THE STUDY ON THE SEISMIC INTENSITY AND GROUND MOTION ATTENUATION RELATIONSHIP OF MODERATE EARTHQUAKE RISK ZONE

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ABSTRACT :
Earthquake ground motion attenuation relationship is the base of compiling seismic zoning map and evaluating seismic safety for engineering sites. Based on the seismic intensity data of the moderate earthquake risk zones in Central China, South China and Northeast China, the seismic intensity attenuation relationship of the moderate earthquake risk zones in China is obtained by regressive analysis. Then, taking the Western America where the ground motion records are abundant as reference region, the attenuation relationship is converted into the ground motion attenuation relationship of the moderate earthquake risk zones in China through the mapping conception. Compared with the attenuation rules in North China, the seismic intensity and peak ground motion acceleration of the moderate earthquake risk zones attenuate more slowly. For small earthquakes, when the distance to the epicenter is same, the seismic intensity and peak ground motion acceleration are larger than that of North China and the difference value decreases gradually as the earthquake magnitude increases.

KEYWORDS:
attenuation relationship, the moderate earthquake risk zones, the mapping conception

1.Introduction

Earthquake ground motion attenuation relationship can be adopted in estimating earthquake ground motion of the engineering sites. It plays a key role in compiling seismic zoning map of the ground motion parameter and is the indispensable fundamental relationship between the seismic safety assessment of engineering site and microzonation.

2.The determination of the attenuation relationship of the moderate earthquake risk zones

According to the historic and recent isoline data of strong ground motion, the attenuation relationship in the moderate earthquake zone where the strong ground motion record is lack is established.

When fitting the attenuation relationship by the earthquake isolines, the magnitude M and the intensity I are required to be measured independently. In this study the earthquake isolines of 51 earthquakes of northeast China, central China and south China are selected as the base of research. These earthquakes distribute as the Table.1 and the earthquake isolines totally come to 126.

Table.1 the distribution of the magnitude

M	<4	4-4.4	4.5-4.9	5-5.4	5.5-5.9	>=6	total
Number	5	5	12	15	8	6	51

2.1.The selection and the method of the intensity attenuation modal

The initial points of the attenuation curves are coincided because the attenuation begins from the same epicenter. In the middle distance the major axis of attenuation is different from the minor axis, while the attenuation curves go to coincidence at the far-field because the influence of the causative structure is disappearance. In this paper we selected the major-minor axis of the elliptic attenuation modal(Chen Da-sheng and Liu Han-xing, 1989):

$$I=a+bM+c_1\log(R_1+R_{0a})+c_2\log(R_2+R_{0b})+\varepsilon \quad (1)$$

I is the seismic intensity; M is the magnitude; R_{0a}、R_{0b} are the near-field saturation factors; R_1、R_2 are the length of the semi-major axis and the semi-minor axis of the elliptic isoline with the seismic intensity I; a、b、c_1、c_2 are the regression coefficients; ε is the random variable in the regression analysis.

Based on the modal above the elliptic attenuation modal of the seismic intensity is obtained.

We take the measure of complementing points to improve the distribution condition of the data in order to make the seismic intensity attenuation curve approaches to the fact at the near-field and the far-field. The morphology of the seismic intensity attenuation curve at the near-field and the far-field can be well controlled by fitting analysis after adding control data.

At the near-field, the intensity of the inner ring isoline is equal to the intensity of zone around the epicenter and this does not show the most seriously damage degree in the meizoseismic area especially in the zone around epicenter(the distance to epicenter less than 5 kilometers). To make the attenuation curve reflect this characteristic we complement some datas properly at the point with different distance to epicenter in the meizoseismic area and these points are called the near-field additional point. The intensity value of the additional point increases by 0.1 to 1 base on the intensity of inner ring isoline.

Additionally, to reflect the disappear of influence of the causative structure at the far-field and the attenuation form tending to be circular, we use the radius of the sensible range as the far-field control point and the sensible intensity value usually takes 3 to 4. It takes 3.5 in the calculation. This is called far-field additional point.

The relationship of the sensible range radius and the magnitude is shown in Table.2 (Wang Su-yun, 1993).

Table.2 the relationship of the sensible range radius(km) and the magnitude(M)

M	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8	$8\frac{1}{2}$
R	15	25	40	75	150	170	200	230	260	340	450	600	800	1100

The distribution of the number of the major axis and the minor axis of the isolines for each magnitude, distance to epicenter and intensity are shown in Table.3 to Table.5.

Table.3 the distribution of the number of the major axis
and the minor axis of the isolines for each magnitude

Magnitude	<4	4-4.4	4.5-4.9	5-5.4	5.5-5.9	>=6
Initial points	11	9	30	35	22	19
additional points	11	11	41	55	33	29

Table.4 the distribution of the number of the major axis and the minor axis of the isolines at each distance to epicenter

Distance	0-9.9	10-29.9	30-49.9	50-99.9	100-149.9	150-199.9	〉=200
Initial points	37	50	19	15	3	1	1
Additional points	51	56	20	18	19	8	8

Table.5 the distribution of the number of the major axis
and the minor axis of the isolines for each intensity

Intensity	III	IV	V	VI	VII	VIII
Initial points	4	21	38	37	20	6
Additional points	22	39	38	39	29	13

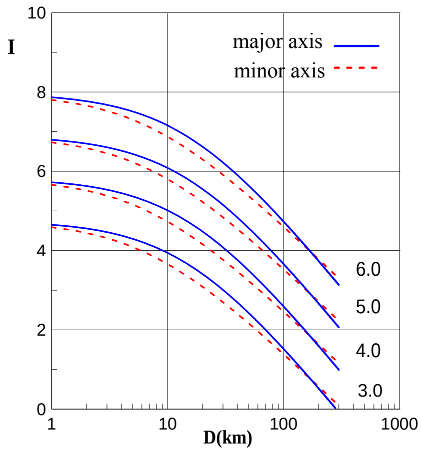
2.2.The fitting result of the earthquake attenuation relationship

Considering the nonuniformity of the spatial distribution of the data, we dispose the major axis and the minor axis data which have increased additional points at the near-field and the far-field by the magnitude weighted method and distance weighted method. After statistical calculation, we obtain the formula of the attenuation relationship of the moderate earthquake risk zones in China.

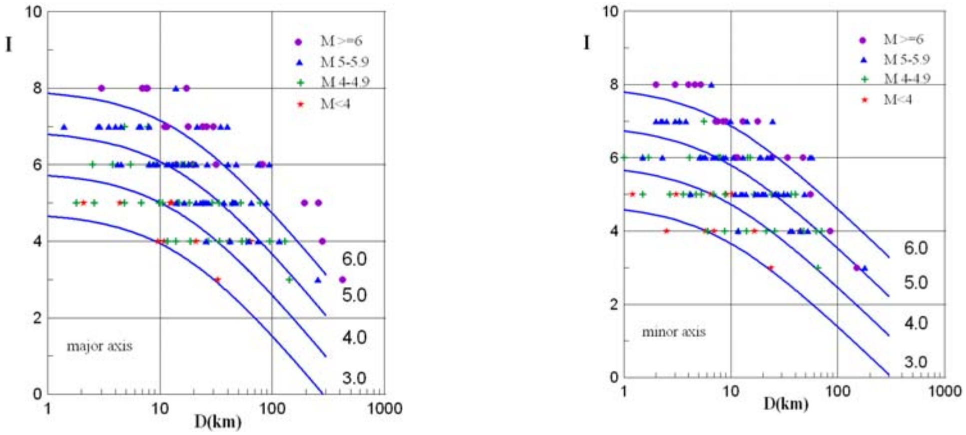
$$\text{Major axis:} \quad I_a = 5.841 + 1.071 \times M - 3.657 \times \log(R_a + 15) \tag{2}$$

$$\text{Minor axis:} \quad I_b = 3.944 + 1.071 \times M - 2.845 \times \log(R_b + 7) \tag{3}$$

The attenuation relationship of the moderate earthquake risk zones are shown in Fig.1.



(a)



(b) (c)

Fig.1 the attenuation relationship of seismic intensity at the moderate earthquake risk zones

3.The determination of the ground motion attenuation relationship of the moderate earthquake risk zones in China and the selection of the reference zone

We adopt the mapping method to determine the ground motion attenuation relationship of the moderate earthquake risk zones in China. The intensity attenuation relationship of the research region should be given for this method and a reference region which has intensity attenuation relationship and abundant strong ground motion records must be selected also. Firstly, we determine the intensity attenuation relationship of northeast China, central China and south China by the intensity data of these regions in this paper. Then, we set the Western America where the ground motion records are abundant and the intensity attenuation relationship is existing as reference region to convert to the ground motion attenuation relationship.

3.1.The mapping method

The mapping method is an earthquake pair mapping method put forward by Hu Yu-xian and Zhou Ke-sen that is a set of method to estimate the ground motion parameter by the intensity attenuation relationship of the research region. Its basic hypothesis is that the parameters magnitude, distance and intensity of the research region and the reference region have the mapping relationship such as the same magnitude or IR mapping, the same distance or IM mapping, the minimum distance distortion (twist) of the earthquake pair mapping, the minimum distance reversible equivalence distortion(twist) of the earthquake pair mapping, and so on. Then, the method make the ground motion parameter and the intensity at the value of M and R of the two regions are both equal.

3.2.The regression method of the ground motion

3.2.1 The improved two-step method

The improved two-step method does some improvement to the regression progress based on the two-step method. Its basic idea is following:

(1) The attenuation form of the ground motion parameter is similar to the region which has the same ground motion attenuation characteristic if the magnitude of the earthquakes are same. So, it can be disposed as the same earthquake if the magnitude is same.

(2) For the attenuation relationship formula (4)

$$\lg Y = c1 + c2\times M + c3\times M^2 + c4\times \lg(R + c5\times e^{c6\times M}) \quad (4)$$

when the magnitude is same,

$$\lg Y(i) - \lg Y(i-1) = c4\times[\lg(R(i)+R0) - \lg(R(i-1)+R0)] \quad (5)$$

According to the formula (5), we can obtain another set of $\triangle Y(m)$、$\triangle X(m)$ by disposing each record with some magnitude at the same way. The results are:

$$\triangle Y(m) = \lg Y(i+1) - \lg Y(i) \quad (6)$$

$$\triangle X(m) = \lg(R(i+1)+R0) - \lg(R(i)+R0) \quad (7)$$

The new formula can be obtained:

$$\triangle Y(m) = c4\times\triangle X(m) \quad (8)$$

That is making a subtracting to the different records of the magnitude on the same level, deleting the item concerned with M and only keeping R0 concerned with M. Supposing R0 is known, the record c4 of any magnitude will be a Fixed value. Therefore, we can regress c4 and R0 based no this. The value taking method of R0 is the same as two-step method which is put forward by Joyner and Boore in 1981. R0 is simply searched to make the regression variance of the formula (8) be the minimum value.

(3) After c4 and R0 are determined the regression formula comes to be:

$$LgY\text{-}D = c1+c2\times M+c3\times M^2 \quad (9)$$

$$D = c4\times \lg(R+R0) \quad (10)$$

This step dose a regression concerned with magnitude and realize the decoupling between magnitude and distance. Furthermore, the regression of the formula (10) has decreased the discreteness and all the seismic records have been used.

3.2.2 the regression method and the determination of the variance

This paper adopted the least square method of single random variable and the standard deviation (const logarithmic standard deviation) is confirmed by formula (11). σ_1 is the standard deviation of (8), σ_2 is the standard deviation of formula (9)

$$\sigma^2 = \sigma_1^2 + \sigma_2^2 \quad (11)$$

3.3.The intensity attenuation relationship and the ground motion relationship of the reference region

We selected the Western America as reference region where the ground motion records are abundant and selected the formula of Chandra(1979). Then, the epicenter intensity I_0 is changed into the magnitude M according to the relation between M and I_0 by Gutenberg & Richter(1956). The intensity attenuation relationship is following:

$$I=0.514+1.500M-0.00659R-2.014\lg(R+10) \quad \sigma=0.274, \ R<300km \quad (12)$$

R is the distance to epicenter, M is the magnitude, σ is the standard deviation.

The ground motion attenuation relationship of reference region is the acceleration fitting result of type II and type III (Huo Jun-rong,1989) of Western America.

The peak ground acceleration relationship of the reference region is:

$$\lg Y=-0.9350+1.2410M-0.0460M^2-1.9040\lg(R+0.3268e^{0.6135M})\sigma=0.1802 \quad (13)$$

Y is the peak acceleration.

The effective peak ground acceleration relationship of the reference region is:

$$\lg Y=0.6430+0.7000M-1.9050\lg(R+0.3268e^{0.6135M}) \quad \sigma=0.1801 \quad (14)$$

Y is the effective peak acceleration.

3.4.The fitting result of the ground motion acceleration relationship

Based on the methods and data above, we obtained the PGA and EPA attenuation relationship which are shown in Table 6, Table 7, Fig.2 and Fig.3.

Table 6 the coefficient and the standard deviation

of the type III PGA of the moderate earthquake risk zones in China

	c1	c2	c3	c4	c5	c6	σ
Major axis	1.4118	0.7711	-0.0234	-2.0293	0.950	0.450	0.085
Minor axis	0.7695	0.7870	-0.0250	-1.7815	0.450	0.500	0.130

Table 7 the coefficient and the standard deviation

of the type II EPA of the moderate earthquake risk zones in China

	c1	c2	c3	c4	c5	c6	σ
Major axis	2.9793	0.6247	0.0	-2.5682	2.789	0.451	0.134
Minor axis	1.8440	0.4804	0.0	-1.7870	1.046	0.451	0.084

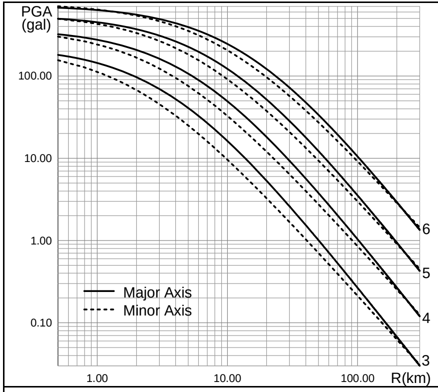


Fig.2 the PGA attenuation relationship of moderate earthquake risk zones

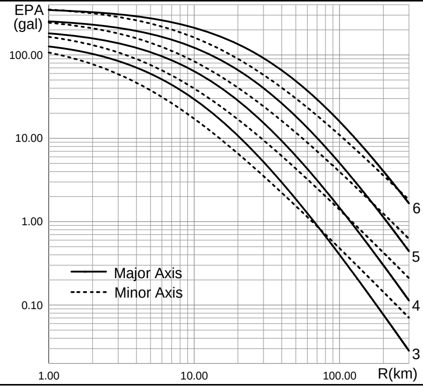


Fig.3 the EPA attenuation relationship of moderate earthquake risk zones

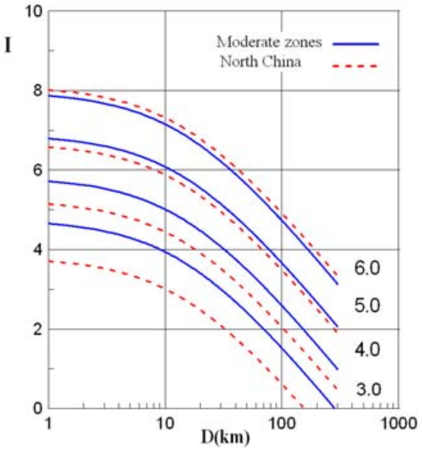
4. Comparison analysis and conclusions

We made a contrast between the attenuation of moderate earthquake risk zones from this study and that of North China. The comparison curves are shown in Fig 4 and Fig 5.

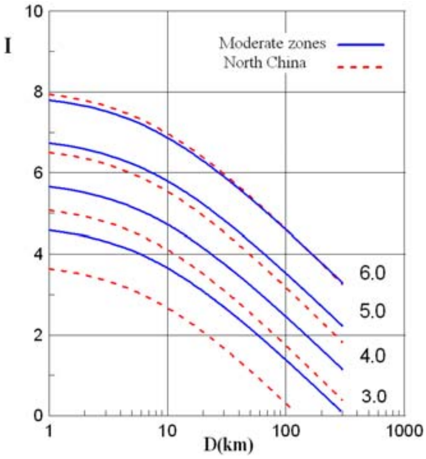
The intensity attenuation relationship of North China is:

$$\text{Major axis: } I_a=3.758+1.434\times M-3.613\times\log(R_a+15) \quad (15)$$

$$\text{Minor axis: } I_b=2.008+1.434\times M-2.958\times\log(R_b+7) \quad (16)$$



a）Major axis



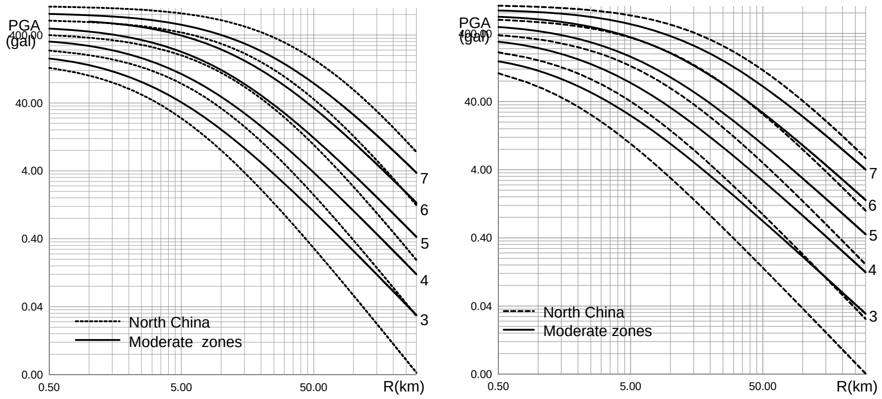
b）Minor axis

Fig.4 Comparison of the intensity attenuation relationship to North China

The coefficient and the standard deviation of the type Ⅱ PGA attenuation relationship of the North China are shown in Table 8.

Table 8 The coefficient and the standard deviation of the type Ⅱ PGA attenuation relationship of North China

	c1	c2	c3	c4	c5	c6	σ
Major axis	1.164	0.846	0.0	-2.446	0.627	0.612	0.260
Minor axis	0.207	0.808	0.0	-2.026	0.183	0.703	0.260



a) Comparison of major axis to North China   b) Comparison of minor axis to North China

Fig.5

Through the comparison we can see that the intensity value of the moderate earthquake risk zones is obviously greater than that of North China for the small magnitude when the distance to the epicenter is same. The difference of the intensity value decreases gradually with the increasing magnitude and the value of the moderate earthquake risk zones can be lower than that of the North China when the magnitude is at a high level. The PGA value of the moderate earthquake risk zones attenuated slowly at the far field and it is greater than that of the North China when the magnitude is low. The difference decreases gradually with the increasing magnitude. The PGA value is lower than that of the North China when the magnitude is at a high level.

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