Study on the disaster mechanism of near-fault pulse-like ground motion of M8.0 Wenchuan earthquake

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Abstract. With the improvement of observation quality, more and more near-fault strong earthquake records have been obtained. Through the analysis of near-fault strong ground motion records of Wenchuan earthquake, the collection and field investigation of seismogenic structural data, as well as the collection and field investigation of near-fault structural damage data, the disaster mechanism of Wenchuan earthquake is studied. The impulsive ground motion (directional effect, permanent displacement effect, etc.) near the fault is determined. It is confirmed that the pulse-like ground motion (directivity effect, permanent displacement effect, etc.) near-fault is the main cause of earthquake damage. Pulse-like ground motion has the characteristics of high peak value, wide frequency band and long duration. Therefore, it is easy to resonate with the structures with different basic periods, thus causing serious direct disasters and indirect secondary disasters.

1. Introduction
Strong motion seismograph has the characteristics of large dynamic range and wide frequency band. During the 512 M8.0 Wenchuan earthquake, valuable near-fault strong motion records have been recorded in the near-fault strong motion seismographs of Wolong Station, Qingping Station, Bajiao station, etc. It provides an opportunity to study the disaster mechanism of near-fault ground motion. In addition, many scientific and technological personnel have studied the seismogenic structure and investigated the structural damage near the fault [1-5]. The purpose of this paper is to combine geology, seismology and seismic engineering on the basis of previous studies to connect the characteristics of near-fault pulse-like ground motion with the earthquake damage of near-fault structure, so as to reveal the damage mechanism of near-fault structure of Wenchuan earthquake (for example, pulse-like ground motion may resonate with foundation, mountain and structure in some way to cause serious damage of near-fault structure).

2. Wenchuan earthquake
On May 12, 2008, Wenchuan earthquake with M8.0 occurred in the Longmenshan seismotectonic belt. The Wenchuan earthquake caused great loss of people and property due to its unique seismogenic tectonic environment, and has been paid great attention at home and abroad. The Beichuan-Yingxiu fault of seismogenic structure is a right-handed thrust fault. The surface rupture is close to 300km (Figure 1). Wenchuan earthquake is a process in which energy is released from several fault structural fracture sections. The release time of energy is long and unprecedented. In the near field, it is easy to produce directivity effect and permanent displacement effect, so as to produce pulse-like ground motion.
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3. Selecting and processing of strong earthquake records

According to the available data and the distribution of strong seismic stations when the Wenchuan earthquake occurred, we selected the main earthquake data of Wenchuan earthquake at the seismic stations as shown in Table 1 and Figure 2-6 to analyze the characteristics of near-fault ground motion. We selected the strong earthquake records of Wolong Station, Bajiao Station, Qingping Station, Jiangyou station and PingwuMuzuo station (Figure 2, Figure 3, Figure 4, Figure 5, and Figure 6). The characteristics of uniform distribution of surface rupture are also considered in the selection of near-fault strong earthquake records. In addition, the high-quality digital strong motion instrument has the characteristics of wide frequency bandwidth and large dynamic range, which provides quality assurance for the research work.

Table 1. Selection of near-fault strong earthquake records

| Station   | Longitude | Latitude | Field | Recorder | Accelerometer | Maximum horizontal peak acceleration (cm/s²) |
|-----------|-----------|----------|-------|----------|--------------|---------------------------------------------|
| Jiangyou  | 104.7     | 31.8     | soluM | MR2002   | SLJ-100      | 511                                         |
| Qingping  | 104.1     | 31.5     | soluM | ETNA     | SLJ-100      | 824                                         |
| PingwuMuzuo | 104.5    | 32.6     | soluM | GDQJ-II  | SLJ-100      | 287                                         |
| Bajiao    | 104       | 31.3     | soluM | ETNA     | SLJ-100      | 633                                         |
| Wolong    | 103.2     | 31.0     | soluM | ETNA     | ES-T         | 957                                         |

In order to retain the permanent displacement information, we give up the commonly used high pass filtering method. However, by making proper baseline correction for the acceleration records of strong ground motion in the near field, the displacement time history with permanent displacement can be obtained after twice integrations.

Figure 1. Distribution of near-fault strong seismic stations and distribution of surface rupture in Wenchuan M8.0 Earthquake
Figure 2. NS direction strong ground motion time history of main earthquake of Wenchuan earthquake in Jiangyou Station

Figure 3. NS direction strong ground motion time history of main earthquake of Wenchuan earthquake in PingwuMuzuo Station

Figure 4. NS direction strong ground motion time history of main earthquake of Wenchuan earthquake in Qingping Station

Figure 5. NS direction strong ground motion time history of main earthquake of Wenchuan earthquake in Bajiao station
4. Analysis on the mechanism of near-fault earthquake disaster

It can be seen from table 1, Figure 2, Figure 3, Figure 4, Figure 5, Figure 6 that the peak accelerations recorded by the near-fault during the main earthquake of Wenchuan earthquake are very high. The recorded peak acceleration at Wolong Station is 925 cm/s², and the velocity time history has pulse characteristics. In the displacement time history, the permanent displacements are obvious, and the nonlinear characteristics are obvious. Pulse-like ground motion has the characteristics of high peak value, large period and long duration. The seismogenic structure is characterized by thrust with dextral rotation. The cause of pulse earthquake should have both directional effect and permanent displacement effect. The above characteristics determine that the impulsive ground motion can resonate fully with the structure of various natural vibration periods, thus causing serious disasters. In the comparative analysis with actual disasters, this viewpoint is verified.

As shown in Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, we selected Xiaoyudong Bridge, Bailu Middle School, Chuanxindian Earthquake Site, Beichuan Earthquake Site and Donghekou Earthquake Site as the investigation points to observe the earthquake disaster of Wenchuan earthquake.

The natural vibration period of the bridge is large. In addition to the high amplitude, the impulsive seismic motion also has rich long period components, and it is easy to resonate with the bridge and cause disasters. It can be seen from Figure 1 that Xiaoyudong Bridge is located between Wolong Station and Bajiaotai Station. According to the records of the two stations, during the earthquake,
Xiaoyudong Bridge undoubtedly suffered from strong near-fault pulse-like earthquake damage, resulting in earthquake damage. It can be seen from Figure 7 that the bridge is seriously damaged.

It can be seen from Figure 1 that Bailu Middle School is close to Bajiao Station, so it should have affected by near-fault pulse-like earthquake during the earthquake, thus causing serious damage. However, it can be seen from figure 8 that during the earthquake, the school itself was not seriously damaged, but slightly damaged. In the middle of the two teaching buildings, along the strike of the seismogenic structure, the whole ground had been uplifted. This situation shows that the foundation of the school site may have some earthquake liquefaction phenomenon during the earthquake, absorbing part of the seismic waves, making the seismic waves not have sufficient resonance with the structure. It has the effect of isolation. As can be seen from figure 5, the permanent displacement of Bajiao Station is as high as 2m. It is not difficult to explain the overall uplift of the school site. Due to the overall uplift of the foundation, and there is no building at the surface rupture, so the surface rupture did not cause structural damage.

It can be seen from Figure 1 that Chuanxindian earthquake site is between the Bajiao Station and the Qingping Station. According to the strong earthquake records of the two stations (Table 1, figure 4 and figure 9), the earthquake should be affected by the near-fault pulse-like ground motion, thus causing serious damage. Chuanxindian earthquake site is the original production base of Sichuan Hongda Co., Ltd. In Wenchuan earthquake, it suffered devastating damage. The liquid ammonia leaked, the sulfur burned, the sulfuric acid leaked, and the house collapsed. 75 people were killed and 61 were injured in the production base, with a direct economic loss of 430 million yuan.

It can be seen from Figure 1 that the Beichuan earthquake site is far away from the initial breaking point of the earthquake, but it is located near the fault. Beichuan is the most severely damaged area in Wenchuan earthquake (Figure 10). The topography between two mountains and one valley in Beichuan might have resulted in sufficient resonance between the mountain and the seismic wave, resulting in serious secondary disasters. The landslides buried a large number of buildings, causing heavy casualties. Beichuan Earthquake Site is near Jiangyou Station. The peak acceleration of Jiangyou station is 511 cm/s². Although the value is relatively high, it is still slightly smaller than the records of Wolong platform, Bajiao and Qingping Station. However, a large-scale coseismic displacement was found in Beichuan. This shows that the ground motion here is very strong. It is not difficult to understand the cause of the serious earthquake disaster in Beichuan.

As shown in Figure 11, the house originally built by Zou family brothers (Zou Jizhong and Zou Duanxing) is shown in the photo. During the earthquake, the houses suffered serious damage and deformation. By comparing the position of loquat trees before and after the earthquake, and that fact after Zou's house on the same plane before the earthquake was staggered by the earthquake, the height between the grounds was about 9.5m, it can be seen that the displacement is at least 9.5-10.9m.
Figure 12. Comparison of mountain landforms before and after Songhekou earthquake

It can be seen from Figure 1 that the Donghekou Earthquake Site is more than 200 kilometers away from the initial breaking point of the earthquake and is at the end of the surface rupture. But it is still near-fault. Although it can be roughly judged from the records of nearby PingwuMuzuo Station (Table 1, figure 3) that the ground motion here has been greatly weakened, due to the landslide of the mountain under the action of earthquake (Figure 12), a tragic disaster was still caused and 780 people were instantly engulfed by landslides. The projectile formed by landslide is as high as 400m, and the buried depth in the valley is as deep as 110m. The reason may be that there are still strong directional effect and permanent displacement effect at the end of the seismogenic structure.

5. Conclusion

Through the analysis of near-fault strong ground motion records of Wenchuan earthquake, the collection and field investigation of seismogenic structural data, as well as the collection and field investigation of near-fault structural damage data, the disaster mechanism of Wenchuan earthquake is studied. Based on the analysis of near-fault strong earthquake records and earthquake damage of Wenchuan earthquake, it is considered that the main cause of earthquake damage is the pulse-like ground motion near-fault. Pulse-like ground motion has the characteristics of high peak value, wide frequency band and long duration. It is easy to resonate with the structures with different basic periods, resulting in serious direct and indirect secondary disasters. At the same time, the terrain and geomorphic environment of the building may deepen the direct and indirect secondary disasters to a large extent.

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