Assessment of Mode Shapes Based Damage Detection Methods for Building Structures

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ABSTRACT

Damage of structures can raise concerns about safety issues to users. Minor damage in structures may not be critical to structural safety; however, users may not exactly know the severity of damage in structures. Thus, structural health monitoring (SHM) becomes a strategy that can estimate current performance and safety of structures. Users can be informed regarding the levels and locations of damage in structures before the damage has been turned into a serious problem. To achieve this goal, dynamic characteristics such as natural frequencies and mode shapes can be employed to derive associated damage indices that inform structural integrity. These characteristics are typically obtained from vibrational measurements of structures through operational modal analysis. Then, damage of structures can be diagnosed from mode shapes. Therefore, the objective of this study is to assess multiple mode shapes based methods for the capability of detecting damage levels and locations. First, mode shapes of buildings are numerically calculated and converted into shear- and bending-type components. Because the shear-type components in mode shapes are more harmful for structures, these components are then employed in all mode shapes based damage detection methods. The damage detection methods considered in this study include the mode shape curvature method, the bending energy damage index method, the least-squares stiffness method, the strain energy damage index method, the continuous wavelet transform method based on mode shape curvatures, and the method of changes in the first mode shape slopes. The capability of these methods for damage location detection is investigated, while the sensitivity of damage levels from these methods are also studied to understand the relationship between the derived damage indices and damage severity. Some modifications are made to the existing methods for better representing damage levels. Moreover, multiple damage locations are considered in this study, and these damage locations are assumed to sequentially occur. A detailed comparison among these methods is carried out, and building structures with various versions of rotational stiffness are explored. As seen in the numerical results, second derivatives of mode shapes (i.e., mode shape curvatures) can better represent damage of buildings in terms of damage locations and levels.