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Floor Dynamic Assessment on Laboratory due to Ground Borne Vibrations using ModalV Analysis from Passing Vehicles

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Abstract. High-tech development on laboratory with high resolution and sensitive device is increased nowadays. This equipment requires very sensitive location to accommodate in a special room, because it may cause improper functioning for a certain devise which required low level of vibration. Due to this problem, the aim of this study are to perform the structural response on two story laboratory subjected to ground vibration input due to traffics and to assess the level of vibration at the floor. The vibrations input are measured by using portable equipment called Laser Doppler Vibrometer. The field measurement is done at the laboratory Block E, Faculty of Mechanical and Manufacturing Engineering at Universiti Tun Hussein Onn Malaysia (UTHM). Finite element ANSYS software is fully utilized to model the building structure and perform analysis in order to determine structural modal and transient analysis for the building. Time history response from ANSYS post-processing is transferred into ModalV analysis in MATLAB software in order to evaluate the vibration criteria level of the floor according to specific overseas guideline. It was found that the vibration response on the middle slab of the first floor at level Vibration Criteria, VC-A or maximum particle velocity level at 50μm/s. Vibration Criteria (VC) curve analysis on floor slab indicated the highest vibration will occur at the middle of floor slab and the lowest vibration will occur at the edge of slab which near the column and below VC-E level for ground floor slab.

Introduction

Ground borne vibration generated by the movement of traffic in the building is a problem that occurs in the development environment. The increasing of traffic volume, vehicle technology which providing speed and increase the axle load of the vehicle contributed the vibration wave to the surrounding area. Traffic vibrations acting on a nearby building is due to the loading of heavy vehicles passing through the high relative velocity on the road plus an uneven surface. The interaction between the tires and the road surface will simulate dynamic movements produce waves and transmitted through the medium of soil, thus act on the foundation of building an adjacent the road [1]. In addition, the dominant frequency of ground borne vibrations from vehicles is classified as low frequency. Therefore, the objective of this study is to investigate the level of floor vibrations in buildings based on the ground vibration input and response to the frequency of vibration from vehicles. The vibration input is obtained from the previous researcher [2] to analyse the observed structure and floor.

Vibration Concepts

The vibration will propagate through the medium of soil into the buildings nearby as shown in Figure 1. Several factors such as the road surface, types of vehicles and speed will induce the wave propagation to the building [1].

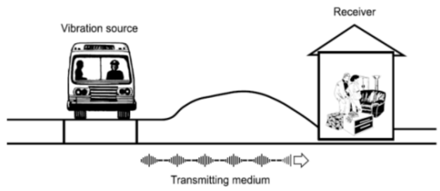


Fig. 1 Vibration propagation induced by traffic [1]

Vibration Criteria (VC) Curve

The vibration criteria curve which developed in 1980 by Gordon [3] indicates a specific standards for applicable of vibration level in the microelectronics, medical and pharmaceutical biology industries. These industries typically use sensitive equipment which is exposed to the low level of vibrations. VC curve is a wave spectrum is designated as one third octave band velocity spectra. The wave spectrum is labelled according to the different magnitudes of the vibration criteria curve ISO level (less sensitive) to VC-E (most sensitive) [3][4]. Generic vibration criterion curves are plotted as shown in Figure 2.

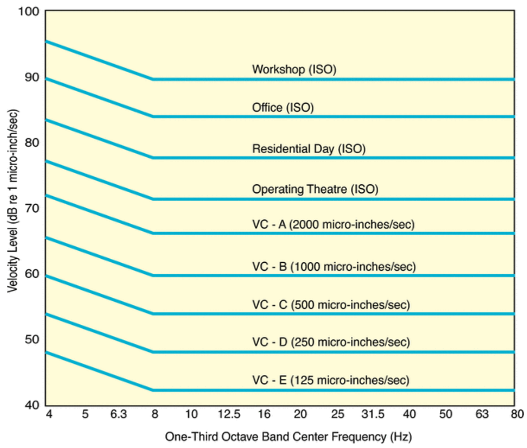


Fig. 2 Generic vibration criteria (VC) curve for vibration-sensitive equipment [3]

Finite Element Modelling (FEM)

Laboratory building E block at Faculty of Mechanical and Manufacturing Engineering (FKMP) is a two-storey building which is near to G3 block. The building has an estimated size (50m long x 32.6m wide x 8m high). This study only focused on E block at the wing side only. Figure 3 shows the view of Block E laboratory building.

Fig. 3 Block E laboratory building

ANSYS and MATLAB software are fully utilised in the FEM to analyse modal and transient analysis by using main menu command, ‘pre-processing’>‘solution’>‘post processing’>‘time history post processing’. In ANSYS, every element is assigned with material constant to define structure properties in term of density, poison ratio and modulus of elasticity. All elements are design in homogeneous and isotropic under BEAM4 and SHELL63 for elastic concrete structure such as beam, column and slab. Then structure is meshed under suitable mesh size and set up the boundary condition on ground floor column to be fixed structure. Then the structure is solved to run modal analysis by Block Lanczos method which is suitable for complicated 3D structure. By taking ten modes for modal analysis, it shows the mode shapes and fundamental natural frequency of the structure.

Then, transient analysis is carried out to determine structural response by time domain in displacement, velocity and acceleration on selected point on floor subjected to vibration inputs from traffic. Transient response due to time domain is transferred into MATLAB software. Further analyses are run in ModalV analysis which is in-house software developed in MATLAB to assess the structure response due to input of vibration and also comparison between the structural performances with generic vibration criteria as shown earlier in Figure 2. The overall process of the finite element analysis in this study is shown in Figure 4.

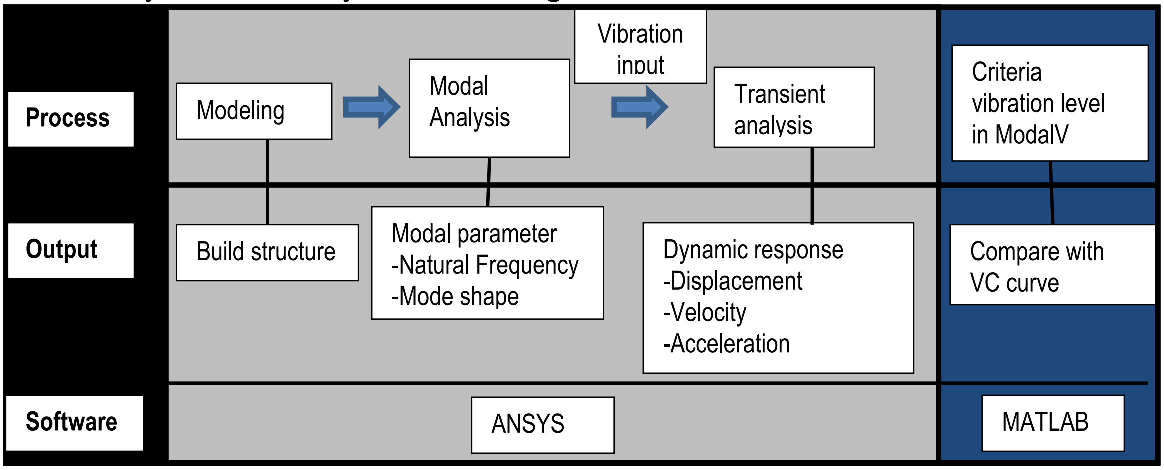


Fig. 4 Vibration assessment analysis process [5]

Natural Frequency and Mode Shape Analysis

The results of modal analysis are carried out by ANSYS shows the fundamental natural frequency is 3.0Hz for the building. This low natural frequency displays global horizontal swayed on the y-axis as shown in Figure 5. Total of 100 modes are analysed to get different types of mode shapes. Vertical deformation is only taken into account to perform the floor vibration assessment due to traffics. Therefore, five modes shape indicate the floor deformation on the building as shown in Figure 6. Floor deformation can be seen at mode 4 (4.08Hz), mode 6 (4.55Hz), mode 7 (4.90Hz), mode 8 (5.20Hz) and mode 10 (5.89Hz) which occurred at the ground floor.

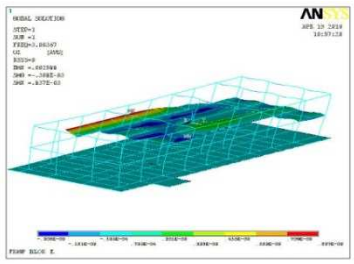
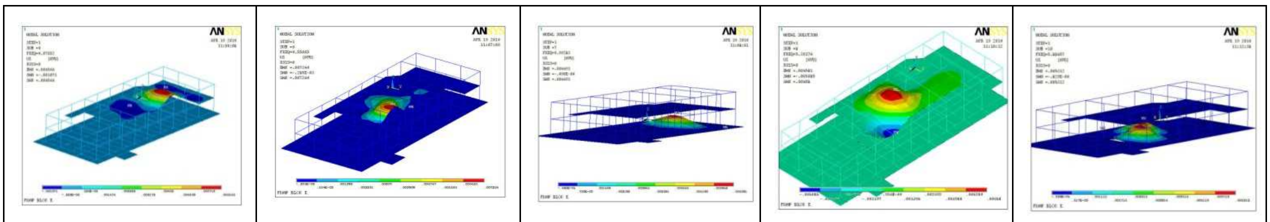


Fig. 5 Mode 1, 3.0Hz



(a) Mode 4, 4.08Hz | (b) Mode 6, 4.55Hz | (c) Mode7, 4.90Hz | (d) Mode 8, 5.20Hz | (e) Mode 10, 5.89Hz

Fig. 6 Mode shape behaviour shows vertical floor deformation on FKMP Block E

Vibration Criteria Analysis

The final stage of analysis in the floor assessment is vibration criteria response on each floor. Based on the Gordon vibration criteria curve, the vibration level is consisting of ISO level which is perceptible to vibration, VC-A, VC-B, VC-C, VC-D and VC-E. Analyses are carried out on both floors, e.g. ground and first floor. Figure 7 indicates time history and VC curve for floors. Ground floor show very low vibration level and most sensitive at below VC-E. It means that the passing vehicles in the adjacent laboratory building does not affect the floor and it is assumed to be adequate location for the most demanding of sensitive systems and other systems requiring extraordinary dynamic stability.

While for the first floor, it shows very opposite floor behaviour when compared to the ground floor. The vibration response plotted at VC-A curve. This means the first floor is less sensitive and adequate in most instances for optical microscopes to 400X, microbalances, optical balances and proximity and projection aligners.

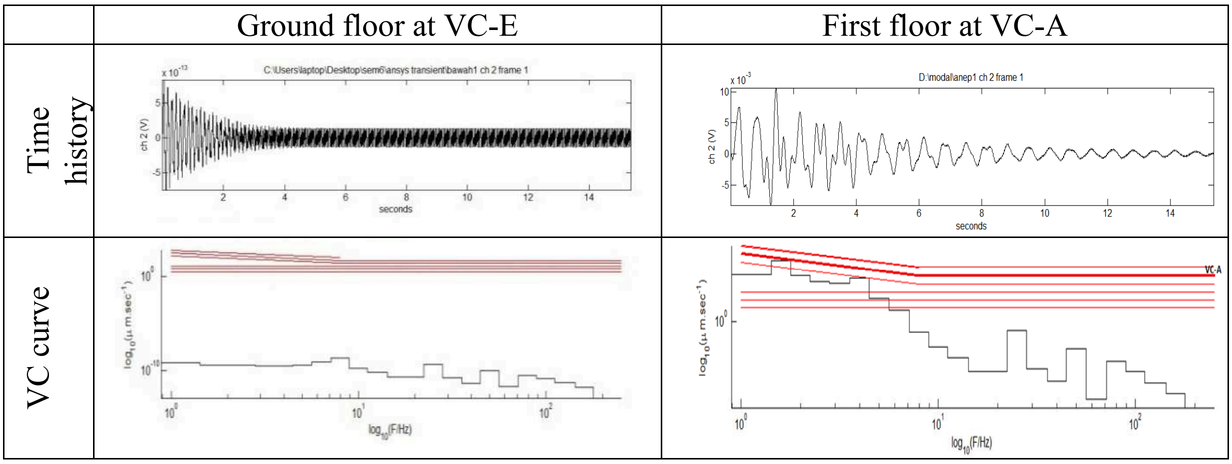
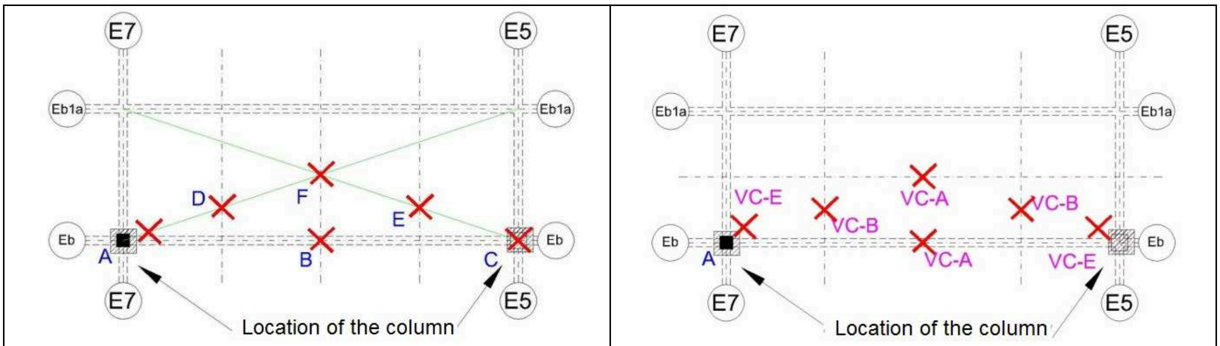


Fig. 7 Time history and VC curve for ground floor and first floor

Further analysis on floor assessment was determined by each point on a floor panel based on vibration criteria curve analysis. The point is chosen based on the location of the columns, the beams and also in the middle of the floor as indicated in Figure 8. Vibration level is found in the middle of the floor at point F gives the highest vibration at VC-A. The middle beam at point B also shows VC-A level which is the amplitude of vibration approximately reached 50µm/s. Point A and C which located near the column shows the minimum vibration at VC-E. While point D and E shows the vibration level at VC-B. The detail description of vibration assessment for each point can be seen in Table 2. It shows that the peak vibration response is occurred at the middle of the floor.



(a) Point location on the floor (b) VC curve at the observed point

Fig. 8 Point location for vibration response at the first floor

Table 2 Vibration assessment on the first floor

Point	VC curve	Location	Description
A	VC-E	Near the column	Lowest vibration
B	VC-A	Middle of the beam	Highest vibration
C	VC-E	Near the column	Lowest vibration
D	VC-B	Between the beam and middle of the floor	Medium vibration
E	VC-B	Between the beam and middle of the floor	Medium vibration
F	VC-A	Middle of the floor	Highest vibration

Conclusion

This study can be concluded that the ground vibration input from passing vehicles contributes to vibration effect on the floor. The floor assessment which referring to the VC curve performance indicated that vibration is most affected at the middle of the floor. Therefore, the owner of the building is recommended to avoid placing the sensitive requirement at the middle of the floor. It is suggested to place the sensitive devices near the column which act as a support system of the building. Besides that, it is also can be concluded that sensitive equipment is suitable to locate at the lower floor when compared to higher floor. Final conclusions can be made as follows:

1. The maximum response amplitude of vibration occurred at middle span of floor at VC-A.
2. The highest floor (first floor) of building experienced maximum vibration level at VC-A.
3. The sensitive equipment is suitable placed at the corner of floor where is near to column structure because of vibration level at VC-E.
4. The sensitive equipment are not suitable placed at the high floor level in building. Therefore, the suitable place is at the ground floor.

Acknowledgement

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