Bridge damage detection by variational mode decomposition and PCA of traffic-induced vibrations under environmental variability

Rick M. Delgadillo*, Fernando J. Tenelema† and Joan R. Casas†

* Civil Engineering Division, Pontificia Universidad Católica del Perú,
Av. Universitaria 1801, Lima, Peru.
e-mail: rick.delgadillo@pucp.pe, web page: https://www.pucp.edu.pe/

† Department of Civil and Environmental Engineering, Technical University of Catalonia (BarcelonaTech), Catalonia, Spain.
Campus Nord, C1 building. Jordi Girona, 1-3, 08034, Barcelona, Spain
e-mail : fernando-josue.tenelema@estudiant.upc.edu
joan.ramon.casas@upc.edu - web page: https://www.upc.edu/es

Key Words: Damage Identification, Bridges, Environmental Variability, Instantaneous Phase Difference (IPD), Variational Mode Decomposition (VMD), Principal Component Analysis (PCA), Hilbert-Huang Transform (HHT).

ABSTRACT

The environmental and operational influence is still a challenging problem owing because they mask structural damage in civil structures such as bridges. However, advances in signal processing and new artificial intelligence and machine learning tools make it possible to derive more robust and accurate methodologies for damage detection and location. This study proposes a novel bridge damage feature by combining the advantages of variational mode decomposition (VMD), Hilbert Transform (HT) and principal component analysis (PCA) algorithm in the presence of environmental variability and using the non-stationary traffic induced vibration. The proposed methodology considers three steps to analyse the dynamic response. The first step is to pre-process the vibration data (accelerations) using VMD, so the raw data is decomposed into a number of intrinsic mode functions (IMF). The second step is to apply the HT to the decomposed IMFs. Finally, Instantaneous Phase Difference (IPD) is obtained and used as damage indicator. PCA is applied to the IPD in order to eliminate the environmental influence and define appropriate criteria for damage detection avoiding false alarms. This methodology is applied to the case of a numerical model of a continuous bridge, showing promising results for damage detection and location under varying environmental and operational conditions.