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AN EXAMPLE OF SEISMIC RISK ANALYSIS IN BEIJING

Hao Xiansheng[1] and Gao Yanping[2]

[1]Graduate School at Nagatsuta, Tokyo Institute of Technology
4259 Nagatsuta, Midori-ku, Yokohama 227, Japan
[2]Central Research Institute of Building & Construction, MMI, China
43 Xueyuan lu Road, Beijing, China

SUMMARY

An accurate comparison in results of estimate seismic risk analysis between fault rupture model (Der Kiureghian & Ang,1977) and point source model (Cornell, 1968) is presented for the city of Beijing. A new function, defined as the shortest distance from epicenter to earthquake fault, is presented in order to distinguish each fault from all of other faults. A method of converting the attenuation law of Modified Mercalli Intensity into peak ground acceleration is developed. The analysis shows that the results obtained from fault rupture model are larger and more reasonable than those from point source model .

INTRODUCTION

China has suffered the world's worst earthquake damage (nearly 1 million died in this century). Beijing is located in a seismic active area, where strong earthquakes have occurred, such as 1679 Shanhe earthquake, M8.0; 1966 Xintai earthquake, M7.2; 1976 Tangshan earthquake, M7.8; etc.(see Fig.1). Since an unexpected earthquake hit Tangshan, in 1976, more serious attention has been focused on the problem to estimate seismic hazards in Beijing area. All the available data from a detail investigation in seismological geology, provided a seismic active faults map in this area. In order to use all the information from numerous faults, a distance function is used to simply distinguish each fault, which is responsible for the earthquakes nearby.

Due to long history of China, many earthquake records in Chinese character can be obtained from the catalogue of Chinese earthquake, from 780,B.C. to 1986 A.D. On the other hand, a few observation data of strong earthquake acceleration records exist for recent years. Basic condition of probabilistic analysis needs great quantities of high quality data, it seems that there are good quantities but low quality of data in China. It is insufficient to use the acceleration attenuation laws. Hence, a method of conversion of attenuation law of Modified Mercalli Intensity (MMI) into that of peak ground acceleration (PGA) is developed.

DIFFERENCE BETWEEN TWO MODELS IN PROCEDURE AND THEORY

Both models of point source (Ref.2) and fault rupture (Ref.1) are used in the probabilistic seismic risk evaluation. Based on the implicit assumption of point source model, the energy of earthquake radiates from a focus in all directions in well distribution. Since point source model modified an uncertainty of attenuation functions and had highly effective calculation speed, especially in the microzoning of seismic parameters, it was widely used in the world. But some problems in the model need to be solved. For instance, it could not deal with a fault line source which is very near a considered site. Instead of that, a long and narrow area source is used to simulate a long fault line, so that numerical instability can occur sometimes.

A fault rupture model, which implicitly assumes that an earthquake originates at the focus and propagates as an intermittent series of fault rupture or slips in the rupture zone of the Earth's crust, can be an improvement in the problems above mentioned and concerned with a random function between fault rupture length S and magnitude M.

The difference procedures and theorem are given as Tab.1.

Tab. 1

	Point Source	Fault Rupture
Tectonic Model	No Rupture	Rupture Length $S=\exp(a*M-b)$
Attenuation Law	Mean Radius R_p	Shortest Radius R_f
Source Geometry	Areas	Lines and Areas

where a = 1.0965; b = 3.6184

The contents and parameters are different although some of analysis procedures for both models consists of same parts as follows:

1) Determine and zone potential seismic subsources by seismogeology.
2) Select an earthquake occurrence model by Poisson's distribution model.
3) Select parameters in seismology and geophysics as follows:

.Earthquake magnitude recurrent curve and relationship between magnitude and frequency in potential subsources.

.Mean rates of occurrence for different magnitude earthquakes $M_i > M$ in every subsources.

.Maximum magnitude M_u and minimum magnitude M_o ,which could be happened in future.

.The attenuation equations of MMI ,acceleration and response spectra which suited to the local condition.

.The uncertainties correction in analysis for some parameters, e.g.,Log normal function for acceleration and normal function for MMI.

.A relation between magnitude M and epicenter intensity MMI is
$I = 1.52*M - 1.4848$.

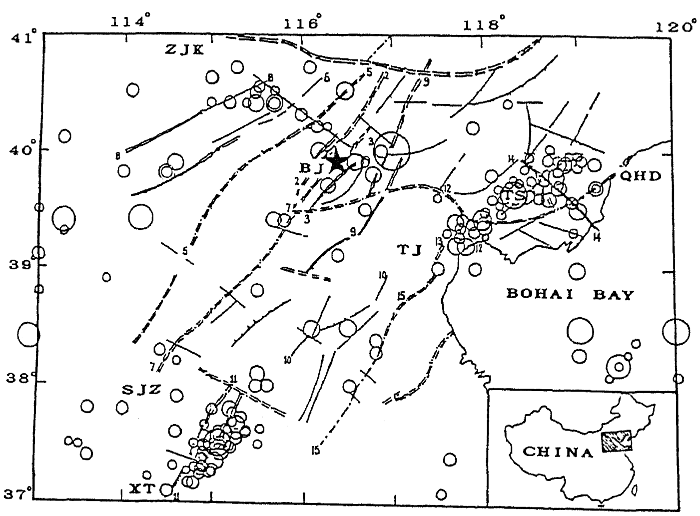

Fig.1 Epicenters and Faults around Beijing

ACCELERATION ATTENUATION LAW DERIVED FROM CONVERSION

A few observation data of strong earthquake acceleration records have been obtained in recent years. Since basic condition of probabilistic analysis needs great quantities and high quality of data, it seems that there are good quantities but low quality of data in China. It is insufficient to use the acceleration attenuation laws. Hence, a method of converting the attenuation law of MMI into PGA is developed.

The attenuation function of MMI, $I_b(M,R)$, is obtained from regression analysis among 19 isoseismal maps during strong earthquakes in the region "b", in where there are a few acceleration data. A distance R can be the shortest radius distance R_f from epicenter to earthquake fault by fault rupture model, or can be mean radius distance R_p by point source model.

In region "a", with a well known attenuation law, PGA attenuation function $Y_a(M,R)$ and MMI attenuation law $I_a(M,R)$ can be obtained.
e.g. $\mathrm{Ln}\, Y_a(M,R) = A + B*M + C*\mathrm{Ln}(R)$; $I_a(M,R) = A + B*M + C*\mathrm{Ln}(R)$.

<u>Method 1</u> An implicit function $I_a(R_o,Y)$ can be given from $Y_a(R_o,M)$ and $I_a(R_o,M)$. Then, an attenuation law $Y_b(M,R_o)$ will be known with $I_a(R_o,Y_a)$ and $I_b(R_o,M)$. We assume that ground motion parameters, such as PGA, are same among common regional conditions with same MMI and same hypocentral distance (Refs.7,8, see the right of Fig.2).

<u>Method 2</u> If a implicit function $I_a(M_o,Y)$is given from $Y_a(R,M_o)$ and $I_a(R,M_o)$, then, an attenuation law $Y_b(M_o,R)$ can also be got with $I_a(M_o,Y_a)$ and $I_b(M_o,R)$. It is an implicit assumption that ground motion parameters are the same among common regional conditions with same MMI and same magnitude (Refs.6,8, see the left of Fig.2).

Those parameters (see Tab.2) converted by means of the methods 1 and 2 as an attenuation equation form is similar.

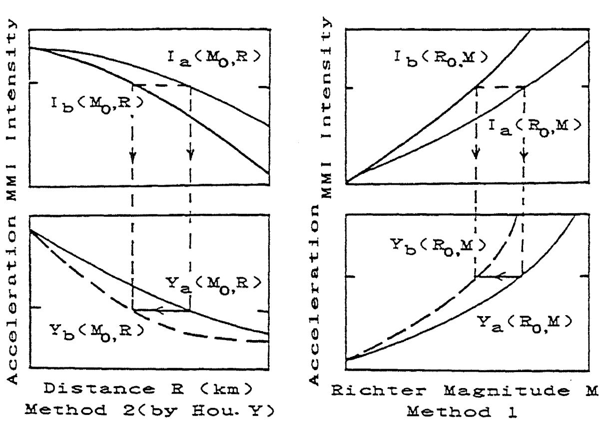

Fig.2 A Conversion Method of Attenuation law as Lack Strong Earthquake Acceleration Data

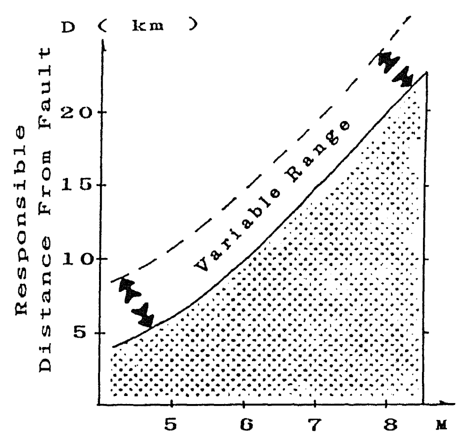

Fig.3 A New Definition of the Earthquake Fault

A NEW DEFINITION OF EARTHQUAKE FAULT IN SEISMIC RISK ANALYSIS

From the detail geological investigation, numerous faults were found in the geological structure map in the area. For the scale of fault: there are small, middle, large, super earth crust faults. For activity: there are active from Tertiary, Quaternary, and recently active faults. Sometime it is difficult to

Tab.2

	A	B	C	γ	δ	Convert	Fig. 8, 9
MMI I_b R_f	2.940	1.4047	1.501	0.9239	0.6116		NO. 1
MMI I_b R_p	2.308	1.5638	1.584	0.9411	0.5370		NO. 2
MMI I_a	-0.753	1.942	1.29	-	-		(Result
PGA Y_a	3.2	0.89	1.17	-	0.62		Curve)
PGA Y_b R_f	4.709	0.644	1.267		0.68	Method 1	NO. 3
PGA Y_b R_f	6.186	0.403	1.361		0.831	Method 2	NO. 4
PGA Y_b R_p	4.419	0.717	1.305		0.677	Method 1	NO. 5
PGA Y_b R_p	5.613	0.547	1.437		0.789	Method 2	NO. 6

where b: a region where attenuation law of PGA is unknown;
a: a region where attenuation laws of PGA and MMI are well known;
f: shortest radius distance by fault rupture model;
p: mean radius distance by point source model.

determine which fault, among several faults in the vicinity, triggered the earthquake. The full information about all faults with earthquake can be proceeded as follows:

There are 3 cases. Case 1, most of the epicenters are located near a fault or a set of faults. Case 2, some of epicenters are located within an area where no or unknown fault structures. Case 3, there are some of faults without any epicenters distributed nearby.

Case 1, According to the earthquake mechanics of shallow sources, an earthquake is triggered by slipping and moving of a fault or a set of faults . Therefore, the fault or the set of faults should be responsible for the earthquake. A responsible shortest distance from a fault to an earthquake epicenter increases with Richter earthquake magnitude. The distance function by statistics is presented to simply distinguish each fault , which triggered earthquakes and could be called **Earthquake fault**, from others (see Fig.3). Considering the uncertainty of the location of earthquake epicenters in history record, the minimum limit can be given, but the upper limit can vary in 2-3 times dependence on region and history record. For those faults, a fault line source can be used in analysis.

Case 2, there may be a potential zone of the crust containing numerous active faults with no dominant orientation, or the location as well as orientations of the faults are completely unknown. An area source can be used in analysis.

Case 3, It is difficult to deal with the relation between the fault and earthquake.

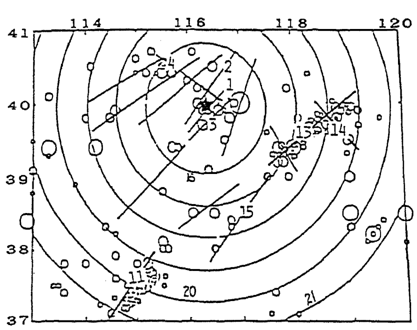

Fig.4 Idealization of Potential Sources by Fault Source Model

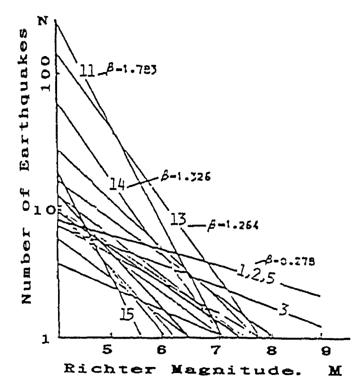

Fig.6 Earthquake Magnitude Recurrence Lines

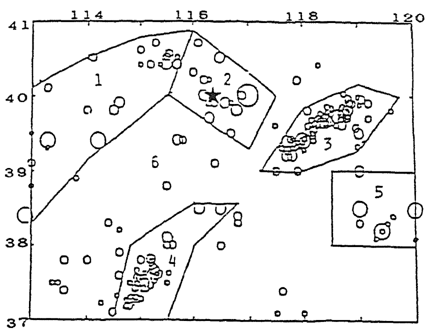

Fig. 5 Idealization of Potential Sources by Point Source Model

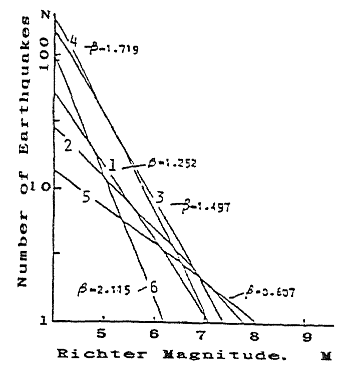

Fig.7 Earthquake Magnitude Recurrence Lines

RESULTS and DISCUSSION

Considering the definition of earthquake fault, 15 earthquake faults, which are regarded as potential earthquake line sources, can easily be distinguished from many other faults. 6 area sources based on fault rupture model also can be regarded as potential earthquake area sources (see Fig.4). On the other hand, a similar idealization of sources by point source model, 5 subsources areas and a background source are regarded as Fig.5. Magnitude recurrence curves on different sources of both models are drawn in Fig.6 and Fig.7, respectively.

Different results are obtained from the two models. The probability of exceedance of PGA and MMI can be seen in fig.8 and Fig.9, respectively. Results obtained for the fault rupture model are larger than those obtained for the point source model, especially in the range of interest in engineering . For example , at an exceedance probability 10 % level for the coming 50 years, MMI of 6.8 and PGA of 100 gal are estimated by point source model; MMI of 8.0 and 200- 225 gal are estimated by fault rupture model.

The reasons of difference are considered as follows:

. Although some procedures are same, contents and parameters are different under two models.

. It is noteworthy that there is uncertainty in the zoning potential sources , which is still a problem we are going to discuss. Because of the difference in the zoning potential earthquake subsources, the earthquake occurrence model (Fig.6,7) and the parameters between model are different. In order to reduce uncertainty, the definition function of earthquake fault is recommended to distinguish each earthquake fault, which is a potential source, from all of other faults in the region.

. In the near field of earthquake, there are big difference between the shortest radius by fault rupture model and the mean radius by the point source model. In the far field of earthquake, there is not such a large difference between them. Since the shortest radius distance and mean radius distance are considered, respectively, in the method of conversion of MMI into PGA, it is reasonable that results obtained from fault rupture model are larger than those from point source model.

. A function of fault rupture length dependence on magnitude was considered in the fault rupture model. It may be the main reason for the results from the fault rupture model to be larger than those from the point source model.

. Some engineering decision officials, planners and designers should understand the analysis methods and uncertainty in the parameters when the results obtained from seismic risk analysis are selected and used.

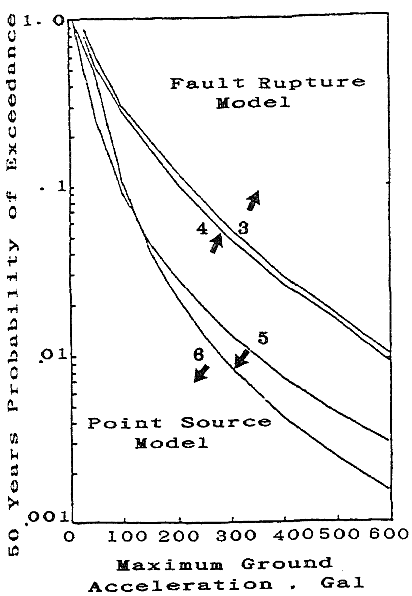

Fig.8 Results of Seismic Risk Analysis
Difference Between Two Models

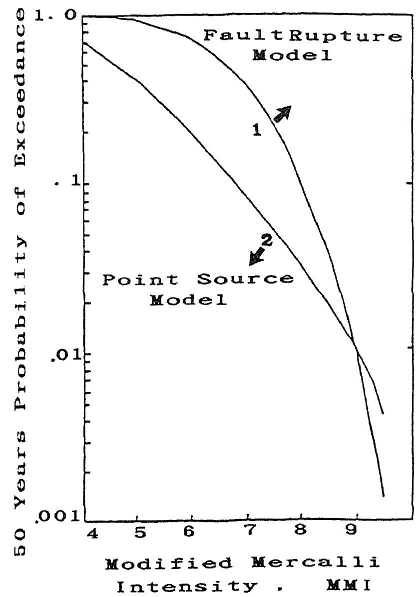

Fig.9 Results of Seismic Risk Analysis
Difference Between Two Models

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