ISSN: 2414-1895 DOI: 10.6919/ICJE.201909_5(10).0031

Identification of concrete modal parameters based on numerical simulation

Xue Li

School of Architecture and Civil Engineering, Southwest University of Science and Technology, Mianyang, Sichuan, 621000, China

495667830@qq.com

Abstract

The identification of structural modal parameters is an important part of obtaining the characteristics of concrete structure. The modal of concrete structure extracts the parameters of structure, such as frequency and mode shape, by processing the corresponding signals, and evaluates the changes of structural parameters. The identification method of modal parameters based on linear system deduction is helpful to the applicability of linear concrete structures. If linear concrete structures are damaged, the concrete structures will be in a non-linear state. If the linear structure principle is still used in the non-linear state, the modal parameters are solved by the method, which will affect the accuracy of the results. Based on this, the modal parameter identification of the structure is discussed by numerical simulation analysis method, and the relationship between the applicability and degree of the modal parameter identification method for the non-linear structure is studied, so that more accurate modal parameters of concrete structure can be obtained. Key words: Data simulation analysis; Structural modal; Parameter identification.

Keywords

Data simulation analysis; Structural modal; Parameter identification.

1. Introduction

In fact, modal identification is system identification, and the ultimate goal of system identification is to predict the impact of the system on vibration. The methods to solve the problem of vibration are to establish numerical models, physical experiments and so on. The premise of using the numerical model is that the parameters such as the structure and size of the system are clearer, other parameters can be set flexibly, and the operation method is more flexible, so that the corresponding dynamic structure can be obtained with certain applicability. However, the numerical model has approximate treatment in grid partitioning, and the response state of the result knowledge structure is not the real response. As an important component of system identification, modal parameter identification can only achieve the ultimate purpose of identifying the parameters of the system model. Based on the numerical simulation analysis of structural modal parameter identification, it is necessary to establish a numerical model by finite element software, obtain the corresponding data by excitation, then obtain the frequency response function by signal, and finally analyze the structural modal parameters by rolling frequency response function. The method of numerical simulation can avoid the noise in the process of signal acquisition and make the loading of excitation signal more flexible. It is very effective to identify modal parameters.

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2. Frequency domain identification of modal parameters

2.1 Single-mode Component Analysis

Single modal identification is a method of identifying modal parameters only once in the output of a single input. For the modal of a certain stage to be identified, the frequency response function will be affected by the modal of the main stage, and the residual modal effect is less. Therefore, the single mode identification method can simplify the impact of other modes. Theoretically, the modal parameters of each stage obtained from different corresponding points are taken as the reference of the whole structure. The errors should be taken into account, and the results of the measured points should be averaged to get the modal results of each stage. Component analysis is an important method to solve single mode identification. It mainly uses the peak value of imaginary part curve of frequency response function to determine the value of a certain stage, and obtains the expression of frequency response function of undamped natural frequency of structure.

$$H(\omega)=\frac{1}{\mathrm{k}}*\frac{1}{1-\frac{\lambda^2}{\omega^2}\omega^2+\frac{\mathrm{j}\omega 2\zeta\frac{\lambda}{\omega}}{\mathrm{k}}}=\frac{1}{\mathrm{k}}*\frac{1}{1-\lambda^2+\mathrm{j}\omega 2\xi\frac{\lambda}{\omega}}$$

$$=\frac{1}{\mathrm{k}}*\frac{1}{1-\lambda^2+\mathrm{j}\omega 2\xi\frac{\lambda}{\omega}}=\frac{1}{\mathrm{k}}*\frac{(1-\lambda^2)-\mathrm{j}2\xi}{(1-\lambda^2)+4\zeta^2\lambda^2}=H_R+jH_I \tag{1}$$

2.2 Multimodal Levy Method

In the process of structural polar mode reference system, if the adjacent modal overlap is used close to the single modal identification method, the identification error may be too large to take into account the influence of drilling mode. Therefore, in the process of multi-period full-tone planting, it is necessary to expand the use range of frequency response so that all phases of the system can be superimposed. After that, it reflects the change of frequency technology, not only the mode within the frequency range. Therefore, multi-modal Levy method can be used to derive. Based on the accelerated frequency response reading and absorption, the process of solution is analyzed and the formula is as follows:

$$H(s)=\frac{a_0+a_1s_r+a_2s_r{}^2+\ldots+a_{2N}s_r{}^{2N}}{b_0+b_1s_r+b_2s_r{}^2+\ldots+b_{2N}s_r{}^{2N}} \tag{2}$$

3. Calculations and experimental verification

The purpose of this modal test is to determine appropriate materials and parameters, so that the natural frequency of the original size model can reach 6-7Hz. The modal analysis of the original size models with different confinement modes and material choices was carried out by using finite element software, and the influence of confinement modes and material parameters on the modal was studied. Select the material that can make the original size model reach the target frequency, calculate the scale model according to a certain proportion, explore the relationship between the scale and frequency, and provide relevant guidance for the actual scale test.

3.1 Modeling Size and Frequency of Cantilever Beam Specimens

Aiming at frequency 6 Hz, the size and material selection of cantilever beam are determined. Considering comprehensively, the length of the cantilever beam is about 3-6 meters, and the section area of the beam is 0.3 X 0.3 m, 0.35 X 0.35 m and 0.4 X 0.4 M. When the cross-section size is 0.3 X 0.3 m, the density is 2581 kg/m3, when the cross-section size is 0.35 X 0.35 m, the density is 2586 kg/m3, and when the cross-section size is 0.4 X 0.4 m, the density is 2590 kg/m3. The first order frequencies of three different cross-section sizes with different lengths are shown in Table 1.

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Table 1: Cantilever Beam Frequency Change Table

Section size/m			
length of beam/m	0.30 X 0.30	0.35 X 0.35	0.40 X 0.40
5.35	6.01008	7.00149	7.99047
5.50	5.68705	6.62543	7.56162
5.75	5.19862	6.06270	6.92513
6.00	4.54927	5.56870	6.35624
6.15	4.54927	5.30059	6.05051

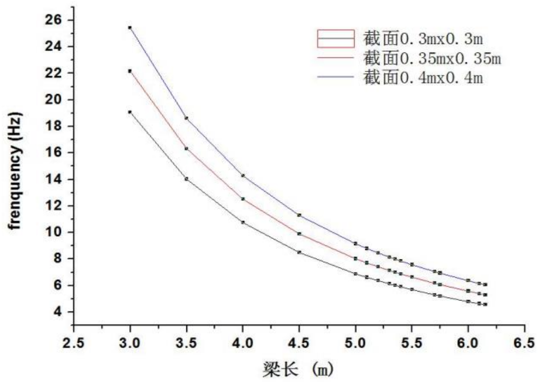

Figure 1. Frequency versus beam length and section size

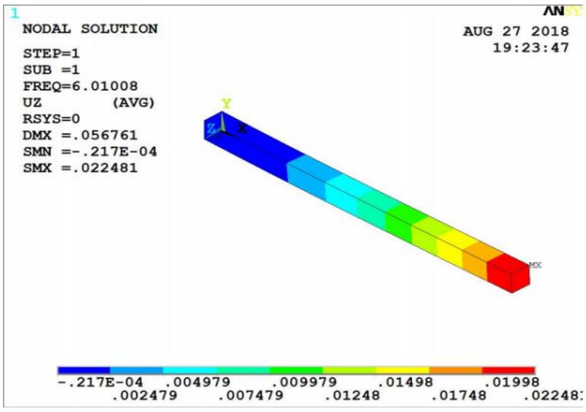

Figure 2. Displacement diagram of cantilever beam with 5.35 m section size of 0.3M

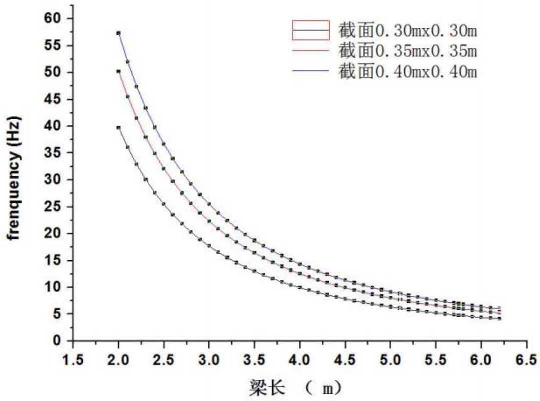

Figure 3. Frequency variation with beam parameters calculated from formulas

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In order to verify the correctness of the numerical simulation results, the parameters of beam length and section size are introduced into the calculation formula of cantilever beam frequency.

$$f_n = \frac{A_n}{2\pi l^2}\sqrt{\frac{EI}{\rho A}} \tag{3}$$

In the formula, E is the elastic modulus of the beam, I is the moment of inertia of the beam section, L is the length of the cantilever beam, and L is the density of the cantilever beam. A is the area of the cantilever beam section. An is the mode factor (A1 = 3.52, A2 = 22.4, A3 = 61.7, A4 = 121.0). The frequency difference between Ansys numerical analysis and cantilever beam frequency calculation formula is acceptable, so the calculation and analysis process is considered to be correct.

4. Tests and Principles

Modal recognition can be divided into frequency domain identification and time domain identification. Compared with time domain modal identification, frequency domain identification is more mature and has more clear physical meaning. The basic theory of this method is as follows: assuming that the system is a viscous damped system, its differential equation is:

$$[M]\left\{\ddot{x}\right\}+[C]\left\{\dot{x}\right\}+[K]\{x\}=\{f(t)\} \tag{4}$$

In the formula, [M] is the mass matrix, [C] is the damping matrix, [K] is the stiffness matrix, {x} is the displacement vector, {f(t)} is the excitation force vector. The transfer function can be obtained by Fourier transform.

$$\mathrm{H_{ij}}(w)=\frac{X_i(w)}{F_j(w)}=\sum_{r=1}^{n}\frac{\varphi_{ri}\varphi_{rj}}{m_r\left[\left(w_r^2-w^2\right)+j2\xi_j w_r w\right]} \tag{5}$$

The transfer function is obtained by exciting a point on the structure and measuring the response at multiple points. After parameter identification, the natural frequency, damping ratio, mode shape and modal stiffness of the structure can be obtained.

As shown in Figure 3.1, six cantilever beams are now placed vertically, and each three is grouped from the beginning to the end. The reinforcement ratio of the first group was 0.816%, and that of the second group was 1.02%. Numbers are 1-6 from the beginning to the end. Each concrete cantilever beam is equipped with five measuring points: end-to-bottom, top, 1/4 span, mid-span and 3/4 span. The test results are shown in Table 2. The comparison between the test results and the numerical simulation results shows that they are basically consistent and can verify each other's correctness.

Figure 4. Placement and test charts of field specimens

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Table 2: Cantilever Beam Frequency Change Table

cantilever beam	length of beam/m	Section size/m	Reinforcement ratio	First-order frequency/Hz	First-order Damping	Second-order frequency/Hz	Second-order Damping	Third-order frequency/Hz	Third-order Damping
first	0.35	0.3X0.3	0.86%	6.35	1.46%	6.35	1.46%	39.06	0.97%
second	5.35	0.3X0.3	0.86%	6.35	1.43%	6.35	1.43%	39.06	1.13%
third	5.35	0.3X0.3	0.86%	6.45	0.81%	6.45	0.81%	38.96	0.93%
fourth	5.35	0.3X0.3	1.02%	6.49	1.30%	6349	1.30%	39.5	1.28%
fifth	5.35	0.3X0.3	1.02%	6.45	0.85%	6.45	0.85%	39.6	0.51%
sixth	5.35	0.3X0.3	1.02%	6.45	1.79%	6.45	1.79%	38.67	0.92%

5. Concluding remarks

Taking cantilever beam structure as an example, the numerical model of modal parameters of water structure is analyzed, and the acceleration frequency response function of the structure is obtained. The modal parameters are obtained by single modal component and multi-modal method. Comparing the structure of linear cantilever beam with that of non-linear cantilever beam, different contrast incentives are applied to the structure of smart beam with slits. It is found that the accuracy of linear identification is better, and the structure of non-linear identification will show different trends with the excitation.

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