EARTHQUAKES AND EARTHQUAKE ENGINEERING IN CHINA

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SUMMARY

China is one of the most earthquake-prone countries in the world and has suffered many disasters. During the last twenty years, especially since the Tangshan earthquake of July 1976 which killed 242,000 people and disabled almost 200,000 people, the Chinese government and the whole society have paid more attention to and made a huge effort to deal with earthquakes. Earthquake engineering became an essential project in the whole country and much more progress has been made since then. In this paper, some brief information about Chinese earthquakes and earthquake engineering is given. It is a simple introduction only, to give a general understanding of China's earthquake problems.

1. EARTHQUAKES IN CHINA

China is one of the countries around the world which experiences frequent earthquakes. In the last 3,000 years there have been written records of more than 800 earthquakes. The earliest record can be found in the Bamboo Yearbook which described the earthquake which took place in 1831 B.C. in Mount Taishan. Strong earthquakes have taken place in most provinces of the country. Since the beginning of this century, more than 500 strong earthquakes over 6 magnitude on Richter-scale have taken place on an average of 6 times per year and 9 earthquakes over 8 magnitude have shaken the country, averaging once in nine years. During the last twenty years, a period of high earthquake activity has occurred in China, and 26 strong earthquakes over 7 magnitude have shaken the continent (see Table 1). Tangshan earthquake of 7.8 magnitude on 28 July 1976 was only one of them.

China is geographically located in the two most active seismic belts on the Earth - the Pacific seismic belt in the eastern part of the country and the Mediterranean-South Asia seismic belt in the west and southwest. Hundreds of faults cut up the continent and many of them are still extremely active. Three main characteristics of earthquakes in China are as follows:

1.1 Large Seismic Area

Strong earthquakes over 6 magnitude have occurred over almost the whole country. The total area which has been considered as the quake-influence field of intensity at MMVII or over is about 3,120,000 square kilometres, or one third of the Chinese territory. Fifty percent of 320 cities in China are located in this zone and 79 percent of 20 megalopolises, each with a population of more than one million, are within the zone. Some very important big cities, such as Beijing, Tianjin, Xian, Lanzhon, Taiyuan, Datong, Huhehat, Baoton, etc are even in the high intensity seismic area of MMVIII.

1.2 High Frequency of Shock

Earthquakes have taken place frequently in China as mentioned above. Moreover, with each earthquake event there was a high frequency of shocks. For example, in the Tangshan earthquake, 5 strong shocks attacked the city with a huge energy, from 6 magnitude to 7.8, during the first few hours and they were followed by hundreds of big aftershocks. In the same year, during the Longling earthquake of 29 May 1976 in Yunnan Province, two shocks of over 7.5 magnitude shook the land within an hour.

1.3 Shallow Earthquake Focus and High Intensity

In China two thirds of earthquakes have taken place inland and most of these have a shallow quake focus - only 10 to 30 kilometres under the ground - but with a very high magnitude. During this century, strong earthquake over 7 magnitude in China have contributed a little more than 10 percent of those throughout the world, but the total energy release from Chinese earthquakes is 20 to 30 percent of the worldwide value. It has been estimated that the seismic energy in the Tangshan earthquake was at least 400 times that of the atom bomb exploded in Hiroshima.

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TABLE 1 - EARTHQUAKES OF OVER 7 MAGNITUDE WHICH HAVE OCCURRED IN CHINA IN RECENT YEARS

	Time (local)					Epicenter position			Magnitude
	year	month	date	hour	min	North latitude	East longitude	Macroscopic epicenter	
1	1966	3	22	16	19	37°32'	115°03'	Dongwang, Hebei	7.2
2	1969	7	18	13	24	38°12'	119°24'	Bohai	7.4
3	1970	1	5	01	00	14°12'	102°41'	Tonghai, Yunnan	7.7
4	1972	1	4	11	16	22°30'	122°0'	East Huoshao, Islan, Taiwan	7.2
5	1972	1	25	11	41	23°12'	121°54'	East Xingang, Taiwan	7.6
6	1972	4	24	17	57	23°30'	121°18'	Fenglin, Taiwan	7.3
7	1973	2	6	18	37	31°'30'	100°24'	Luhuo, Sichuan	7.9
8	1973	7	14	12	51	35°18'	86°30'	North of Xizang	7.3
9	1973	9	29	08	44	41°48'	130°54'	Huichun, Jilin	7.7
10	1974	5	11	03	25	28°12'	104°06'	Yongshan, Yunnan	7.1
11	1974	7	5	03	30	45°0'	94°06'	East Suhaitoquan, Xinjiang	7.1
12	1974	8	11	09	14	39°24'	73°48'	Kashi, Xinjiang	7.3
13	1975	1	19	16	02	31°54'	79°12'	Zhada, Xizang	7.1
14	1975	2	4	19	36	40°42'	123°0'	Haichang, Liaoning	7.3
15	1975	3	23	15	32	22°24'	121°48'	Southeast sea, Taiwan	7.0
16	1976	5	29	20	23	24°36'	98°42'	Longling, Yunnan	7.5
17	1976	5	29	22	00	24°36'	98°48'	Longling, Yunnan	7.6
18	1976	7	28	03	42	39°24'	118°06'	Tangshan, Hebei	7.8
19	1976	7	28	18	45	39°42'	118°48'	Tangshan, Hebei	7.1
20	1976	8	16	22	06	32°42'	104°06'	Pingwu, Songpan, Sichuan	7.2
21	1976	8	23	11	30	32°30'	104°12'	Pingwu, Songpan, Sichuan	7.2
22	1976	11	7	02	03	27°24'	100°54'	Ninglang, Yunnan	7.0
23	1977	11	18	13	20	32°12'	88°00'	Qilan Lake, Xizang	7.1
24	1978	7	23	22	42	22°36'	121°06'	Sea near Taidong, Taiwan	7.4
25	1978	12	23	19	23	23°0'	122°06'	East Sea, Taiwan	7.2
26	1985	8	23	20	41	39.4°	75°2	Wugia, Xinjiang	7.4

2. EARTHQUAKE DAMAGE IN CHINA

The loss of life in earthquakes that have occurred in China are the greatest in the world. According to the records, 5 terrible earthquakes, each with more than 100,000 people losing their lives, have taken place in the earthquake history of the world. Three of these were in China. For example in 1556 the Huaxian County earthquake of 8 magnitude in Shanxi Province killed 830,000 people, the largest loss of people during one earthquake in the world. In 1920 the Haiyuan earthquake of 8.5 magnitude in Ningxia Province killed 200,000 people, and 242,000 people lost their lives in the Tangshan earthquake previously mentioned, which is the largest number of deaths so far during this century. The total deaths of people during earthquakes in this century is about one million, of which 44 percent were Chinese people, that is 442,000. In the 1970's, which was a decade of high earthquake activity worldwide, the total deaths caused by earthquakes was 416,000 people, of which 63 percent were Chinese, and 56 percent of a total of 388,000 disabled people were Chinese.

Moreover, earthquakes caused a very heavy loss of property in China.

According to the statistics of 11 recent strong earthquakes, the extent of collapsed buildings and construction was more than 100 million square metres. In the Tangshan earthquake, the direct economic loss was 10 billion yuan (1 yuan ≐ 0.5 $NZ) and another 10 billion yuan was spent for the reconstruction of the city. During that earthquake 95 percent of the buildings in Tangshan City collapsed or were seriously damaged. Fifty percent of all the various equipment was destroyed. The communication, sewage, water supply and power supply systems were ruined. The railways, roads and bridges were wrecked. The whole city was swept away within a moment. The Haicheng earthquake of 7.3 magnitude on 4 February 1975 in Liaoning Province, was predicted successfully and most of the people were evacuated a few hours before, however, the direct economic loss was 800 million yuan and the reconstruction cost was 450 million yuan, although few people were killed during that disaster.

The main reasons for severe earthquake damage in China are as follows:

(1) Naturally the high frequency and intensity of earthquakes is the essential reason, especially since many of the earthquakes have taken place in or near big cities where there were many factories and a large population, a situation which cannot be avoided.

(2) Most of the civil or industrial buildings and construction lacked an aseismic capability because there was no demand for earthquake resistance when they were built and no attention was paid to seismic factors in the city plan, or to site selection. The collapse and severe damage of such buildings caused the main losses during earthquakes.

(3) Underestimation of the earthquake danger led to inadequate protection for many areas. In the past, many cities were considered to be in a non-earthquake zone or low seismic intensity zone for which no protective measures from earthquakes were required. However, since the 1960's most of the strong shocks in China have taken place in these areas. For example the Xingtai Earthquake of 7.2 magnitude in Heibei Province in 1966, with an intensity of MMX, destroyed the city and killed 7900 people. This had been considered as an MMVI intensity area which means there was no necessity for earthquake protection. Also Tangshan City was originally considered as an MMVI seismic intensity location, but the actual intensity of the Tangshan earthquake in 1976 reached MMXI. Inadequate protection from earthquakes inevitably caused large damage.

(4) Research for earthquake forecasting is just beginning in China as it is in the rest of the world. It has usually been impossible for people to make good preparation just before a strong quake. Many secondary hazards (fire, flood etc) caused by Chinese earthquakes have increased the loss.

3. THREE PERIODS OF CHINESE EARTHQUAKE ENGINEERING

There was no earthquake engineering in China until the foundation of People's Republic of China. Since 1949, the history of Chinese earthquake engineering can be divided into three periods.

3.1 The First Period: From 1949 to the Xingtai Earthquake of 1966

Because there had been no history of strong earthquakes taking place in big cities or industrial areas people had no correct estimation of the earthquake danger. Moreover, financial difficulties were a great problem and the perceived risk did not justify a large expenditure on earthquake protection since this would have increased construction costs by 8-16 percent. The government therefore decided to leave earthquake protection problems out of consideration for most buildings and construction except for 156 major state projects for which the protection measure was to keep them away from active faults and high intensity seismic areas. To pursue this programme it was necessary to know what the seismic history was in China, where the earthquake danger areas were, and how to decide the basic quake intensity of an area. Some research work was done on these topics and preliminary basic earthquake intensities for 298 cities were set up by 1958. In this period, the main method for earthquake protection was to select a good project site and sometimes to adjust the plan and/or height of a building, if necessary. There was no earthquake-resistance code, no special state office and only a few people engaged in earthquake engineering. This period was the beginning of Chinese earthquake engineering.

3.2 The Second Period: From the Xingtai Earthquake of 1966 to the Tangshan Earthquake of 1976

On 8 and 22 March 1966, two strong quakes of 6.5 and 7.2 magnitude shook the same city - Xingtai of Hebei Province, near Beijing. This was the first time that a terrible earthquake had taken place in a populated centre since the foundation of the People's Republic of China and it resulted in 7,900 people being killed, and the collapse of 30 million square metres of housing. The government paid a great deal of attention to the disaster. The Chinese State Council decided to set up the Earthquake-Resistance Office of the Beijing-Tianjing Area to take responsibility for quake-resistance problems of this area and the Earthquake Office for Quake-Forecasts. It was at that time that the two main systems of Chinese earthquake engineering management were founded.

During this time, a great amount of investigation and research work about strong earthquake damage was carried out and a lot of useful information about 9 strong earthquakes was obtained. This provided the basis for further research on earthquake engineering and the formulation of various codes or standards. The Government ordered that every project must be designed and constructed for earthquake resistance in seismic areas and that old buildings and construction should be strengthened. A great deal of work was done. The first unified code "Aseismic Design Code for Industrial and Civil Buildings" (TJ11-74) was published in 1974 and the first Chinese seismic intensity map was also published. This was the period when Chinese earthquake engineering was firmly established and started developing.

3.3 The Third period: From the Tangshan Earthquake of 1976 to the Present

The Tangshan earthquake was an incredible disaster and shocked the whole Chinese society. Everyone became extremely concerned about earthquakes and a great deal of attention was paid to reducing seismic damage. Special state and local offices were set up to take the responsibility for earthquake forecasting and earthquake resistance. Some universities and colleges set up special courses and research into earthquake engineering. Earthquake engineering became a major item in the Chinese National Plan and the annual money spent in this area has been more than 300 million yuan since 1977. About 20 various special law codes, regulations and standards have been published. Exchange and cooperation for earthquake engineering at home and abroad has been emphasised. China has signed various governmental and non-governmental agreements for earthquake engineering with more than 10 countries, such as the United States, Japan, New Zealand, Yugoslavia, Rumania etc. China has organised 4 international, 7 national and many local conferences on earthquake engineering, and 14 national work meetings in this period. This period has been a time when Chinese earthquake engineering has developed quickly and made much more progress.

4. MAIN TASKS FOR CHINESE EARTHQUAKE ENGINEERING

How can earthquake damage be reduced? Generally speaking, there are 3 ways to do this: (a) To learn to control earthquakes. This is very difficult and beyond our experience, and no success can be obtained in a short time; (b) Earthquake forecasting, which has sometimes been achieved in some countries including China, with some further progress being made. It is not easy to forecast an earthquake with sufficient accuracy and reliability, and earthquake forecasting is only in its infancy. It can never do much more to reduce the disaster than the reduction of casualties; (c) Earthquake resistance and protection, is the most effective way, and many countries have been trying their best to provide this. The emphasis of Chinese earthquake engineering is in this area as well. The main tasks for earthquake engineering in China are as follows:

4.1 Earthquake Damage Investigation and Research

Earthquake damage investigation and research is very important work which can help people to understand the earthquake resistant capability of various buildings, structures, bridges, life-line projects, facilities and equipment, etc., and the reasons for their damage. Each earthquake is actually a complete engineering test of many kinds of items, which can give a great amount of useful information about earthquake engineering. China has been giving this matter a very important position. The content of investigation is diverse, including earthquake mechanism, intensity distribution, engineering geology and hydrogeology, structure damage, secondary disaster and various losses etc. The technique of investigation ranges from personal to well-organised, from single item to whole system, and from general to detail. China has already had much detailed reporting about all the strong earthquakes and damage of the last 20 years including the huge books "Tangshan Strong Earthquakes", and a plan for collecting and analysing all the materials about strong earthquakes over 7 magnitude during the last 70 years is now being carried out.

4.2 Scientific Research and Tests

Scientific research and tests are being carried on all over the country including the basic theoretical study of engineering seismology and practical aseismic techniques and measurement research. Thousands of professors, engineers, technicians and workers are engaged in this work. There are more than 40 special structure laboratories where earthquake engineering tests can be done in China and more than 300 research items have been completed ranging over a wide field. These include:

- Analysis on seismic danger and seismic zoning in cities.
- Strategy of earthquake prediction, aseismic plans and measures and economic benefit from reducing earthquake disasters in cities.
- Aseismic design and strengthening techniques for structures.
- Aseismic measures for rural constructions.
- Aseismic characteristics of super high-rise structures, nuclear power station structures, hydraulic structures, off-shore platforms etc.
- Aseismic problems of life-line projects and energy supply systems.
- Computerisation of aseismic design and calculation.
- Test techniques and equipment.
- Data processing and strong earthquake observation.
- Elastic and Plastic vibration theory and earthquake isolation.

In China, strong earthquake observation, as a basic work, developed very quickly, from two organizations and 20 instruments before Tangshan earthquake to 22 organizations and more than 250 fixed instruments and 200 movable instruments at present. More than 2,000 earthquakes have been recorded with a maximum acceleration being 0.3 g. A cooperation for strong earthquake observation between China and America has been going on in China for three years.

4.3 Aseismic Design for New Structures

According to the statistics of 130 earthquake disasters throughout the world, 95 percent of the deaths and injuries were caused by the collapse of structures. After the Tanshan earthquake, aseismic design for new structures became necessary. Various aseismic design codes, regulations and standards are required by law and everyone must obey them. The principles of aseismic design are helping to keep people and valuable equipment safe from earthquake disaster with the aim of ensuring there is no damage in structures with small quakes (1.55 degrees lower than design intensity) and no collapse of structures with large quakes (0.5 - 0.7 higher than design intensity). The range of aseismic design has recently been enlarged from areas of likely VII - IX intensity to cover areas with likely magnitudes of VI - X. Strength and deformation of structures must be calculated by the base shear force method, the modal analysis method or direct dynamic method, depending on the importance, size and structural form. No building is allowed to be built in seismic areas in China now unless it has been designed aseismically.

4.4 Aseismic Strengthening for Old Structures

A very large number of old buildings and constructions in seismic areas are insufficiently earthquake resistant, but their further use is unavoidable. An effective way to improve their earthquake resistant capability is aseismic strengthening. The job of aseismic assessment and strengthening for every existing industrial and civil building and construction, as well as various structures and engineering facilities, began in all seismic areas in 1978. Since then 2.5 billion yuan has been spent on this task and many items of aseismic strengthening have been completed, including 185 million square metres of buildings and many main bridges, reservoirs, ports, etc. All aseismic strengthening tasks in most of 47 major earthquake protection cities have been successfully finished. Many effective, simple and economical measures and methods have been created, and this experience will be useful and helpful in future work.

Through aseismic strengthening, structures have been greatly improved in aseismic strength, integrity and deformation ability. The positive efforts of aseismic strengthening have shown some benefits during some recent earthquakes. For example, in the Daofu earthquake of 6.9 magnitude in January 1981 in Sichuan Province, a strengthened post office building and grain depot withstood the strong attack very well, while all the unstrengthened houses around were severely damaged. In the Heze earthquake of 5.9 magnitude in November 1983 in Shandong Province, the medicinal building of Heze City Hospital was damaged badly because it had no strengthening but the clinic building nearby which had been strengthened had no damage. It is certain that earthquake damage will be reduced for strengthened buildings and also their service life will be prolonged.

4.5 Plan of Urban Earthquake Disaster Prevention

The degree of an earthquake disaster as a whole depends on the comprehensive aseismic capability of the area, especially in cities, including not only engineering problems, but also social problems. In order to reduce earthquake disaster, a total plan for earthquake disaster prevention is necessary. For six years, China has been studying and making a plan for urban earthquake disaster prevention as a whole in many cities, which involves many aspects, such as city planning, land usage, seismic microzoning, life-line systems, traffic, preparation against and repair of earthquake damage, secondary disaster prevention, and public security, etc. An official document "Draft Provision for Formulation of Urban Earthquake Disaster Prevention" was published in 1985 as guidelines for this task. This work has been finished in several cities.

5. CHINESE ADMINISTRATION OF EARTHQUAKE ENGINEERING

The State Seismology Bureau and its branches in most Provinces have responsibility for earthquake forecasting, seismic geology, observation stations of earthquake activity and zoning basic intensity for seismic areas etc.

The State Earthquake Resistance Office and more than one hundred related organizations all over the country have responsibility for earthquake disaster prevention, aseismic design and strengthening etc.

Ministry of Civil Administration has responsibility for earthquake disaster relief and treatment.

6. ASEISMIC ENGINEERING DEPARTMENT OF CRIBC

The Aseismic Engineering Department of CRIBC of MMI, PRC (Central Research Institute of Building abd Construction of the Ministry of Metallurgical Industry) to which the author belongs, is a special unit in China for Earthquake Engineering research with three sections: Aseismic Structures section, Aseismic Geology section and Vibrating Machinery foundation section, and two laboratories - the Dynamic Test House and the Soil Mechanics House. The staff of some 80 people, half of them being scientists, are now engaged in various research projects, such as aseismic reliability and earthquake damage estimation, aseismic measures for structures, base isolation, computerisation of aseismic design, protection of life-line projects, liquefaction potential assessment and preventative measures, dynamic methods for assessing various foundations, consulting on structural design, dynamic measurement techniques, earthquake response spectra and microzonation, etc. The research emphasis in this department is placed upon industrial construction and a special state aseismic design code for industrial structures, as well as several regulations, are being formulated by its staff. The financial fund for this department comes mainly from contracts and consultations. There are some scholarship positions of M.Eng degrees for young people every year. A good relationship between this department and the International Society of Earthquake Engineering is developing. Many famous scientists have visited this department, including Dr. R.I. Skinner of PEL, DSIR of New Zealand, and seven of its staff are working or studying in the United States, Japan, Canada or New Zealand. The Aseismic Engineering Department of CRIBC is playing a more and more important role in the Chinese Earthquake Engineering area.

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