FRP AS POTENTIAL SOLUTION FOR VIBRATION PROBLEM IN CONCRETE SLAB

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Abstract. Vibration is a common problem in concrete slab system when designed using ultimate strength capacity which producing slim structure. Although this elemen strong enough to sustain the loads, however another problem emerges because vibration of the element is not anticipated during the design. This study was selected from experimental data conducted on two story buildings system. Thin slab member of 120 mm in two story building showed vibration problem during sevice life. Two sensors was located on slab and middle beam to study behaviour of slab system due to human activity load. Numerical study was elaborated in this research for comparison. Strengthening of the slab using Fiber reinforced polymer (FRP) was applied to the slab system to reduce detrimental effect of vibration on slab.

1. Introduction

Fibre reinforced polymer (FRP) is a composite material made of a polymer matrix reinforced with fibres which are usually glass, carbon, aramid, or basalt. Over the last few decades, application of FRP in construction industry has been developed [1]. FRP structural form can be in form of FRP deck panel, FRP pultrude structural profile for building and bridge construction [2]. It has been more than four decade this material used as strengthening structure because of FRPs is an efficient and affordable solution in replacing steel reinforcing bars in concrete structure due to its corrosion resistance, lightweight, durable, and high strength. In footbridge application, FRP was used for slab which subjected human activities [3].

Vibration measurement has been proven to be promising in Structural Health Monitoring (SHM) [3][4]. It can be used for studying behavior of structure such as vibration in building, damage in structure by evaluating natural frequency and other dynamic parameters.

This study was to evaluate performance of concrete slab system in two story office building as showed in Figure 2. The slab was subjected to walking load to evaluated whether frequency and acceleration complied with recommendation standard for human comford [5][6]. Strengtheing with FRP box beam as additional secondary beam in slab system was applied in the numerical model to overcome exaggerated vibration on concrete slab.

2. Vibration due to human activity

The comfort of building occupants and safe building conditions are important requirements in designing building structures. The dynamic response of the building if it is loaded by dynamic loads needs to find the response. One of them is that humans are able to generate strength far greater than their own body weight through energetic activities such as walking or jumping. As mentioned, the load generated by humans is difficult to predict in detail and the amplitude and frequency will vary under different types of induction. Consequently, it is necessary to categorize the various induction caused by humans based on the frequency and amplitude domains.

The frequency and amplitude caused by human activities such as walking, dancing and jumping cause forces on the floor. These forces will cause vibrations in the floor system because the building structure and the force of human movement cannot be isolated [7]. The vibrations caused by pedestrians can induce impulsive dynamic rhythmic loads in the vertical and horizontal directions which are dominated by the pacing rate. The pacing rate for walking is between 1.6 and 2.4 steps per second, i.e. 1.6-2.4 Hz (slow to fast walking) while for a jogging step speed it is around 3 Hz [7].

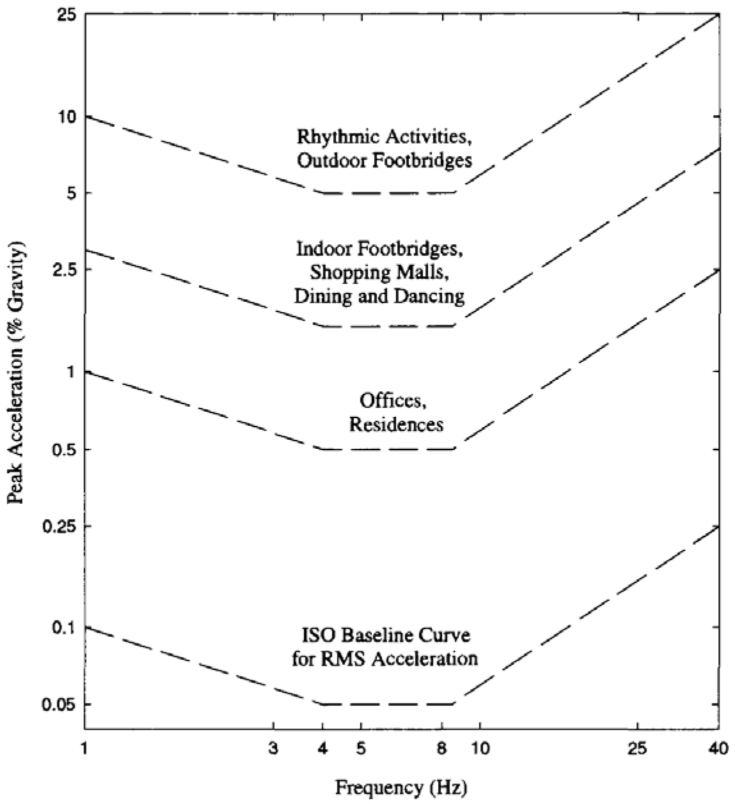


Figure 1. Recommendation acceleration peak for human comfort due to vibration [5]

3. Case Study

3.1 Experimental Method

This field study was conducted on the second story building at University of Lampung. Slab panel has dimension of 7.2 m length and 5.7 m width with thickness of 120 mm. Slab supported by four side primary beams with dimension of 350 mm width and 600 mm height. Two secondary cross beams devided slab panel on the middle as shown on the Figure 2. Those dimension are 250 mm width and 550 mm height. Four column supported four main beams has dimension 400 x 600 cm^2.

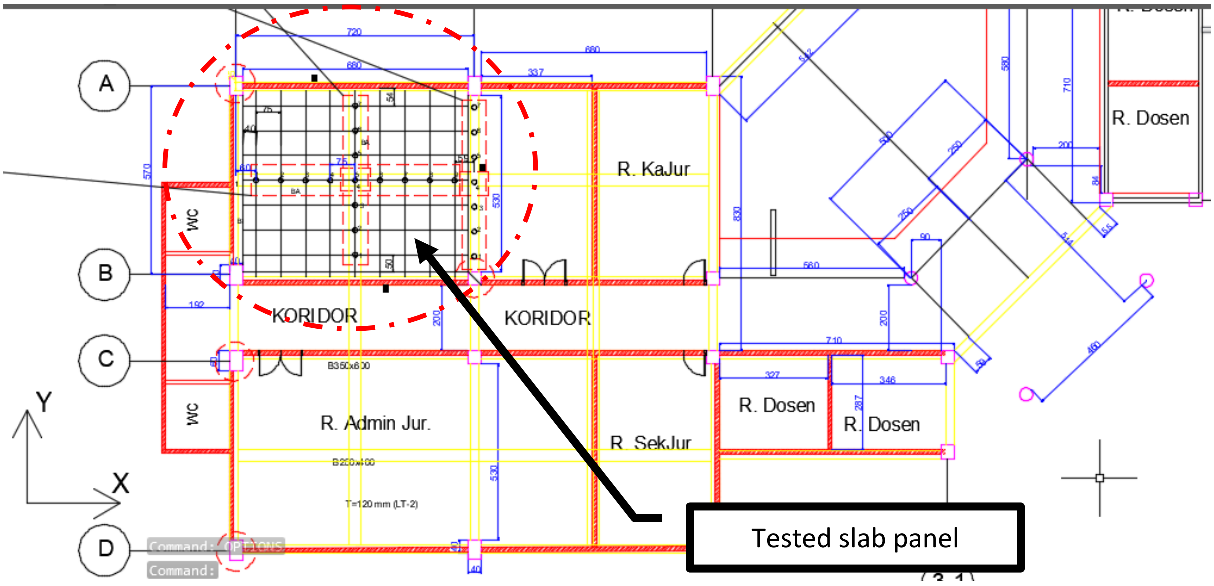


Figure 2 Slab panel was tested on the field location

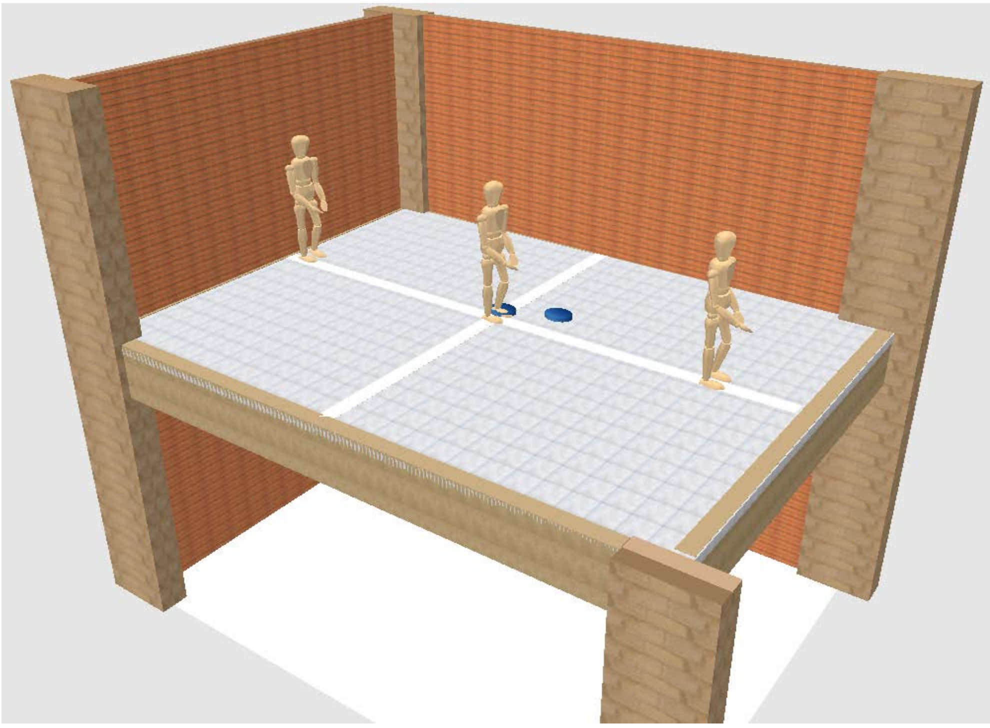


Figure 3. Tesing illustration when slab tested under walking person and respon of slab recorded using two accelerometer which located on slab and beam in the middle of slab

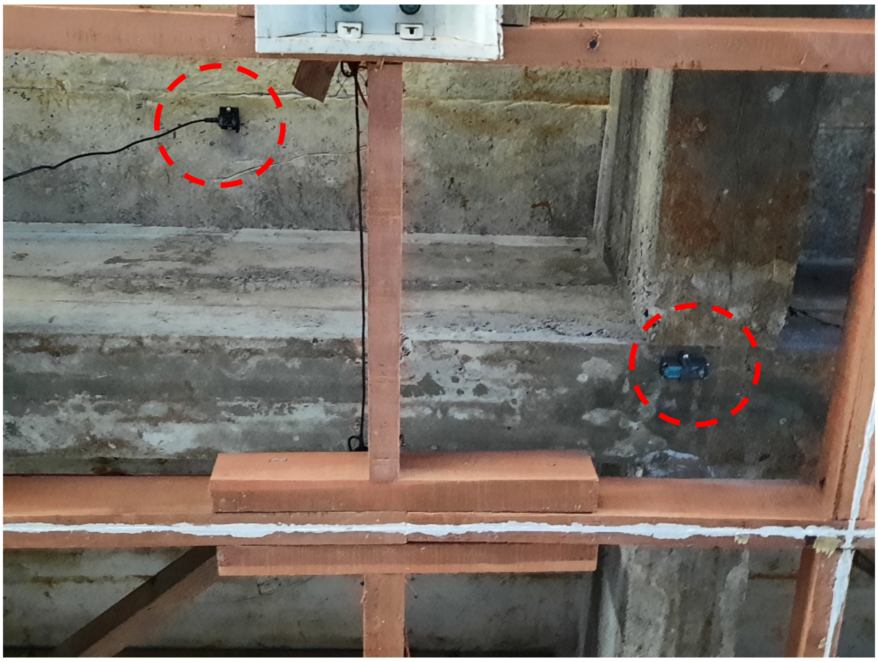


Figure 4. Two accelerometer for recording acceleration of slab and beam.

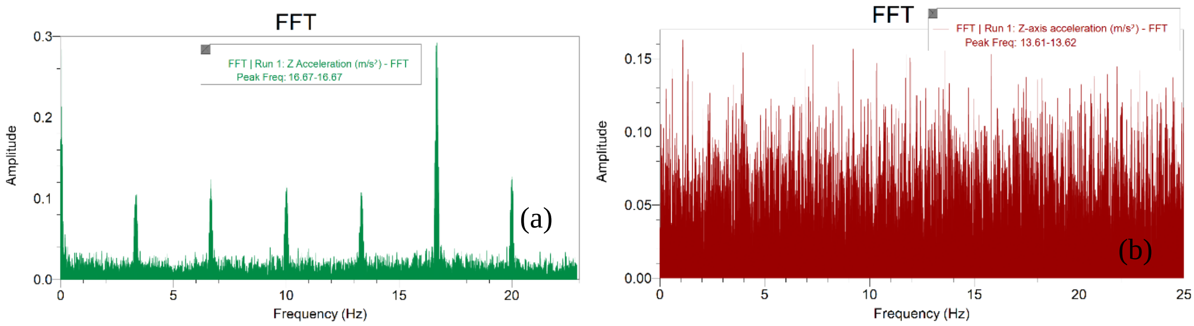
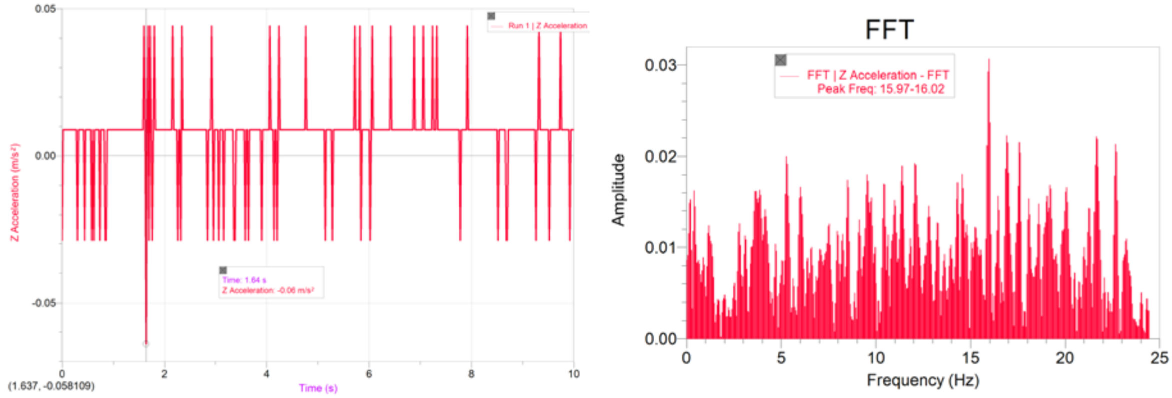


Figure 5. Natural Frequency of slab (a) and beam (b)

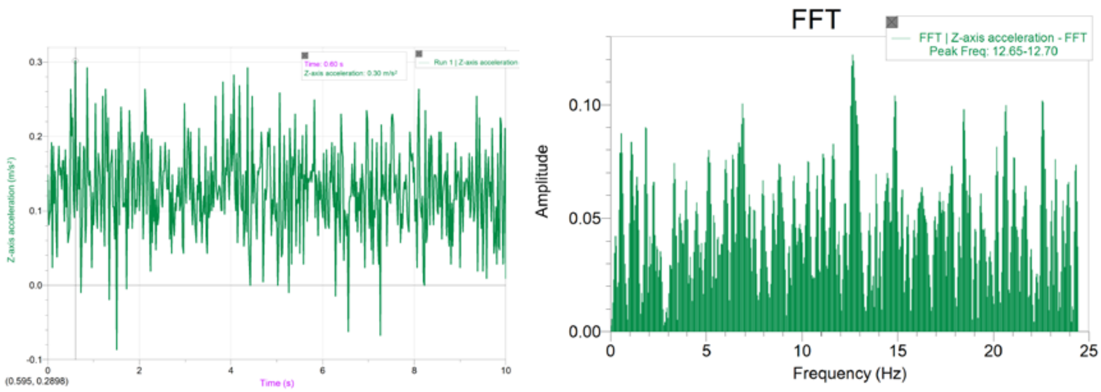
Figure 5 showed natural frequency of slab and beam obtained from two sensors located below the slab and secondary beam. By using Fast Furier Transform method which convert a signal from time space to frquency domain, it found natural frequency of slab and beam were 16.67 Hz and 13.61 Hz respectively.

Figure 6. Slab was tested under walking load



(a) (b)

Figure 7. (a) Vertical acceleration on slab; (b) Frequency of slab due to human walking load



(a) (b)

Figure 8. (a) Vertical acceleration on slab; (b) Frequency of beam due to human walking load

Figure 7 showed frequency of slab due to human walking load in long direction of slab system. The vertical acceleration showed value of -0.06 m/s^2 which was higher than 0.5% G (=0.04905 m/s^2) as recommended. This lead to uncomfort for human activity in the building. The frequency of slab due to this walking load was 16.02 Hz which was outside the recommendation range of comfort.
Figure 8 showed frequency of secondary beam due to human walking load in long direction of slab system. The vertical acceleration showed value of 0.30 m/s^2 which was higher than 0.5% G (=0.04905 m/s^2) as recommended. This lead to uncomfort for human activity in the building. The frequency of slab due to this walking load was 12.65 Hz which was higher than recommendation value.

3.2 Numerical Method

It is necessary to compare the experimental method with other method such as theoretical method or numerical method. Here was used the numerical method to get more insight dynamic charateristic of the slab system such as mode shape, frequency for some modes, and psudo acceleration spectrum which somehow time consuming using theoretical method.
Slab was modelled as single panel which supported by four columns as showed in Figure 9. First model showed slab without strengthneing and the second model was slab strengthening using FRP box beam in Y direction. Figure 10 showed first three shape of slab system which have frequency of 13.417 Hz, 21.464 Hz and 24.624 Hz respecively when period changed to frequency. Natural frequency of this slab system is smaller than experiment which was 16.67 Hz, and symilar to the frequency of the beam which

was 13.61 Hz. Natural frequency obtained from both results, experimental and numerical were still higher compared with standard recommendation curve for offices bulding which is between 4 Hz to 8 Hz.

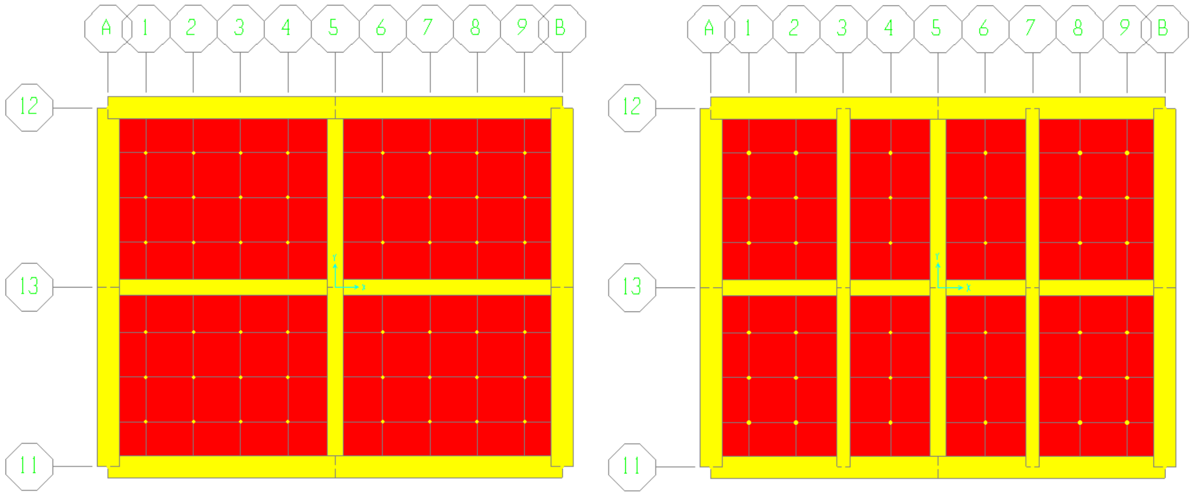


Figure 9. (a) Slab model without strengthening, (b) Slab model with strengthening with FRP box beam in Y direction.

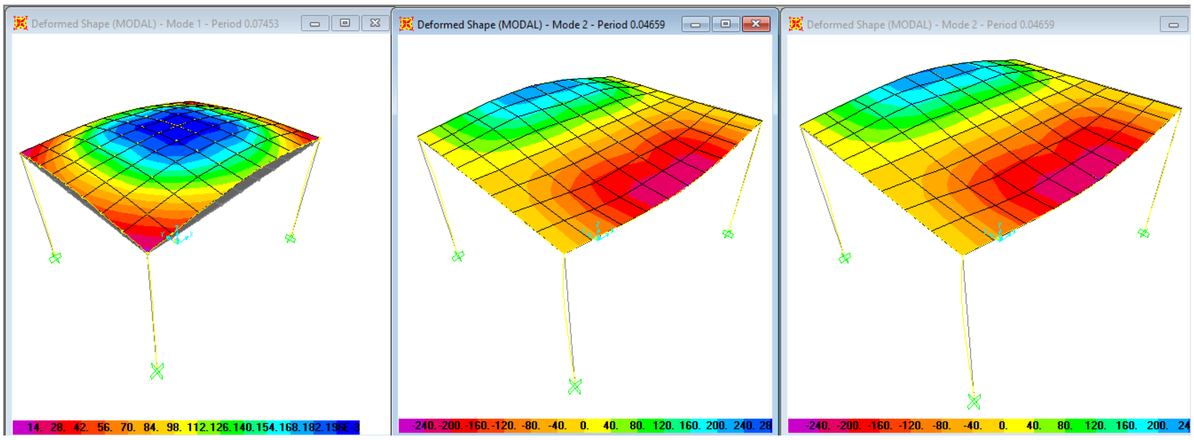


Figure 10. First three mode shape of unstrengthening concrete slab system.

Figure 11 showed the relationship between Pseudo Spectral Acceleration and frequency of concrete slab that strengthened with FRP box beam. The slab was subjected to a person walking on slab in longitudinal direction. Analysis included damping for 0%, 2% and 3 %. Due to this walking load natural frequency of slab reduced to 12 Hz from previous non-strengthening slab which was 13.417 Hz (-10.56%). With assumption that FRP box beam can absorb the energy with damping 2% to 3%, the peak acceleration of the slab far reduced to 0.0184 m/s^2 and 0.0131 m/s^2. This acceleration is below the recommendation standard curve. This was good outcome although the natural frequency not reduced significantly using this strengthening system.

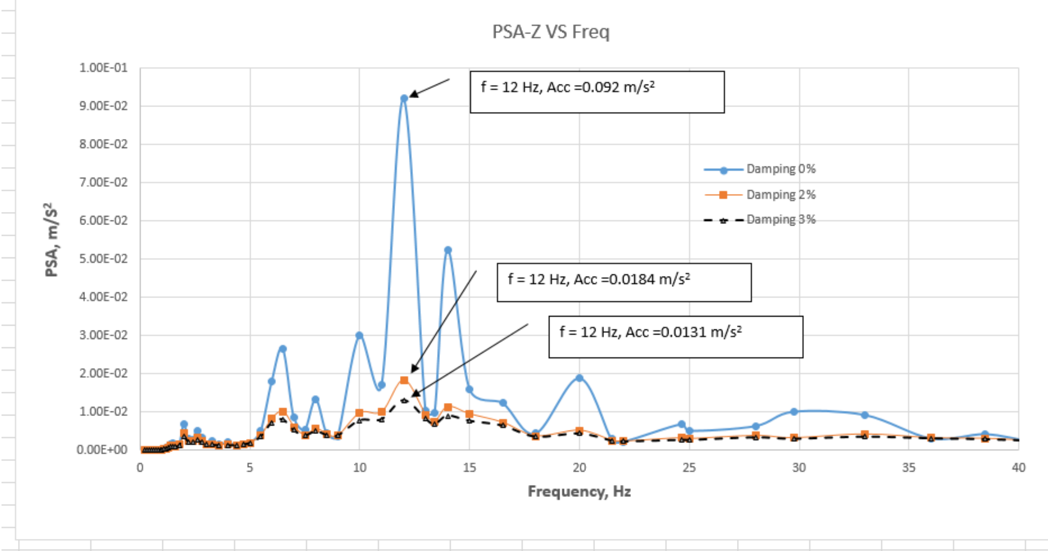


Figure 11. Frequency vs Pseudo Spectral Acceleration for concrete slab

4. Conclusions

From experimental study and numerical study were conducted in this research, it can be concluded as follows:

1) Experiment study for unstrengthening concrete slab system showed natural frequency of beam and slab were 16.67 Hz and 13.61 Hz respectively.Whereas numerical method showed natural frequency of slab system was 13.417 Hz which similar with one of the experimental results.
2) Both experimental and numerical results had natural frequency higher than recommended value for human comford in office which was between 4 Hz to 8 Hz.
3) Peak Accelerasi in vertical direction (Z-axis) for slab is 0,09 m/s^2 , it is still higher than limitation which is 0,5% G (0,045 m/s^2) for residence/office. However, strengthening with FRP box brought this value down to 0.018 m/s^2 and 0.013 m/s^2 for damping of 2% and 3% respectively. That meant the FRP box system was potential for giving solution in vibration problem in concrete slab.
4) It was still need considered to reduce natural frequency of the slab by making it thicker. Thin slab will give vibration problem on slab.

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