A Harmonized Probabilistic Seismic Hazard Assessment for Northern China-Pakistan Economic Corridor

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Abstract
The China-Pakistan Economic Corridor (CPEC) has many strong earthquakes and tectonic activities. In recent years, different probability seismic hazard assessment (PSHA) projects has been done around the area. This paper made a harmonized PSHA for this area. This paper concluded that in the most areas of northern CPEC, the Peak Ground Acceleration (PGA) with 10% probability of exceedance in 50 years is around 0.2g~0.3g, and northern Pakistan has the highest seismic hazard along the northern CPEC.

Keywords: China-Pakistan Economic Corridor; Seismic hazard; Model harmonization; Peak Ground Acceleration

1. Introduction
Strong earthquake ground motion can cause destruction of the buildings, and lead to earthquake disasters. It is of great help to prevent earthquake disasters by providing appropriate seismic fortification parameters for structural design. Therefore, seismic hazard and risk assessment has important practical and social value.

Different institutions have made Probabilistic Seismic Hazard Assessment (PSHA) works in different areas. Therefore, along those area borders, there may be several PSHA results because different institutions may use different PSHA methods and build different hazard models. If we want to get a harmonized PSHA result for the whole area, we should do seismic hazard model harmonization at the borders. This is what we managed to do in this paper.

We took the northern part of the China-Pakistan Economic Corridor (CPEC) as the study area (Figure 1). The CPEC connects Xinjiang and Pakistan, and is an important economic way in the One Road One Belt Project. The northern part of CPEC is in Tianshan-Karakoram area, and is situated at the center of Eurasia Continent, where has...
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many tectonic activities. Three PSHA results have been made in this area, which are PSHA for Central Asia, the Middle East and China respectively. Northern CPEC is right at the intersection of these areas, and different projects give different hazard results in the same area. Consequently, it is meaningful to make a harmonized PSHA in the area.

Bindi et al. (2012) conducted a PSHA study in Central Asia. In this study, area source model is used. The seismicity model only considers shallow earthquakes with focal depth less than 50 km. Seismic hazard parameters use macro-seismic intensity. The study used OpenQuake to produce a intensity distribution with 10% probability of exceedance in 50 years of the Central Asia (Figure 2). The results show that the intensity of VII in the region with the highest seismic hazard in Central Asia is less than 475 years in the vicinity of the South Tien Shan area.

In 2005, Danciu et al. (2015) made PSHA for the Middle East. They weighted averaged the hazard result by area source model and fault source model, and got a hazard map of Peak Ground Acceleration (PGA) with 10% probability of exceedance in 50 years of the area (Figure 3).

In 2016, the fifth version of Seismic Hazard Map of China (Figure 4, GB 18306-2015) was published. This map shows seismic hazard with 10% probability of exceedance in 50 years of China. And there have also been other researches on seismic hazard of China (Yan et al., 2013).

Fig. 1 Study area – Northern CPEC

Fig. 2 Intensity map with 10% probability of exceedance in 50 years of Central Asia (Bindi et al, 2015)

Fig. 3 Seismic hazard map of PGA with 10% probability of exceedance in 50 years of the Middle East

Fig. 4 The fifth version of Seismic Hazard Map of China (GB 18306-2015)
Thanks to the cooperation between ETH Zurich, Global Earthquake Model (GEM) Foundation and Institute of Geophysics, China Earthquake Administration (CEA), we were able to work together and engaged in producing a harmonized seismic hazard map in Northern CPEC. The work will be introduced below.

2. Seismic Hazard Model Harmonization for Northern CPEC

Seismogenic source model

Central Asia

Seismogenic source model in Central Asia is built by the project of Earthquake Model of Central Asia (EMCA, Bindi et al. 2012), as shown in Figure 5. Central Asia is separated into ten seismic belts (in thick red lines) and 131 seismogenic sources (in thin red lines) in total.

The Middle East

Seismogenic source model in the Middle East is built by the project of Earthquake Model of the Middle East (EMME, Danciu et al, 2015), as shown in Figure 6. The Middle East Area is separated into three tectonic types: Active Shallow Crust (ASC, in white), Stable Continental Crust (SCC, in gray) and Subduction Intraslab (SI, in brown). In the Middle East, there are 213 ASCs, eleven SCCs and six SIs in total.

Source model harmonization

We can see sources by three institutions in Northern CPEC as shown in Figure 9. To do harmonization, we managed to delete entire pieces of overlapped sources as shown in Figure 10. Then we sew the edges and gaps, as shown in Figure 11.
Changing seismicity parameters

For the sources whose areas are changed, their seismicity parameters should also be changed. For one source, it has $a$-value and $b$-value according to Gutenberg-Richter relationship. We suppose its original $a$-value is $a$, and $a'$ after changing. Then $a'$ can be calculated by

$$a' = \lg(10^a \cdot \frac{S'}{S})$$

(1)

Where $S$ and $S'$ are source’s areas before and after harmonization. Then we get a harmonized source separation of South Tienshan as shown in Figure 12.

Choosing Ground Motion Prediction Equation (GMPE)

The harmonized source model should use the same GMPE model. We chose Yu et al. (2013)’s GMPE which is used in Seismic hazard map of China. The equation is as follows:

$$\lg Y = A + BM + C \lg (R + D e^{EM})$$

(2)

where $Y$ is ground motion parameters, $M$ is magnitude, $R$ is epicenter, $A$, $B$, $C$, $D$ and $E$ are constants.

Seismic hazard result

The seismic hazard map of PGA with 10% probability of exceedance in 50 years of Northern CPEC by harmonized model is shown in Figure 13. From the hazard map, we can find western part of Northern CPEC has the highest seismic hazard. In Central Xinjiang and the center of Central Asia, seismic hazard is low.
3. **Conclusion**

From the study above, we can get several conclusions as follows:

1. Western part of Northern CPEC has the highest seismic hazard.
2. In Central Xinjiang and the center of Central Asia, seismic hazard is low.
3. In Northern Xinjiang and Northern Kazakhstan, Seismic hazard is low.

There are also some topics that need discussion:

1. When dealing with seismicity parameter harmonization, we took a simple way that change a source’s parameter according to its area change with the assumption that the seismicity is the same on unit area. There is also a more precise way that using earthquake catalog to get the seismicity parameter.
2. Along borders, different models lead to different hazard result for the same place. The reason of the difference needs more study in the future.
3. We took the GMPE of Yu et al. (2013) as the harmonized GMPE. It needs to study if it is the most suitable one.

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**Reference**


