Vibration Response on MiNT-SRC Building due to Ground Borne Vibrations From Humans Using Finite Element Modeling

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Abstract. Low amplitude of vibration response on laboratory is important problem to explore due to human activity like footstep or walking. Human activity such as walking will produce low vibration amplitude that can affect the sensitivity of sensitive equipment inside the research or laboratories facilities. Microelectronic and Nanotechnology-Shamsuddin Research Center (MiNT-SRC) building at UTHM is selected to be a location for ground borne vibration measurement due to human activities. The research center is chosen due to sensitivity equipment in the building that prone to vibration effect. Finite element modelling is used to analyse the vibration response distribution to overall building. Vibration data input from field measurement is analysed in ANSYS software based on finite element method, and then further analysis in MATLAB software. A ModalV analysis program in MATLAB is used to produce one third octave velocity spectra and vibration criterion curve for the observed floor. The study shows that the vibration criterion for MiNT-SRC building is classified as VC-E at ground floor and VC-B at the first floor. Thus, based on the result analysis, the sensitive equipment is most suitable to locate at the ground floor of MiNT-SRC building.

Introduction

In civil engineering field, the structure like building is highly exposed to the vibration phenomenon. There are lot of causes which is contributes to vibration response in the building, where it may vary both is space and in time [1]. Generally, structure of a building is exposed with two main vibration sources which is internal and external vibration source [2]. This case study is needed because to better understanding the effect of the low frequency vibrations of the sensitive equipment, then to enable designers to provide or proposed a suitable condition of building structure without waste the cost due to overdesign the facilities. Generally, modern and sophisticated laboratories building required very high standard of vibration sensitivity level because the equipment inside the building is very sensitive to the motion of vibration. Furthermore, vibration at the equipment base can cause internal components, specimen of study or produced items to move relative each other [3].

Vibration response for studied building is determined by using finite element modelling method to recognize generic vibration criterion of the studied building based on Gordon recommendation [4]. Vibration response on the studied floor of the building should below the sensitive level requirements of equipment to enable the equipment used in standard and suitable environment condition.
Reviews on Vibration Principle Theory

In engineering scope, the vibration is referring to repetitive, periodic, or oscillatory response of a mechanical system [5]. Usually, the rate of vibration cycles is expressed as frequency in unit Hertz (Hz). Vibration may occur when the physical body is exposed to the repetitions force that acting on it. Furthermore, vibration source is classified into two classification which vibration from internal sources and external sources. Focusing on this study, the vibration response of the studied building just involved internal sources of vibration which is due to human movement. Basically, vibration on a building that cause by walking activity which is continuous excitation is assumed as perfectly periodic [6]. An example of oscillation of periodic vibration due to forcing function from walking activity is shown in Figure 1. The dynamic loading of vibration when applied to floors structure is refers to the oscillatory motion that effect to the building and the occupant during the normal everyday activities [6]. According to Brad Pridham ground borne vibration should be an important consideration during the design of research and healthcare facilities [7]. Generally, vibration response analysis for a building was done based on the case of earthquake analysis where the structure system is exposed to external force [8].

Generic Vibration Criterion

Generic vibration criteria is developed and used as references to provide frequency dependent sensitive for all type of sensitive equipment and procedure [7]. In 1980, the criterion is developed response for a need of requirement for design standards to accommodate a wide range of sensitive equipment that used in the microelectronic, medical and biopharmaceutical industries [4]. The generic criteria curves are proposed by Colin Gordon as shown in Figure 2. The generic criteria curves Colin Gordon are created based on the set of one third octave band velocity spectra level which is from VC-A to VC-E [9].

Finite Element Modelling Methods

MiNT-SRC building is a combination of two storey buildings at building A and one storey building at building B. The length for the overall building is about 50m, while the width is about 43 m. The building is modelled in ANSYS software based on the actual material parameter where density is 2400kg/m$^3$, Young’s modulus, E is 38GPa and Poisson Ratio is 0.2. Modal damping ratio is assigned to be 2% for concrete structural material [10]. The geometry of the building is modelled with 200mm×500mm of beam size for the overall building and 150mm thickness for overall slab of the building. For the column structure, the building is provided with necessary support system based on the drawing from 400mm×600mm of the larger column size to the smallest column size which is 200mm×200mm.

The finite element modelling (FEM) is a numerical technique that can be applied to obtain solutions to variety of problems in engineering fields. The finite element method is a process to
finding an approximate solution of a given boundary value problem. In this study, the ANSYS software is be used to perform finite element method for determine the vibration response on MiNT-SRC building. Then vibration response data is further analysed by implemented the related algorithm in MATLAB software to obtain vibration criterion curve for the studied building.

Modal and Transient Analysis

In ANSYS, modal analysis is a process to determine the vibration characteristic which is natural frequencies and modal shape of a structure. Generally, Block Lanczos Eigen solver is used to solve the FEM in the ANSYS software, where this algorithm system is suitable for large scale model of modal analysis [8]. While, Transient analysis is a process that analysed the dynamic response of a structure subjected to loads with arbitrary behavior in time. Time history and frequency is the result that obtained from this analysis.

Mode Shape and Natural Frequency

The result of mode shapes and frequency can be obtained by performing a modal analysis in ANSYS software. The mode shape and natural frequency is important dynamic properties result where it is used as first stage for another advance and detailed dynamic analysis such transient analysis. Table 1 shows the summary for the all 10th modes of modal analysis result.

<table>
<thead>
<tr>
<th>Mode</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (Hz)</td>
<td>2.89</td>
<td>3.26</td>
<td>3.62</td>
<td>4.77</td>
<td>5.31</td>
<td>5.61</td>
<td>6.03</td>
<td>6.53</td>
<td>6.75</td>
<td>6.83</td>
</tr>
<tr>
<td>Maximum deflection (m)</td>
<td>0.0026</td>
<td>0.0024</td>
<td>0.0029</td>
<td>0.0224</td>
<td>0.0157</td>
<td>0.0071</td>
<td>0.0064</td>
<td>0.0115</td>
<td>0.0110</td>
<td>0.0075</td>
</tr>
</tbody>
</table>

First mode shape is generated lower frequency value which is 2.89Hz and caused the deformation of building shape with maximum deflection of 0.0026m. While, the frequency value up to 6.83Hz at tenth mode shape analysis, which causes the building shape to deform with maximum deflection of 0.0075m. The largest deformation of the building happens at 4th mode shape, where the maximum deflection is 0.0224m at the frequency value of 4.77Hz. This condition defines that the maximum deflection may not necessarily happen at the higher frequency. Figure 3 shows example of mode shape for the first and tenth mode of modal analysis.

![Fig. 3 Mode shape of the MiNT-SRC building for (a) The first mode, (b) Tenth mode](a) Mode 1, 2.89Hz (b) Mode 10, 6.83Hz)
**Time History and Frequency**

Five points of analysis location at the studied building floor is chosen to perform the transient analysis as shown in Figure 4. Responses at ground floor show that the peak amplitude happens at about 7Hz to 8Hz as shown in Figure 5(a), while the peak amplitude at first floor happens about 1Hz to 2Hz as shown in Figure 5(b), while point 5 that located near to support at first floor in Figure 5(c). The peak amplitude is different for both floors because the ground floor is set as fixed base onto the ground, while first floor set to be free. By determines the peak amplitude of frequency for the studied floor, the behavior of floor can be observes based on the ten modes of mode shape in Modal analysis. For example, at the ground floor where the peak frequency is about 7Hz, the floor behavior is node deformation as shown in the mode shape of the tenth mode at Figure 3(b). Time history graph shows the maximum acceleration response at point 2 is about $1.2 \times 10^{-11}$ m/s$^2$ at ground floor, while at first floor is about $0.7 \times 10^{-3}$ m/s$^2$. As the ground floor is assumed as rigid base the acceleration response at ground floor is smaller than the first floor. This condition is similar with the point 5 analysis where it located nears to support system at the same floor panel of point 2. The maximum acceleration value at point 5 is about $1.25 \times 10^{-4}$ m/s$^2$ where it is much small than at point 2. This is because the structural systems become more rigid to the vibration transmission when it is near to supports system.

![Fig. 4 Point location for transient analysis in building A](image)

**One Third Octave Velocity Spectra**

One third octave velocity spectra graph is obtained by using ModalV program in MATLAB software. The graph is compared to generic vibration criterion curve that generated on the same graph. From the analysis, the one third octave velocity spectra for the overall ground floor is found lie on the vibration curve VC-E region. At the first floor, the overall point of analysis is generated the one third octave velocity spectra that situated at vibration criteria curve, VC-B region where the RMS velocity response is about 13 µm/s as shown in Figure 6(a). Furthermore, the vibration criteria for analysis point that located nearest to support shows the different criteria as shown in Figure 6(b), where the one third octave velocity spectrum is lie on vibration criteria curve, VC-E region. This shows that the rms velocity is dropped to 1 µm/s as the structural system become more rigid when it nearest to the support system.

![Fig. 5 The vibration response graph, time history and frequency value for the studied floor](image)
Conclusions

As a conclusion, it can be proved that the vibration response of the MiNT-SRC building can be determined by using finite element modeling method. The result of ModalV analysis is accepted because all the analysis process has been done based on the standard operation and procedure. In addition, the vibration criterion for the overall MiNT-SRC building is satisfied and suitable to locate all the sensitive equipment. The overall vibration criterion for ground floor is VC-E, while for the first floor is VC-B. The overall vibration criterion for ground floor is VC-E, while for the first floor is VC-B. In addition, the vibration criteria is more sensitive when it is near to the support of the building.

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References