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Damage detection in bridge structures by the Ritz vectors in the modal strain space

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Abstract

In the study by the Ritz vectors extracted from flexibility matrix, the damage is identified. The flexibility matrices are applied in the modal strain space. The validity of the method is demonstrated using experimental modal data of bridge structures. Levels of damage on the slab of two-girders, simply supported bridge and a plate girder are well localized. The proposed method can detect the damage in bridge structures using a limited number of sensors and vibration modes.

Keywords: damage, bridge, flexibility, modal strain, Ritz vector.

1. INTRODUCTION

In the new industrial societies, there are increasing demands for infrastructures such as bridges. Over the years, these structures suffer severe strength and stiffness reduction due to deterioration, accidental loads, natural hazards and lack of repair. The damage affects the performance and the serviceability of the structures. Thus identifying the damage and maintaining the serviceability of the structures became conspicuous problem in structural engineering. For damage identification, numerous nondestructive damage detection (NDD) methods have been developed. Some of the NDD methods, such as ultrasonic, radiography, magnetic particle and dye penetrate apply to a specific portion of the structures [1]. The increased size and complexity of today's structures reduce the efficiency of these methods. Vibration based identifying methods are more efficient and aim at detecting, locating and quantifying the damage of the entire structure. The vibration based methods utilize the dynamic response of the structure including changes in modal parameters (frequencies, mode shapes and damping ratios). Damage identification methods based on dynamic characteristics have attracted much attention in recent years. The attractiveness of these approaches can be attributed to the fact that dynamic characterization of the structure, in many cases, is easier to perform in the field than static characterization. The vibration based methods have been developed increasingly and there are a wide range of scientific literatures that dealing with this subject. From these scientific literatures, it is well recognized the methods that utilize the mode shapes are more efficient in damage identification. To show the damage localization and severity, the mode shapes must be analyzed and rearranged in appropriate form [2,3]. For this purpose, the methods such as strain mode shapes, strain energy and flexibility matrices have been proposed. Pandey et al. [4], showed that damage occurred in structure, led to local changes in the shape of curvature mode shapes. Salawu and Williams [5] evaluated the performance of some procedures for locating damage using mode shape curvatures. Mode shape curvatures that introduced as modal strains are widely used to damage identification methods. Wahab and DeRoeck [6], investigated the curvature damage factor in a prestressed concrete bridge. Maeck and DeRoeck [7], calculated the bending and torsional stiffness changes using modal curvatures or modal strains. The strain based approaches require the direct measurement of dynamic strains or computing the second derivatives of measured modal displacements. In these methods, the noise induced by the measurement cause errors in computation of modal strains by numerical procedures. In addition, some of numerical methods for obtaining modal curvatures lead to inaccurate results. Maeck [8], proposed an optimization method to calculate the curvatures and removing the noises from experimental data. By using Maeck method, the modal strains are obtained with good accuracy and the boundary conditions can be imposed.

The ratio of changes in the modal strain energy has been utilized in detecting structural damages. Stubbs et al. [9] presented a method to locate damage from the decrease in modal strain energy between two