Chapter 7
Structural Identification and Numerical Models for Slender Historical Structures

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ABSTRACT

In the present chapter the theoretical basis of different methods developed for the calibration of FEMs are discussed. In general, Model Updating techniques are based on the use of appropriate functions that iteratively update selected physical properties (characteristics of the materials, stiffness of a link, etc.). In this way the correlation between the simulated response and the target value could improve if compared to an initial value. The FE model thus obtained can be used for a detailed structural analysis with a great confidence. The technique described in the first part of the chapter is applied to the evaluation of the structural properties of the tower of the Provincial Administration Building in Bari (Italy).The final purpose is to predict the performance of the tower to different combinations of static and dynamic loads, i.e. earthquakes or other induced vibrations. Ambient vibration tests have been performed on the above mentioned tower with the aim of determining its dynamic response and developing a procedure for modeling this building (Foti et al., 2012a). The Operation Modal Analysis (OMA) has been carried out both in the frequency domain and in the time domain to extract the dominant frequencies and mode shapes of the tower.

INTRODUCTION

The use of Finite Element Models (FEMs) for modelling and simulating in detail the behavior of buildings is becoming a popular and useful means for defining the structural and dynamical behavior of civil buildings (Mottershead et al., 1993; Brownjohn et al., 2000; Brownjohn et al., 2003; Ceravolo, 2008; Atamturktur et al., 2010; Betti et al. 2011; Oliveira et al., 2012; Castellano et al., 2015; Diaferio, 2015; Zarate & Caicedo, 2008; Zhang et al., 2000). The always

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bigger calculus power of the modern processors makes easy the realization of FEMs with a very big number of elements. As a consequence it is easier to simulate also complicate structures with an high level of accuracy. The main problem is related to the difficulty of tuning the model to the real building, especially in the evaluation of geometrical data and materials' properties. For this reason, modern techniques for correctly tuning the model have been recently introduced. The most interesting methods are based on experimental data obtained with non-destructive tests. The latter is a necessary condition especially when the analysis is carried out on historical and important buildings (Bayraktar et al. 2009; Brownjohn et al., 2000, 2003; Carnimeo et al., 2015; Chang et al., 2001; D'Ambrisi et al. 2012; Debnath et al., 2012; Diaferio et al., 2007, 2010, 2014a, 2014c, 2014e, 2015; Feng et al., 1998; Florin & Sunai, 2010; Foti, 2013, 2014; Foti et al., 2011, 2012b, 2014, 2015; Gentile & Saisi, 2007, 2013; Ivorra & Palleres, 2006; Julio et al., 2008; Jaishi et al., 2005; Lepidi et al., 2009; Lourenço, 2002; Magalhaes et al. 2008, 2010; Oliveira et al., 2012; Osmancikli et al., 2012; Pagnotta, 2008; Sevim et al., 2011; Tomaszewska et al., 2012; Vincenzi, 2007;).

CALIBRATION OF FINITE ELEMENT MODELS

Methods Based on Matrix Updating

The structural analyses carried out by using FE calculous codes allow to obtain important diagnostic information about the behavior of existing buildings. The procedure used for the fine calibration of the FE model of a structure is called 'Model Updating'. It reproduces the real behavior measured during experimental tests of dynamic identification.

This methodology may be considered an indirect diagnostic non-destructive technique. It is non-destructive because the physical parameters of the materials (i.e. Young modulus) and the mechanical parameters of the structure (i.e. masses, stiffness) are estimated on the basis of the dynamic behavior of the structure, without any damage or change of the structure itself. The methodology is indirect because the Model Updating is a typical inverse problem. The input that generates that response, in fact, is estimated only on the basis of the response of the structure itself.

Most part of the Model Updating methods are based on a minimization process of an objective function, usually defined in terms of the difference between the response of the real system and the FE model (Atamturkur & Laman, 2010).

Objective Function

In order to define the objective function to minimize in the procedure of Model Updating, it is necessary to consider the classical equation of motion in the time domain for a N Degree of Freedom (DOF) system:

$$[M]\cdot\{\ddot{X}\}+[C]\cdot\{\dot{X}\}+[K]\cdot\{X\}=\{F\} \tag{1}$$

where [M], [K] and [C] are, respectively, the matrices of mass, stiffness and damping. $\{X\}$, $\{\dot{X}\}$ and $\{\ddot{X}\}$ are, respectively, the displacement, velocity and acceleration vectors; $\{F\}$ is the vector of the applied external forces. Equation (1) may be written in a scalar form in the frequency domain in terms of the i^{th} eigenvalue equation corresponding of the i^{th} vibrating mode:

$$(-\overline{\omega}_i^{2}\cdot[M]+j\overline{\omega}_i\cdot[C]+[K])\cdot\{\overline{\phi}\}_i=\{0\} \tag{2}$$

where $j=\sqrt{-1}$, $\overline{\omega}_i$ is the i^{th} complex eigenvalue whose imaginary part corresponds to the i^{th}

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