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Procedia Structural Integrity 5 (2017) 347–354

Structural Integrity Procedia

www.elsevier.com/locate/procedia

2nd International Conference on Structural Integrity, ICSI 2017, 4-7 September 2017, Funchal, Madeira, Portugal

Estimation of the dynamic modal parameters of a small-scaled mockup

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Abstract

This paper presents the experimental and numerical research carried out on a reduced-scaled model to obtain and simulate its dynamic modal properties. A roving impact hammer test was carried out to identify the dynamic modal properties of the structure. The measured input and output values were acquired using a Data Acquisition System (DAQ) in order to compute the corresponding Frequency Response Function (FRF) to characterize its dynamic response. Finally, the experimental results were used to optimize the parameters of a numerical model of the mockup. In this case, the model updating procedure is based on an optimization problem in which a set of parameters representing uncertainties in the modeling process of the mass, stiffness and damping is optimized to minimize the difference between the predicted and measured dynamics of the actual structure.

Peer-review under responsibility of the Scientific Committee of ICSI 2017

Keywords: Modal analysis; vibrations; model updating

1. Introduction

This paper is devoted to characterize the dynamic properties (frequencies, modal shapes and damping) of an experimental mockup consists on a three-story structure in a shear frame configuration, which can be modeled as a three degrees-of-freedom (DOFs) structure with three lateral displacements representing the vibration of each mass.

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2452-3216 © 2017 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the Scientific Committee of ICSI 2017
10.1016/j.prostr.2017.07.181

Nomenclature

$H(\omega)$	transfer function
$F(\omega)$	system input/forcing
$X(\omega)$	output/response
φ	mass-normalized mode vector
N	number of nodes
f	natural frequency in Hz
$X(t)$	displacement vector
$\dot{X}(t)$	velocity vector
$\ddot{X}(t)$	acceleration vector
M	mass matrix
K	stiffness matrix
C	damping matrix
$\ddot{x}_g$	seismic acceleration
Γ	position vector
α_i	tuning coefficients
x	vector with the updated parameters
x_{LB}	lower bound
x_{UB}	upper bound
$f_\omega(x)$	difference between numerical and reference frequencies
$f_\varphi(x)$	correlated mode shapes
ω	natural frequencies in rad/s
β	weighing factor (frequency)
δ	weighing factor (modes)
λ	weighing factor (damping)
φ_i	experimentally measured mode shapes
φ_i^*	theoretically predicted mode shapes
ξ	damping ratio
ξ_i	experimentally measured damping ratios
ξ_i^*	analytically predicted damping ratios
I	identity matrix

Modal testing represents a well-known experimental approach to study of the vibration or dynamic characteristics of mechanical systems (Ewins 1984, Schwarz and Richardson 1999). Experimental modal techniques include modal excitation techniques, Frequency Response Function (FRF) measurements processed within a Fast Fourier Transforms (FFT) analyzer, and also modal parameter estimation from a set of FRFs (using a curve fitting procedure). This paper highlights the application of a modal excitation technique with an impulse hammer to obtain the FRFs of the structural system. At first, the experimental setup of the structural model used in this investigation is presented. Then, the modal properties of the experimental model were estimated using a system identification procedure on the basis of the response to an impulse excitation. The results obtained with this procedure were then used to update a numerical model of the experimental mock-up.

2. Experimental model

The experimental mockup represents a reduced scale model of a three-story building structure with a maximum weight of 20 kg. The prototype should allow a three-dimensional (3D) or a shear frame analysis depending on the stiffness of the columns and mass properties of each floor. The 3D mode is intended to study the response of asymmetric plan systems. Finally, the geometric properties of the columns and the mass of each floor should provide a first natural frequency of around 2.0 Hz. The frame is modular measuring only 290x290x1080 mm. Each of the four