Department of Civil Engineering and Engineering Mechanics
Columbia University

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644 Mudd

Quantitative Structural Health Monitoring of the Civil Infrastructure

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Predictive health monitoring of the civil infrastructure will require the development of advanced sensing techniques capable of providing quantitative information on the damage state of civil engineering materials. Starting at the material level, this talk will report on research that involves a combination of sensing techniques and physics-based models to characterize damage in cement based materials and metals. By focusing on nonlinear acoustic techniques, it is possible to measure absolute, strength based material parameters that can then be coupled with multi-scaled material and uncertainty models to enable accurate and quantitative life prediction. The first demonstration involves an application of nonlinear ultrasonic Rayleigh surface waves to characterize damage in A36 steel specimens. It is shown that fatigue damage produces increased acoustic nonlinearity that leads to the generation of measurable higher harmonics in initially monochromatic Rayleigh wave signals. Quasi static and fatigue tests are interrupted at different damage states for the nonlinear ultrasonic measurements. The experimental results show a quantitative relationship between acoustic nonlinearity and remaining specimen life, and demonstrate the feasibility for the quantitative inspection of steel bridge components prior to the formation of micro-cracks. Next, nonlinear resonance vibration techniques are used to characterize alkali-silica reaction (ASR) damage in concrete. This work was originally developed as a procedure to screen for potentially reactive aggregate in a quick and quantitative fashion. Changes in the measured nonlinearity are benchmarked against results from expansion and petrographic analysis to develop a relationship between damage state and measured nonlinearity. This research shows that the nonlinear parameter is more sensitive to damage than linear acoustic measurements and can accurately characterize the reactivity of a variety of aggregates as well as characterize damage in situ. A simple, physics-based model to explain observed nonlinear behavior of ASR-damaged concrete specimens is also presented. The talk will end with applications to the energy infrastructure including characterization of high temperature creep and irradiation damage in stainless steels.

Biosketch
Prof. Jacobs received his PhD in Engineering Mechanics from Columbia University and joined the faculty of Georgia Tech in 1988. Professor Jacobs' research focuses on the development of quantitative experimental methodologies for the nondestructive evaluation and health monitoring of structural materials. His current research is focusing on the application of advanced sensing techniques for the quantitative characterization of material state and damage, with an emphasis on nonlinear ultrasound. Dr. Jacobs has authored/co-authored over 180 papers in refereed journals and conference proceedings, and has graduated over 12 PhD and 43 MS students.