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Investigation of Concrete Floor Vibration Using Heel-Drop Test

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Abstract. In recent years, there is an increased in floor vibration problems of structures like residential and commercial building. Vibration is defined as a serviceability issue related to the comfort of the occupant or damage equipment. Human activities are the main source of vibration in the building and it could affect the human comfort and annoyance of residents in the building when the vibration exceed the recommend level. A new building, Madrasah Tahfiz located at Yong Peng have vibration problem when load subjected on the first floor of the building. However, the limitation of vibration occurs on building is unknown. Therefore, testing is needed to determine the vibration behaviour (frequency, damping ratio and mode shape) of the building. Heel-drop with pace 2Hz was used in field measurement to obtain the vibration response. Since, the heel-drop test results would vary in light of person performance, test are carried out three time to reduce uncertainty. Natural frequency from Frequency Response Function analysis (FRF) is 17.4Hz, 16.8, 17.4Hz respectively for each test.

1. Introduction

Vibration is not a major problem in a structure. It is been stated by Gaspar [1] and Saidi [2] that excessive floor vibration are generally not a safety concern for a building, but it because of annoyance and discomfort. Excessive vibration typically occur in light weight floor, floor systems with low stiffness where the floor dominant natural frequency is close to the excitation frequency and floor with low damping. Based on Alam [3] vibration becomes a greater problem when thinner floor deck, less structural damping and long span floor structure.

William [9] stated that, internal source are one the vibration source that acting inside a building, there are several sources that acting on the building which is mechanical excitation like washing machine or human acting (eg: walking or jumping) itself. The possibility of internal source



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vibration can be felt by human or residents in a building depends on the frequency source and resonance source and damping of the structural element that propagate the vibration through the building. This problem is more common happen on high rise building.

Research conducted by Fahmy [4] was about case study on 120mm concrete slab over composite deck framed with steel floor beams, each 3m spacing; with 18 m span length and girders. The heel-drop impact is realized by a series of movement of a man with 75kg weight and the position of leg must correct while doing the test. Two heel-drop tests of the research were conducted for the floor systems with and without raised floor respectively. The results show that before and after the installation of raised floor. The average damping ratio of floor system without raised floor was 1.351%. The average of floor system with raised floor was 1.510% and its higher than situation of without raised floor but still lower than 3.0% critical for floor with non-structural components suggested by AISC [10].

Another case study conducted by Nguyen [5] on office floor of a multi storey building in Melbourne has disturbing walking induced vibration problem. A number of physical heel drop were performed on a problematic floor bay that was most annoying area of the building with floor beam span up to 12.7m. The result of natural frequency about 6.2 Hz and modal damping value around 2.5-3%. FE model of the floor was created and calibrated which predicted a natural frequency of 6.22Hz. Based on this investigation, use of the lower velocity limit in the EUR DG (as opposed to the upper velocity limit) is suggested to provide a more comparable outcome to the AISC [10]

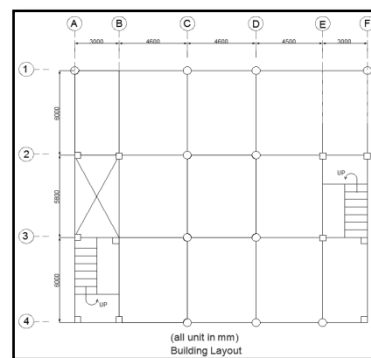
Thus, this research focused on a real building, Madrasah Tahfiz at Yong Peng which is had a complain about vibration problem. Although it is a new building and still under construction, but it is seem have a vibration problem when there is a presence of human load. The heel-drop were carry out on the first floor of the building to determine the vibration behaviour. The aims of this research to understand the vibration behaviour and to check the human limitation of the floor. This is because the owner of the building complains that they can feel uncomfortable when someone do the rhythmic activities such as running or jumping.

1.1 Details of Building

Two-storey building of Madrasah Tahfiz at Yong Peng, Johor been selected in this research. Even though the building is still under construction, the information of the building is lacking. Thus, the site investigation has been conducted to get the detail of the building including the dimension of the beams, columns and floor layout as illustrated in Table 1 and the floor layout as shown in Figure 1 and Figure 2 respectively.

Table 1. Details of the building

Types	Dimension (mm)
Circular column	300 ϕ
Slab thickness	125
Floor height	3500
Beam size	600x250

**Figure 1.** First floor of the building**Figure 2.** Layout of the 1st floor

2. Heel-drop Test

Heel-drop was conducted on the selected panels (panels A-B/1-2, C-D/2-3 and B-C/3-4) as shown in Figure 3. The gridline of the position of accelerometer as shown in Figure 4. Grid point have been set up with equal distance of 1200mm away from each point. The accelerometers are placed accordingly at the grid point labelled to capture the response of the floor. Heel-drop input has been located 100mm away from the centre of grid point as shown in Figure 4.

Heel-drop testing carry out with a 75 kg person stand at the location as mentioned before. First keep the knee straight, then shift the weight of the feet (refer Figure 5a). Relax and allow the body to fall essentially free to the floor (refer Figure 5b). Each of tests repeated 10 times to reduce uncertainty. The impact forces from heel-drop and the acceleration response as depicted in Figure 6a and 6b, respectively.

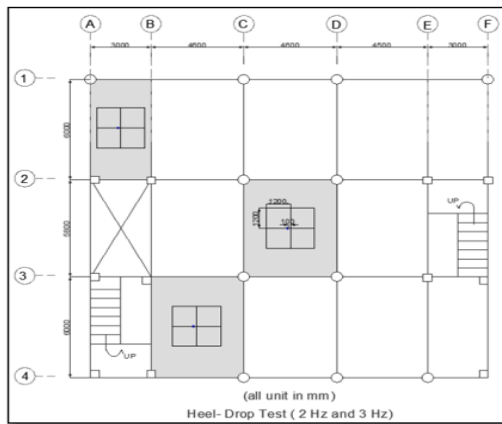


Figure 3. Layout for location of heel-drop test

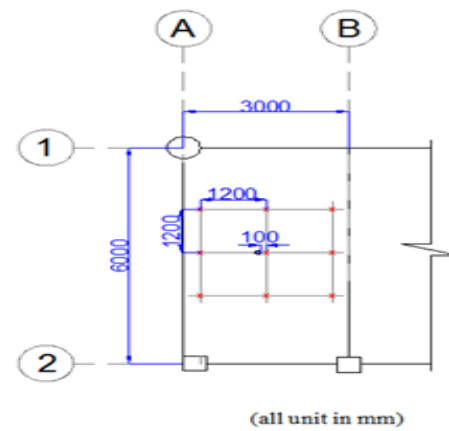


Figure 4. Gridline line for each bay



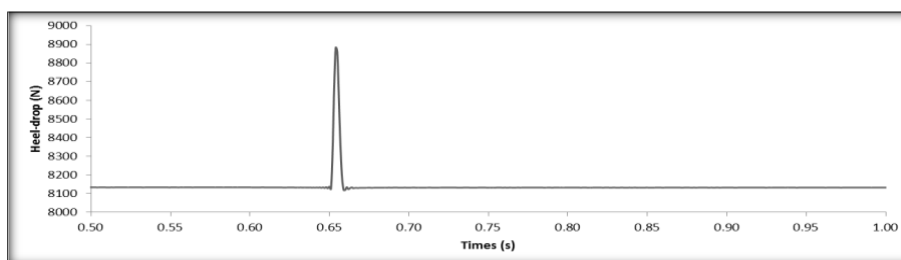
(a)



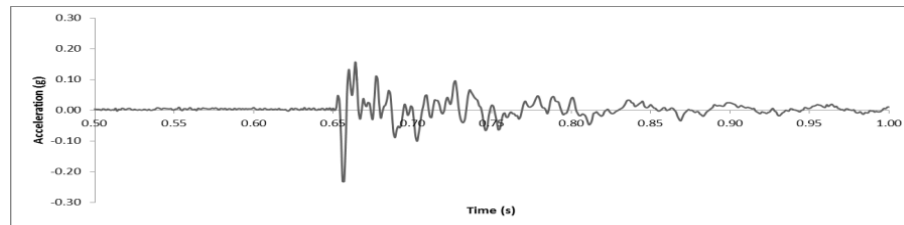
(b)

Figure 5. Position of heel-drop test

a) Impact force



b) Acceleration response

**Figure 6.** Heel-drop impact force and acceleration responses**3. Experimental Analysis***3.1 Frequency Response Function (FRF)*

In order to determine the vibration parameter, Frequency Response Function (FRF) has been calculate using Me'scope package. FRF is a characteristic of a system that has a measured response resulting from a known applied input. A linear system such as an SDOF and MDOF, when subjected to sinusoidal excitation at the same frequency and at specific amplitude that is characteristic to the frequency of excitation. A frequency response function is a transfer function that expresses in the frequency domain and can be formed from measured data [8].

3.2 Frequency and Damping

The acceleration responses in the time domain were converted to a FRF as depicted in Figure 7. Then, the curve- fitting method was used to estimate the natural frequency, damping ratio and mode shapes of the floor. The natural frequency of the floor was selected based on the higher peak of the graph as shown in Figure 8. The first natural frequency from each tests are in range 16.5-17.5 Hz, as illustrated in Table 2.

Table 2. Frequency and damping ratio

	Frequency (Hz)	Damping ratio (%)
Test 1	17.4	2.21
Test 2	16.8	2.06
Test 3	17.4	2.21

Also, the damping ratio are calculated using the following equation based on logarithmic decrement [3].

$$\zeta = \frac{1}{2\pi j} \ln \frac{a_i}{a_{i+j}},$$

Where, ζ is the damping ratio, a_i is the first acceleration peaks of record, a_{i+j} is the $(i+j)$ th acceleration peaks of record. Tables 2 illustrated the frequency and damping ratio that get from FRF analysis in range 2.05-2.22%.

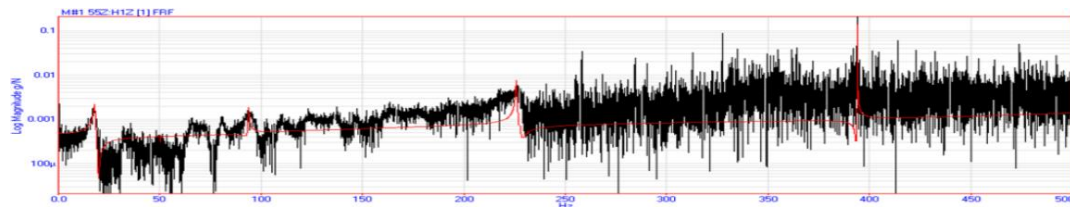


Figure 7. FRF spectrum and curve fit graph

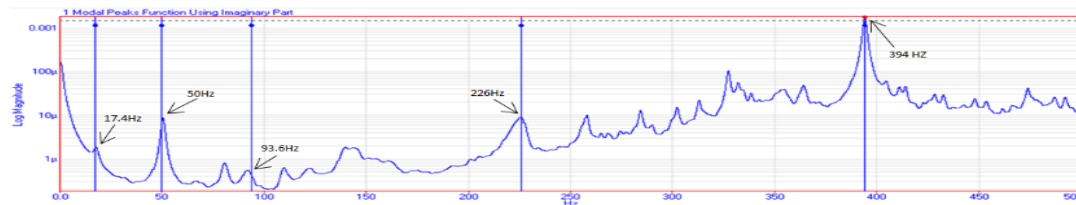
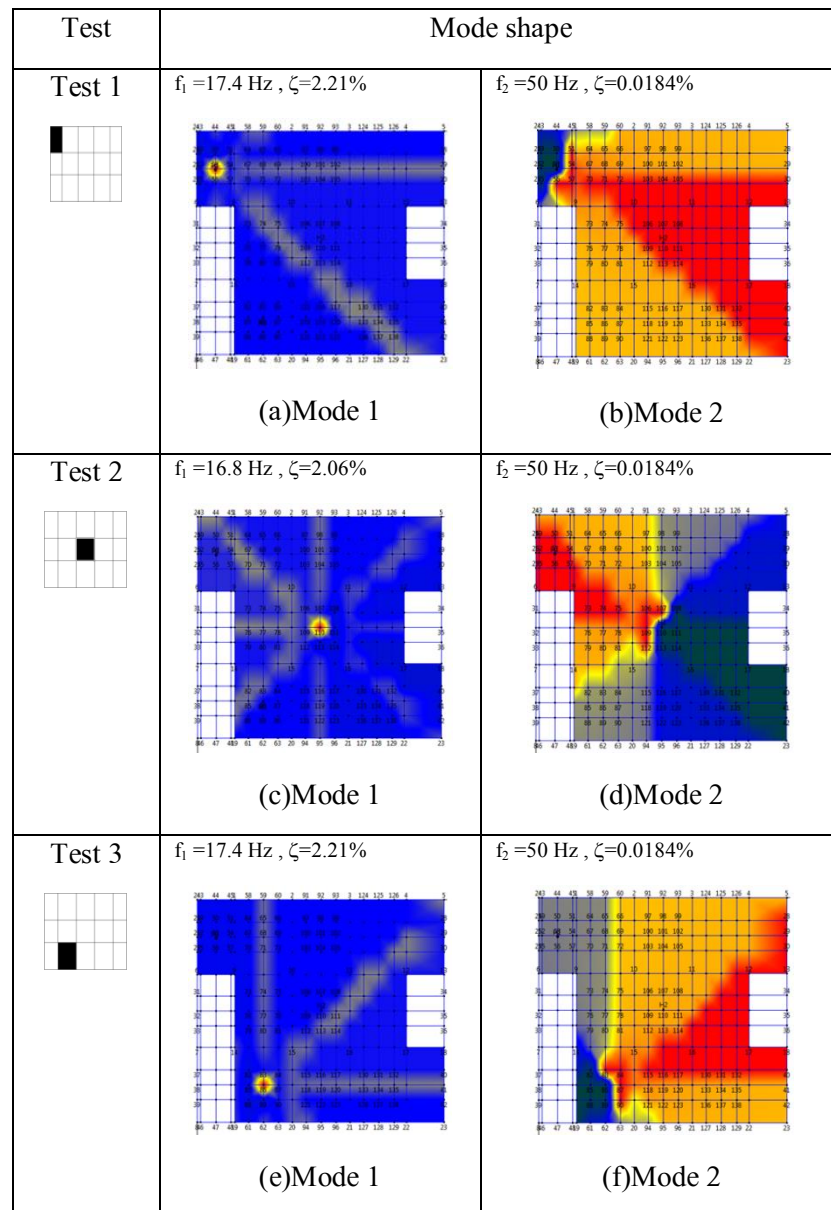


Figure 8. Modal peak function

3.3 Mode shape

Mode shape analysis is used to determine the condition of the floor structure of the building when subjected to different frequency modes. In this research, mode shape analysis was performed from the FRF analysis. Mode shape was performed to determine the condition of the floor when subjected to the load. Figure 9a-9e illustrated the first two mode shape with different location of load subjected. The red area of the mode shape is defined as critical area which is high displacement, while the blue area is positive area with minimum displacement. Figure 9a and Figure 9e visualized how the vibration transmitted on the floor once get impact from heel-drop. It shows the wave propagation is 45° to 90° from the position heel-drop to the right of floor. For test 2 (Figure 9c) shows the vibration transmitted the whole floor once force was subjected.

**Figure 9.** Mode shape behaviour of floor

4. Conclusion

The main conclusion that can be made from the case study is:

- The first natural frequency is in range 16.8 Hz to 17.4 Hz. Therefore above the 8Hz limitation that suggestion by [4][6][7]. Thus, this floor has no issues due to human induced vibration.
- The experimental damping ratio for first mode concrete floor is in range 2.0-2.3 % and recommended damping ratio for the same floor based on [7], 2.0-3.0% for bare concrete floor. Therefore, the damping ratios are accepted based on recommended from previous study.

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