THE SEISMO-GEOLOGICAL BACKGROUND AND THE EARTHQUAKE RESPONSE OF TYPICAL STRUCTURES IN BEIJING

Zhou Xiyuan[I] Tung Jingzheng[II]

Fu Shengcong[II] Zhang Zaimin[II]

ABSTRACT

This paper mainly discusses the influence of soil layer characteristics on the severity of earthquake damage of typical structures subjected to ground motion. For evaluating the spacial distribution of ground motion parameters and that of earthquake damage of typical structures, an approach based upon the regional seismicity and site condition analysis has been suggested. The procedure of estimating the damage distribution is examined by comparing with the damage caused by Tangshan Earthquake in 1976. The result shows some correspondence between them.

FOREWORD

The experiences of previous earthquakes show that due to the difference of local site conditions, the damage of structures may be very different even though they are in areas of the same seismic intensity. Investigation of the Haichen Earthquake in China in 1975 shows that the damage percentage of brick houses decreased rapidly with the distance from the seismic focus, but brick chimney in Yingkow, as far as 28 KM from the epicenter suffered nearly equal to that occured in the focus region(6). This is usually explained by the fact that there are thick Quaternary deposits underlying the district. After the Tangshan Earthquake in 1976 the statistics of Beijing district showed that the damage percentage of brick houses has a spacial distribution different from that of brick chimneys.

In order to estimate the influence of soil layers on the severity of earthquake damage of different types of structures, it seems to be necessary to study the dynamic properties of the soil layers and their influence on the parameters of strong ground motion and spectrum characteristics, and at the same time to consider the dynamic characteristics and earthquake resistant capability of structures. With this in view, this paper tries to discuss the regional distribution of the degree of earthquake damage of typical structures during some future earthquakes in the urban districts of Beijing.

I Director Engineer; II Engineer, Research Institute of Building Earthquake Engineering, Chinese Academy of Building Research

II Engineer, The Beijing Municipal Bureau of City Planning Department of Geotechnical Exploration

AN OUTLINE OF THE METHOD USED

The following procedure of analysis has been suggested as one of the possible means of predicting regional distribution of earthquake damage of structures:

1. The probable source of earthquake with specified magnitude is determined on the basis of the materials considering the seismicity and seismic geology and intensity zoning map of its own area and neighbouring area.

2. The peak acceleration, predominant period and duration of the rock motion induced from the probable earthquake source is estimated by making use of the empirical data of the variation of these parameters as a function of epicenteral distance.

3. Referring to the existing accelerograms of this area in consideration, the predominant period and peak acceleration are modified to be used as a prescribed input excitation acting on the bed-rock surface.

4. The calculating mesh is fixed in accordance with the spatial distribution of various strata. The earthquake response of the soil layers under the action of the input excitation to the basement rock is analyzed on the basis of the dynamic properties and propagation velocities of the strata. The ground motion parameters and response spectra are then calculated (1-4). Finally the two dimensional least-square fitting is used for ploting some isograms of ground motion parameters.

5. The effective seismic factor (i.e. the weighted average value of the acceleration response spectrum within the period range of the structure) is determined for each type of structures. Using this factor and considering the aseismic capability of the structures, the spatial distribution of the degree of damage can be evaluated. Finally the total earthquake disaster may be evaluated on the summing up of the damage distributions of all kinds of structures due to the possible seismic sources.

ESTIMATION OF THE EARTHQUAKE RISK AND THE PARAMETERS OF ROCK MOTION

Beijing is located in the earthquake zone of North China. Since 438 B. C. there were 168 earthquakes in historical record, the seismic focus of which might be in Beijing district or its neighbouring area. The highest seismic intensity was as high as VIII, according to Chinese intensity scale.

The tectonic unit of Beijing district is the intersecting site of the EW--striking tectonic system with the Neocathaysian System. The Neocathaysian tectonic system widely spreads in North China with a large number of fractures, showing clear activity since the late geological time. The distribution of earthquake in recent years coincides with the extension of the fracture zones. This is the major earthquake-generating structure in this district, and the current earthquake all occurred along the major fracture zones. which shows that the Neocathaysian system is by far the most active structure up to the present in this district. In the hundred years to come the threat of the earthquake in Beijing is expected to occur at some place of the district in southeastern direction where the NE and EW striking geological fractures are complicated and intersected. It has not been seen that there is a tectonic background generating an earthquake of magnitude exceeding 6, although medium earthquake may occur in some place near the urban district. Besides, the possibility of major earthquake occuring in the north-western part of the district cannot be excluded. After analysing and comparing the effect of all possible sorts of seismic sources, we mainly concentrate our attention to the effect of the major earthquake taking place at somewhere about 40 KM in the southeastern direction of Beijing. Acording to the curves of variation of peak acceleration and predominant period as function of epicentral distance(3), we divide the urban region into 3 subregions as shown in Fig.4. The parameters of the input rock-motion corresponding to these three subregions are shown in Table 1.

LOCAL GEOLOGY AND DYNAMIC PROPERTY OF SOIL LAYER IN THE URBAN REGION

Beijing is situated at the Northwestern edge of the North China Plain. It is surrounded by mountains on the western, northern and northeastern sides of it. On its southeastern side is the Bohai Gulf. The district can be called as "Beijing Bay" from the viewpoint of ancient geography, and urban region of Beijing is at the southeastern corner of "Beijing Bay". The geologic structure of this area consists mainly of large scale downward belt and upward belt striking in the NNE direction. The Beijing Plain is located within one of the downward belts, and is generally known as "Beijing Seg", whose northwestern boundary is the Wanzhan--Gourieying fault, and the southeastern boundary is the Nanyuan-Ton County fault. Within this seg the NNE and NE fractures are the dominant geologic structures showing clear activity. In the seg the early Jurassic, Cretaceous, early Tertiary, late Tertiary strata had been deposited. From the schematic cross section through the urban area shown in Fig. 1 it can be noted that the "Beijing Seg" acquired a thick layer of Tertiary deposit underlying the Quaternary deposit layer, and there is a distinct boundary surface seperating the two deposit layers with quite different rigidities. Therefore, the Tertiary stratum is treated as the basement rock in the following analysis. The Quaternary layers of loose deposits had settled down on the ancient topography of Tertiary stratum since Quaternary period. The overburden thickness is varying in the range of about 15-200M, and is gradually increasing from west to east as shown in Fig. 5. The inclination of the basement rock surface and that of the soil layers generally are comparatively small (about 0.004 - 0.009) so that the strata can be considered as horizontal mediums. Fig. 2 shows the values of predominant periods at various locations.

In the urban region the soil deposits consist of gravel, sand, clay and saturated soft clay (recent deposit) as shown in Fig. 5 The grain size is decreasing from west to east. Some danamical experimental results for typical soils are shown in Fig. 3.

RESULTS AND ANALYSIS

An estimation of the ground motion parameters has been made following the procedure described above. The urban region of 800 KM^2 is divided into 200 blocks each of about 3-5 KM^2, and a soil column is taken from each of the block in order to analyse the earthquke response. The nonlinear behavior of the soil layers has been considered in terms of equivalent linearization method by repeatedly adjusting the shear modulus and damping factor according to the strain level. As an example the isogram of peak acceleration of the ground surface is given in Fig. 4. From this diagram the variation of ground motion parameters with the site can be found out, and it will be noted that the acceleration of the bed-rock is increasing from NW to SE but that of the ground surface is decreasing from SW to NE, however their trend of variation is nearly orthogonal. The relationship between the configuration of response spectrum and the representative soil profiles are illustrated graphically in Fig. 5.

For the sake of estimating the influence of soil conditions on the effective seismic load induced in a structure, the spatial distribution of seismic factor of three typical structures widely used in Beijing have been considered. Based on the statistical data of dynamic tests the natural period of 5-7 storey brick houses, multistoried (12-13 story) framed buildings and 30-45 M high brick chimneys in urban area of Beijing are 0.28-0.32 sec., 0.65-0.75 sec. and 1.0-1.2 sec. respectively. For simplicity we assume the natural period values of these structures evenly distributed over their corresponding ranges of period. In that case for each sort of structure, the average value of the acceleration response spectrum within the corresponding period range may be accounted as the effective seismic factor in the considered block. And then the values of acceleration corresponding to the respective natural period ranges of the three typical structures are taken from the response spectrum and drawn by two dimensional leastsquare fitting as shown in Fig. 6. From Fig. 6 & Fig.2 it can be clearly seen that the spatial distribution of the seismic factor has a definite relation with the predominant period of soil layers. Those sites, where the seismic factor is comparatively large, are found to have predominant period close to the natural period of the structure. It is also seen from the figures that for brick houses, whose natural period is rather short, the seismic factor decreases with increasing thickness of the Quaternary cover. This is because the predominant periods in most of Beijing urban regions are longer than the natural periods of that sort of houses.

Since the aseismic capability of structure of the same category should be about the same, the distribution of their damage in a future earthquake should be roughly in accord with the variation of seismic factor at different locations. This result would have some significance for the work of municipal planning and construction in view of prevention of earthquake disaster. In order to be able to make comparatively correct prediction on the severity of earthquake damage of various categories of structures in future earthquakes, more intensive research and analysis on the aseismic strength of structures seems to be necessary.

MACROSCOPIC CHECK

The Tangshan Earthquake of our country on 28th July 1976 induced a shock of intensity VI in Beijing, resulting in a certain extent of damage to some brick houses and brick chimneys. For the sake of checking the correctness of the procedure used in this paper, we have chosen 14 construction sites of different severity of earthquake damage from diagrams representing the damage percentage of brick houses (5-7 story) and brick chimneys (30-45 M) and calculated the seismic response corresponding to the Tangshan Earthquake in Beijing by making use of the procedure mentioned above. In accordance with the empirical data about the variation of ground motion parameters with the epicenteral distance, for the Tangshan Earthquake, we adopted bed-rock peak acceleration of 30 gal and predominant period of 0.7 sec. for earthquake response analyses. The result of our analysis is shown in Fig.7, from which it can be seen that when the seismic factor α of these structure sites is greater, the damage percentage is also comparatively higher. The critical value of α, above which damage would be developed in some degree is 200 gal for brick houses and 150 gal for brick chimneys. This result confirms the rough correspondence between the estimation made by the method described in this paper and the actual macroscopic damage induced by the earthquake.

CONCLUDING REMARKS

In this paper an attempt has been made to assess the probable distribution of effective seismic factor of typical structures in some future earthquake by combining the results of macroscopic observation and earthquake response analysis. On this basis the total earthquake sisaster may be evaluated according to the aseismic capabilities of various kinds of structures. The basic method to realize this approach is pointed out and the applicability in practice is demonstrated by an example observed in Beijing area during the Tangshan Earthquake in 1976. The results in this paper are obtained on the assumption of rigid bedrock, therefore it seems to be necessary to further study the influence of radiation damping and surface wave in future.

REFERENCES

1. I. M. Idriss, H. B. Seed: Seismic Response of Horizontal Soil Layers, Journal of the Soil Mechanics and Foundations Division, Proceedings of ASCE vol.94, SM4, July, 1968.

2. R. V. Whitman etc: Accuracy of Modal Superposition of One -Dimensional Amplification Analysis, Proc. Int. Conf. on Microzonation, I, Seattle, 1972.

3. H. B. Seed, I. M. Idriss and F. W. Kiefer: Characteristics of Rock Motions During Earthquakes, Earthq. Eng. Res. Center, Report EERC 68-5, Berkley, University of California.

4. Tung Jing-zheng, Zhang Zai-ming, Tan Hai-shan: The Geological Condition and Dynamic Properties of Soil Layers in Urban Region of Beijing, The Report of Research on the Earthquake Effect of Site Condition, Part one, 1978 (in Chinese)

5. Fu Sheng-con, Zhou Xi-yuan, Yang De-lin: The Analysis of Earthquake Response of Soil Layers in Urban Region of Beijing, The Report of Research of the Earthquake Effect of Site Condition, Part two, 1978 (in Chinese)

6. The Research Team of Strong Ground Motion: The Relationship Between Damage Distribution and Site Condition in Haichen Earthquake, The Report of Research of Earthquake Engineering, 1975, Institute of Engineering Mechanics, Academy of China (in Chinese)

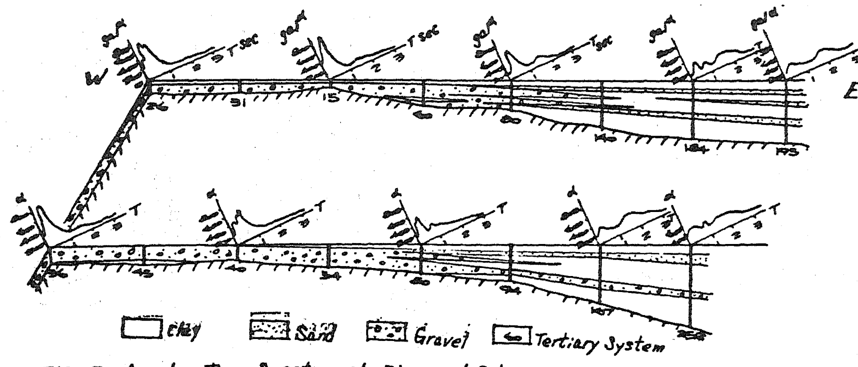

Fig. 5 Acceleration Spectra at Different Sites Along E – W profiles

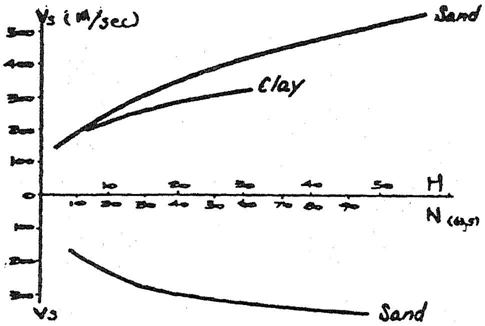

Fig 3 – (a) Some Dynamic Experimental Results for Typical Soils

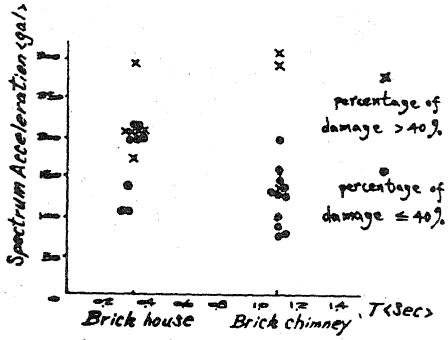

Fig 7. The effetive Seismic factor of the brick house and chimney

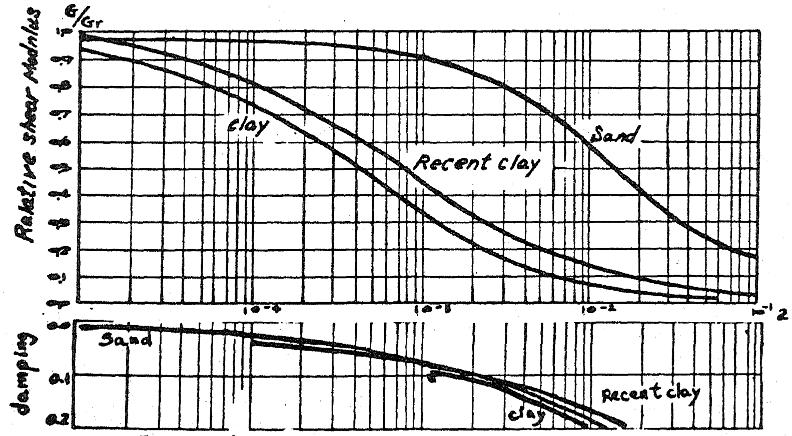

Fig 3 — (b)

TABLE 1

Subregion	parameters of rock motions	
	peak acceleration (gal)	predominant period (sec)
A	125	0.3
B	100	0.3
C	75	0.32

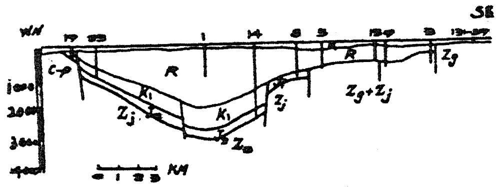

Fig 1. Schemetic Geologic cross section through Beijingurban area

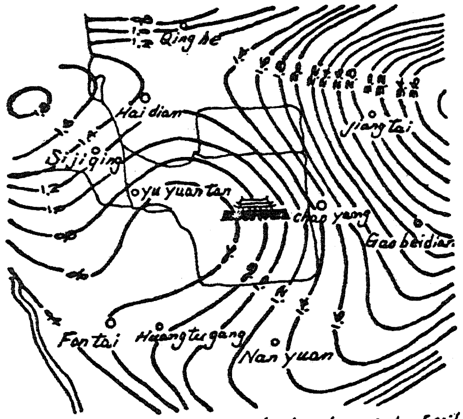

Fig. 2 The Isolines of predominant period of soil layers Note: Numers are Values of Predominant Period in units of sec.

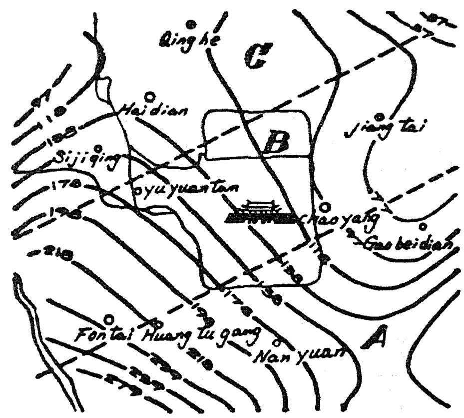

Fig 4. Isolines of peak Acceleration on Ground Surface Note: Nuber sare Value of Acceleration in gal

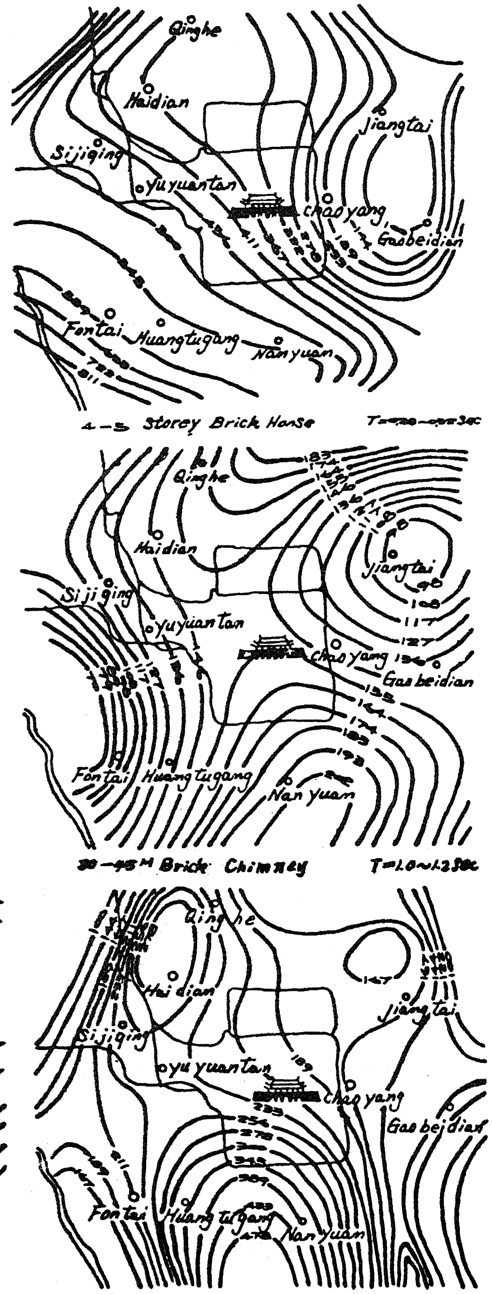

Fig. 6 The Distribution of Seismic Factor For Three Typical. structures Note: Numbers. are Valnes of Spectrum Acceleration. in gal.