XV International Conference on Durability of Building Materials and Components
DBMC 2020, Barcelona
C. Serrat, J.R. Casas and V. Gibert (Eds)

Dynamic Observability Method for Durability Assessment Considering Measurement Noise

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Keywords: *Durability, Structural System Identification, Dynamic Observability Method, Frequencies，Mode shapes.*

1 Introduction

Understanding and identifying the change in the structural parameters provides new approaches to evaluate its durability. The development of Observability method (OM) makes many contributions to deal with the remaining problem of SSI. The static observability method can successfully deal with the partial observability problem and achieve an accurate assessment. However, the standard observability method used with dynamic data was deficient in identifying degradation processes.

This paper proposes a new constrained dynamic observability SSI methodology, which allows the identification of a subset of characteristics of a structure, related to the durable parameters of structures such as stiffness and mass. Subsets of natural frequencies and modal shapes are used. It is a powerful tool to detect the change of structural parameters. Firstly, the description of dynamic constrained OM method is demonstrated step by step using a flowchart.

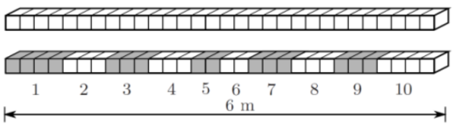
The constrained dynamic observability is based on the dynamic equation of motion of a system including the eigenvalue and mode shape. And the key point is to let all the unknowns of the system to one column vector and identify the relationship of the coupled unknowns and the single ones. Last but not least, the objective function is the combination of the differences between the measured and estimated frequencies and the gaps between 1 and modal assurance criterion, as shown in Equation (1).

$$E = \sum_{i=1}^{R} (\Delta f_i)^2 + \sum_{i=1}^{R} \left(1 - \frac{\left[\emptyset_{mi}^T \overline{\emptyset_{mj}} \right]^2}{(\emptyset_{mi}^T \emptyset_{mi})(\overline{\emptyset_{mj}}^T \overline{\emptyset_{mj}})} \right) \quad (1)$$

The constrained dynamic observability method was used to analysis the stiffnesses of a RC beam, which has 30 elements, 10 parts in figure 1 a). The theoretical values of RC beam were obtained from the published paper by E. Simoen. 100 samples of frequencies are generated for theoretical values with an error of 2% while 100 samples of mode-shapes are obtained with an error of 10%, because frequency accuracy obtained from dynamic tests is normally higher than for mode shapes.

Figure 1 b) shows the estimated mean values of the 100 samples and their standard deviations for the estimated stiffness along the beam. It is shown how the errors in the mean values are less than 2% and the biggest standard deviations less than 1.5%, which is a reasonable range for parameter evaluation.

In order to show the possible applications and potential of the proposed methodology, a 13-story building is presented to do the local identification of EI_1 and EI_2 under two sets, as shown in Figure 2 a). 100 samples are obtained assuming 2% and 5% errors to the frequencies and mode shapes. Figure 2 b) shown the maximum standard deviations is 2.0% and the means of EI_1 and EI_2 are very close to the true value in 2.3% error, which is fully demonstrated its suitability.



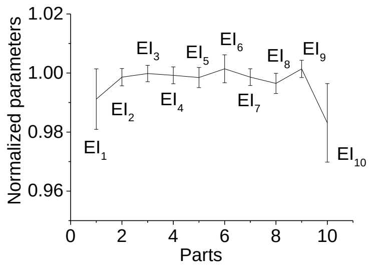
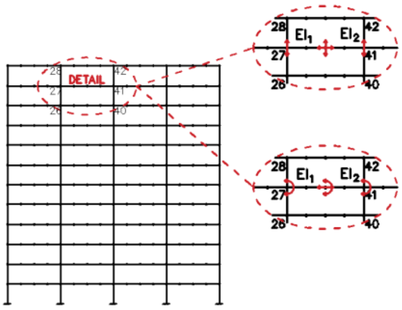


Figure 1. a) Set-up of static loading. b) Mean and standard variance of stiffness.



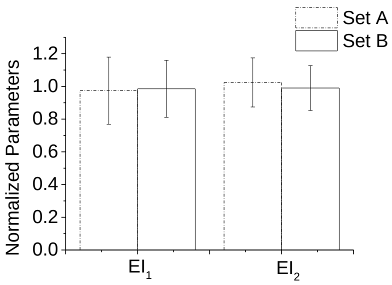


Figure2. a) Sets of measurements used in the local analysis. b) Mean and standard variance of stiffness.

In conclude, the merit of the dynamic constrained observability analysis is demonstrated in the analysis of a RC beam and a large frame structure. What is more, the application of the method can efficiently identify the possible damages existing in the structure that may affect its durability.

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