STATIK & DYNAMIK

CoDA Concrete Damage Assessment by Coda Waves

RUHR UNIVERSITÄT BOCHUM

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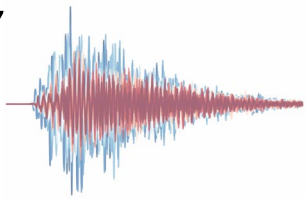
A VIRTUAL CODA WAVE INTERFEROMETRY LABORATORY FOR DAMAGE ASSESSMENT IN REINFORCED CONCRETE STRUCTURES



Doctoral defense by GIAO VU

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Concrete infrastructure ages long before it fails visibly. Detecting that deterioration early – while repairs are still cheap – is one of the central challenges in structural health monitoring. Coda Wave Interferometry (CWI) offers a promising solution by exploiting the late-arriving portion of ultrasonic measurements. Having travelled repeatedly through the material, these waves sample a far larger volume than conventional methods and are sensitive to microstructural change. Embedded ultrasonic sensors are inexpensive, making CWI an attractive basis for permanent monitoring systems. The obstacle is interpretation: a measured signal change tells us that something has happened inside the concrete, but not what, where, or how severe.

This thesis closes that gap with a virtual CWI laboratory. Meso-scale models simulate the cracking process and the ultrasonic waves travelling through it, linking a structure's internal state directly to its measured response. The framework was validated against real experiments from material specimens up to reinforced concrete beams, across varying mixtures, structural layouts, and sensor configurations.

The result is a quantitative map from velocity change to what engineers care about: crack width, reinforcement strain, stiffness degradation. The synthetic data then trained a transformer-based classifier which, after domain adaptation, predict damage states from real measurements with good accuracy.

Together, the framework provides scalable tool for designing sensor networks, generating validated training data, and translating monitoring signals into decisions.

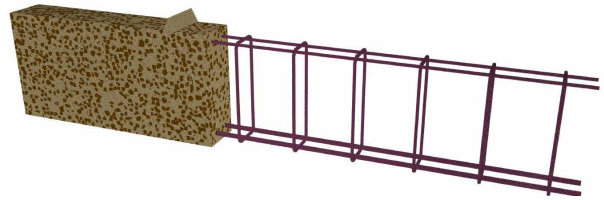

Figure 1a: Digital twin of a reinforced concrete beam.

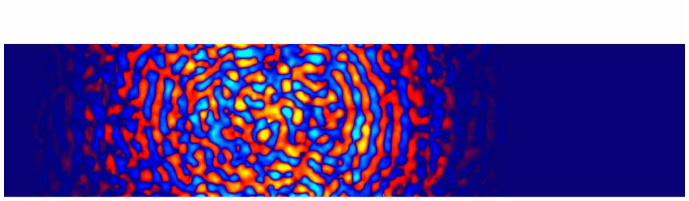

Figure 1b: An ultrasonic shear wave in a reinforced concrete beam, showing the diffuse wave field that arises from scattering at the concrete's heterogeneities.

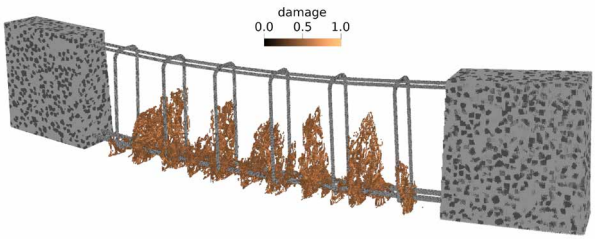

Figure 2a: The mechanical response of a reinforced concrete beam under four-point bending, with cracking localized in the central zone.

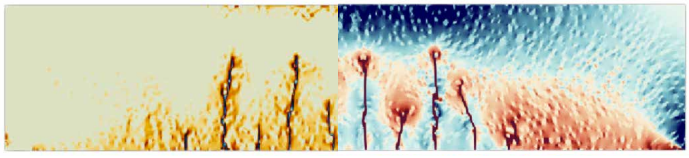

Figure 2b: Simulated damage field (left) and volumetric strain field (right) on a longitudinal section through the beam.

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Lehrstuhl für Statik und Dynamik | Prof. Dr. Roger A. Sauer, Prof. Dr. techn. Günther Meschke | Universitätsstr. 150, 44801 Bochum | sd@rub.de, www.sd.rub.de