



Effect of Damping and Stiffness Constants on the Vibration Properties of Seismic Building: Simulation Approach

Aji Masa'id¹, Bhre Wangsa Lenggana¹, Ubaidillah¹ (✉), Fitriani Imaduddin¹, Yusep Muslih², Harjana³, Gigih Priyandoko⁴, and Fajri Sri Ardion¹

- ¹ Department of Mechanical Engineering, Engineering Faculty, Universitas Sebelas Maret, Surakarta 57126, Indonesia
ajimasaid@student.uns.ac.id, ubaidillah_ft@staff.uns.ac.id
- ² Department of Civil Engineering, Engineering Faculty, Universitas Sebelas Maret, Surakarta 57126, Indonesia
- ³ Department of Physics, Mathematics and Natural Science Faculty, Universitas Sebelas Maret, Surakarta 57126, Indonesia
- ⁴ Departement of Electrical Engineering, Universitas Widyagama Malang, Malang, Indonesia

Abstract. By utilizing additional smart dampening devices, semi-active vibration control is considered a powerful way of lowering the dynamic reactions of structures. The task is carried out by making diagrams in Simulink and the Matlab program. This is used to determine the natural frequency of a building and the vibration response that occurs in the building. In addition, the shape mode of a building model that will be tested with the application of damping devices can also be known. In this paper, simulation by Simulink will be elaborate to observe the effect of damping and stiffness constants on the vibration properties of a seismic building to evaluate shape mode and vibration response of structure model. The building simulation is a model of a four-story building. The response from the fourth floor achieved the highest peak displacement at 3.7 cm and reached stability with the longest time of 550 ms.

Keywords: Natural frequency · Shape mode · Vibration response

1 Introduction

Earthquakes are one of the natural disasters that often occur in several countries. This results in losses in the form of material, physical and mental [1]. These losses can be minimized by using several methods, one of which is the application of damping technology to building structures, such as residential buildings, office buildings, and bridges [2]. Viscous damping technology is quite popularly used to anticipate earthquakes [3].

However, before fabricating the prototype of the MR damper as a device that can be applied and tested, it is better to use a numerical approach to avoid fatal errors [4]. One approach that can be done is to use software such as Matlab [5]. This approach is carried out by making diagrams in Simulink and the Matlab program [6]. This is used

to determine the natural frequency of a building and the vibration response that occurs in the building [7].

This paper contributes a simulation approach to a model of a four-story building to observe the effect of damping and stiffness constants on the vibration properties of a seismic building to evaluate the shape mode and vibration response of the structure model.

2 Methodology

The design of the building structure model and the MR damper that have been determined both in terms of material and performance is an important part of the accuracy of the approach. The parameters that need to be considered, as shown in Table 1, greatly affect the results of the approach taken with Matlab.

Table 1. MR damper building structure parameters.

Parameter	Value	Unit
F_1	11.6	N
F_2	46.6	N
F_3	105	N
F_4	186.6	N
c	6.64	Ns/cm
$m_1 = m_2 = m_3 = m_4$	10	kg
$k_1 = k_2 = k_3 = k_4$	276.4	kg/s ²

Furthermore, the model of the building structure is changed in the form of a Simulink diagram. It aims to determine the vibration response and the value of the natural frequency of the building structure. Then the shape mode is known through a simple Matlab program with the specified parameters (Fig. 1).

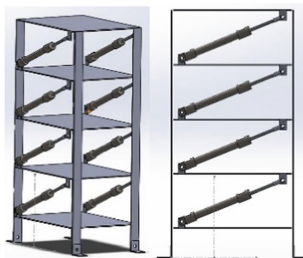


Fig. 1. Design of a four-story building.

The design of a four-story building is equipped with a damper on each floor. The dampers are installed diagonally and two dampers are installed on each floor.

3 Result and Discussion

After all of the parameters are entered into the MATLAB Simulink program, the simulation process is then carried out. One example of the results of the simulation approach is shown in the figure below (Fig. 2).

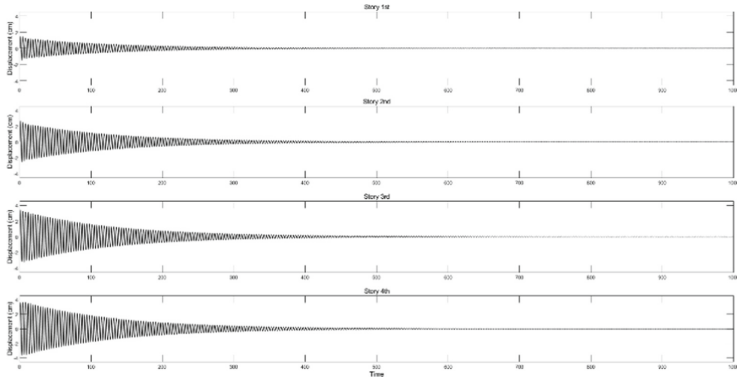


Fig. 2. Vibration response.

From the Figure, it can be seen the results of the Vibration Response from the first story to the fourth story. The results of the first Vibration Response Story obtained a peak displacement of 1,75 cm and reached stability at 400 ms. The second story has a peak displacement of 2,8 cm and reaches stability after 500 ms. The third and fourth stories obtained almost the same peak displacement at 3.5 cm and 3.7 cm, respectively, and reached stability after 550 ms for the third story and 570 ms for the fourth story, respectively (Fig. 3).

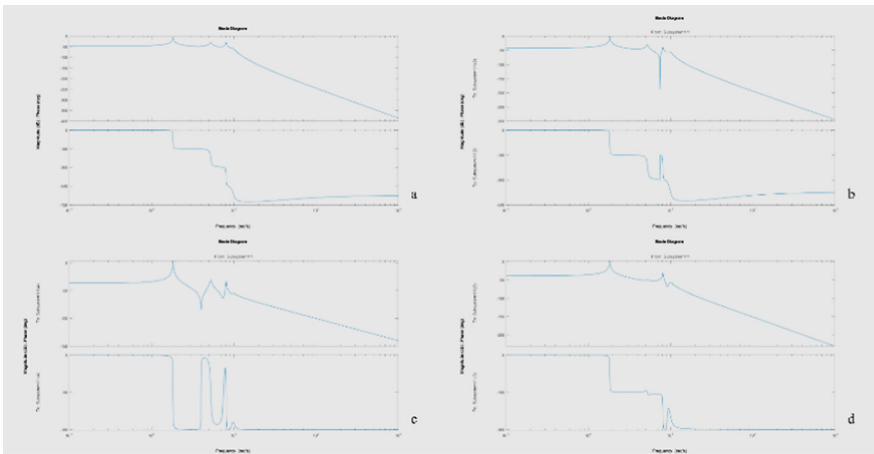


Fig. 3. Simulink Bode Plot Result (a) 1st Story (b) 2nd Story (c) 3rd Story (d) 4th Story.

Next is shown in the Figure Bode Plot of each floor which is represent the actual behaviour of the building for a given condition, Figures (a) through (d) showing the first through fourth floors, respectively. The Bode Plot is a combination of magnitude, expressing the magnitude of the frequency response, and a phase plot, expressing the phase shift. Both quantities are plotted about the horizontal axis proportional to the logarithm of the frequency (Fig. 4).

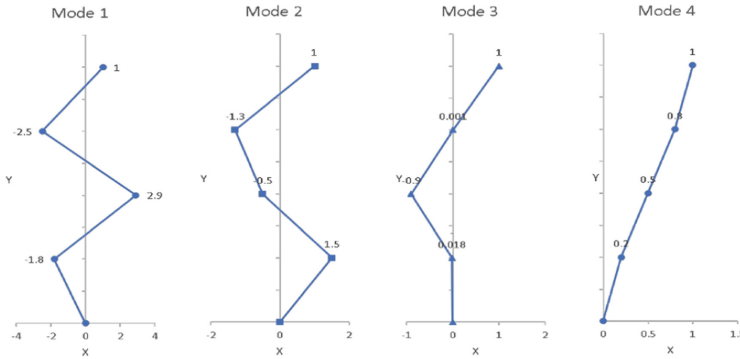


Fig. 4. Structure shape mode.

The Figure above shows several forms of vibration mode, obtained from the equation of motion that affects the stiffness of the building structure k , mass m , and natural frequency ωn . The structural mode shape is an important step in the research because with it we can predict the response of the building when it receives a certain load.

4 Conclusion

Vibration mode was obtained from the equation of motion that affects the stiffness of the building structure k , mass m , and natural frequency ωn . Natural frequency, shape mode, and modeling vibration response to a model of a four-story building with the installation of an MR damper have been discussed in this paper. Diagrams in Simulink and the Matlab program have been carried out. The vibration response from the fourth floor achieved the highest peak displacement at 3.7 cm and reached stability with the longest time of 550 ms.

Acknowledgment. The authors gratefully acknowledge the hibah WCR.

References

1. Irjaya, N., Pamungkas, A.: Penentuan Zona Kerentanan Bencana Gempa Bumi Tektonik di Kabupaten Malang Wilayah Selatan. *J. Tek. POMITS* **3**(2, 3), 107–112 (2014)
2. De Roeck, G., Degrande, G., Lombaert, G., Müller, G.: Active and semi- active control of structures: a review of recent advances. In: *Proceedings of the 8th International Conference on Structural Dynamics EYRODYN* pp. 62–69 (2011)
3. Heysami, A.: Types of dampers and their seismic performance during an earthquake. *Curr. World Environ.* **10**, 1002–1015 (2015). <https://doi.org/10.12944/cwe.10.special-issue1.119>
4. Zapateiro, A.M., Pozo, F., Karimi, H.R., Luo, N.: Semiactive control methodologies for suspension control with magnetorheological dampers. *IEEE/ASME Trans. Mechatron.* **17**(2), 370–380 (2012). <https://doi.org/10.1109/TMECH.2011.2107331>
5. Imaduddin, F., Mazlan, S.A., Zamzuri, H.U., Fatah, A.Y.A.: Testing and parametric modeling of magnetorheological valve with meandering flow path. *Nonlinear Dyn.* **85**(1), 287–302 (2016). <https://doi.org/10.1007/s11071-016-2684-6>
6. Pokaad, A.Z.B., Hudha, K., Nasir, M.Z.B.M., Ubaidillah, N.A.: Simulation and experimental studies on the behaviour of a magnetorheological damper under impact loading. *Int. J. Struct. Eng.* **2**(2), 164 (2011). <https://doi.org/10.1504/IJSTRUCTE.2011.039422>
7. Utami, D., et al.: Material characterization of a magnetorheological fluid subjected to long-term operation in damper. *Materials* **11**(11), 2195 (2018). <https://doi.org/10.3390/ma11112195>