SENSITIVITY BASED STRUCTURAL MODEL UPDATING OF IDEALIZED SHEAR FRAMES USING OPERATIONAL MODAL DATA

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***Keywords**: model updating, sensitivity, operational modes, optimization, stiffness*

1. INTRODUCTION

Model updating is the modification of a numerical model of a structural system such that the response of the modified numerical model becomes consistent with the experimental (real-world) results. In this paper, we have updated the structural model using eigenvalues/vectors sensitivity to get the stiffness parameters for three idealized shear frames of 4, 7, and 10-storey reinforced concrete (RC) frames using limited operational modal data.

2. METHODOLOGY

Operational modal data (frequency and mode shapes) for the shear frames are identified using the Frequency Domain Decomposition (FDD) method[1] for the response obtained due to the application of white noise of 0.01hz to 100 Hz range for 2 minutes.

A least square minimization problem with the objective function of error residual vector of frequency and mode shapes between analytical (from numerical modal) and identified (from operational modal analysis) is formulated[2], as:

$$minimize\ x\ \ for:$$

$$\sum_{i=1}^{n_{modes}}\left(\frac{(\lambda_i{}^{id}-\lambda_i{}^{ana}(x))}{\lambda_i{}^{id}}w_{\lambda i}\right)^2+\left(\left(\frac{\phi_{i,l}^{id}}{\phi_{i,r}^{id}}-\frac{\phi_{i,l}^{ana}(x)}{\phi_{i,r}^{ana}(x)}\right)w_{\phi i}\right)^2$$

Here, the first part represents the relative error in eigenvalues and the second part describes the relative error in eigenvectors. As the identified mode shapes are not determined absolutely and can be scaled differently, relative values are used instead of absolute values[3].

In the above minimization problem, x is the vector of updating variables which is obtained for the minimum value of the objective function using the trust region reflective algorithm for optimization in MATLAB. The Jacobian of the residual vector wrt the updating parameter (x) also known as the sensitivity is used to direct the optimization to the minimum. The k+1th iteration updated stiffness is obtained by: $K^{k+1}=K^k+xK^0$

In this paper, the model updating is performed for three types of shear frames varying the damping of the structure (1-5%), no. of modes of the structure (2-3), and no. of measured degree of freedoms (few to all dofs). The result obtained from this operational modal data is compared with the result obtained using modal data obtained from eigenvalue analysis.

3. RESULTS

A summary of the results and comparisons for different cases of model updating is represented in Table 1.

Table 1: Comparative results of the model updating

SN	Frames	Average Error in updated parameters %				
		Damping 1%		**Damping 5%**		**EVA**
		nm=2	**nm =3**	**nm=2**	**nm =3**	**nm=2**
1.	**4 storey**					
1.1	4 dofs*	5.17	9.42	5.65	-	<0.1
1.2	3 dofs*	6.21	9.84	12.49	-	<0.1
1.3	2 dofs*	7.26	10.06	15.02	-	<0.1
2.	**7 storey**					
2.1	7 dofs*	2.65	6.53	9.76	-	<0.1
2.2	5 dofs*	5.28	7.80	24.32	-	<0.1
2.3	4 dofs*	15.01	13.38	20.71	-	<0.1
3.	**10 storey**					
3.1	10 dofs*	3.18	6.49	14.89	7.34	<0.1
3.2	7 dofs*	7.22	7.61	20.61	16.75	<0.1
3.3	6 dofs*	9.23	7.83	28.37	22.31	<0.1

*:measured dofs;nm:no. modes;EVA:eigenvalue analysis

4. CONCLUTIONS

It is difficult to obtain higher modes and the higher modes will become more spurious with the increase in damping of the structure resulting inaccurate updating. On the other hand, it is possible to update the structural model with the limited no. of measured dofs and limited no. of modes for operation modal analysis. The accuracy depends on the accuracy of modal parameters. The frequency parameters can be obtained relatively more accurately compared to the mode shapes parameters. If the modes are spurious, the higher weightage to the residual involving eigenvalues is suggested. Finally, if we can improve the mode shape vectors with the use of existing database combining with this method, it is possible to do the modal updating accurately for the structure with limited measured dofs and limited no. of modes.

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