Impact of Progressive Corrosion on Nonlinear Damping Behavior in Reinforced Concrete Elements

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Corrosion of reinforcement in reinforced concrete (RC) structures is a well-known cause of deterioration, which can severely affect the structural integrity and safety. Traditional methods for assessing corrosion damage, such as visual inspection and localized testing are widely used, but they often fail to detect early-stage corrosion, particularly when surface damage is not visible. Therefore, potential of vibration-based damage detection methods to detect corrosion damage has been the interest of recent research and modal damping has been drawn attention due to its pronounced sensitivity to minor damage. Therefore, this study investigates the effect of progressive corrosion on the modal vibration behavior of RC elements, focusing on how changes in damping characteristics can offer valuable insights into the early stages of corrosion damage. This research proposes a novel approach for non-destructive monitoring of corrosion-induced degradation in RC structures by analyzing the nonlinear changes in damping behavior. In this study, T-shaped RC specimens with concrete grades C25, C30, C40, and C50 were subjected to progressive corrosion through the impressed current method. The corrosion levels were controlled to induce localized multiple damage stages, allowing the investigation of its effect on the modal damping response. Free vibration tests were conducted after each corrosion level, and the time history data were processed using Variational Mode Decomposition to isolate mono-frequency modal vibration response. The study used both Decay Curve Method for overall damping analysis and the Instantaneous Logarithmic Decrement method to obtain insights into the nonlinear damping behavior and its sensitivity to corrosion damage. The results revealed that corrosion-induced changes in modal damping behavior were more complex than previously understood. The magnitude and time domain variation of the damping response were strongly influenced by the progression of corrosion. As corrosion develops, the damping behavior changed increasingly nonlinear particularly during its early stages. This nonlinear behavior was observed to be diminished beyond a certain threshold, at which state corrosion-induced cracks become sufficiently wide that interfacial friction between crack surfaces is no longer effective in energy dissipation. The study demonstrated the sensitivity of nonlinear damping to early corrosion damage, particularly in high strength concrete. It was observed in the experiment that even 2% mass loss due to corrosion was detected through proposed nonlinear damping analysis method which is not feasible in conventional visual inspection methods. These findings provide a new insight into the potential of nonlinear modal damping as a sensitive and reliable vibration-based damage indicator for detecting the corrosion-induced damage in RC structures at its initiation.

Keywords: corrosion detection, nonlinear damping identification, modal damping ratio, vibration based damage detection

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