Preliminary Evaluation of Crustal Medium Parameters in Western China

Xingqun Zheng[1a*], Zhengru Tao[1b*]

[1]Key Laboratory of Earthquake Engineering and Engineering Vibration, Institute of Engineering Mechanics, China Earthquake Administration, Harbin 150080, China

Abstract. The establishment of attenuation relation of ground motion is always an important research content in engineering earthquake field. In seismology-based ground motion attenuation relationship and ground motion simulation using the stochastic method, regional parameters are necessary. These parameters involve stress drop $\Delta\sigma$, two segmentation points R_1 and R_2 of the geometric spreading item, Q_0 and η of the inelastic attenuation item and the near-surface high-frequency decay parameter κ_0, which reflect the regional crustal medium and site characteristics and have little relation with the earthquake size. In this paper, we take Sichuan, Yunnan and Xinjiang regions in western China as examples and we inverse the parameters for each region by micro-genetic algorithm. The inversion ranges of crustal media parameters in the three regions were determined respectively. Finally, we get the inversion results of every parameters and find that the parameters of the three regions have a great difference.

1 Introduction

Generally, the characteristics of ground motion are expressed by amplitude, duration and spectrum characteristics. The attenuation relation of ground motion expresses the influence of three main factors on ground motion: source, propagation path and site condition, which is an important research direction of engineering seismology. In seismic hazard analysis, it is necessary to estimate the expected ground motion of engineering site with the help of such relations.

In essence, attenuation relationship is empirical and based on the observation data of strong ground motions. Although China is a country prone to earthquakes and has the earliest recorded earthquake history in the world, in the early 1980s, with the development of digital strong earthquake observation technology, digital strong seismometer was introduced.

With the development of strong earthquake network[1] and the earthquake activity in recent years, the data amount of strong earthquake database in China is increasing gradually. In the regions with abundant strong earthquake records, some researchers have tried to directly establish the regional attenuation relationship by statistical regression of regional earthquake data, but some results are limited by insufficient data and have low reliability. We provided the seismology-based ground motion prediction models [29]-[30], in which the regional parameters were inversed by small earthquake data of the broadband seismological network. In this paper, we attempt to use limited strong motion data in the inversion.

2 Data and processing

The seismicity in Sichuan area (97°21 '-108°31' E, 26°03 '-34°19' N), Xinjiang area (73°40 '-96°23' E, 34°22 '-49°10' N) and Yunnan area (97°31 '-106°11' E, 21°8 '-29°15' N) is more active in China. The distribution of strong motion stations and epicenters in each study area is shown in the figure 1-6.

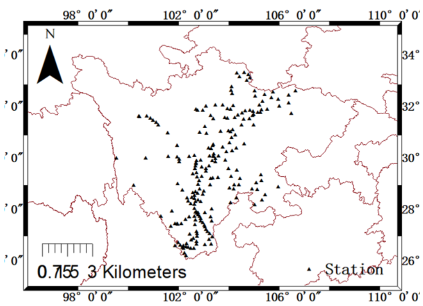

Figure 1. Station distribution in Sichuan area

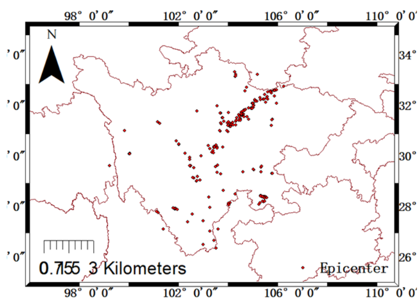

Figure 2. Epicentral distribution in Sichuan area

a*1754453830@qq.com, b*taozr@iem.ac.cn

 https://doi.org/10.1051/e3sconf/202340601003

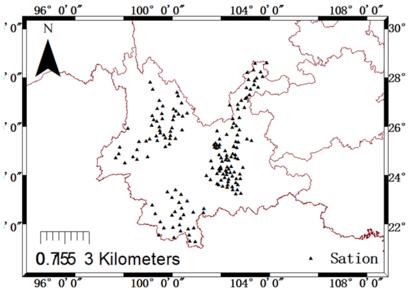

Figure 3. Station distribution in Yunnan area

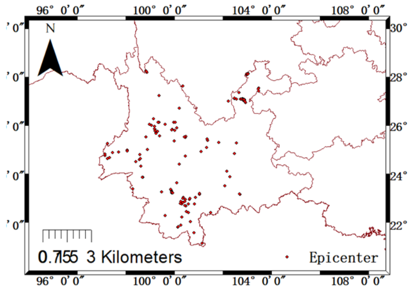

Figure 4. Epicentral distribution in Yunnan area

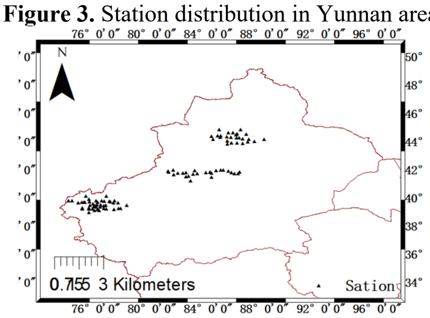

Figure 5. Station distribution in Xinjiang area

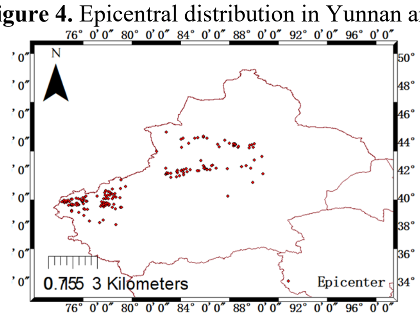

Figure 6. Epicentral distribution in Xinjiang area

A total of 19,137 records were collected from the National Strong Earthquake Network Center in the three study areas. These include 8,373 strong earthquakes records at 334 stations in Sichuan area and 4713 strong earthquakes records at 167 stations in Xinjiang area, and 6051 strong earthquakes records at 429 stations in Yunnan area. The strong motion data are all acceleration records, with the time interval of 0.01s or 0.005s. The 30s main shock section after the arrival of S wave is selected as the research object.

Earthquake magnitude is a relative measurement of earthquake size. The earthquake magnitude used in this paper is moment magnitude M_w, while the seismic records collected give surface wave magnitude M_S. Therefore, the seismic moment M_0 is obtained according to equation (1), and then the moment magnitude is calculated according to equation (2).

$$\lg M_0 = M_s + 16.1 \tag{1}$$

$$M_w = \frac{2}{3lgM_0} - 10.7 \tag{2}$$

The distance used in this paper is hypocentral distance. According to the longitude and latitude information of stations (X_1, Y_1, Z_1) and the epicenter (X_2, Y_2, Z_2) provided in the records, it is converted into geodetic coordinates by equation (3), and then the epicentral distance is obtained by equation (4). According to the focal depth of each earthquake, the corresponding hypocentral distance can be easily obtained.

$$\begin{cases} X = r \times sin\theta \times cos\varphi \\ Y = r \times sin\theta \times sin\varphi \\ Z = r \times cos\theta \end{cases} \tag{3}$$

where r is the radius of the earth, and the value is 6370km; φ is the longitude (°); θ is 90° -latitude (°).

$$R = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2 + (Z_1 - Z_2)^2} \tag{4}$$

After the above processing, all the data were screened out as M_W= 3.5 - 5.5, signal-to-noise ratio greater than 3, and each station had at least 3 strong earthquake records. The data were preprocessed by baseline correction, filtering, S-wave extraction and other operations to form the strong motion database of small earthquakes. The data distribution in each study area is shown in figure 7-12.

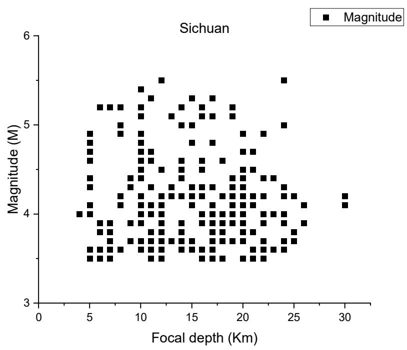

Figure 7. M_W - focal depth distribution in Sichuan area

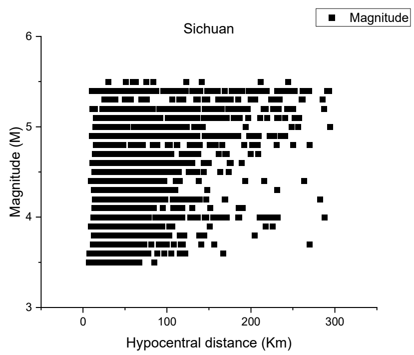

Figure 8. M_W – hypocentral depth distribution in Sichuan area

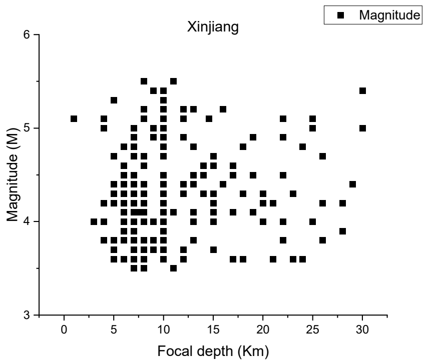

Figure 9. MW - focal depth distribution in Xinjiang area

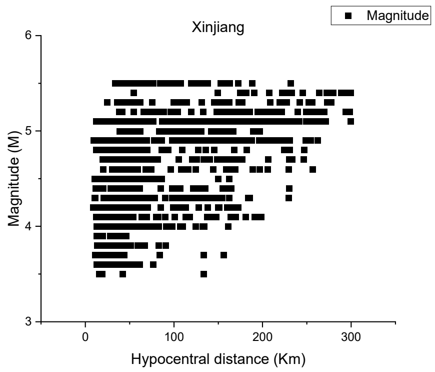

Figure 10. MW – hypocentral depth distribution in Xinjiang area

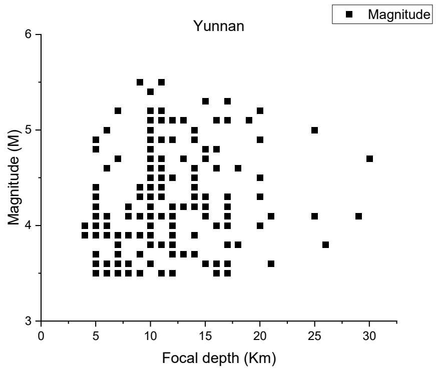

Figure 11. MW - focal depth distribution in Yunnan area

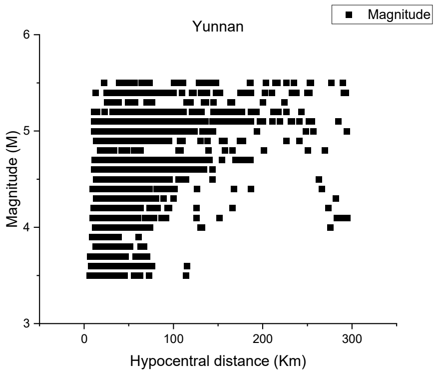

Figure 12. MW – hypocentral depth distribution in Yunnan area

3 Regional parameter inversion

3.1 Determination of inversion range

The efficiency of inversion depends on the search range of each parameter. If the range is too large, the search speed will be slow; if the range is too small, the optimal solution may not be covered and the inversion will fail. In this paper, the search scope of six regional parameters is determined based on the numerical expansion of other seismological results. Published values of stress drop, quality factor and κ_0 for three regions from various sources [2]-[24] are collected to determine the ranges of inversion parameters for each region, as shown in Table 1.

The two geometric attenuation parameters are related to regional crustal structure and are seldom studied in China. For the western United States, a three-section expression, with segment point R_1 with 70km±5km, and R_2 with 130km±10km, is used [25]-[28], which can be taken for reference.

Table 1. Inversion ranges of parameters in each region.

Region	**Δσ (bars)**	**κ_0 (s)**	**Q_0**	**η**	**R_1(km)**	**R_2(km)**
Sichuan	40-200	0.01-0.08	90-400	0.5-1.1	50-100	100-150
Yunnan	40-200	0.01-0.08	150-300	0.2-0.7	50-100	100-150
Xinjiang	1-220	0.01-0.08	150-500	0.4-0.8	50-100	100-150

3.2 Inversion Results

In this paper, three administrative regions were first used for inversion of the parameters sorted out above. The inversion results are shown in Table2.

Table 2. Inversion results in each administrative region.

Region	**Δσ (bars)**	**κ_0(s)**	**Q_0**	**η**	**R_1(km)**	**R_2(km)**
Sichuan	113.4310	0.0445	294.9536	0.7821	78.6776	116.6680
Yunnan	92.4870	0.0452	240.0641	0.5538	77.6925	135.5043
Xinjiang	65.0083	0.0654	331.5061	0.6811	79.1897	130.1730

By comparing the inversion results, it is not difficult to see that the parameters of the three regions are different. Two segmentation points R_1 and R_2 of the three study areas are similar. But stress drop and quality factor of the three study areas have a great difference.

4 Conclusion

This paper is only a preliminary study by the limitation of data, in which site condition is absence and station location need to be corrected further. We discuss the practicability of parameter inversion by strong ground motion records of small earthquakes. Based on the research in this paper, it is not difficult to infer that the seismic energy attenuation rate in Xinjiang region is faster, and the overall Moho depth in three regions is similar. We will carry out an overall study on western China and compare it with the research results in this paper. Based on this paper, the parameters of crustal medium obtained by us play an important role in establishing the attenuation relation of ground motion in western China. By considering the site condition of stations and corrected station location, the inversion of regional parameters need to be investigated in the future.

Acknowledgments

This work was supported by National Natural Science Foundation of China (Grant No. 51678540, 51478443 and 51178435). Data for this study are provided by Institute of Engineering Mechanics, China Earthquake Administration.

References

1. Li X J 2015 *Seismological and geomagnetic observation and research*. **36(04)**: 2.
2. Wang H W, Ren Y F and Wen R Z 2017 *Chinese journal of geophysics*. **60(10)**: 4117-4123.
3. Fu L, Li X J and Rong M S et al. 2018 *Acta seismologica sinica*. **40(03)**: 374-386.
4. Fu L and LI X J 2017 *Chinese journal of geophysics*. **60(08)**: 2935-2947.
5. Liu L F, Su Y J and Liu J et al. 2010 *Earthquake research*. **33(03)**: 314-319.
6. Wang Z Y, Zhao P P and Bo J S et al. 2017 *Earthquake engineering and engineering vibration.* **37(02):** 10-15.
7. Wen R Z, Wang H W and Ren Y F et al. 2015 *Journal of Harbin Institute of Technology*. **47(04)**: 58-63.
8. Hu Y X and Zhang M Z 1984 *Earthquake engineering and engineering vibration*. **4 (01)**: 1-11.
9. Wang H W, Ren Y F and Wen R Z 2021 *Earthquake engineering and engineering vibration*. **9(02)**: 181-191.
10. Fu L, Li X J and Chen S 2019 *Journal of applied basic and journal of engineering science*. **27(6)**: 1294-1307.
11. Cong L L, Hu J F, and Fu Z W et al. 2002 *Science in China Series D: Earth Sciences*. **32(08)**: 617-624+705.
12. Zhao C P, Chen Z L and Hua W et al. 2011 *Chinese journal of geophysics.* **54(06)**: 1478-1489.
13. Zhou S H and Jiang H K 2017 *Earthquake research in China*. **33(01)**: 23-37.
14. Nan F F, Gong G B and Yang X et al. 2018 *Seismic and geomagnetic observation and research*. **39(06)**: 7-15.
15. Bao J Z, Wang S B and Zhang F 2016 *Earthquake Disaster Prevention Technology.* **16(02)**: 293-301.
16. Li J, Zhou L Q and Wang H L et al 2017 *Earthquake research in China*. **33(02)**: 229- 238.
17. Tang L L and Li Z H 2011 *Acta seismologica sinica.* **33(02)**: 134-142+270.
18. Li W Q, Wei B and He J G et al. 2017 *Earthquake research in China*. **33(01)**: 81-90.
19. Nirupal M M T S and AYi X G et al. 2016 *Journal of inland earthquake*. **30 (01):** 41-48.
20. Pan Z S, Liu H and Gu M J et al. 2010 *Northwestern seismological journal*. **32(04)**:357-362+410.
21. Li Z H, Zhu C Y and Xia A G et al. 2010 *Earthquake research in China*. **26(03)**: 340- 348.
22. Zhao C P, Xia A G and Zheng S H et al. 2005 *Earthquake Research in China.* **2005(01)**: 61-69.
23. Liu J M and Li Z H 2014 *Earthquake research*. **34(01)**: 77-86.
24. AYi X G, Nirupal M M T S and Zuripia B et al. 2015 *Plateau earthquake*. **27(01)**: 23-30.
25. Aki K 1980 *Phys. Earth planet.* **1(21)**:50-60.
26. Anderson J G and Hough S E 1984 *Bull. Seismological Soc. America.* **5(74)**:1969- 1993.
27. Boore D M 2003 *Pure Appl. Geophys*. **3-4(160)**: 635-676.
28. Atkinson G M and Boore D M 1995 *Bull. Seismological Soc. America*. **85(1)**: 17-30.
29. Tao Z R, Tao X X and Cui A P 2016 *Natural Hazards and Earth System Sciences.* **16(5)**:1145-1155.
30. Jiang W, Tao X X and Tao Z R 2022 *Soil Dynamics and Earthquake Engineering.* (**156**): 107220.