

Long-period ground motion effect in Shaanxi Province of Changning Ms6.0 earthquake

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Abstract. At 22:55 on June 17, 2019, an earthquake of magnitude 6.0 occurred in Shuanghe Town, Changning County, Yibin City, Sichuan Province. In Shaanxi Province, the obvious earthquake sense appeared in some places which are 600 km to 800 km away from the epicenter. Based on the collection, collation and analysis of the data about Weihe Basin, Hanzhong Basin and Ankang Basin in Shaanxi Province, and the analysis of representative seismic network records and seismic wave propagation distance in each basin, the mechanism of the long-period disaster induced by the Changning Ms6.0 earthquake in Shaanxi Province is revealed. This study has a positive significance for the seismic fortification of long-period structures in this area, the scientific popularization of long-term ground motion effect, and the avoidance of earthquake panic.

1 Introduction

With the development of economy, there will be more and more long-period structures (high-rise buildings, long-span bridges, large-scale liquid storage tanks, etc.). These long-period structures often resonate with long-period ground motions in the far-field of large earthquakes, resulting in earthquake sense and earthquake damage. There are many typical long-period earthquake disasters in the world. During the 1964 Shinjuku earthquake in Japan, a large oil storage tank in the city shook, causing a fire. During the Romanian earthquake on March 24, 1977, the high-rise buildings of Sofia 450 km away from the epicenter, and the high-rise buildings of svishtov 240km away from the epicenter were seriously damaged. During the Gediz earthquake in 1979, the Tofas factory in Bursa City, 135 km away, was in the intensity zone of V. However, the structure of the plant was seriously damaged, and the local intensity of the plant reached VIII. When the earthquake of M7.7 occurred in central Japan in 1983, a fire was caused by oil spilling from oil storage tanks in Akita city. In Xinshu City, 270km away from the epicenter, 13 of the oil tanks with liquid level shaking period of about 10 seconds overflowed and the accessories on the top of the tanks were damaged. During the 1985 Mexico earthquake with M8.1, some high-rise buildings were seriously damaged in Mexico City about 400 km away from the epicenter. During the 1994 Taiwan Strait earthquake with M7.3, Shanghai residents living on the ground floor felt no sense of it, while residents above the 10th floor felt it, showing strong reactions such as standing unsteadily and lying on the tables (Liu et al., 1999). When the South Yellow Sea earthquake of magnitude 6.1 occurred in November 9, 1996, 5 of the

24 5-meter lightning eliminators at the top of the Oriental Pearl TV Tower in Shanghai with a height of 458m dropped. The Tower is about 160km from the epicenter. The Wenchuan earthquake on May 12, 2008 caused severe long-term earthquake damage in Weihe Basin, Hanzhong Basin and Ankang Basin in Shaanxi Province. T The long distance and the strong earthquake damage are unprecedented (Li, 2018). Based on the fact that a large number of long-term earthquake damage exists, it is imperative to carry out effective seismic fortification for long-term buildings. At 22:55 on June 17, 2019, an earthquake of Ms6.0 occurred in Shuanghe Town, Changning County, Yibin City, Sichuan Province. In Shaanxi Province, in some places which are 600 km to 800 km away from the epicenter, obvious earthquake sense appeared, causing earthquake panic. The Ms6.0 earthquake caused such a strong earthquake sensation in Weihe Basin, Hanzhong Basin and Ankang Basin, 600 km to 800 km away. Zhang et al. (2019) conducted an emergency investigation on geological disasters induced by the Changning earthquake, Issa Ismaili et al. (2019) studied the geomagnetic variation of Changning earthquake by using Parkinson's vector detection, Liao Hongyue (2019) studied the relationship between medium and long-term micro anomalies of Ionospheric TEC and Yibin earthquake, Li yan'e et al. (2019) explored the stress change and triggering process before the Changning earthquake, Chang Zufeng et al. (2020) studied the geological structure origin of Changning earthquake, and Chang Zufeng et al. (2020) studied the geological structure origin of Changning earthquake. In the above studies, there is no research on the mechanism of long-period earthquake sense in Shaanxi Province, caused by Changning earthquake. Through the collection, collation and analysis of the data of Weihe Basin,

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Hanzhong Basin and Ankang Basin in Shaanxi Province, as well as the analysis of representative seismic network records and seismic wave propagation distance in each basin, the mechanism of long-period earthquake sense in these basins caused by the Sichuan Changning MS6.0 earthquake is revealed. This study has a positive significance for the seismic fortification of long-period structures in this area, the scientific popularization of long-term ground motion effect, and the avoidance of earthquake panic.

2 Macro sense of the Changning Ms6.0 earthquake in Shaanxi Province

According to the official determination of China Seismic Network: at 22:55 on June 17, 2019, an earthquake with Ms6.0 occurred in Shuanghe Town, Changning County, Yibin City, Sichuan Province. The epicenter was located at 28.34 degrees north latitude, 104.90 degrees east longitude, and the focal depth was 16 kilometers. The long-period earthquake senses of the high-rise buildings which are located in Weihe Basin, Hanzhong Basin and Ankang Basin, and are 600 km to 800 km away from the epicenter, are obviously felt in Shaanxi Province. According to netizens in Ankang, there were people running crazily down the stairs in some areas such as Shiquan. Wang Pengfei, who lived in the northern suburb of Xi'an, was watching TV at home when he suddenly saw that the clothes drying pole on the balcony tilted, and then the windows and doors rang, and the chandelier in his home kept shaking for dozens of seconds. "On the 25th floor, I felt the earthquake. At first, I thought it was an illusion. The lights in the house were shaking and the watch was shaking. When I opened the door and went out, I found that the neighbors were outside the door to discuss what had just happened," netizen "feimiaomiao" in Xi'an wrote in the Wechat circle of friends. In Chang'an South Road, Xi'an City, some of the residents ran to the courtyard from upstairs. On the 27th floor of Dongtai City Light District in Xi'an, someone saw the water in his fish tank shaking strongly. Someone saw the light shaking and ran downstairs with his family. Generally speaking, The earthquake senses of the high-rise buildings in Xi'an, which is far away from the epicenter, are strongly felt, while those in Hanzhong and Ankang near the epicenter are relatively weak.

3 Analysis of distance factor

Distance is an important factor affecting long-period ground motion. Generally speaking, the longer the distance is, the richer the long-period components are. Even if the peak acceleration far away from the epicenter is very low, it will often cause obvious long-period earthquake sense and earthquake damage. This is the result of resonance between long-period ground motion and long-period structure. At 22:55 on June 17, 2019, an earthquake with a magnitude of Ms6.0 occurred in Shuanghe Town, Changning County, Yibin City, Sichuan Province. The epicenter was about 800km away from Xi'an in Weihe basin, 600km away from Hanzhong

Basin and 650km away from Ankang basin (Fig. 1). The earthquake was felt in Shaanxi Province, which is 600 km to 800 km away from the epicenter, which caused a considerable degree of earthquake panic. The phenomenon that the earthquake with only magnitude 6.0 caused such a strong earthquake senses in Weihe Basin, Hanzhong Basin and Ankang Basin 600 km to 800 km away, is unprecedented. There is no doubt that long distance played an important role.

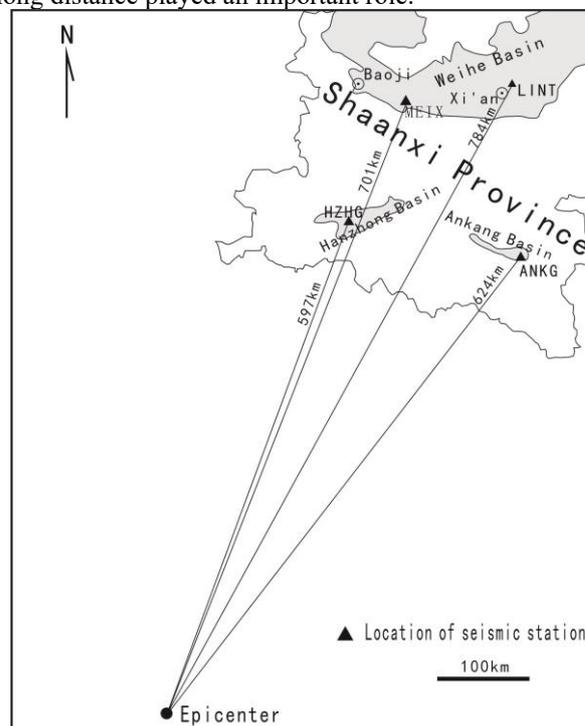


Fig. 1 Spatial distribution of seismic stations, basins and Changning earthquakes in Shaanxi Province

4 Analysis of basin effect

Many areas (especially big cities) are located in basins with thick sedimentary layers. The basins are composed of alluvial deposits and sedimentary rocks with a relatively new age. Compared with the underlying bedrock, their wave velocities are lower. The thickness of the basin ranges from several hundred meters to more than ten kilometers. The seismic waves sealed in the basin with deep sedimentary thickness may have great destructive potential. When simulating the seismic response of soil layer, it is usually assumed that the soil layer is horizontally layered. The specific method is shown on the left side of Figure 2. The seismic wave entering the soil layer can resonate in the soil layer, but can not be sealed in the soil layer. However, when the seismic wave is a long-period ground motion of more than one second, the wavelength of the seismic wave will be far greater than 30 meters. The amplification effect of seismic waves in soil layer is controlled by geological structures which are hundreds or thousands of meters deep. In most cases, such as in sedimentary basins, geological bodies are not horizontal. If the seismic wave enters the basin from the edge of the basin, the seismic wave may be trapped in the basin when the

incident wave incident at a supercritical angle. The results of internal total reflection at the bottom of the deposit due to this reason are shown on the right side of Figure 2. At the bottom of Figure 2, the simple calculation results of the seismic response of the basin are compared with the seismic response results in the horizontal stratification. In both cases, the plane wave incident from the bottom at a certain angle. As shown in the left figure, in the horizontal soil layer overlying the bedrock, the amplification of seismic wave relative to the underlying bedrock occurs due to the wave impedance effect. However, in a basin, in addition to this amplification effect, when body waves enter the basin from the edge, they will be trapped in the basin and generate surface waves across the basin. The existing empirical ground motion attenuation relationship does not distinguish the site on the shallow alluvium from the field in the deep sedimentary basin for statistical analysis. It may underestimate the ground motion in the basin.

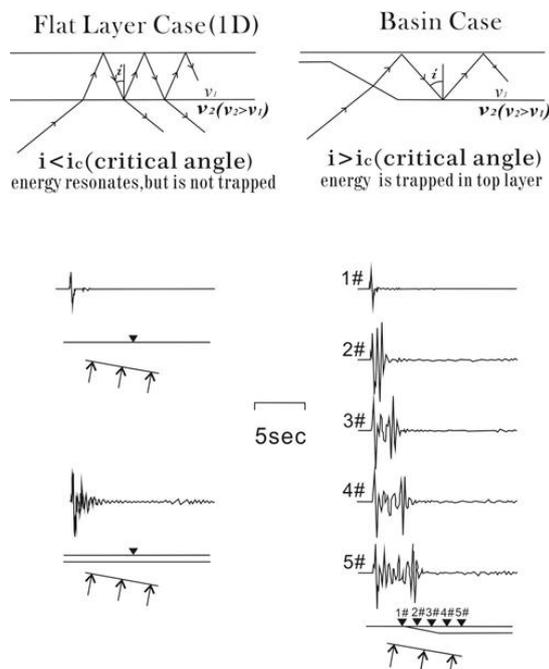


Figure 2 Basin edge effect (Somerville, 2003)

Weihe River Basin is located in the central part of Shaanxi Province. It stretches about 350 km from Baoji in the west to Tongguan in the East. It is 85 km wide in the East and 30 km in the West. At the bottom of the basin, the terrain of Guanzhong Plain is higher in the West and lower in the East, and the central part is relatively flat and wide, with an average altitude of about 400 meters. The total area of Guanzhong Plain is 39064.5 square kilometers, accounting for 19% of the total land area of Shaanxi Province (205800 square kilometers). Weihe Basin has a huge thickness of Cenozoic sediments, and the surface is covered by Quaternary. Up to now, more than ten deep holes have been drilled in the basin, but none of them have penetrated the Cenozoic strata. According to the preliminary analysis of geothermal drilling and geophysical exploration data, the Cenozoic Weihe Basin is mainly composed of fluvial lacustrine facies with a sedimentary thickness of 6000-7000m. The lithofacies

assemblage is that sandstone intercalated with mudstone interbedding, which is characterized by positive cycle deposition, coarse in the bottom and fine in the upper. Figure 3 shows the Quaternary isopach map of Weihe Basin. As can be seen from Figure 3, the thickness of Quaternary System in Weinan is up to 1200 meters. The thick sedimentary layer in Weihe Basin has a strong amplification effect on long period ground motion.

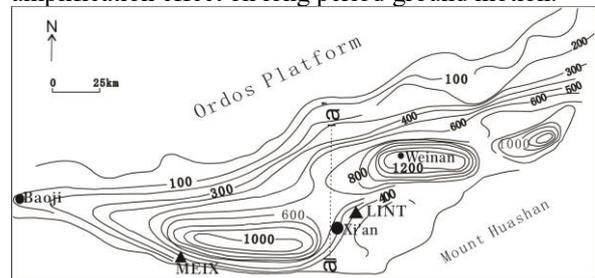


Figure 3 Quaternary isopach map of Weihe Basin (unit: m)

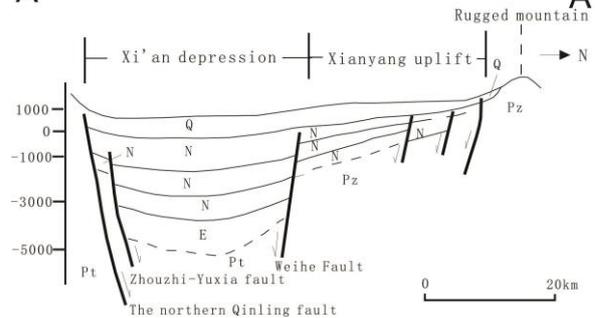


Fig. 4 Profile of Weihe Basin (Wang, 1986)

As shown in Fig. 3 and Fig. 4, the profile map of Weihe Basin (Wang, 1986) shows that, in addition to the extremely thick Quaternary sedimentary layer on the surface of Weihe Basin, there is a certain dip angle in the southern margin of Weihe Basin (the northern edge fault of Qinling Mountains) where the Changning seismic wave first reaches, which may create conditions for the edge effect of Changning seismic wave on the northern edge of Weihe Basin.

Generally speaking, the larger the scale of the basin, the easier it is to resonate with the long-period ground motion with longer wavelength. Because of the large scale of Weihe Basin, it is easy to resonate with long-period ground motion, so as to increase the long-period earthquake sense and damage. The scale of Hanzhong Basin and Ankang basin is much smaller than that of Weihe Basin, but their resonance potential with long-period ground motion should not be ignored. Hanzhong Basin is a faulted basin formed since Quaternary. It is located in the south of Qinling Mountains. Hanjiang River passes through the middle of the basin. There are many sedimentary types in the basin, such as quaternary alluvial, proluvial and eluvial slope deposits. The thickness of sediments varies greatly and the phase transformation is complex. Hanzhong Basin starts from Wuhou Town of Mianxian County in the west to Longtingpu of Yangxian County in the East, with a length of 116 km and a width of 5-25 km from north to south. The river terrace is developed with an average altitude of about 500 meters. In Hanzhong Basin, river terraces are developed with an average altitude of about 500 meters. Hanzhong Basin is a long and narrow trough

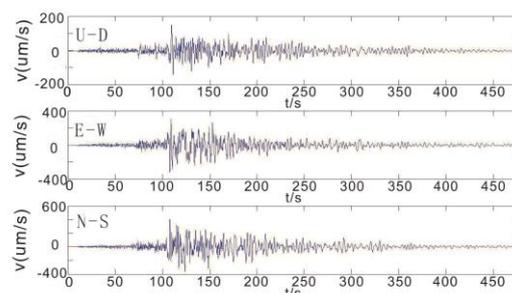
intermountain subsided basin, which is formed by alluvial deposition of Hanjiang River. It is covered with Quaternary clay, loess like sandy clay and gravel, forming a fertile field. Due to the imbalance of neotectonic movement, the Quaternary sediments in the basin are quite different in both vertical and horizontal directions. Along the east-west direction of the basin, the sedimentary thickness changes greatly. In the area between the west of Baocheng and the north of Lianshui, the Quaternary sedimentary thickness is more than 500m; In Pu Town, the sedimentary thickness is 200-400m; in Yangxian County, it is about 150m; in some sections, the thickness is 30m.

The landform of Ankang basin is "one river is sandwiched with two mountains." Ankang basin is adjacent to Qinling Mountains in the north and Bashan mountain in the south. The terrain is relatively gentle compared with Qinling Mountains, and most of them are round or beam shaped hills. There are five small basins in the middle, which are called Ankang basin. They are more than 100 kilometers in length from east to west. The width in Shiquan is about 3 kilometers, and the width in Hanbin is about 8 kilometers. The Hanjiang River meanders through the basin. The loose deposits in Ankang Basin are thin, and the long-period effect of earthquake is relatively small.

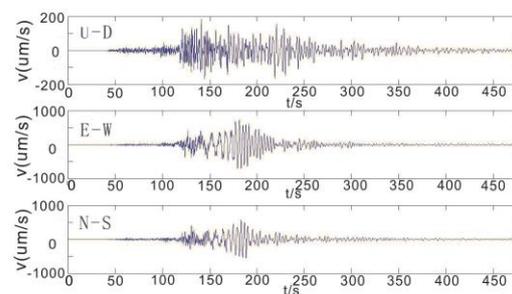
5 Analysis of seismic wave characteristics

As shown in Fig. 1 and Fig. 5, the seismic records of seismic network in Weihe Basin (a, b), Hanzhong Basin (c) and Ankang basin (d) are shown in Fig. 5. Because of the small amplitude, the Changning earthquake did not trigger strong motion instruments in Shaanxi Province, so no corresponding strong earthquake records were obtained. This is a big regret of this study. But surprisingly, the records of the seismic network shown in Fig. 5 clearly reflect the amplification of long-period ground motion by distance and basin effect. As shown in Figure 1, the epicenter distance of HZHG station is 597km, and that of ANKG station is 624km, they are far away from those of Meixian station (701km) and Lintong station (784km) in Weihe basin. In engineering, for the seismic effect, the distance of 100km is a great difference. Generally speaking, if the basin effect is not considered and only the influence of distance is considered, the long period component of long-term ground motion at Hanzhong and Ankang stations is less than that at Meixian and Lintong stations (Figure 5 witnesses this feature), and the amplitude of ground motion is larger than that of Meixian and Lintong stations. However, it can be seen from Figure 5 that the amplitude of ground motion at Meixian and Lintong stations is almost 1.5-2.0 times of those at Hanzhong and Ankang stations. There is no doubt that basin effect plays a more important role besides the amplification effect of distance on long-term ground motion. The scale of Weihe Basin is much larger than that of Hanzhong Basin and Ankang basin, and the Quaternary is thicker. Therefore, the Weihe Basin is more likely to amplify the

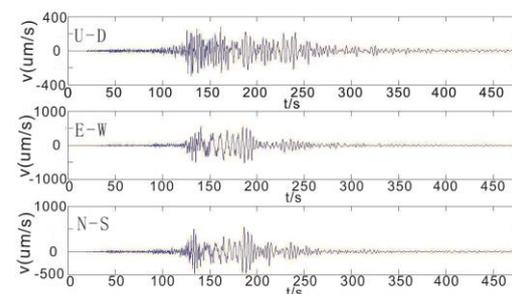
long-term ground motion. In addition to the strong amplification of long-period ground motion by the thick sedimentary layer, the basin edge effect of long-period ground motion is more likely to be produced. It is worth noting that although the site type of seismic station is bedrock site, there is still a gap from soft to hard strata from top to bottom, and the amplification effect of surface layer on long-term ground motion is relatively large. In addition, the ground motion of the seismic station may also be affected by the ground motion of the nearby soil layer. For bedrock site, it is absolutely capable of recording basin edge effect (basin edge effect will make contribution to seismic station ground motion). To say the least, even a pure bedrock basin has the ability to produce basin edge effect.



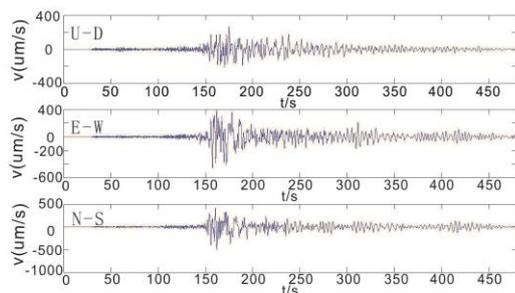
(a) Seismic data of ANKG station (the epicenter distance was 624km)



(b) Seismic data of HZHG station (the epicenter distance was 597km)



(c) Seismic data of MEIX station (the epicenter distance was 701km)



(d) Seismic data of LINT station (the epicenter distance was 784km)

Fig. 5 Seismic records of seismic network

6 Conclusions

At 22:55 on June 17, 2019, a Ms6.0 earthquake occurred in Shuanghe Town, Changning County, Yibin City, Sichuan Province. In Shaanxi Province, in some places which is 600 km to 800 km away from the epicenter, the obvious earthquake sense appeared. Based on the collection, collation and analysis of the data of Weihe Basin, Hanzhong Basin and Ankang Basin in Shaanxi Province, as well as the analysis of representative seismic network records and seismic wave propagation distance in each basin, it is shown that the long-period earthquake senses caused by the Sichuan Changning Ms6.0 earthquake in Shaanxi Province is caused by the long-period effect of the far-field basin of moderate strong earthquakes. This study has a positive significance for the seismic fortification of long-period structures in this area, the scientific popularization of long-term ground motion effect, and the avoidance of earthquake panic.

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