ICNEM
International Conference on Nonlinear Elasticity in Materials

Contribution ID: **35** Type: **not specified**

Stress- and time-dependent elastic properties in a test bridge model: from high to low frequencies

Wednesday 16 July 2025 10:50 (35 minutes)

Highly complex engineered materials, such as concrete, exhibit a systematic evolution of their elastic properties when subjected to the effects of static and dynamic loads. Such systematic evolution can be observed in phenomena like the acoustoelastic effect, when analysed as a function of stress, and in the slow dynamics—the fast softening and log-time relaxation processes—when examined as a function of time. The physical and theoretical description of such behaviour is rooted in nonlinear elasticity paradigms. Although the underlying physical mechanism responsible for this behaviour remains an open research area, it has been observed in laboratory experiments that such stress and time dependencies are majorly present in flawed materials. As a result, there is a growing interest in studying construction materials from the perspective of nonlinear elasticity for the development of damage assessment practices.

In this work, we investigate the time and stress dependence of the elastic properties of an outdoor-conditioned, two-span reinforced concrete test bridge across different temporal scales. We also explore the potential relationship between this behaviour and the physical state of the structure, with particular attention to the possible presence of imperfections. We monitored changes in the dynamic elastic properties on the bridge subjected to the effect of dynamic impulsive excitations superimposed on five different compressive forces using high-frequency embedded ultrasound sensors and low-frequency conventional seismic equipment.

The high-frequency data enable investigations into the stress dependency of impulsive-source-induced slow dynamics in concrete at four locations on the bridge using relative velocity changes and the energy content of the ultrasound signals. We observed that the elastic softening and relaxation processes are accompanied by energy dissipation, both of which occur at different magnitudes on both spans of the bridge. Those differences in magnitude are correlatable with ultrasound velocity values, which suggest relatively different integrity levels on both spans of the bridge.

The low-frequency data allow for the estimation of stress-dependent modulus changes of the fundamental standing wave of the bridge. We characterised this classical nonlinear effect using the acoustoelastic effect, and according to these results, subtle differences can be observed between the two spans of the bridge, which correspond to the results obtained from the high-frequency data.

This investigation led us to conclude that there is a relationship between nonlinear elastic phenomena and the relative integrity level of an in-situ concrete structure, allowing for the identification of soft microstructures within the concrete structure's composition, potentially affecting its performance.

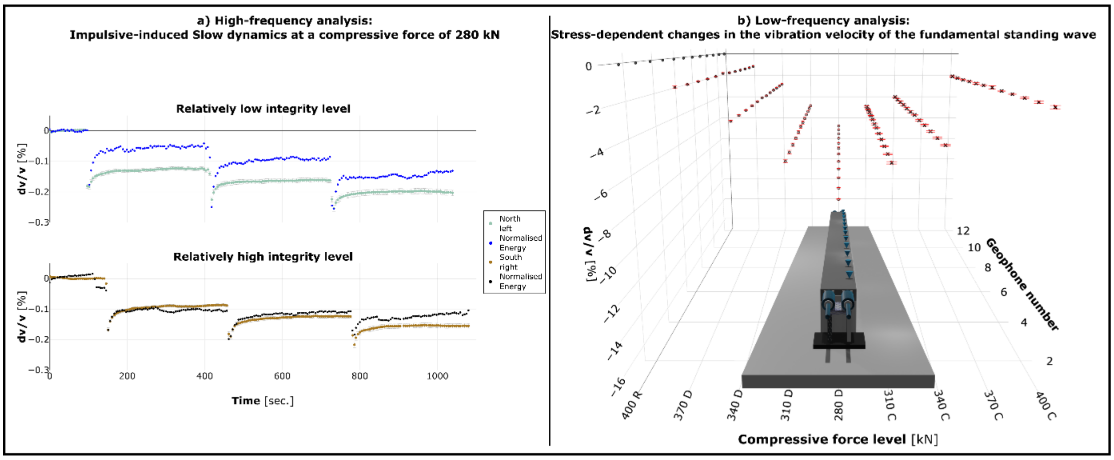

Figure 1: Nonlinear elastic behaviour in the bridge at different frequencies (a) High-frequency analysis showing three consecutive impulsive-induced slow dynamics effects, with relative velocity changes and energy content measured at two locations on the bridge with differing structural integrity. These estimates were obtained under a compressive force of 280 kN. (b) Low-frequency analysis showing relative velocity changes in the fundamental vibration mode of the structure as a function of stress along the bridge.

Primary authors: DOMINGUEZ-BUREOS, Marco (Institute of Geophysics, University of Hamburg, Germany); SENS-SCHONFELDER, Christoph; NIEDERLEITHINGER, Ernst (Bundesanstalt für Materialforschung und -prüfung (BAM), Germany); HADZIIOANNOU, Celine (Institute of Geophysics, University of Hamburg, Germany)

Presenter: DOMINGUEZ-BUREOS, Marco (Institute of Geophysics, University of Hamburg, Germany)

Session Classification: Instantaneous nonlinearity and NDT

Track Classification: Instantaneous nonlinearity and NDT