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Structural Parameter Identification of a Containment Using Dynamic Response Measurements

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1. Introduction

Measuring response of a structure to identify structural degradation in its early stage and to establish appropriate measures has been adopted as a main discipline to maintain structural integrity of the structure [1]. However, to date, only a few attempts have been made for a containment mainly because of difficulties in artificially exciting the structure and concerns on measurability of ambient vibration considering its enormous dimensions. Recently, successful application of ambient vibration based modal parameter identification technique to containments has been reported [2, 3].

In this paper, using the extracted modal parameters of the containment of the Wolsung Unit 2, the structural parameter of the structure is identified. In identifying the structural parameter, a sensitivity based system identification (SI) method is utilized. The identification results along with the theoretical basis and numerical verification results are summarized in this paper. The identified structural parameter shows good agreement with other nondestructive test results.

2. SI Theory

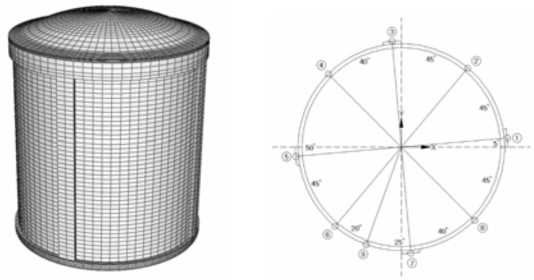
The SI method, first applied to the inverse heat transfer problems in early 1960s, has been adoped to civil engineering structures since early 1970s. To date, the SI methods applied to civil engineering structures include time domain identification methods, perturbation methods, sensitivity based methods, frequency response function methods, etc [4]. Among these methods, the sensitivity based methods have been gained more acceptance due to their stable and robust parameter identification ability [4]. In the first-order-approximation-based sensitivity methods the relationship between the modal parameters and the structural [system] parameters is described as follows:

$$Z = F\alpha \tag{1}$$

where Z and α are vectors include fractional changes of modal parameters and structural parameters, respectively, and F is a sensitivity matrix which relates the fractional changes of the modal parameters and the structural parameters. In this paper, the sensitivity approach represented in Eq. 1 is utilized in identifying the structural parameter of the containment.

3. Numerical Verification

The feasibility of identifying structural parameters using the extracted modal parameters using ambient vibration measurements is verified via a numerical model for the Wolsung Unit 2 (Fig. 1(a)). To simulate the ambient vibration of the containment, external forces, applied to the wall of the containment model, are constructed based on the frequency information of the rotatory machines inside the containment. Fig. 1(b) shows the sensor locations assumed for the verification. The modal parameters of the containment are obtained using both free vibration analysis and modal analysis based on the forced vibration results. The peak picking method is utilized in the process of the modal analysis.



(a) numerical model (b) sensor locations

Fig. 1. Numerical model and sensor locations for Wolsung Unit 2.

The correlations between the modes from the free vibration analysis and the modal analysis are established using the modal assurance criterion (MAC) described in Eq. 2.

$$MAC = \frac{\left|\Phi_i^T \Phi_j\right|^2}{\left|\Phi_i^T \Phi_i\right|\left|\Phi_j^T \Phi_j\right|} \tag{2}$$

where Φ_i is the i[th] mode shape.

The resulting MAC values are summarized in Table 1. In the table, it can be seen that one-to-one correlations exist, but relatively low correlations are observed between the two matching modes. In usual correlation studies for one dimensional structures, e.g., beam structures, using only numerical results, typical MAC values between the matching modes are greater than 9.50 [5]. The authors believe that the low correlation values are due to the symmetry of the structure which produces two very close analytical modes in orthotropic directions.

Table 2 shows the SI results using two modes, i.e., extracted modes 2 and 3. Even though there are four modes available for the SI, only two modes are utilized in the process of the SI based on the experiment results from the Wolsung Unit 2 [3]. The elastic modulus of concrete is selected as the target structural parameter. In the table, it can be seen that the SI method can estimate the structural parameter accurately. Note that the SI is performed using the obtained natural frequencies.

Table 1: MAC values (numerical study)

numerical modes(Hz)	extracted modes (Hz)			
	1(4.20)	2(7.52)	3(8.01)	4(9.77)
1 (3.39)	0.000	0.001	0.022	0.216
2 (4.18)	0.008	0.011	0.001	0.000
3 (4.18)	0.944	0.012	0.024	0.000
4 (7.57)	0.047	0.934	0.121	0.000
5 (7.57)	0.006	0.001	0.000	0.000
6 (7.95)	0.000	0.034	0.764	0.004
7 (8.09)	0.000	0.000	0.046	0.003
8 (9.77)	0.001	0.019	0.000	0.999

Table 2: SI results

	Target	Initial	Final	Error
E (GPa)	2.90	2.47	2.89	0.3%

4. Structural Parameter Identification

The structural parameter of the containment of Wolsung Unit 2 is estimated using the identified modal parameters [3]. First, the correlations between the numerical and experimental modes are established. Fig. 2 and Table 3 show the numerical and experimental mode shapes and MAC values. The table shows that only one mode has acceptable correlation of 0.728.

Based on the correlation results, the SI is performed using one mode. The elastic modulus of the concrete of the containment is selected as the target structural parameter. Using the SI process summarized in Section 2, the elastic modulus of the containment is estimated as 31.2GPa which is 14.7% greater than the design value. Considering the non-destructive test results for the periwall and buttress concrete in 2007, which reported that the elastic modulus of concrete was 20% greater than the design value, the SI result seems reasonable.

5. Conclusions

The elastic modulus of concrete of Wolsung Unit 2 containment is estimated using the extracted modal parameters from the ambient vibration measurements. The SI estimates 14.7% greater value than the design value. Considering the non-destructive test results, the estimated structural parameter value is reasonable.

Table 3: MAC values

numerical modes(Hz)	extracted modes (Hz)	
	1 (8.09)	9.28 (Hz)
5 (7.57)	0.728	0.098
6 (7.95)	0.088	0.350

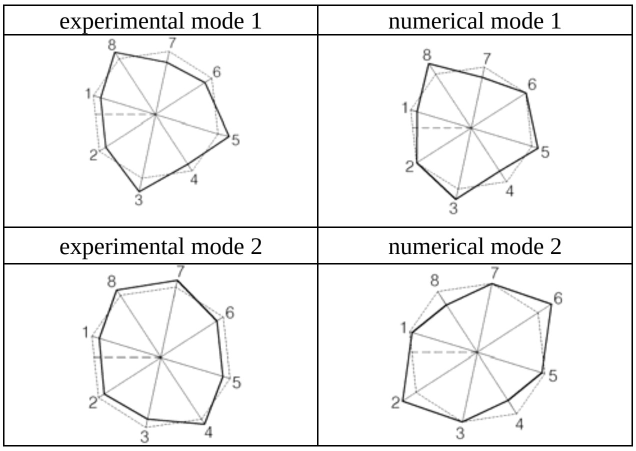


Fig. 2. Numerical and experimental modes

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