Exploration of Weihe River Fault at the Site of Weihe Bridge on National Highway 310 Xi'an Transit Highway

Zhuo Lin¹, Youliang Shu¹, Jumei Bian¹ and Chunfeng Li¹*

¹ Earthquake Administration of Shaanxi Province, Xi'an, Shaanxi, 710068, China
*Corresponding author’s e-mail: 765248381@qq.com

Abstract. In this paper, the Weihe fault on the site of Weihe Bridge on State Highway 310 Xi'an Transit Highway is explored by combining high-density resistivity method with borehole geological section. The specific location of Weihe fault on the site of Weihe Bridge is determined, which provides a basis for seismic fortification and potential seismic source zoning of Weihe Bridge on State Highway 310 Xi'an Transit Highway.

1. Introduction
Weihe fault is a large fault that runs through the central and western part of Weihe basin, with a total length of 200 km. The near field area belongs to the eastern section of Weihe fault on the northern boundary of Zhouzhi-Huxian fault depression, and is also a section with strong activity of Weihe fault. "Xi'an City Active Fault Testing and Exploration" (Feng Xijie, 2008) and "Guanzhong Four City Seismic Zoning Project" (Chen Dangmin, 2011) have done a lot of ground investigation, shallow seismic, drilling and trenching work on the Weihe River fault. Based on the analysis of previous data, it is inferred that the Weihe fault passes through the site of the Weihe River Bridge on Jingwei Road, which is proposed to build 310 State Road, and may be located on the Bank of the Weihe River. Near, but the exact location is unknown. The concealed part of the fault needs to be further determined. Therefore, we adopt the method of high-density resistivity detection and combining with borehole geological section to explore the hidden fault in this section, and determine the specific situation of the fault in the site. The results of this work provide a basis for the division of potential seismic source area and seismic fortification of Weihe Bridge site on 310 Xi'an National Highway Transit Highway.

2. Weihe fault
The structure of the main active faults in the region is well developed. The strike of the fault is mainly NE-E and nearly E-W. followed by NE and NW. The location and characteristics of the faults are detailed in Figure 1 and Table 1.
The main active faults in the site area of Weihe Bridge Project are the Weihe Fault (F3). The distribution of faults and the activity of faults are detailed in Figure 2 and Table 2.
### Table 2. Brief Table of Main Faults and Their Activities in Site Area.

| Number | Fault name | Subsection       | Trend, Tendency, Inclination (°) | Intraregional length (Km) | The Latest Age of Activities | The closest distance between fault and site |
|--------|------------|------------------|---------------------------------|---------------------------|-----------------------------|------------------------------------------|
| F3     | Weihe fault | Eastern Sector   | Near EW S 70°                   | 95                        | Qh                          | Go through                               |

The site of Weihe Bridge of the proposed 310 Xi'an National Highway Transit Highway Project starts at the North Bank of Weihe River on Jingwei Road and ends at the river embankment on the South Bank of Weihe River. The total length of the bridge is about 1186 M. The main design parameters of the bridge are detailed in Table 3. The Weihe fault passes through the site, but its specific location is unknown. This paper mainly explores the fault and determines the specific situation of the fault in the site.

### Table 3. Overview of the proposed Weihe River Bridge.

| Bridge name                        | Pile number of starting point and end point | Bridge width (m) | Highest bridge height (m) | total length of bridge (m) |
|------------------------------------|--------------------------------------------|-----------------|--------------------------|---------------------------|
| Weihe River Bridge on Jingwei Road | K39+152.5-K40+338.5                         | 16.0            | 15.0                     | 1186.0                    |

### 3. Detection of Weihe River Fault by High Density Electrical Method on Weihe River Bridge Site

The specific location of the Weihe fault crossed from the site area is unknown. First, we use high-density electrical prospecting to determine the specific location of the fault. We have laid an electrical survey line from north to South on the Bank of the Weihe River. The distance between measuring points is 6m, the length of the line is 64 points, and the length of the line is 378m, as shown in Figure 3.
Flash RES64 ultra-high density electrical meter produced by Australian R&D center is selected for testing. After field testing, the apparent resistivity data collected in the field are inverted and forward calculated with flashres64 software to eliminate various interference factors, and a smooth resistivity contour is obtained. The test results are shown in Figure 4.

![Figure 4. The results of apparent resistivity measurement by high density resistivity method.](image)

It can be seen from the profiles and image maps of the ρs isoline that in the range of test depth, the upper lithology is not uniform, resulting in the disorder of the local resistivity isoline of the surface layer. There are obvious resistivity differences at 200 meters (the position of the red dotted line). The resistivity of the left side of the dotted line is about 50Ω•m, while that of the right side is about 350Ω•m. Judging from the whole contour profile, the stratum at 200 meters of the survey line is discontinuous and the resistivity anomaly is obvious. It is inferred that there may be a fault passing through here, and the corresponding highway mileage is about K39+580. Its exact location needs further verification by drilling.

4. Drilling exploration and data analysis in site
According to the test results of high density electrical method, four boreholes (Figure 3) are laid from north to south near the anomaly of electrical method, namely, ZK-4, ZK-5, ZK-6 and ZK-2. Combining with the drilling strata of XK-6 boreholes in the geotechnical engineering survey data of 310 Xi’an transit highway, the vertical section map of boreholes of Weihe Bridge on Jingwei Road is drawn (Figure 5).
From the graph, it can be seen that the silty clay layer is discontinuous in depth of 2.8-15m and elevation of 357.7-349.3m. It is absent in borehole ZK-4 and mileage K39+560 (near faults). There are obvious vertical displacement phenomena in the silty clay layer between borehole XK-6, mileage K39+518 and borehole ZK-5 and mileage K39+590. The elevations of the top and bottom of the north side of the fault are 357.7m and 354.2m, respectively. The elevations of the south side of the fault are 352.3m and 349.3m, with a relative height difference of 4.9m-5.4m. The south side descends and the north side rises relatively. It is a normal fault inclined to the south. Its characteristics are consistent with the activity characteristics of Weihe fault. It shows that the Weihe fault extends eastward from Yaodian and Zhangjiawan to the site of Weihe Bridge. It is located between borehole XK-6 and borehole ZK-5, near borehole ZK-4, and its mileage is about K39+554 (corresponding longitude and latitude 34.4385, 109.0018), and its north-south error is about 20m. This result is basically consistent with that of high density electrical method. According to the stratigraphic structure, the silty clay is the alluvial facies stratum of early Late Pleistocene, so the fault activity time is Late Pleistocene.

5. Conclusion
According to the comprehensive analysis of high density resistivity test results and borehole geology, the distribution of Weihe fault in Weihe Bridge site is as follows: Weihe fault crosses the site at K39+554 mileage of Pile No. of Weihe Bridge at 310 Jingwei Road, National Highway, and the active time of the fault is Late Pleistocene. It is suggested that the necessary engineering treatment should be
carried out for this fault according to the importance of the project during the construction period to avoid the impact of ground dislocation on the project.

Acknowledgement
This study is financially supported by China Seismological Array Exploration - Central North China Region (No. DQJB16A03-XX).

References
[1] Bian, J.M., (2015) Earthquake Safety Assessment Report of National Highway 310 Xi'an Transit Highway Project Site. Engineering Report. Earthquake Administration of Shaanxi Province.
[2] Chen, D.M., (2011) Seismic microzonation of Xi'an City. Engineering Report. Earthquake Administration of Shaanxi Province.
[3] Feng, X.J., (2008) Report on active fault detection and seismic risk assessment in Xi'an City. Engineering Report. Earthquake Administration of Shaanxi Province.
[4] (2005) Seismic Safety Assessment of Engineering Sites (GB17741-2005). Standards Press of China, Beijing.