A Study of Vibrations on Monopole Billboard Construction Induced by Earthquake Excitation

Nuthnapa Triepaischajonsak\textsuperscript{1}, Chak Chantalakhana\textsuperscript{2} and Khemapat Tontiwattanakul\textsuperscript{2}

\textsuperscript{1} Electrical and Electronic Standards Laboratory Thailand Institute of Scientific and Technological Research Bangkok, Thailand  
\textsuperscript{2} Department of Mechanical & Aerospace Engineering King Mongkut’s University of Technology North Bangkok Bangkok, Thailand

Corresponding author. E-mail: nuthnapa@tistr.or.th

Abstract. Effects of earthquake on large billboards become significant issue after occurrence of disasters recently in Thailand. Two set of measurements were carried out, finding natural frequencies of actual large billboard. First set of measurements was made using accelerometers and the last one was made using non-contact laser vibration measurement. The test results show that, at low frequency, these natural frequencies correspond to transient vibrations of earthquake motion. The distinguished vibration occur at frequencies between 0.09 to 85 Hz. A simple billboard model is also presented here. The solutions to the problem are present especially for suture zones in Thailand.

Keyword: Monopole Billboard, earthquake excitation, vibration, Laser measurement

1. Introduction
Thailand has increasingly been affected from earthquake especially in suture zone as shown in figure 1 \cite{1}. The vibration of significance occur at frequencies between 0.2 to 20 Hz \cite{2}. Although many papers \cite{3 to 6} studied strength of billboard structure and large structure for avoiding fatigue or reducing its probability, those concerned the effects in term of wind load as its regulation in Thailand \cite{7}. Wind-induced structural vibration, can lead to damage due to fatigue, however mostly its damage can be found either on its advertisement board or the whole billboard falling down. This is specific only for monopole billboard construction as shown in Figure 2 \cite{8 to 11}. This paper studied the effects of large billboard due to earthquake excitation, which recently becomes a significant issue as earthquakes increase in magnitude especially in the northern part of Thailand. Two sets of measurement were carried out at Bangpoo, Samutprakarn province.

2. Billboard Description
Two sided outdoor advertising billboard monopole, as shown in Figure 3, situates at Bangpoo, Samutprakarn province, where sea breeze blow during measurements taken. Billboard considered is of dimensions 7m wide and 4m height. The total height of pole is 7.5 m with its circumference of 1.84 m. At the top of the billboard, there are six spotlights hanging with cantilever (three spotlights for both sides).
Figure 1. Suture zones in Thailand [1].

Figure 2. Billboards were blown over by strong winds [8 to 11].

Figure 3. Specifications of the billboard and its measurement points.
3. Measurements

Measurements were separated into two parts: measuring vibration with accelerometers and non-contact laser vibration measurement. Such measurements were carried out to find natural frequency corresponding to vibration of earthquake motion.

3.1 Measuring vibration with accelerometers

For the first measurement, accelerometers were mounted 2m from the bottom as shown in Figure 4. The following equipment was used: accelerometers B&K type 4507B001 with frequency range 0.1 Hz to 6 kHz. The vibration response were recorded at a sampling frequency of 2 kHz for 120 seconds. The measurement were taken at the time of trucks passing by. Because of sea breeze blowing, this was also one source of those loads taken. In order to excite thin-walled vibration mode, small impact was applied. Although, this mode should be excited using large impact. Because of not allowing any damage to the billboard, small impact was done.

![Figure 4. First measurement and its position, 2m from the base.](image)

3.2 Non-contact laser vibration measurement

For second measurement, remote sensing vibrometer RSV-150 was used with controller RSV-E-150B, at a sampling frequency of 48 kHz for about 20s each point. The vibrometer was set up about 100m perpendicular to the billboard. The position of 14 measurements is shown in figure 3. At P12, this is the same point as in the first measurement. The vibration response using accelerometer was also acquired to compare those data at the same point.

4. Conclusion

Results show separately for both measurements as shown in Figure 6 and Figure 7. The natural frequency found at P8 might be the combination mode between board and pole as shown in Figure 8. The simple model was constructed using SOLIDWORKS program with the properties of ASTM A36 steel.

4.1 Results: Measuring vibration with accelerometers
The natural frequencies found are 69.1 Hz, 82.1 Hz, 150.4 Hz, 183 Hz and 200 Hz. Due to the small impact, these frequencies correspond to thin-walled vibration.

At very low frequency, such frequencies found are 1.628 Hz, 2.116 Hz and 2.686 Hz. These frequencies correspond to spotlights on the top of the billboard.

Figure 5. Second measurement: non-contact laser vibration measurement.

Figure 6. Vibration response from first measurement.
4.2 Results: Non-contact laser vibration measurement
The natural frequencies found, for laser vibration measurement, are shown in Table I.

Table I. All Natural Frequencies Found From Laser Vibration Measurement

| Position | Natural frequencies found (Hz) |
|----------|--------------------------------|
| P1       | 0.14, 0.32, 0.41, 0.69, 2.61, 7.14, 11.05 |
| P2       | 0.09, 0.23, 0.6, 2.33 |
| P3       | 0.18, 2.52, 3.36 |
| P4       | 0.09, 0.32, 2.61, 3.39, 11.08, 53.1, 74.84 |
| P5       | 0.92, 1.6, 2.61 |
| P6       | 0.09, 0.27, 0.87, 3.39 |
| P7       | 0.09, 0.14, 2.38, 3.43, 10.44, 11.26 |
| P8       | 0.14, 2.49, 10.44, 45.14, 62.48, 74.34, 107.12 |
| P9       | 0.09, 0.14, 2.71, 3.39 |
| P10      | 0.09, 0.27, 2.5, 10.39 |
| P11      | 0.08, 0.14, 2.43, 10.07, 11.03 |
| P12      | 0.09, 2.56, 10.3 |

Figure 7. Vibration response from second measurement at P12.
It was found that the whole body of billboard vibrate at frequency of 0.09 Hz. This might transmit though ground borne vibration as its ground property of soft soil. Four types of the ground were classified [12]. However, this paper cannot identify the vibration source at frequency of 0.09 Hz.

As a sensitivity of remote sensing vibrometer RSV-150 is better than accelerometer B&K 4507B001, the frequency at 0.09 Hz can be found only from non-contact laser vibration measurement. At frequencies of 1.628 Hz, 2.116 Hz and 2.686 Hz, they corresponded to the spotlights hanging with cantilever on the top of Billboard. Such vibrations transmitted through the pole. Therefore they were found from accelerometer measurement at P12. These frequencies were also found on the board and point P12 from non-contact laser vibration measurement.

Figure 8. Vibration response from second measurement at P12.
5. Conclusions And Suggestions

5.1 Conclusions
Thailand has increasingly been affected from earthquake. The effect of earthquake might cause damage on large billboard depending on the amplitude at natural frequencies. The natural frequencies, of large billboard, found are 69.1 Hz, 82.1 Hz, 150.4 Hz, 183 Hz and 200 Hz. These frequencies correspond to thin-walled vibration, due to small impact. The frequencies of 69.1 Hz and 82.1 Hz, this might be the combination mode between board and pole as shown in the simple model.

At low frequency range, such frequencies found are 1.628 Hz, 2.116 Hz and 2.686 Hz. These frequencies correspond to spotlights on the top of the billboard. For the middle frequency range, about 10 to 11 Hz, this corresponds to mode shape of board only.

5.2 Suggestions
Earthquake vibration should be taken into account as occurrence of disasters is increased. In order to prevent the damage, Figure 9 shows additional construction of large billboard. As the damage mostly found either on its advertisement board or the whole billboard falling down, the solution to this problem might reduce damage at least from the whole billboard falling down. This issue should be considered as a regulation, if possible.

Figure 9. Solution to the problem specific only on monopole billboard construction.

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References
[1] Department of Disaster Prevention and Mitigation, Ministry of Interior, Thailand.
[2] Retrieved as of https://www.src.com.au/earthquakes/seismology-101/what-is-an-earthquake, Earthquake Monitoring since 1976, Seismology Research Centre.
[3] P. Warnitchai, S. Sinthuwong, and K. Poemsanthitham, “Wind Tunnel Model Tests of Large Billboards,” Advances in Structural Engineering, Vol.12 No.1, pp.103-112, 2009.
[4] V. Boonypainyo, “Wind-Related Disaster Risk Reduction Activities in Thailand,” Department of Civil Engineering, Thammasat University.
[5] Retrieved as of https://blog.gooshared.com/view/52##stash.DMpyFxSz.dpuf, C. Jitjaujun.
[6] S. Neridu, V. D. Kumar, and A. Dongre, “Impact on Structural Behavior due to Installation of Billboard,” Journal Teknologi (Sciences & Engineering), pp.89-98, 2017.
[7] Department of Works and Town & Country Planning (DPT).
[8] Retrieved as of http://users.ece.utexas.edu/~kwasinski/ikegrid.html
[9] Retrieved as of http://www.ci.texarkana.tx.us/gallery.aspx?PID=87
[10] Retrieved as of https://www.dailymail.co.uk/news/article-2499851/Typhoon-Haiyan-Full-horror-destruction-Philippines-revealed.html
[11] Retrieved as of https://www.google.com/imgres?imgres=imgres?imgurl=https%3A%2F%2Fi.ytimg.com%2Fv%2FBlYInHoplw%2Fmaxresdefault.jpg&imgrefurl=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DB3u9InHoplw&docid=e8mid5eV9ve53M&tbmvid=eHSLDZ54xSJVM%3A&vet=10ahUKEwijt3PXBytLgAhUHq48KHTFYJDjQMwhLKBEmwEw.i&w=1280&h=720&itg=1&bih=568&biw=1114&q=billboard%20damage%20from%20wind&ved=0ahUKEwijt3PXBytLgAhUHq48KHTFYJDjQMwhLKBEmwEw.iact=mrc&uact=8
[12] N. Triepaischajonsak, D.J. Thompson, C.J.C. Jones and J. Ryue, “Track-based control measures for ground vibration – the influence of quasi-static loads and dynamic excitation,” 10th International Workshop on Railway Noise, Nagahama, Japan, October 2010, pp.237-244.