High-frequency fatigue experiment using Dynamic Mechanical testing (DMT) and in-parallel extraction of complex mechanical properties using Dynamic Mechanical Analysis (DMA)

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Due to cyclic load, fatigue affects brittle materials like (ultra) High-Performance Concrete (UHPC) used in marine and civil structures, resulting in unexpected failures. Additionally, in order to analyze mechanical properties of materials, understanding how materials respond to different frequencies is crucial for industrial designers. When a material is subjected to more fatigue cycles, its mechanical properties undergo changes. To extract material's properties under fatigue load at a specific cyclic speed, It is necessary to obtain the mechanical response of the material at the same frequency speed. Cyclic load tests are conducted to determine how fatigue affects the material and the number of cycles it will take to fail is experimentally determined. The problem with such tests is that they are potentially expensive, i.e., it could take a long time since the number of loading cycles can be extremely high. Moreover, it is not possible to observe the evolution of (micro-)cracks within the different damage phases of cycling tests. It is also challenging to characterize the material's small-strain stiffness evolution. This research aims to investigate the use of high-frequency excitation with a (large amplitude) dynamic mechanical testing (DMT) for the High Cycle Fatigue experiments and also in-parallel extraction of material properties with a (low amplitude) Dynamic Mechanical Analysis (DMA). The test setup applies excitation using high-voltage piezoelectric actuators and then the failure modes of the material will be examined. The excitation frequency for the fatigue test is between 10 and 200 cycles per second which allow for reducing the experimental investigation time to failure. Further, it allows investigation of the effect of frequency on the number of cycles to failure. In addition, the (rate-dependent) complex mechanical properties of the materials in tangential space are obtained in frequency between 0.01 Hz to 1000 Hz using direct measurement with DMA method; while, the observed mechanical properties of these materials change with increasing frequency. In the case of materials' behavior, by increasing the frequency, Young's modulus increases and Poisson's ratio decreases. Experimental fatigue results will be presented for (U)-HPC and Berea sandstone samples. Harmonic experimental data include (direct) strain measurements in axial and circumferential directions as well as forces in axial directions. In addition, the resulting complex Young's modulus and evolving damage-like "history" of HPC and Berea sandstone specimens will be shown.