MASS DISTRIBUTION EFFECT ON THE FINITE MODEL UPDATING USING OPERATIONAL MODEL ANALYSIS TECHNIQUE

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Abstract- The findings of a model update investigation on a planar steel shear frame modal are presented in this paper. The operational modal analysis from the modal ambient vibration data were utilized to update the finite element model of the structure. The model of the structure was created using information from the model design paperwork. To increase the connection between observed and estimated modal parameters, several model parameters were adjusted using an automated approach. The parameters to be adjusted by the updating program were chosen with care to guarantee that the model modifications were meaningful, physically reliable, and realistic. The model update procedure is highlighted in the study.

Keywords- Ambient vibration, Finite Element model, Model parameters, Operational modal analysis.

1 Introduction

Ambient vibration testing is the most cost-effective non-destructive testing approach for obtaining vibration data from big civil engineering structures among the various methods for obtaining vibration data for Output Only Modal Identification [1]. The fundamental advantage of this approach is that no artificial sort of stimulation is required to ascertain the dynamic features of the structure of interest. Human activity, traffic, wind, and micro-tremors continuously excite a civil engineering structure, and with the right equipment and data analysis system, one may use these natural building excitations to evaluate the structure's dynamic qualities.

From the standpoint of structural engineering design practice, there are various reasons for doing vibration measurements in an existing building. For example, the client of a building in a seismically prone zone could be curious about whether the construction follows contemporary practice of seismic engineering design. If the structure is discovered to be vulnerable during a major disaster, structural adjustments in various portions of the structure may be required. The structural engineer who is in charge of this structural upgrade would attempt to offer a design that meets the local building code's safety and serviceability standards in the most cost-effective manner. Not only would a good assessment be required by the structural engineer, but it would also necessitate the creation of a computer model with realistic finite elements, which could be used to evaluate alternative scenarios of a retrofit. Based on the factual state of the structure, including its dynamic properties, a computer-based analysis should be done to validate the structural properties and its response to various static and dynamic loads. In these cases, not only is it good to have, but it is also an economical method for determining the features of civil engineering structures in terms of dynamic behavior experimentally. But also, to have economical methods for gaining complete confidence that the structure's finite element model is a true representation of the physical structure [2].

In order to accurately simulate civil engineering structures using finite element techniques, it is necessary to model the structural geometry, material properties, member fixities, connection types, and underlying assumptions in great detail. However, the results of the finite element model are only approximations and may not accurately reflect the structural behavior. To confirm the finite element model outputs, structures are dynamically tested under operational conditions. The accuracy between the expected and measured OMA (Operational Modal Analysis) outcomes can always be improved with the finite element model upgrades [3]. For structural engineers, particularly in regions with high seismic risk, understanding the behavior of ancient buildings that have undergone structural alterations, restorations, and damage over time remains a significant problem. Due to the many uncertainties that exist in historic structures, the study of constructed heritage for its protection and conservation is an important research area. Finite element modelling has emerged as the most popular and practical technique to analyze the behavior of complex masonry buildings. Yet, the discrepancy between numerical and experimental analysis could result in inaccurate findings. Techniques for model updating can minimize the disparity between the behavior of the numerical models and the testing findings [4].

The density of the load and its magnitude have increased, and the regulations' criteria have also been stricter, all of which have affected the design of structures nowadays. The numerical modelling of the structure is completed in accordance with current regulations to ensure the basic requirements, notably the mechanical resistance and stability. Because of several assumptions, conceptions, discretization, and parameterization that are included during numerical modelling, the results may not always accurately represent the actual structural response. In order to reduce the differences between the actual and expected structural responses, experimental investigations (static as well as dynamic tests) and finite element model updating approaches can be used to determine the hidden resistance of these structures [5].

The analytical finite element (FE) model of any structure can be enhanced using the finite element model updating (FEMU) method from its experimental modal test data. To remove any uncertainties or errors in the analytical FE model, FEMU is still mostly applied to structures. A variety of FEMU approaches can be used to reduce uncertainties in the FE model of real engineering structures [6]. The purpose of this research is to demonstrate how Output-Only Modal Identification approaches can be used in combination with Model Updating tools to construct trustworthy models of civil engineering structures.

Since 1998, researchers from many universities and industry have conducted a series of ambient vibration experiments to determine the modal properties of civil engineering structures and structural models [7]. The dynamic property of interest in this study is the initial natural frequencies of the primary deflection axis. This paper uses a mass distribution effect on finite model updating using an operational model analysis technique to justify different parameters involved in modal updating, which are involved in changing different modal properties. Although these changes are so minute that their effect may be neglected, The modal description, experimental procedure, modal updating, and conclusion of this research work are discussed one by one in detail.

2 Model Description

The model considered in this study was the steel shear frame model. It's a 3-story shear frame, two-dimensional and quite regular. The model is rectangular in plan with no projections or setbacks. The dimensions that are typical of the upper, middle, and lower floor beams are all the same, which is about 25.33 mm by 25.33 mm, while the dimensions of the columns are 28.43 mm by 2.10 mm. All three stories of the frame are equal, which is about 300 mm in height. The width of the frame model is the same throughout its height, which is about 274 mm. The total height of the frame model is about 900 mm. The frame model structure was fixed on the concrete bed with the help of steel screws. An overview and typical cross-sectional dimensions of the model are presented in Figure 1.

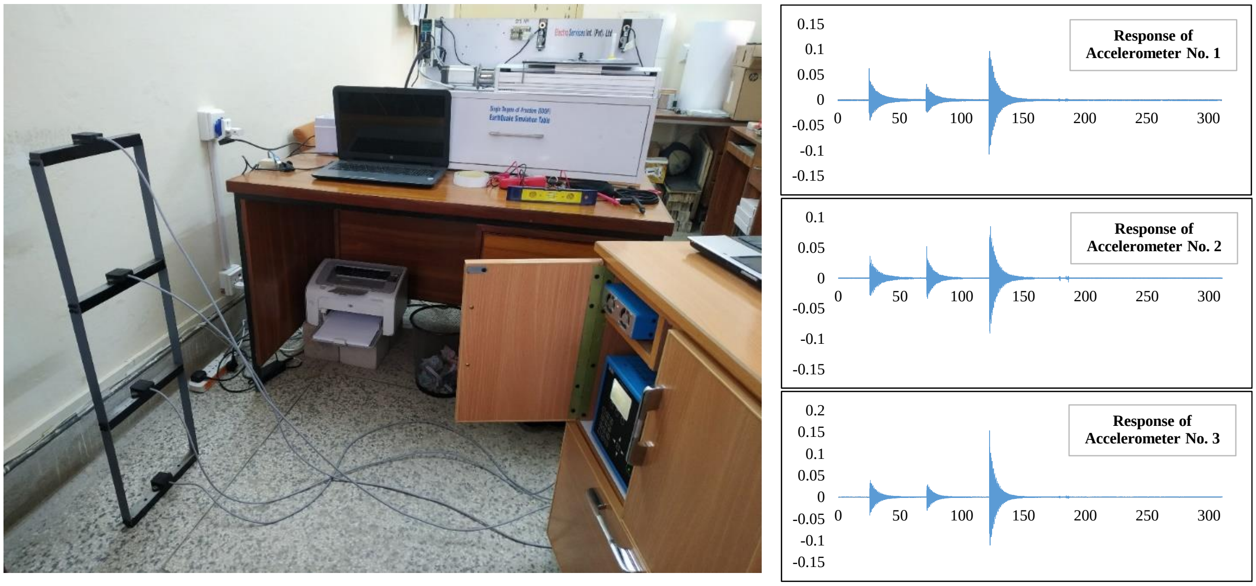

Figure 1. Experimental setup and structural response accelerograms excluding fixed base

3 Experimental Procedure

A Vishay System7000 with 128-channels (supported with MEMS accelerometers having a sensitivity of 1000 mV/g) was used to conduct the vibration measurements. Every story, starting from the top down to the last one, has accelerometers installed on the top and middle of every beam. The model was simplified to a rectangle with nodes arranged vertically. By assuming rigid body motion of the floor beams, the modal characteristics of the shear type building model were determined using the OMA technique under ambient vibrations. Table 1 lists the first three natural frequencies of vibration. The OMA results are compared with the time domain approach, stochastic subspace identification (SSI), and the analytical calculations. The choice of SSI was mainly due to the fact that the stimulus is unknown in the case study of this research work. Therefore, this specialized algorithm of stochastic subspace identification (SSI) has been applicable that only requires knowledge of the response and does not require knowledge of the stimulus.

Table 1: Eigenvalues for model frame building

Mode	OMA Results (Hz)	SSI Results (Hz)	Analytical (Hz)
1	3.64	3.67	3.28
2	10.16	10.15	10.05
3	14.78	14.78	14.51

4 FEM Updating

Using a manual updating procedure, the reference presents [8] an attempt to link experimental and analytical modal features of model building. That research clearly demonstrates the challenges and limitations of attempting for a civil engineering structure to get a satisfactory general combination between operational and analytical modal characteristics. As a result, it was decided to update the structure's initial FE model using a more efficient platform. The CivilFEM tool [9] was chosen for this project, which includes different tools for integrating test and Finite Element analysis data quickly and effectively. An analytical study included correlating the OMA and FEM models' inherent frequencies until an acceptable connection was found. The provided information on the FE model utilized in this research as well as the parameters chosen for model updating are presented in the below sections [10].

4.1 FE model of shear frame

To generate an "initial" model of the structure, FE modelling and analysis capabilities were used. The geometry and material attributes of the model were developed using information already known. The ground level/base was considered "fixed" based on the testing data. The model comprised the key structural elements (columns and header beams). 3D beam-column components were used to model the beams and columns. All the properties of the model are the same throughout the height of the model. The design specifications given in the general material properties were used to determine the steel material properties. The model had 9 beam-column elements and 8 nodes, single material characteristics, and 2 possible element geometries in total. As a result, a three-degree-of-freedom Finite Element model was built.

4.2 Parameters for model updating.

Model updating parameters are listed below:

• The beams, columns Modulus of elasticity, *E*.

• Mass density of the same elements mentioned previously.

The mass density of each element can be varied to see how sensitive the model is to the mass distribution of model elements coupled to the structural system of the model. The moment of inertia and, as a result, the lateral stiffness of the columns are two tough features for model frame constructions. The value of I is largely dependent on the type of material used and how the composite action of the construction materials is accounted for in the model. Furthermore, because a column's stiffness varies greatly as a function of the column's effective length, changes in the values of I can be understood as needed model adjustments to significantly depict the column's effective length.

4.3 Results of model updating

Table 2 shows the resulting modal frequencies after various iterations of parameter updating. The table indicates the operational frequencies (OMA) and FEM frequencies after and before updating. This table shows that some of the revised model's frequencies are, for all intents and purposes, identical to the operational ones. The third mode has the highest difference, roughly 1.3%, although this is still suitable for practical applications.

FEM tools made changes to the FE model to achieve the compared values shown in the previous table. The entries in the table are assumed to be in meters, kilograms, and newtons. Furthermore, a sensitivity study of the frame model to modifications in different parameters revealed that their overall impact isn't significant, which shows the negligible differences in the model parameters as shown in the table above.

Table 2: Eigenvalues after FE model updating

Mode	OMA Freq.	FEM Before	FEM updated (Hz)	
			Freq.	Diff. (%)
1	3.64	3.49	3.62	-0.6
2	10.16	9.70	10.23	0.7
3	14.78	13.88	14.97	1.3

5 Conclusion

Experimentation and analysis were used to establish the natural frequencies of the steel shear frame modal. This case study demonstrates that using the results of an operational model analysis, it is possible to update the model effectively. The automatic model-updating makes it much easier to figure out which model parameters can be changed to improve the comparison between operational and analytical results. In this regard, the finite element model update-based updating techniques can be applied to correct the simulated FE model and remove the difference between the FE model outputs and measured data. Reviewing and effectively implementing the automatic model-updating method on the shear frame modal is the primary accomplishment of this work. Updates can be made to the simulated FE model quickly and easily without taking a lot of time, The effective use of updating methods is important. The analyst must, however, decide whether to accept the changes or not and to show how useful the suggested changes.

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