Damage Detection in Reinforced Concrete Beams Based on the Ritz Vectors

Neda Baghiee[1], Kazem Moslem[2], Mohamad Reza Esfahani[3] and Jalil Rezaee Pazhand[4]

1- PhD in Structural Engineering, Ferdowsi University of Mashhad
2-Assistant Professor, Civil Engineering Department, Ferdowsi University of Mashhad
3-Professor, Civil Engineering Department, Ferdowsi University of Mashhad
4- Professor, Mechanical Engineering Department, Ferdowsi University of Mashhad

1-ne_ba43@stu-mail.um.ac.ir
2-moslem@ ferdowsi.um.ac.ir
3-esfahani@ferdowsi.um.ac.ir
4-jrezaeep@ferdowsi.um.ac.ir

Abstract

This paper presents a method to identify damage in reinforced concrete beams based on the Ritz vectors. The Ritz vectors are derived from flexibility matrix and statistical approaches are utilized to detect damages. The procedure is evaluated by finite element models of reinforced concrete beams. The localization approach based on the Ritz vectors is applied to single, multiple and distributed damage scenarios. The validity of the method is demonstrated using experimental modal data of reinforced concrete beams monitored from initial state to failure in the laboratory. Numerical and experimental results show that the method successfully detects the damages by only a limited number of vibration modes.

Keywords: Beam, Concrete, Damage, Flexibility Matrix, Modal, Ritz Vectors.

1. INTRODUCTION

In the new industrial societies, there are increasing demands for infrastructures such as bridges. Over the years, these structures suffer sever 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. Vibration based damage identifying methods are efficient and aim at detecting, locating and quantify 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). It is well recognized the methods that utilize the mode shapes are more efficient in damage identification [1]. To show the damage location and severity, the mode shapes must be analyzed and rearranged in appropriate form [1, 2]. For this purpose, the methods such as strain mode shapes, strain energy and flexibility matrices have been proposed. The flexibility based identification methods have advantages in structural health monitoring. The flexibility matrix can be calculated easily from the measured first few modes of the structures, and the damage index can be computed by comparing the flexibility matrices in the pre- and post-damaged states. Some of the methods used for this purpose are heuristic, conceived for particular types of the structures, and few can operate with multiple damage scenarios and with an arbitrary number of sensors [3]. In this paper the flexibility damage index based on the Ritz vectors is improved by using statistical approaches. The Ritz vectors are extracted from a flexibility matrix constructed using measured vibration data. The proposed method is verified through the numerical and experimental procedures. For experimental verification, modal tests are conducted on reinforced concrete beam specimens in before and after the damage. In numerical simulation, intended damage are applied on the simulated beam specimens through a finite element software.

2. Theoretical Background

Since the flexibility matrix can easily and accurately be estimated from the first few modes of vibration of the structure, many efforts have been made to find the damage indices using this matrix. The components of the flexibility matrices are deformations corresponding to static forces of unit magnitude acting at the coordinates of a structure. The flexibility matrix is divided into two parts: the modal flexibility matrix F_m