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STUDY ON NUMERICAL ANALYSIS OF HIGH RISE BUILDING

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Abstract - This paper presents the numerical study conducted on a structure of three floor height building structure. Most vibrations are undesirable and can cause damages to the buildings, machines and people all around us. The vibration wave from earthquakes, construction and winds have high potential to bring damage to the buildings. Excessive vibrations can result in structural and machinery failures. This failure is related to the human life and environment around it. The effect of vibration which causes failure and damage to the high rise buildings can be studied through the numerical analysis. This research aims to study the numerical analysis of high rise building through the simulation using MATLAB R2015a. A lumped mass model of three degrees of freedom (3DOF) is designed using MATLAB R2015a to identify the displacement, acceleration and mode shape of the 3DOF during vibration. The model designed is the physical representation of actual building structure in real life.The considered factors are the mass of the building and the stiffness of the structures scale which will be used for the simulation. Thus, the result obtained will be comparable with the real life effect. Based on the result from simulation study, by applying the forces of vibration on the building model the displacement, acceleration and mode shape can be analyzed. The result obtained can be used in future for further analysis during the experiment analysis.

Keywords - Degrees-Of-Freedom, Displacement, Acceleration, Mode Shape.

I. INTRODUCTION

Vibration is something that is related with the oscillatory motions of bodies and the forces associated with them [1]. Vibration is usually undesirable in machines and structures which produce stresses, unwanted noise and failure to the components due to looseness in connections or fatigue. Vibration also gives effect to the structure of buildings. When a structure experiences mechanical vibration at its natural frequency, spawned by wind loads or earthquake, resonance occurs. The high amplitude of vibration caused by resonance may be destructive or simply unpleasant to the users. To account for damage caused by structural vibrations, the structure will require maintenance or reconstruction.

Advances in designing new structural systems, combination of usage new materials, and increase in developments of design methods and computational software, have made possible the construction of extremely tall buildings in this era. However, the increasing in height of the high-rise building structure is a great challenge for the engineers and researchers in this field. Although there are many difficult technical problems in design, the most critical issues are definitely the effects of wind and earthquakes on these structures.

Safety and serviceability are two important criteria that must be considered when designing the buildings. The high rise buildings become more slender and flexible as their height increase. In that case, the building which is constructed will be very sensitive to wind excitations resulting in serviceability issue. In most cases, the inherent damping for a high rise building itself is insufficient to overcome the serviceability requirements. Furthermore, the remote earthquakes has been proved that it has the strength to generate base shears up to a magnitude comparable to the notional horizontal load, which is sometimes even larger than the wind loading [2]. In particular, tall buildings will be very sensitive to dynamic excitations by long-period earthquakes [3].

That is why vibration analysis approach is very important in reducing the failure and damage of structures. With this approach, the lump parameter is converted into an equivalent multi degree of freedom. The simplest degree of freedom is the single degree of freedom for linear system which can be generated from the second-order ordinary differential equation of motion. This would be first step before developing the equation of natural frequency and also the displacement mode from the mode shape of buildings. This will then results in developing the value for mean displacements, velocity and acceleration [1]. The increase in the number of degree of freedom will make the derivation of differential equation of motion more complex. Thus understanding the degree of freedom will help in vibration analysis for buildings development.

When height of the building increases, it is important to ensure the adequate value of stiffness to resist lateral forces induced by wind, or earthquakes. It is well known that high-rise structures will experience along-wind vibration and across-wind vibration, as well as a torsional response. The former is due to the buffeting induced by fluctuations in the wind velocity and the across-wind force, and the responses are mainly governed by vortex shedding. For slender structures, the across-wind vibration is usually more severe than the along-wind vibration [5].

1.1 Scope of Study

Simulation study is one important method in this research. The objective of the simulation study is to determine the displacement, acceleration and mode shape for the building structure. The research can be helpful for the lecturers to teach mechanical vibration especially on the degree of freedom systems through teaching aids for better understanding and visualizing using this three storey building structure model.

MATLAB R2015a software is the software that is utilized in simulation study. Using MATLAB R2015a software, coding is generated to calculate the natural frequency and modes shape for building structures. The derivation of equation of motion is the formula used in MATLAB coding to determine the result for the multi-storey of building.

Furthermore, displacement, acceleration and mode shape of the building are influenced by three factors which are the mass of the building, the stiffness of the structure and the damping coefficient of the building. For this study, the considered factors are the mass of the building and the stiffness of the structures. Therefore, the MATLAB coding can be used to calculate the result with various mass and stiffness of the structures.

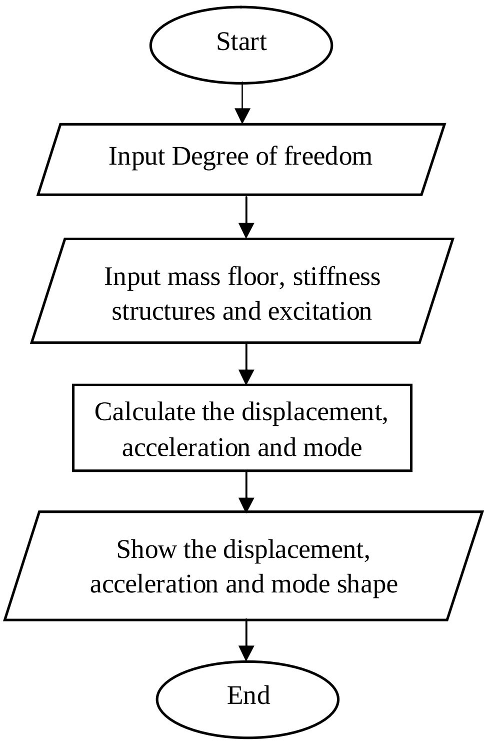

Figure 1. Flowchart of study

1.2. Theory

1.2.1. Single Degree of Freedom System

Single degree of freedom system can be described as a lumped mass, m, supported by a massless column with certain stiffness, k.Definition of single degree of freedom can be defined as the mass assumed to be rigid, the spring and the damper assumed to have no mass and the mass is only considered to be able to move in one direction along the length of the spring [9].

The equation of motion for free vibration can be expressed as [10]:

$$m\ddot{u} + c\dot{u} + ku = 0 \quad \textbf{(1)}$$

In free vibration, the structure will vibrate at its natural frequencyw_n. The natural frequency can be explained as the number vibration cycles per time unit where usually measured in radian per second. For single degree of freedom, the natural frequencycan be calculated by:

$$w_n = \sqrt{\frac{k}{m}} \quad \textbf{(2)}$$

The natural period $T_n$of the structure can be described as the time taken for the structure to complete one cycle of vibration. The formula for the natural period is:

$$T_n = \frac{2\pi}{w_n} \quad \textbf{(3)}$$

The system can be disturbed from static state by applying external force Por load. This will force the system to vibrate. In this condition, the equation of motion that can be used is:

$$m\ddot{u} + c\dot{u} + ku = P \quad \textbf{(4)}$$

The examples of external force that is used to force the system to vibrate are seismic force, wind load and others [9, 10].

1.2.2. Multi Degree of Freedom System

In multi degree of freedom system, the equation of motion for a free vibration can be expressed as [6,9]:

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} = 0 \quad \textbf{(5)}$$

Besides that, the equation of motion for forced vibration can be expressed as:

$$[M]\{\ddot{u}\} + [C]\{\dot{u}\} + [K]\{u\} = P \quad \textbf{(6)}$$

This system will produce various deflection shapes where each shape that is deflected is called as mode shape. The number of mode shape is equal to the number of the system's degree of freedom.

II. DETAILS EXPERIMENTAL

2.1. Materials and Procedures

For this research, the MATLAB coding is generated based on the flowchart above. Firstly, the coding asks for the degree of freedom. The degree of freedom depends on the number of storey building that need to be analyzed. Increasing number of storey will increase the number of degree of freedom. Then, the coding asks for the mass of the building and the stiffness of structures depending on the degree of freedom. Mass of the building and stiffness of structures are used to calculate the displacement, acceleration and mode shape of the building. The result will be shown after the calculation is done.

The MATLAB coding is developed to find the simulation study result for this research. Below is the MATLAB coding that is being used in this research.

III. RESULTS AND DISCUSSION

3.1. Result of Simulation

A determination of simulation study is very important. This simulation study will lead to the findings of displacement and acceleration of the threestorey building model. It is difficult to calculate the natural frequency of any vibrational system which consists of more than one degree of freedom or one mass. Higher degree of freedom will introduce higher number of equation of motion which means the calculation and derivation to find the natural frequency will be longer and more difficult to be solved analytically. Therefore, the simulation study can help to determine the natural frequency by using MATLAB software. The result from the simulation study is very important before further analysis can be done in the experimental study. The result below show the displacement analysis for each storey of the building during simulation

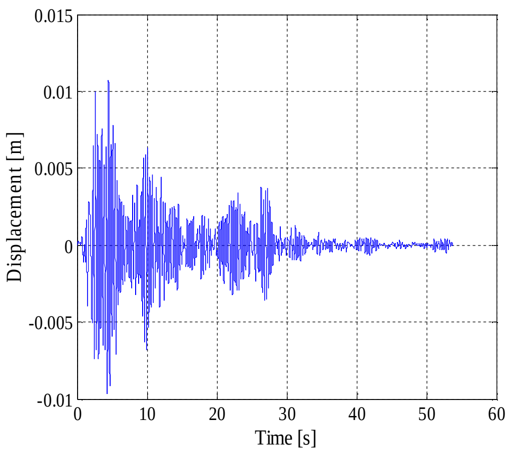

Figure 2.Displacement analysis of 1st storey

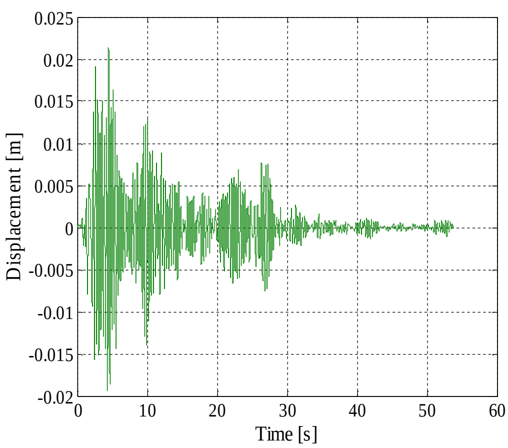

Figure 3.Displacement analysis of 2nd storey

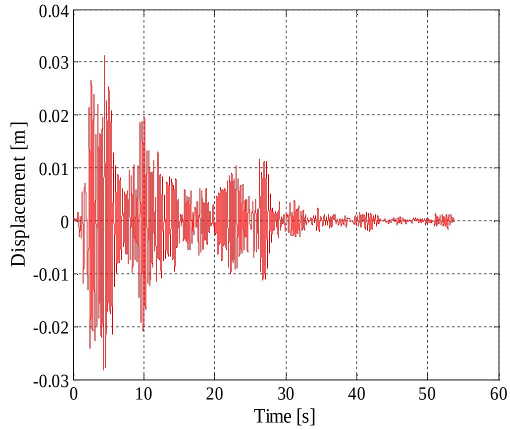

Figure 4.Displacement analysis of 3rd storey

Based on the displacement analysis of each storey building the maximum displacement of the building can be measured. The 3rdstorey building shows the maximum displacement. The 1ststorey has the lowest displacement.

The next result is on the acceleration analysis from the simulation. The result below show the acceleration analysis for each storey of building during simulation.

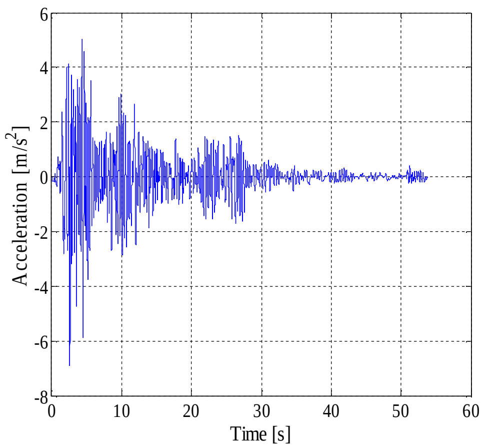

Figure 5.Acceleration analysis of 1st storey

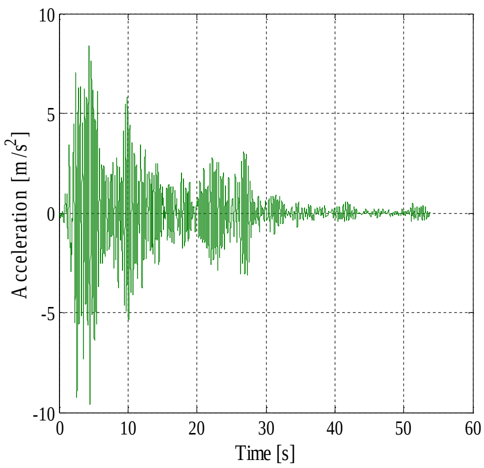

Figure 6.Acceleration analysis of 2ndstorey

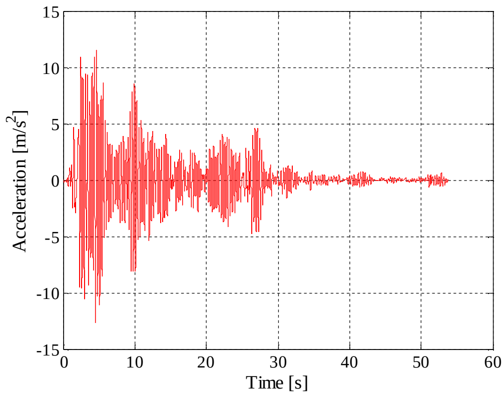

Figure 7.Acceleration analysis of 3rd storey

Based on the acceleration analysis of each storey building the maximum acceleration of the building can be measured. The 3rdstorey building had shown the maximum acceleration. The 1ststorey has the lowest acceleration.

3.2. The Mode Shape of the Simulation

Figure 8 shows the mode shape of the lumped massthat is generated from MATLAB R2015a. For the three storey building model, three mode shapes are produced. The mode shape 1 all floors move to the right.

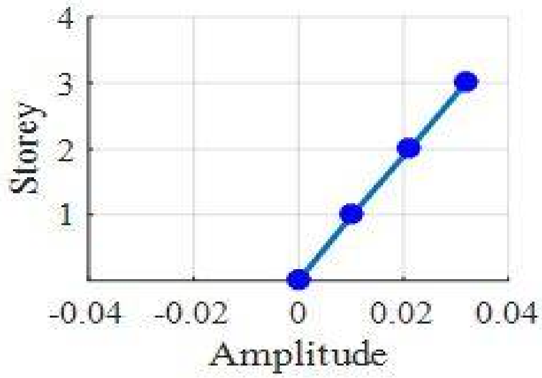

Figure 8.Mode shape 1

Figure 9 shows the mode shape 2 of the lumped mass that is generated from MATLAB R2015a. From this figure, all the floors move to the right but in a straight line vertically.

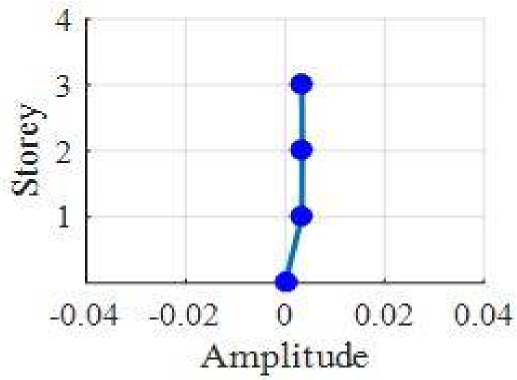

Figure 9.Mode shape 2

In Figure 10 the mode shape 3that is generated from MATLAB R2015a is shown. For the mode shape 3, the floor 2 and floor 3 move in same direction to the left and the floor 1 move to the right.

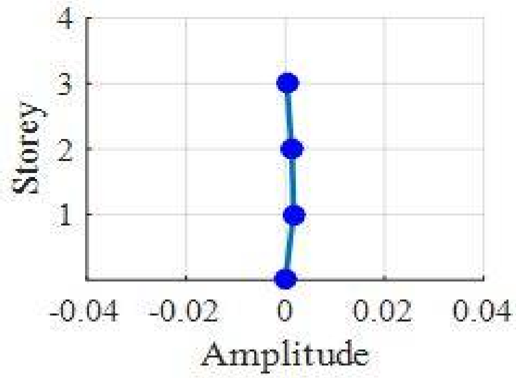

Figure 10.Mode shape 2

CONCLUSIONS

In this research, the simulation study has been done to study the displacement, acceleration and mode shape for the building structure based on the random exitation. The objective of the simulation study to obtain the result of the displacement, acceleration and mode shape for the three degree of freedom building has been achieved. The results show that in simulation study, that are conducted which the masses of the floor and stiffness are variable. Thus the result obtains shows that the third floor has the highest displacement and highest acceleration. The mode shape obtained also has been analyzes to know the movement of each floor during vibration.

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