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Long Period Seismic Waves Developed at Local Distances

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ABSTRACT

Long-period seismic waves have two types. One of them is caused by far-source earthquakes and the other one is caused by near-field type earthquakes. [1]. Long-period seismic waves can be most destructive waves since they amplify their effect when they are passing through the sedimentary areas. There are many examples in literature that shows the devastating effects of long-period seismic waves. The most shocking example is Mexico City, which is located 400 km away from the 1985 Michoacan Earthquake (Mw=8.0) [2]. The aim of this study is to detect the long period seismic waves which will affect Marmara Region and generate relationship according to the path and source. On May 24, 2014 Mw=6.9 Gökçeada earthquake has occurred and after this event, there was far source long period ground waves observed in Marmara Region. We used 5 stations to compare the wave characteristics. Gökçeada station which is located 40 km away from the epicenter is the closest station to the North Aegean Earthquake, and the other 4 stations which are located near İstanbul are 300 km away from the epicenter. We observed long period seismic waves at these stations. The aim of future studies is to produce long period ground waves map for Marmara Region, and determine their effects, especially for İstanbul.
Keywords: Long period sesimic waves, near field, far source, Marmara Region, İstanbul

1. INTRODUCTION

Long period ground motion is a highly important issue nowadays because of the number of high period structures increases such as high rise buildings, suspension bridges, oil storage tanks, offshore oil drilling platforms, etc. According to [1] there are two types of long-period ground motions. One of them is caused by large subduction zone earthquakes and moderate to large crustal earthquakes, they called it far source long period ground motions. These kinds of waves tend to amplify in distant sedimentary basins with the help of the path effect. The second type of long-period ground motion waves is near fault long-period ground motion. Their generation is caused by the source effect of forward rupture directivity. Long period ground motions consist of mostly surface waves with longer duration in far source and shorter duration in near-fault. These two types of waves have a devastating effect on metropolitan areas especially located in or near the sedimentary basins because they attenuate slowly with distance and site effects amplify these motions in distant sedimentary basins. There are many examples of how they can be devastating, such as 1985 Mihoacan earthquake (Mw=8.0)[3] and Tokachi-oki earthquake(Mw=8.3)[4].
Since they have a hazardous effect on metropolitan areas, their early warning has a huge importance topic for urban areas. Especially high rise buildings such as skyscrapers have high periods and tend to resonate with these kinds of waves and shake for minutes. Even they do not crumble, people who live in these structures can be trapped in elevators and get panic. To prevent chaos shutting the vital systems

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such as a throttle or stopping the elevator in the nearest floor, early warning system should be adapted and developed.
In this study, we have a very good example of these kinds of waves generated by the May 24, 2014 (Mw 6.9) North Aegean earthquake (Figure 1). Location of the earthquake is 300 km away from İstanbul metropolitan area and long period ground motions can be clearly observed from the recordings at Büyükada, Heybeliada, and Burgazada in the Marmara Sea and Tuzla located along the coast.

2. GEOLOGICAL SETTING OF MARMARA REGION

The Marmara Sea is located in a transition region where the dextral strike-slip regime of the North Anatolian Fault (NAF) to the east meets the extension regime of the Aegean Sea to the west and contains about 230 km long and 70 km wide marine basin with a shallow shelf to the South [5] [6]. The NAF splits into two main branches called as northern NAF and southern NAF [7].

There are three main basins in the Marmara Sea, Tekirdağ, Central and Çınarcık in the northern Marmara Sea. They are separated by topographic highs, the Western and Central highs. Tekirdağ and Çınarcık basins have high local seismicity because of their depths and bathymetric gradients [8] [5]. [9] studied for the first time 3-D view of the basement topography beneath the Marmara sea and suggested that the presence of clear basement depression reaching down 6 km depth below the sea level beneath three deep basins. The observed basement depth beneath the North İmralı is about 4 km and the North İmralı and the Çınarcık Basins are separated by an E-W high rising up to 3 km, and local depth of the pre-kinematic basement is about 5 km. The Central High rises up to 3 km depth below sea bottom at between Central and Çınarcık basins. There is a link between Tekirdağ and Central basins which is forming a large 60 km long basement depression reaches up to 6 km below the seafloor. Western High bathymetric data show that low velocities exist down to 6 km depth below the sea level and also there is no evidence in the basement high [9].

3. 24 MAY 2014 NORTH AEGEAN SEA EARTHQUAKE MW=6.9

On May 24, 2014, a magnitude Mw= 6.9 earthquake has occurred in the Northern Aegean Sea. Its location was in the western part of the North Anatolian Fault Zone and has a depth of 20 km in the sea between the Aegean islands of Gökçeada, Turkey and Samothraki, Greece (Figure 1). The main shock had a right lateral strike-slip faulting with strike 70º from the north.

The epicenter of the earthquake was about 300 km away from the İstanbul metropolitan area, but its effect on high rise buildings was obvious. Many buildings shaked for about 10 minutes because of the generation of the long period ground motion in distant sedimentary basins. Waves resonated with buildings natural period.

Figure 1. Distance between the location of the earthquake and Istanbul

4. DATA AND METHOD

In this study accelerometer and velocity records were used to analyze characteristic long-period ground motion. 5 stations were chosen Gökçeada, Buyukada, Heybeliada, Burgazada, and Tuzla. These stations belong to Boğaiçi University Kandilli Observatory and Earthquake Research Institute Regional Earthquake Tsunami Monitoring Center. Gökçeada station is the closest station and it is 40 km away and the other station is about 300 km away from the earthquake epicenter. The reason for using these stations is to see the differences between wave characteristic. Pseudo velocity spectrum and fourier transform of the records were also used to compare the period range of the waves.

5. RESULTS AND DISCUSSION

As indicated before sedimentary basins amplify these kinds of waves. Therefore, Gökçeada station records long period ground motion waves cannot be clearly seen, their duration is about 20 seconds. (Figure 2).

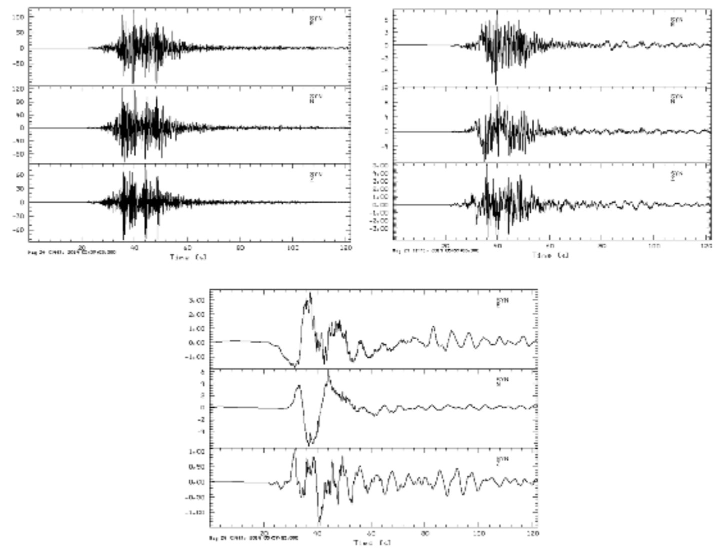

Figure 2. Acceleration(lef handside up),Velocity (right handside up) and Displacement (bottom) Records of North Aegean Sea Earthquake from Gökçeada Station

When we looked at the pseudo velocity spectrums of Gökçeada Station, the period range differs from 2 seconds to 4 seconds and this may cause resonance with high buildings (Figure 3). This period range may not affect high period structures because generally these structures natural period is higher than 4 seconds. 2 to 4 second period may affect 10 or 15 floor buildings. Also, there is no sedimentary basin evidence that amplifies these waves. When we compare the early warning stations which are located in the Marmara Region, especially near metropolitan area İstanbul, the duration of the waves is up to 100 seconds (Figure 4). Also, fourier transform of Buyukada, Heybeliada, Burgazada and Tuzla stations, the period range of the waves is up to 10 seconds (Figure 5 and Figure 6). This may be an evidence for sedimentary layers amplify these kinds of waves, since the ray path includes sedimentary basins, probably caused by Central Basin. During the North Aegean Sea earthquake, İstanbul city affected by these waves. Some of the high rise buildings were shaken for 15 minutes. 10 seconds period affected high period structures since they have tended to resonate. At this point, it could be said that not only the expected big Marmara earthquake affect Marmara region, but also these types of waves could cause damage. The new generation of early warning systems could be developed in these ways since their durations are longer than normal waves and warning would be more trustworthy. For example the duration of North Aegean Sea earthquake was about 86 seconds and the early warning algorithms solved the earthquake in 36 seconds, providing 50 seconds early warning time for some vital automatic measures such as cutting down of the natural gas systems, stopping the elevators, suspensions of the serious surgeries etc. in İstanbul and Marmara Region.

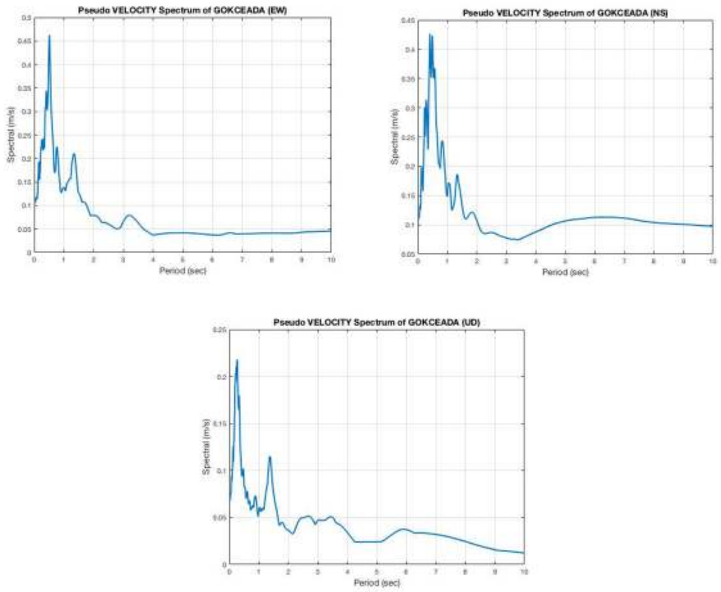

Figure 3. Pseudo Velocity Spectrums of Gökçeada Stations for North Aegean Sea Earthquake

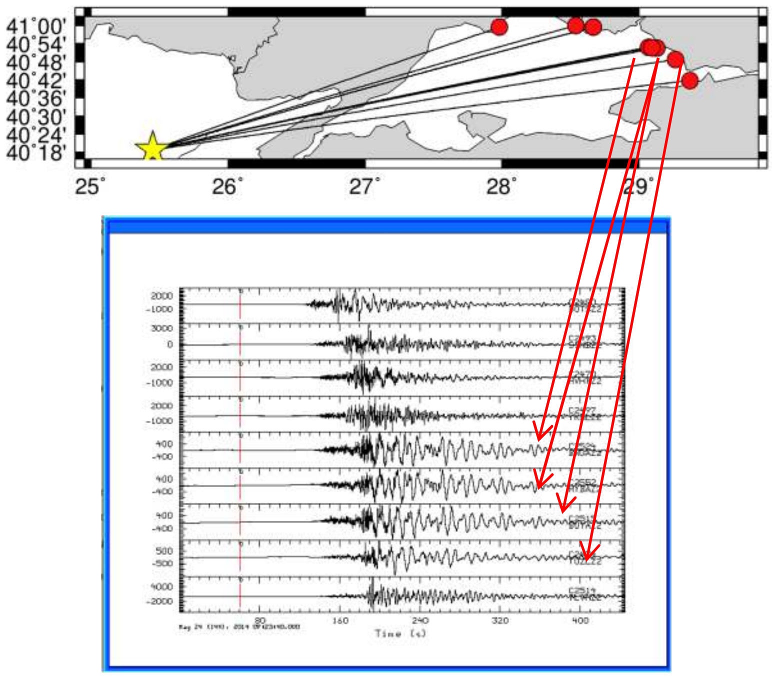

Figure 4. Velocity records of early warning stations for North Aegean Sea Earthquake

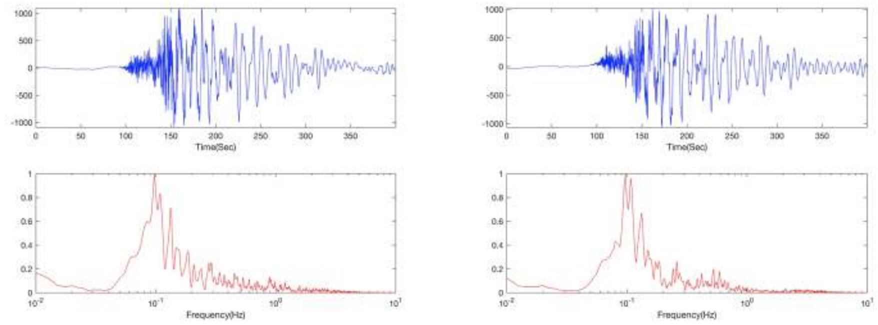

Figure 5. Fourier Transform of Burgazada (left) and Buyukada (right) Station for North Aegean Sea Earthquake

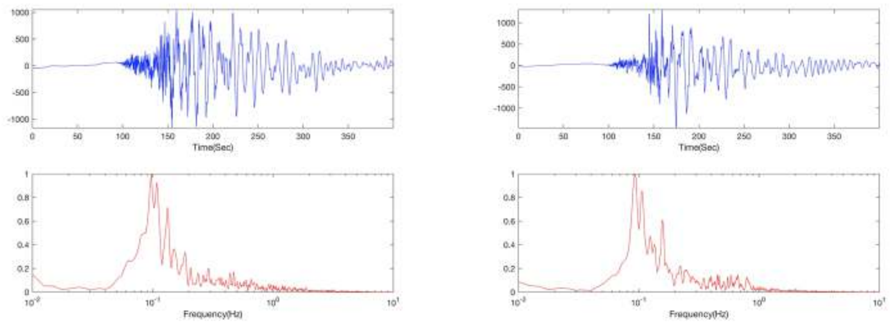

Figure 6. Fourier Spectrum of Heybeliada (left) and Tuzla Station (right) for North Aegean Sea Earthquake

4. CONCLUSION

Long period ground motion is a highly important issue nowadays because of the number of high period structures such as high rise buildings, suspension bridges, oil storage tanks, offshore oil drilling platforms etc. increases. These waves have a tendency to amplify when they are passing through the sedimentary basins. In Marmara Region, there are 3 sedimentary basins Çınarcık, Central, and Tekirdağ. High period structures are usually located in the Marmara Region in Turkey. So they are at risk because they inclined to resonate with this kind of waves. These phenomena are clearly indicated in the records of the 24 May 2014 North Aegean Sea Earthquake. The waves with periods are up to 10 seconds at Buyukada, Heybeliada, Burgazada and Tuzla stations are presented as an evidence of the sedimentary layer amplification of the waves in the region. Therefore, it is vital to develop early warning systems which are compatible with long period waves since the warning durations for long period waves are longer than the normal type of waves.

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