EARTHQUAKE RESPONSE OF HIGH-RISE BUILDINGS DUE TO LONG-PERIOD GROUND MOTIONS IN THE BANGKOK METROPOLITAN AREA DURING THE 2025 MYANMAR EARTHQUAKE

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1. INTRODUCTION

In the 2025 Myanmar earthquake, many high-rise buildings in the Bangkok Metropolitan area of Thailand were shaken, and some were damaged even though the area is located at an epicentral distance more than 1,000 km. In particular, a building under construction collapsed resulting in casualties. Furthermore, water overflowed from pools on the roofs of the high-rise buildings. Videos of these high-rise buildings during the earthquake have been posted on internet video-sharing sites. Since there have been no large historical earthquakes in Bangkok, the damage caused to the high-rise buildings by this event has become a major public concern. It is known that this area is covered with thick deep sediments, which can amplify long-period ground motions at periods more than 1 second (e.g., Poovarodom and Jirasakjamroonsri, 2015; Subedi et al., 2021; Ornthammarath et al., 2023). It is highly expected that the amplification of long-period ground motion by the deep sediments can affect the large seismic response of the high-rise buildings in the Bangkok Metropolitan area during this earthquake.

In this study, we estimated the behavior of the high-rise buildings in the Bangkok Metropolitan area during the earthquake by analyzing videos and microtremor data to understand the relationship between the seismic response of the high-rise buildings and the long-period motions of the earthquake.

2. VIDEO DATA OF HIGH-RISE BUILDINGS

We collected video data of high-rise buildings during the earthquake captured in the Bangkok Metropolitan region from the video sharing sites. We found the video data of 35 high-rise buildings with a basis on the criteria that the entire building was included in the videos and/or that the natural period could be identified by water overflow from the buildings as explained later. The collected data include the videos of the collapsed under-construction building. The locations of the buildings are displayed in Figure 1. The investigated buildings range in heights from 87 to 315 meters with 25 to 79 floors. The time-lengths of the videos are 7 to 61 seconds. In some of these high-rise buildings, damage to non-structural components was observed, such as the falling of glass fences from the rooftop pools and damage to walkways connecting the multiple buildings.

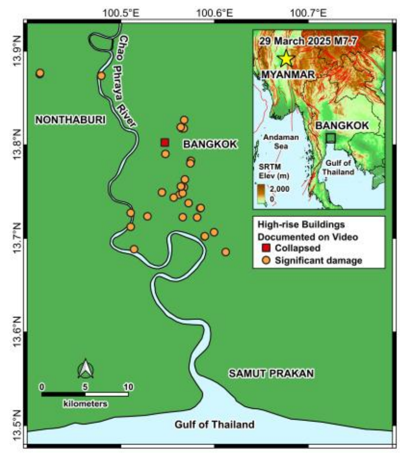

Figure 1. Locations of buildings where the videos were taken.

Figure 2. Example of investigated buildings and its rooftop pool.

3. ANALYSIS OF VIDEO DATA

The video data were analyzed using two methods discussed in Wenzel et al. (2025). One of the methods is to estimate a natural period from time-intervals between images of water overflowing from a pool on the roof of a building. The time intervals of overflowing water mass in the video are averaged to estimate a natural period.

Another method is based on a pixel tracking of video images for an estimation of a building displacement waveform. We prepared reference points at the two sides of the low part of a building and target points of its top part in the first scene of the video as shown in Figure 3. When the lower part of a building is not visible in the video, the reference points can be chosen to be on a nearby low-rise building. A pair of the reference points on the both sides was selected from the standard deviation of the distances of the two points on the both sides during all time-slice images of the video. The selected pair of the reference points were used to eliminate a camera movement on each image. Then we estimated relative displacement between each target point and the middle position of the selected pair of the two reference points. This processing for each image was repeated for whole the video images to derive a displacement waveform of the top of the building. Since the displacement of the low part of the building can be regarded as same as those of ground surface at long-periods, the estimated displacement is the same as the building displacement relative to the ground movement. It is noted that Figure 3 contains 10 target points for understanding the variation of the displacement waveforms of the 10 target points. The detailed procedures can be seen in Wenzel et al. (2025).

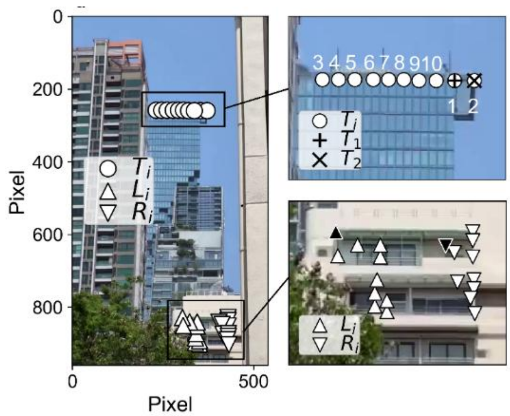

Figure 3. Reference points (R_i and L_i) and target points (T_j) in pixel tracking of video.

The natural periods of the 26 buildings were obtained by the water spillages from the rooftop pools with the video analysis, while the displacement waveforms were estimated for 6 buildings with the pixel tracking analysis. The natural periods were estimated from their displacement spectra. It is noted that the natural periods of the four buildings among the 6 buildings were also obtained from the water spillage analysis. Although the video data for the collapsed building have been examined to retrieve a displacement waveform, we still have difficulty to have a reasonable displacement.

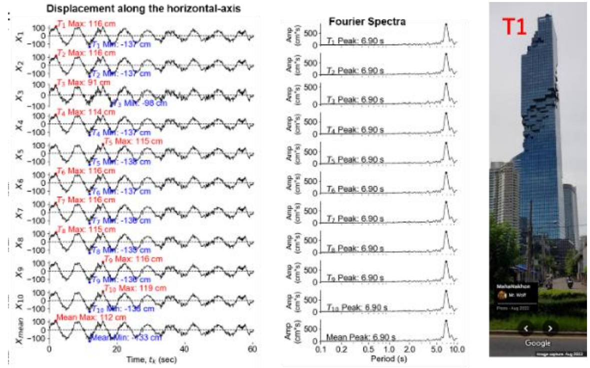

Figure 4. Example of results of pixel tracking of video data.

An example of the results of the pixel tracking of the video data is shown in Figure 4. We prepared 10 target points at the top of the building. The ten displacement waveforms and their Fourier spectra exhibit identical features characterized by the long-period and monochromatic motions. This indicates sufficient reliability of the displacement waveforms from the pixel tracking of the video. The natural period estimated from the spectral peaks of the 10 displacement waves is 6.9 seconds in average and the maximum amplitude of the displacement is 130 cm for this building.

The estimated natural periods from the water spillage analysis and the pixel tracking are summarized with the height of the buildings in Figure 5. Many of the buildings that experienced the water spillages are 100 to 200 meters tall, and have natural periods from 3 to 5 seconds. The empirical equation of natural periods with building heights in the previous study (Ornthammarath et al., 2025) is indicated by a solid line in the figure. Most of the natural periods estimated from the videos are longer than those calculated from the empirical equation. A linear regression line for the relation of the natural periods estimated during the earthquake with the building heights is displayed by a broken line in the figure. This indicates that the estimated natural periods are 30 percent larger than those from the existing equation. The difference can be understood as nonlinear effects of the building responses due to the ground motion during this event.

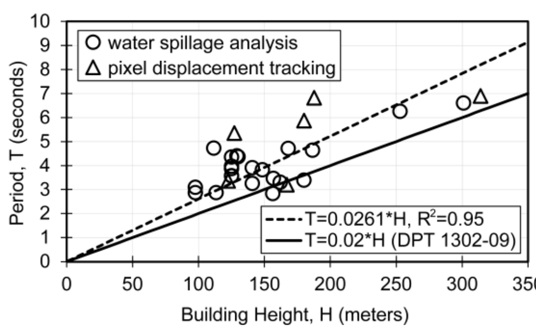

Figure 5. Relation of natural periods of buildings with their heights.

4. FEATURES OF EARTHQUAKE GROUND MOTION

The earthquake ground motion records were observed in and around the Bangkok Metropolitan area during this event. The records were observed at sites outside of the Bangkok basin by broad-band seismometers (Thai Seismic Monitoring Network, 2025) and at sites in the basin (Ornthammarath et al., 2025; Maruyama et al., 2025) as shown in Figure 6. We investigated characteristics of the long-period components in the observed records in Figure 7. Each trace in the figure indicates ground velocity which is normalized with its maximum value. The earthquake motions at all the stations including the sites in the mountain areas continue for long times. Figure 7 shows the results of the multiple filtering analysis applied to the radial components of the records at the stations in and out of the Bangkok basin. The amplitudes at periods longer than 2 seconds are clearly seen in the records at KMUA in the basin. Similar long-period motion is also dominant in the records at NAYO located out of the basin. Since the source fault length of the main shock is about 350 km (USGS, 2025), the source rupture time on the source fault plane is more than 120 seconds. The long-lasting motions at the stations out of the basin can be considered as the source effects which are common for the ground motions at all the stations including the stations in Bangkok basin.

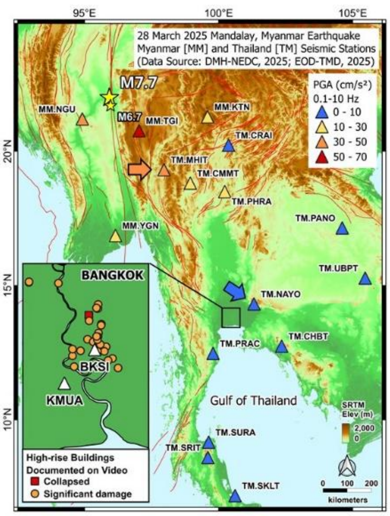

Figure 6. Locations of earthquake ground motion observation stations (white and blue triangles).

The peak ground velocities (PGVs) at the stations are also shown in the right panel of Figure 7. The large PGVs are observed at the two sites in the basin. The amplification of ground motion due to the sedimentary layers is well-known in the Bangkok basin as explained earlier. For example, Ornthammarath et al. (2023) revealed the amplifications at periods longer than 1 second from earthquake records of moderate events. Poovarodom and Jirasakjamroonsri (2015) indicated that the sediments with thicknesses of more than 600m are responsible to the long-period amplification. Therefore, the differences in the PGVs can be understood as the site effects by the sediments of the Bangkok basin. Furthermore, the spectrum at the site in the basin in Figure 8 clearly indicates dispersive features of the long-period motion. This suggests that surface waves are responsible to the long-period motions in the basin area.

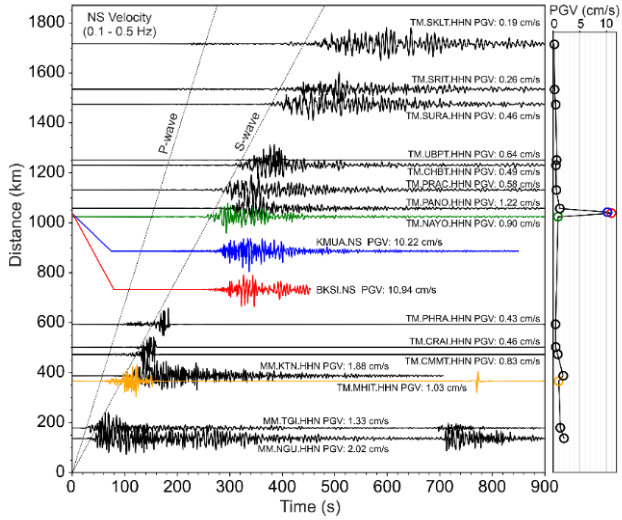

Figure 7. Ground velocities observed at stations in Figure 6 (left). Each trace indicates velocities in north-south orientation. The maximum ground velocities are also plotted in the right panel.

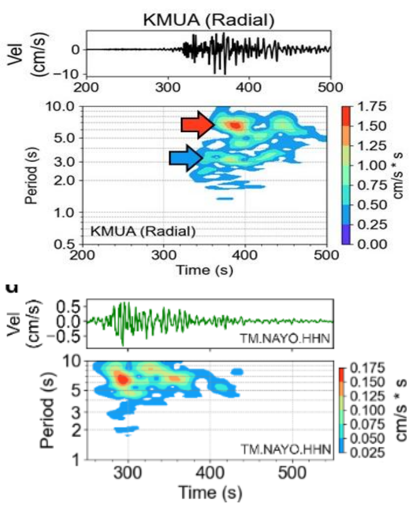

Figure 8. Results of multiple filtering analysis of north-south oriented velocities at KMUA and NAYO in Bangkok basin.

5. FILED SURVEYS

In May 2025, microtremor observations were conducted in some of the above-mentioned high-rise buildings where video analysis was conducted. Acceleration sensors were temporarily installed at four positions on the roof and a central position at a basement of five buildings. Single-point microtremor observations using a long-period high-sensitivity velocity sensor were also conducted on the ground surface near 13 buildings including the five buildings for the building vibration surveys.

We, here, report the results of the microtremor observation on the surface near the 13 buildings. Figure 9 shows the horizontal-to-vertical spectra (H/Vs in the following) of microtremors at the sites along line A from the north to the south of the basin. The H/V at each site has two peaks in a period range longer than 1 second. One is a peak at a period less than 3 seconds, and another is a peak at a period longer than 6 seconds. The first peak is similar to those identified in the previous microtremor surveys (e.g., Poovarodom and Jirasakjamroonsri, 2015). The second peak longer than the first one was not clearly found in the previous surveys. This peak may be caused by the amplifications of the sedimentary layers deeper than those investigated in the previous research. These two peaks have crucial effects on the seismic responses of the high-rise buildings in the Bangkok area, because this period range for the two dominant peaks are similar to those of the natural periods of the buildings examined in the video analysis.

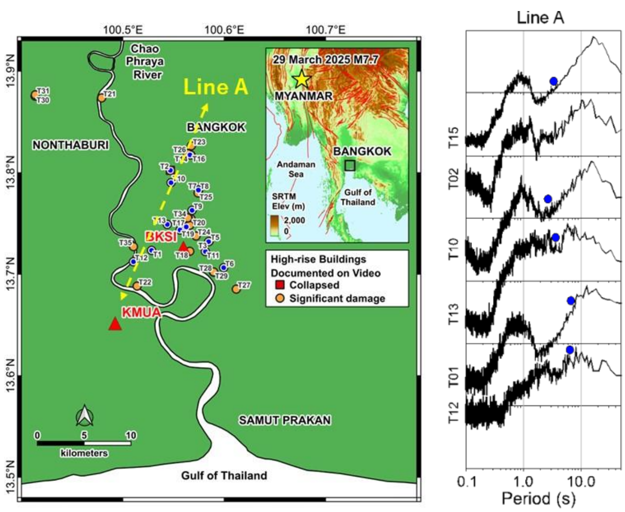

Figure 9. Microtremor H/V spectra at sites along the line A. Blue dots in right panel shows natural periods of buildings near the sites from the video analysis.

6. CONCLUSIONS

In the 2025 Myanmar earthquake, the long-period ground motion was dominant in the Bangkok Metropolitan area which is far from the epicenter, and high-rise buildings shook strongly. The source rupture effects and the deep soil amplifications of the Bangkok basin are crucially responsible to the large long-period motion and the earthquake responses of the high-rise buildings in the area. The effects of the deep soil amplifications to high-rise buildings must be included in their seismic design in the Bangkok Metropolitan area.

Such shaking of high-rise buildings due to relatively distant earthquakes has also been observed in Singapore (Megawati et al., 2003) and Metro Manila (Andaya et al., 2022) during the past events. It therefore is a common problem for high-rise buildings in megacities in Asia. In the future, it is expected that seismologists and earthquake engineers work together to evaluate long-period ground motion and consider measures to prevent damage to large-scale structures.

7. BIOGRAPHY

Hiroaki YAMANAKA received B. Eng. in applied geophysics from Waseda University, Japan, in 1983, and Dr. Eng. in engineering seismology from Tokyo Institute of Technology in 1989. He was a research fellow at Tokyo Institute of Technology and University of Southern California from 1989 to 1990. He worked as a research engineer in strong motion seismology for Kajima Corporation from 1991 to 1995. He was an associate professor in 1995-2011 and a professor from 2011 to 2024 at Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology. He has been a professor since October, 2024 at Department of Architecture and Building Engineering, School of Environment and Society, Institute of Science Tokyo.
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