Data-Driven Multi-Scale Analysis for Early Damage Assessment of Concrete Structures using Coda Waves

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The early detection and mitigation of damage in concrete structures can significantly decrease the cost of maintenance and repair associated with concrete infrastructure. Load-induced microcracking, a manifestation of weak material degradation, is a precursor to localized damage (macrocracking) in concrete structures and can be detected through the use of multiple-scattered late arriving ultrasonic signals, also referred to as coda waves [1].

In this study, a multi-scale approach combining computational modeling, wave propagation simulations, and machine learning techniques is employed to investigate the relationship between material degradation and coda wave variations at both the specimen and structural levels.

At specimen level, the virtual lab simulations of realistic mesoscale concrete models [2] are used to simulate damage initiation and progression at the specimen scale [3]. It is followed by wave propagation simulations on the virtual specimens at different levels of damage. Machine learning techniques are then employed to create a classifier for the prediction of damage based solely on the obtained synthetic ultrasonic coda signals [4, 5]. The classifier is validated using experimental coda signals obtained from laboratory tests.

At the structural level, the effect of boundary and geometrical conditions on coda signals is evaluated through 4-point bending simulations of a reinforced concrete beam. Finally, a strategy for predicting the state of damage at the structural level based on information from the specimen scale is presented.

References

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