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Influence of intensity parameters of earthquake on response of reinforced concrete structures

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Abstract. Earthquake is one of the most frightening and destructive phenomena of nature. The destructive capacity of an earthquake depends on various parameters. Without characterising earthquake time history data to the required intensity parameters, its effect on structures cannot be predicted. The influence of intensity parameter of earthquake on the destructive capacity of a structure is essential in the vibration control scenario also. In the present paper, three reinforced concrete (RC) framed structures with natural frequencies 4.688 Hz, 1.762 Hz, 1.661 Hz are used to investigate the influence between the intensity measures and the response. 20 ground motion time history data were selected with predominant frequency ranging from 1 Hz to 12.5 Hz. Some available intensity measures were used to characterise this data. 3D model of the structure was analysed in ETABSUL 13.1.3 software with diaphragm rigidity at floor level. Modal analysis was used to find the modes and corresponding time periods. Linear time history analysis was done for the three models for all the ground motion data. It is noted that four intensity parameters namely predominant frequency, Peak Ground Acceleration, Velocity Spectrum Intensity, Housner Intensity has an appreciable influence on the response.

1. Introduction

It is an established fact that the characterisation earthquake time history data and their selection based on intensity parameters will better predict the effects of earthquake on structures. The prime objective of the study is to find the influence of intensity parameters of earthquake on response of reinforced concrete structures. Details of the models used for analysis is given in Table 1. The natural frequencies of the Model C1, Model C2 and Model C3 are 4.688 Hz, 1.762 Hz, and 1.661 Hz respectively. 3D model of the structure was analysed in ETABSUL 13.1.3 software with diaphragm rigidity at floor level. Modal analysis was used to find the modes and corresponding time periods. Linear time history analysis was done for the three models for all the ground motion data considering the first three modes only. The response parameters used for the study are maximum top storey displacement and maximum top storey acceleration.

Table 1. Details of models used for the study

Model	No of Bays		Bay size[m]		No of Storey	Storey Height [m]	Beam Size [mm x mm]	Column Size [mm x mm]	Slab Thickness [mm]
	In X	In Y	In X	In Y					
C1	2	1	5	4	1	3.5	250 × 400	250 × 450	100

C2	2	1	5	4	3	3.5	250 × 400	250 × 450	100
C3	2	2	5	4	3	3.5	250 × 400	250 × 450	100

2. Intensity Parameters

Several intensity parameters are available for characterising an earthquake time history. The intensity parameters are found out using the software SeismoSignal. Table 2 gives the intensity parameters for the 20 ground motion data chosen. For the present study, the intensity parameters predominant frequency, peak acceleration, velocity spectrum intensity and Housner intensity of the ground motions are used, the definition of which are as follows:

2.1 Predominant frequency

Frequency at which the maximum spectral acceleration occurs in an acceleration response spectrum calculated at 5% damping.

2.2 Peak ground acceleration (PGA)

$$PGA = \max|a(t)| \tag{1}$$

2.3 Velocity spectrum intensity (VSI)

$$VSI = \int_{0.1}^{2.5} S_v(\xi = 0.05, T)\, dT \tag{2}$$

2.4 Housner spectrum intensity (HI)

$$HI = \int_{0.1}^{2.5} PSV(\xi = 0.05, T)\, dT \tag{3}$$

Where S_v - Spectral velocity, ξ - Damping ratio, *PSV* - Pseudo Spectral Velocity

3. Results and Discussions

To find the influence of the selected intensity parameters on the response namely, maximum top storey displacement and maximum top storey acceleration, analysis results are depicted in the form of plots. Figure 1 and figure 2 shows the influence of predominant frequency content of a ground motion to maximum top storey displacement and acceleration respectively for all the three models. It is found that the response (displacement and acceleration) is maximum for predominant frequencies around the natural frequency of the models.

Table 2. Intensity measures for 20 ground motions

No	Accelerogram	Predominant Freq. [Hz]	PGA [m/sec^2]	VSI [m]	HI [mm]	Total Time [sec]
1	Chi Chi-CHY034	1.064	3.038	1.959	1.795	197.000
2	Landers-Yermo fire station	1.471	2.402	1.504	1.494	44.000
3	Loma Prieta-Foster city	1.563	1.049	0.755	0.746	30.025
4	Northridge-Wrightwood jackson flat	1.786	0.554	0.216	0.187	60.000
5	Loma Prieta-Hollister south and pine	1.852	3.635	2.526	2.516	59.985
6	Cape Mendonico-Eureka myrtle and west	3.125	1.511	0.746	0.719	44.000
7	Morgan hill-Sf intern airport	3.125	0.469	0.135	0.109	24.000
8	Big Bear-San Bernardino	3.571	0.988	0.665	0.639	100.000
9	Santa Cruz mtns-lower crystal spring dam	3.571	0.556	0.212	0.202	40.000
10	Loma Prieta-sunol fire station	3.846	0.829	0.300	0.280	39.130
11	Sierra Madre-san marino southwestern academy	3.846	1.347	0.333	0.241	40.000
12	Landers-Palm spr fire station	4.167	1.332	0.638	0.615	70.000
13	Morgan hill-Gilroy array	4.545	2.201	0.788	0.725	39.980
14	Northridge-Santa monica	4.545	8.664	1.719	1.663	40.000
15	Northridge-West covina s orange	4.545	0.622	0.289	0.271	36.480
16	Sierra Madre-Vasquez rocks park	5.000	1.229	0.084	0.055	40.000
17	Northridge-Wrightwood swarthout	7.143	0.464	0.159	0.128	40.000
18	Landers-Silent vall poppet	8.333	0.489	0.115	0.112	55.000
19	Sierra Madre-Tarzana cedar hill nursery	8.333	0.756	0.132	0.103	40.000
20	Landers-Lucerne	12.500	7.130	1.838	2.106	48.125

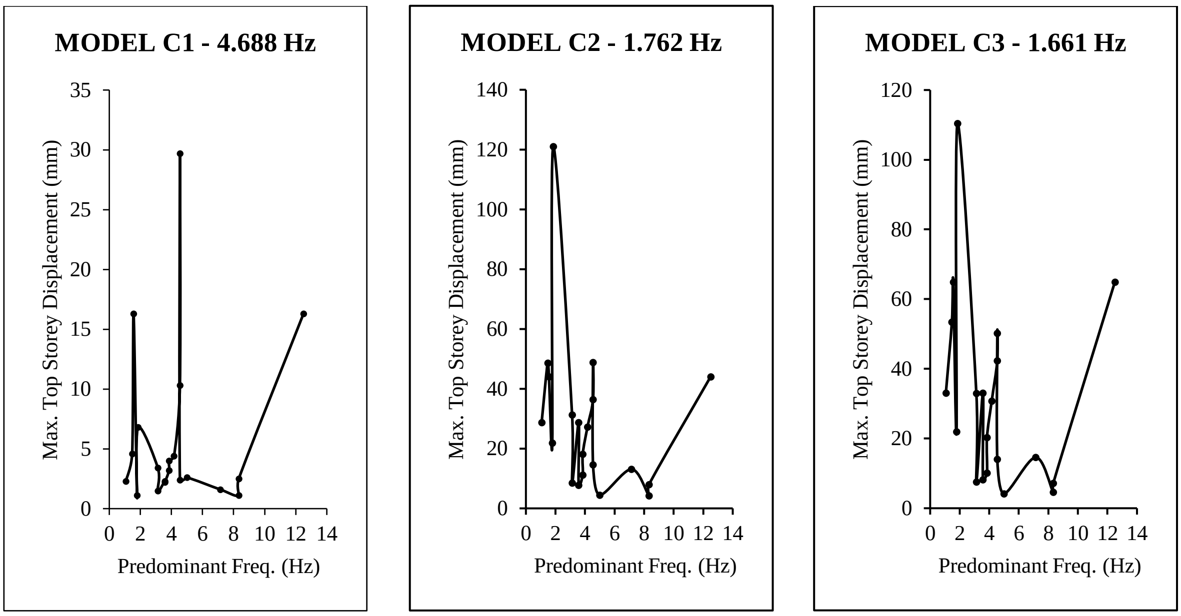

Figure 1. Maximum top storey displacement vs Predominant frequency of earthquake

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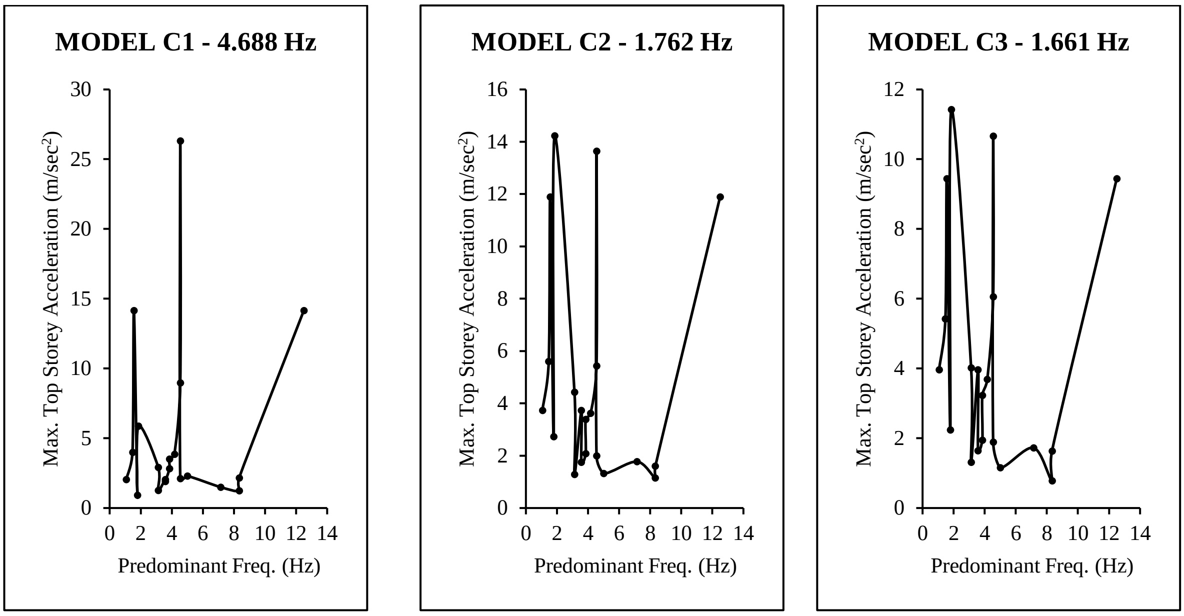

Figure 2. Maximum top storey acceleration vs Predominant frequency of earthquake

Figure 3 and figure 4 shows how the 3 models respond to the different earthquakes with different peak ground acceleration (PGA). For Model C1, for increasing PGA, the response (displacement and acceleration) of the structure increases. While for Model C2 and Model C3, the plots first shown an increasing and then a decreasing trend in the response parameters with the increase in PGA.

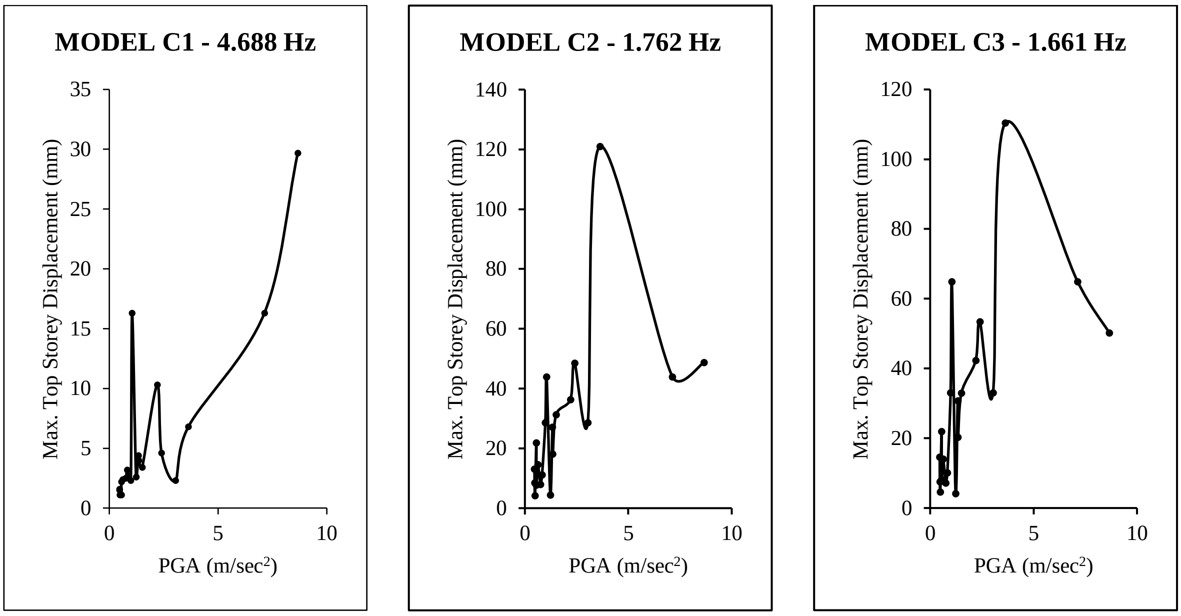

Figure 3. Effect of PGA on Maximum top storey displacement of the structure

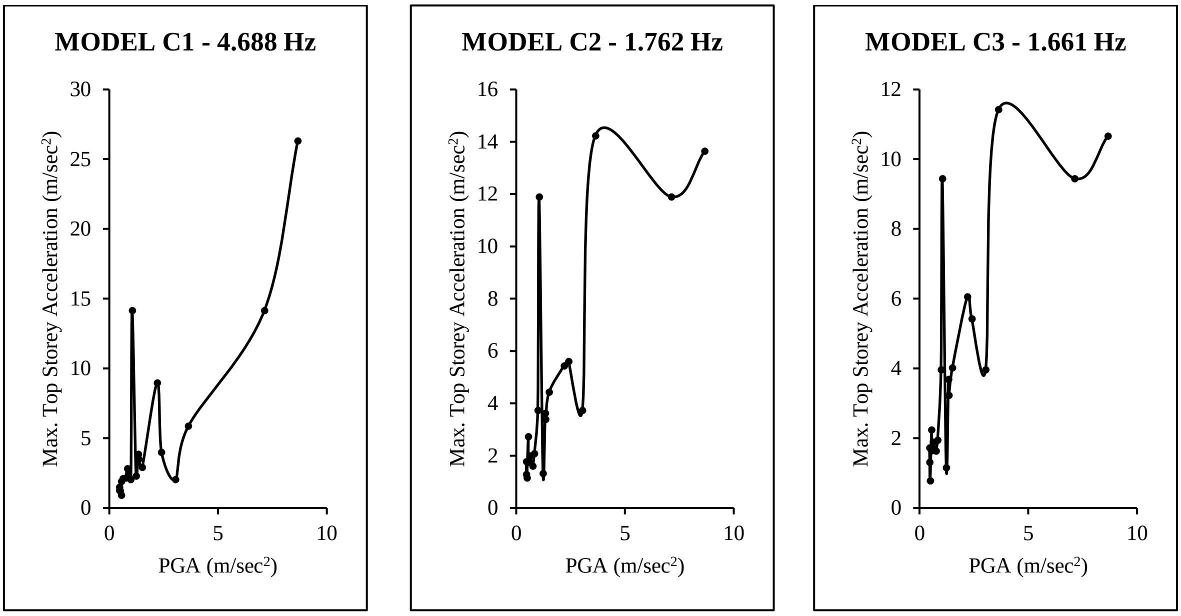

Figure 4. Effect of PGA on Maximum top storey acceleration of the structure

Figure 5 to figure 8 shows how the three models respond to the different earthquakes with different velocity spectrum intensity (VSI) and Housner intensity (HI). For Model C2 and Model C3, for increasing VSI and HI, the displacement and acceleration response of the structure increases. While for Model C1, with increasing VSI and HI, no increasing trend in response is observed. All these trends stress the need for a more elaborate study in this connection.

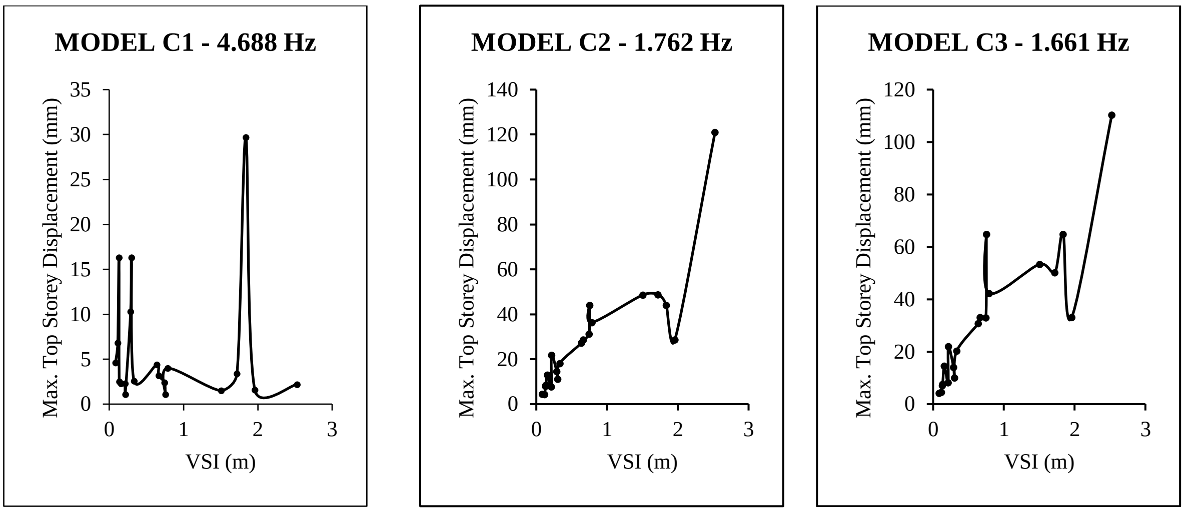

Figure 5. Effect of Velocity Spectrum Intensity on Maximum top storey displacement of the structure

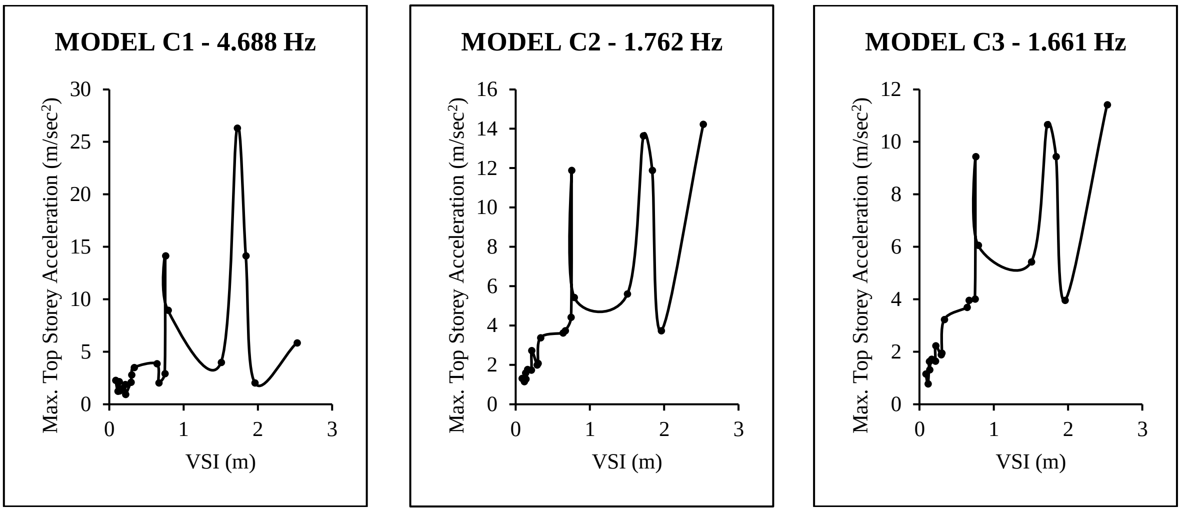

Figure 6. Effect of Velocity Spectrum Intensity on Maximum top storey acceleration of the structure

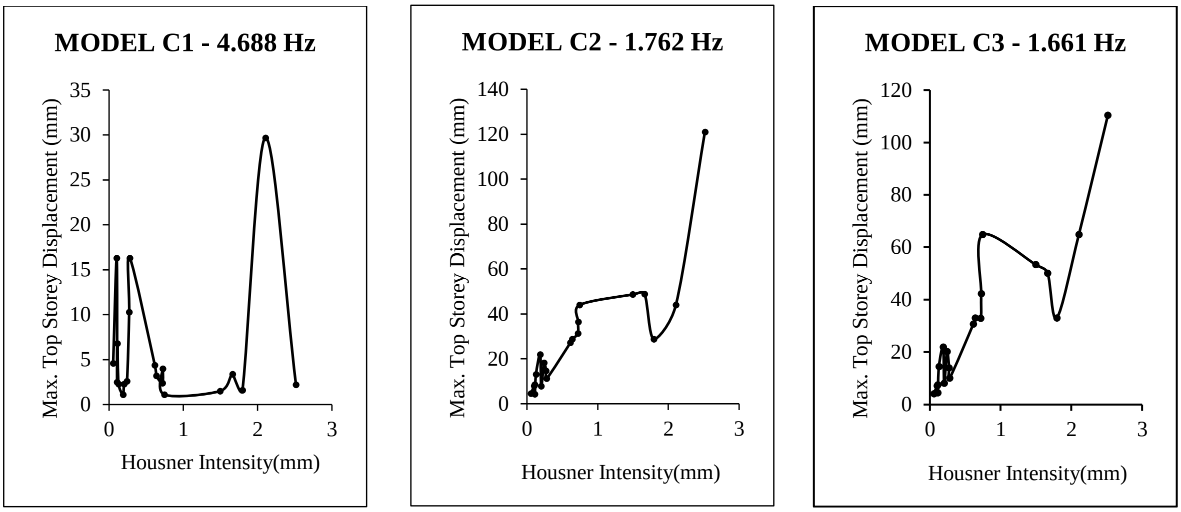

Figure 7. Effect of Housner Intensity on Maximum top storey displacement of the structure

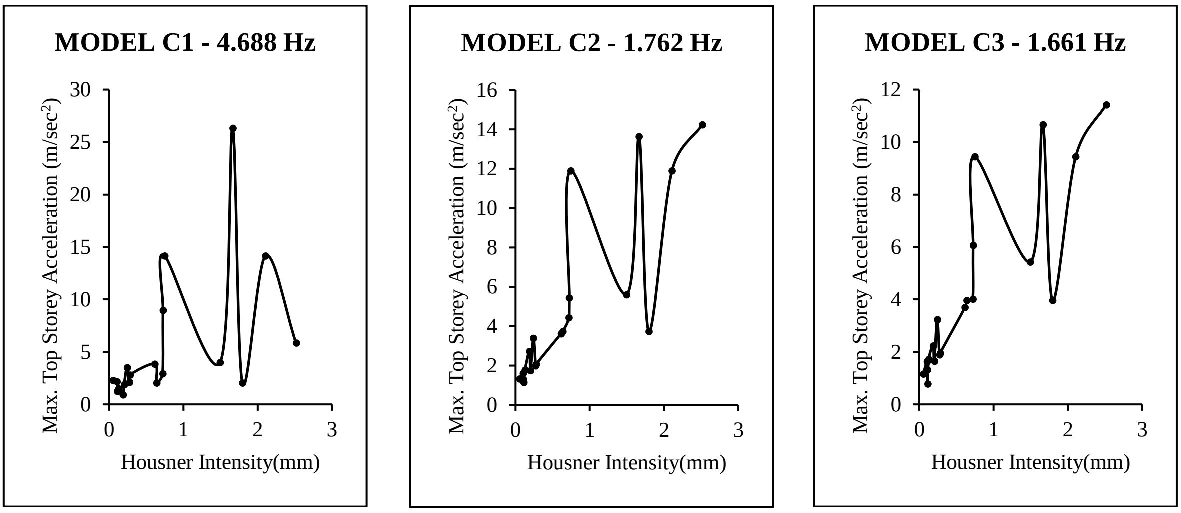

Figure 8. Effect of Housner Intensity on Maximum top storey acceleration of the structure

4. Conclusion

The present study outlines the influence of various intensity parameters of earthquake on response of reinforced concrete structures. From the results, it is inferred that when the predominant frequency content of the earthquake matches with the natural frequency of the structure, the response (displacement/acceleration) value becomes a maximum. It is observed that for single storey, PGA happens to be a good measure to predict the trend of response. For multiple storey, VSI and HI gives a much better increasing trend. These studies are expected to throw light in connection with the guidelines proposed (IS 1893 (Part 1):2016) in the context of avoiding certain modes of vibrations of building.

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