CC(t,\varepsilon) = \frac{\int_{t_1}^{t_2} u_u(t+\varepsilon)u_{pt}(t)dt}{\sqrt{\int_{t_1}^{t_2} u_u^2(t+\varepsilon)dt \int_{t_1}^{t_2} u_{pt}^2(t)dt}}$$

Comparison of consecutively recorded signals with a reference gives the relative velocity change between source and receiver over time

Results

The Ultrasound velocity change is closely linked to the change in concrete temperature (Fig.2). A linear relation between the two quantities can is evident, showing a gradient between $0.03\ \%/K$ and $0.06\ \%/K$ (Fig.3). Linear detrending can not remove high frequency daily variations (Fig. 4). The authors propose to apply a low pass filter in long term monitoring to reduce the influence of high frequency daily variations (Fig.4).

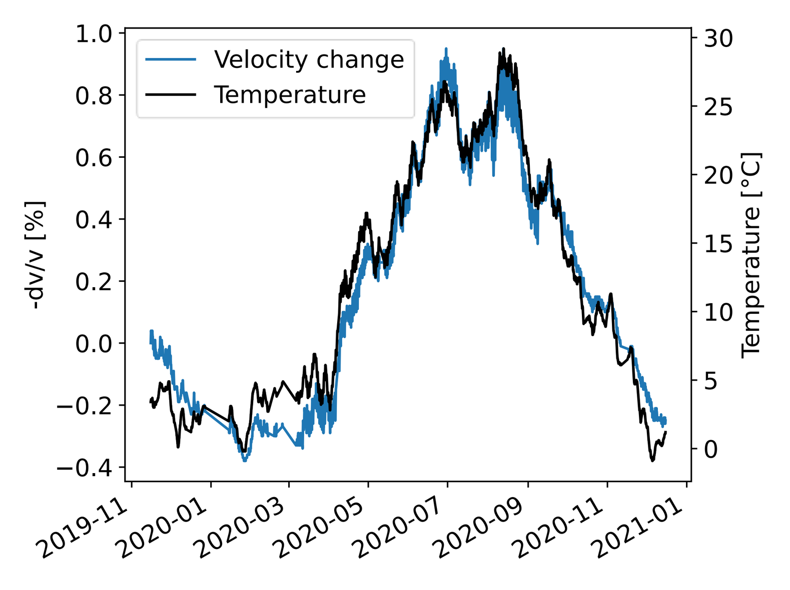

Fig. 2: Velocity and Temperature change over one year

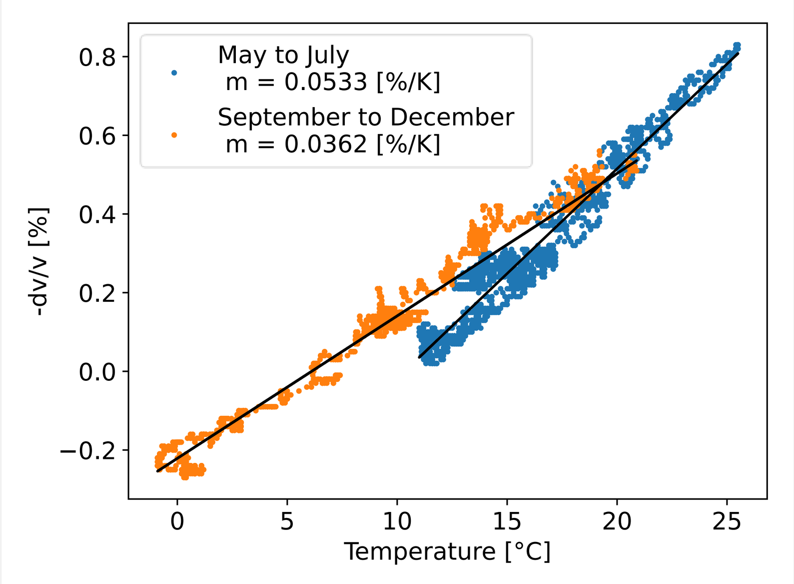

Fig. 3: Velocity change versus Temperature change

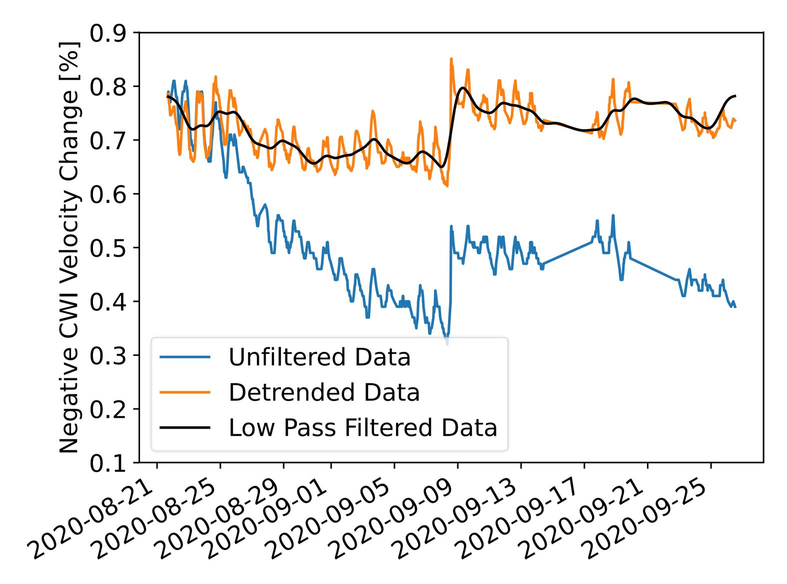

Fig. 4: Approaches to remove temperature influence

Key Findings:

- Linear relation between (negative) CWI velocity change and temperature
- The gradient of velocity versus temperature is slightly different for cooling and heating phases
- Laboratory and large-scale experiments show similar behavior
- Nonlinear and high frequency effects remain and need to be removed in a different way

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[1] Epple N., Barroso D.F., Niederleithinger E. (2021) Towards Monitoring of Concrete Structures with Embedded Ultrasound Sensors and Coda Waves – First Results of DFG for CoDA. In: Rizzo P., Milazzo A. (eds) European Workshop on Structural Health Monitoring. EWSHM 2020. Lecture Notes in Civil Engineering, vol 127. Springer, Cham

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