Structural Damage Identification of Reinforced Concrete Beams Strengthened by CFRP Sheets

Neda Baghiee[1], Mohamad Reza Esfahani[2], Kazem Moslem[3] and Jalil Rezaee Pazhand[4]
1-PhD Student, Ferdowsi University of Mashhad
2-Professor, Civil Engineering Department, Ferdowsi University of Mashhad
3-Assistant Professor, Civil Engineering Department, Ferdowsi University of Mashhad
4-Associate Professor, Mechanical Engineering Department, Ferdowsi University of Mashhad
esfahani@ferdowsi.um.ac.ir

Abstract

This paper presents a methodology for the use of vibration monitoring as a tool to assess the damage of reinforced concrete beams strengthened by CFRP sheets. The method is based on the experimental flexibility matrices of reinforced concrete beam specimens. The specimens were gradually damaged and the changes of modal parameters were measured from the initial to the failure state. The noises were removed from the experimental data and the flexibility matrices were estimated by the three lower frequency modes of the beam specimens. The results show that the changes of flexibility matrices can successfully detect the damage by using a limited number of vibration modes. The method can also shows the effect of increasing bending stiffness of reinforced concrete beams after applying the CFRP sheets.

Key Words: CFRP Sheet, Damage Identification, Flexibility, Modal, Reinforced Concrete beam.

1. Introduction

The damage affects the performance and the serviceability of the structures. Thus identifying the damage and maintaining the serviceability of the structures are conspicuous problems in the 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 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). 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.

Dynamically measured flexibility matrix indices have also been proposed for damage detection of structures. The flexibility based identification methods have advantages in structural health monitoring. The flexibility matrix can calculated easily from the measured first few modes of the structure, without needing the numerical procedures. The damage index can compute by comparing the flexibility matrices in the pre- and post-damaged states. Pandey and Biswas [2] presented damage detection and localization method based on the flexibility changes in the structure. They computed the maximum absolute value of flexibility changes in the pre- and post-damaged states. Bernal [3] proposed a damage localization method based on changes in measured flexibility that was general with clearly tractable theoretical base. The Bernal's approach was called DLV or damage locating vectors. These vectors define a basis for the null space of the change in flexibility [3]. Zonta et al. [4] estimated the flexibility matrix in a strain coordinate system. This matrix referred to as strain-flexibility matrix and the changes of each its diagonal element, can be utilize as damage index. Patjawit and Kanok-Nukulchai [14] proposed the global flexibility index (GFI), for health monitoring of highway bridges. The GFI index is the spectral norm of the modal flexibility matrix.

The aim of this study is to identify the changes of stiffness of reinforced concrete beams due to damage and CFRP strengthening. The identification is based on the dynamically measured flexibility matrices. For the purpose a series of dynamic and static tests are conducted on reinforced concrete beams. The dynamic test data are processed and the flexibility matrices are obtained by three lower measured natural frequencies and mode