TAIWAN

- EARTHQUAKE HAZARD MITIGATION IN TAIWAN

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1 INTRODUCTION

Taiwan lies between 21°40' and 25°20' north latitude and 119°30' and 122°30' east longitude. It has an area of about 36,000 sq km and a population of around 21 million. This island is located at a complex juncture between the Eurasian Plate and the Philippine Sea Plate. Around the north and east of Taiwan, the Philippine Sea Plate subducts beneath the Eurasian Plate to the north along the Ryuku trench. The Eurasian Plate underthrusts the Philippine Sea Plate to the east along the Manila trench at the south of the island. These cause this area to be of high seismicity.

According to the plate tectonic setting, the Taiwan region was divided seismologically into three zones. The earthquakes in the northeastern seismic zone are associated with the northward subduction of the Philippine Sea Plate. The earthquakes in the eastern seismic zone are associated with the oblique collision between the Philippine Sea Plate and the Eurasian Plate along the Longitudinal Valley in eastern Taiwan. The earthquakes in the western seismic zone are much less than those in the northeastern and eastern seismic zones. Earthquakes in this western seismic zone are scattered throughout Taiwan Island and the western and southwestern offshore areas. Figure 1 shows the schematic lithospheric plate structure in and around Taiwan and Figure 2 shows the stereographic projection of hypocenters of earthquakes. When comparing seismic activity in different regions of the Asia-Pacific area, it can be found that seismic activity in Taiwan is characterized by high frequency and extensive distribution.

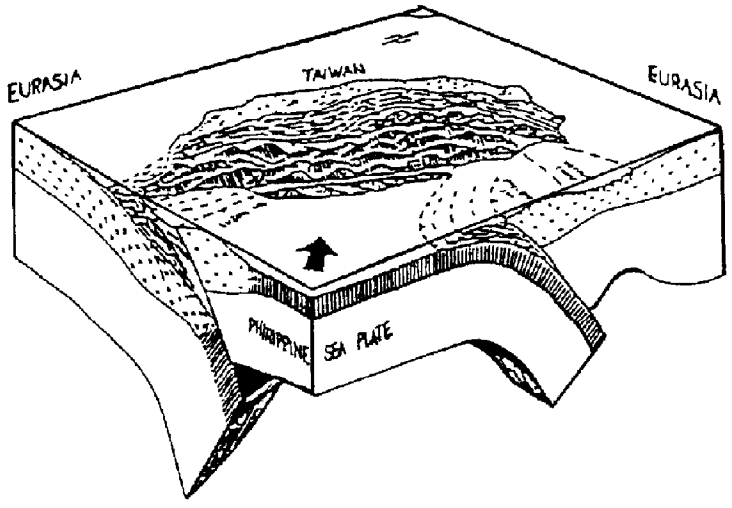

Figure 1: Lithospheric plate structure in and around Taiwan

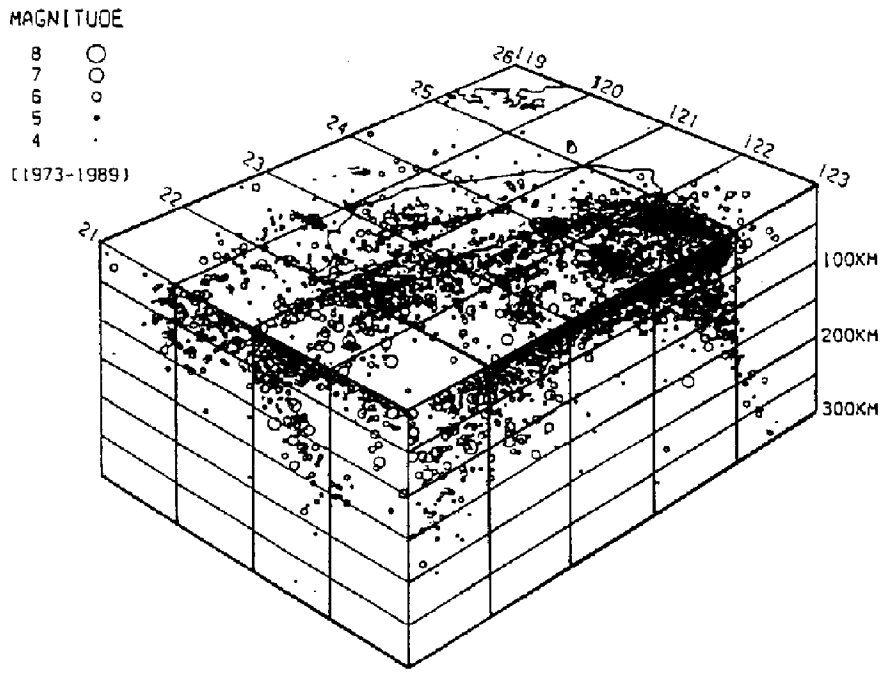

Figure 2: Hypocenters of earthquakes with magnitude M ≥4.0 from 1973 to 1989

The history of earthquake activity in the Taiwan region can be dated back to the seventeenth century. Prior to 1897, the historical records of earthquakes primarily consist of governmental documents. Based on the description of damage, there were about six earthquakes having magnitude equal to or greater than 7.0 during the period from 1644~1895. Before 1935, the record for smaller earthquakes (i.e., M≤5.5) is definitely incomplete because of poor magnification of instruments. From 1936 to 1979, earthquakes with magnitude greater than 5 are believed to be complete. In late 1972, the Taiwan Telemetered Seismographic Network (TTSN) was developed. Since then, earthquakes with magnitudes greater than 2.0 have been closely monitored and recorded.

The earthquakes in Taiwan generally have a complex structural background. Most of the disastrous earthquakes in the history have occurred in the west seismic zone which is a densely populated zone in Taiwan. Table 1 lists the recorded disastrous earthquakes and their damage reports. The epicenters of the most disastrous earthquakes are shown in Figure 3. According to the investigation on earthquake disasters, casualties and economic losses from destructive earthquakes are caused by the destruction of buildings and by associated disasters such as fires. Taiwan is now evolving from a developing country to a developed country and an earthquake-prone area. Therefore, whenever an earthquake occurs, the Taiwan Government has to pay attention to the area. It must not only make efforts to reduce seismic disaster but also to accumulate experiences in earthquake prevention and resistance as well as disaster relief.

Generally, earthquake disaster reduction can be grouped into two categories: pre-disaster side, including earthquake prediction and hazard mitigation, aseismic design for buildings and civil engineering structures, publicity and education; and post-disaster side, mainly involving rescue and relief, rehabilitation. The seismic hazard management relating to these items is discussed.

TABLE 1: DISASTROUS EARTHQUAKES IN THE PAST 250 YEARS IN TAIWAN AREA

Time					Epicenter	Mag.	Population		House	
Year	Mo.	Day	Hour	Min.		M_L	Death	Injured	Collapse	Semi-Collapse
1736	1	30	1-3		Taiwan	6.5	372	129	698	
1792	8	9	13-15		Chiayi	7.1	617	781	24621	953
1811	3	17	3-5		Hualian	7.5	21	16	41	
1815	10	13	21-23		Hualian	7.7	113	2	243	
1839	6	27	7-9		Chiayi	6.5	117	534	7515	
1845	3	4	11-13		Taichung	6.0	381	-	4220	
1848	2	12	7-9		Changhua	7.1	1030	-	13993	8671
1862	6	7	21-23		Tainan	7.0	>500	>1000	>500	
1867	12	18			Keelung	7.0	>100		-	
1881	2	18	13-15		Miaoli	6.2	11		>210	
1882	12	9	21-23		Taitung	7.5	10		>40	
1904	11	6	4	25	Douliu	6.3	145	158	661	3179
1906	3	17	6	42	Minhsiung	7.1	1258	2385	6769	14218
1906	4	14	3 7	18 52	Dianzikou	6.6 5.8	15	84	1794	10037
1909	4	15	3	54	Taipei	7.3	9	51	122	1050
1916	8	24	15	27	Nantu	6.4	16	159	614	4885
1917	1	5	0	55	Puli	5.8	54	85	130	625
1935	4	21	6 6	2 26	Guandaoshan	7.1 6.0	3276	12053	17907	36781
1941	12	17	3	19	Chungpu	7.1	358	733	4520	11086
1946	12	5	6	47	Singhua	6.3	74	482	1954	2084
1951	10	22 11	5	34 29	Hualian	7.3 7.1	68	856	-	2382
1951	11	25	2	47	Taitung	7.3	17	326	1016	582
1959	8	15	16	57	Hengchun	6.8	17	68	1214	1375
1964	1	18	20	4	Baihe	6.5	106	650	10500	25818
1986	11	15	5	20	Hualian	7.0	15	62	35	32

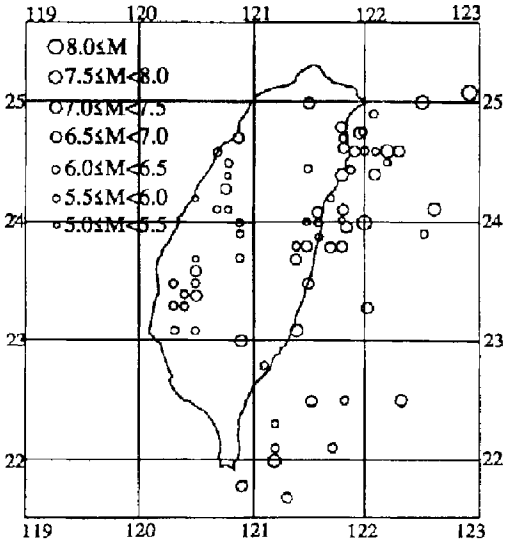

Figure 3: Epicenter location of historical disastrous earthquakes

2 EARTHQUAKE PREDICTION AND HAZARD MITIGATION RESEARCH IN TAIWAN

Earthquake prediction and hazard mitigation research includes earthquake monitoring and survey and forecasting. The Central Weather Bureau, under the Ministry of Transportation and Communication, is in charge of the unified leadership and management of the national effort regarding earthquake monitoring. At present a number of earthquake-monitoring systems have been set up. There are now over 500 professional monitoring stations and observation points distributed throughout the island. These monitoring actions and surveys of natural earthquakes serve as a foundation for natural disaster reduction. At present, another set of networks for seismic warning systems is also being developed and will be set up in Taiwan. The Institute of Earth Science, Academia Sinica, established in 1973, is in charge of earthquake hazard mitigation research and strong motion seismology research. In addition, mobile observations of gravity, geomagnetism, crustal deformation profiles and strong motion characteristics are also carried out in this Institute. Earthquake prediction, one of the frontier topics in geoscience, is also under research from the point of view of observation techniques, instrumentation, data processing, and the post-seismic estimation of earthquake. Because of the complex physical mechanism of the seismogenic process and intricate precursory phenomena, earthquake prediction research does not have great achievements in Taiwan.

Throughout the exploration of the past 20 years, great achievements in research on strong motion seismology have been made in Taiwan. The research serves as a foundation for seismic hazard reduction. Based on data and information regarding strong ground motion and disasters provided by monitoring and survey, seismic hazard reduction and disaster prevention can be taken directly.

3 EARTHQUAKE RESISTANCE RESEARCH AND PREVENTION MEASURES IN TAIWAN

Earthquake disaster resistance usually refers to earthquake engineering measures taken for fixed assets in danger of disasters. Therefore, making proper investment in earthquake disaster resistance is important. The Taiwan Government asks that all civil engineering structures in seismic regions must be protected against earthquakes, and decided to assess the seismic capability of all existing buildings. Since 1980, seismic prevention and a seismic design review system have been adopted for buildings higher than 45 meters. It is believed that the implementation of such seismic design review system greatly impelled the work of earthquake resistance and prevention in reducing losses from seismic disasters.

Three five-year Hazard Reduction Programs which include earthquake hazard mitigation program have been conducted under the National Science Council since 1982. These provide research funds to academic fellows and universities for research on natural hazard. Through these programs, the seismic hazard analysis relating to design has been developed. Following these programs, the iso-acceleration map of Taiwan area for a return period of 475 years and the seismic zoning map for design have also been developed. These are shown in Figure 4 and Figure 5, respectively. The Taiwan area is divided into four zones: zone A1 (seismic factor greater than 0.32g), zone A2 (seismic factor 0.24 to 0.32g), zone B (seismic factor 0.18g

to 0.24g), and zone C (seismic factor smaller than 0.18g). Besides, a national building code has also been prepared by the Ministry of Interior. It serves as an earthquake resistant design guide for building design.

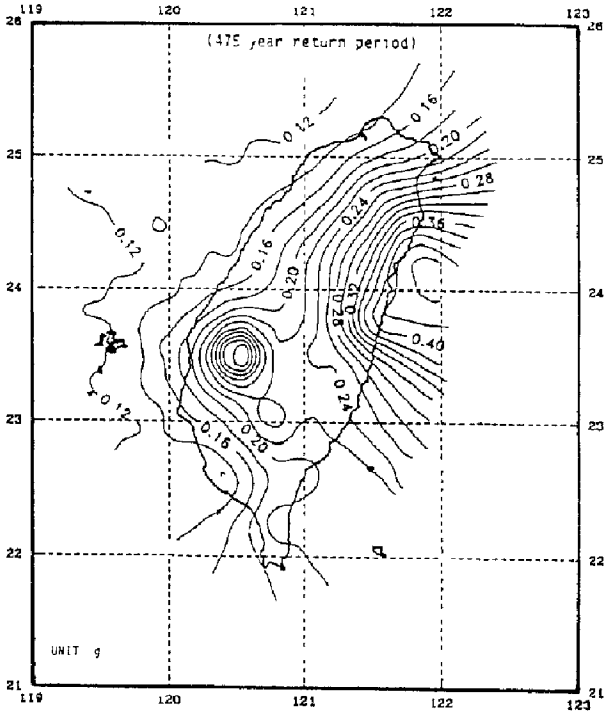

Figure 4: Iso-acceleration map of Taiwan for a return period of 475 years

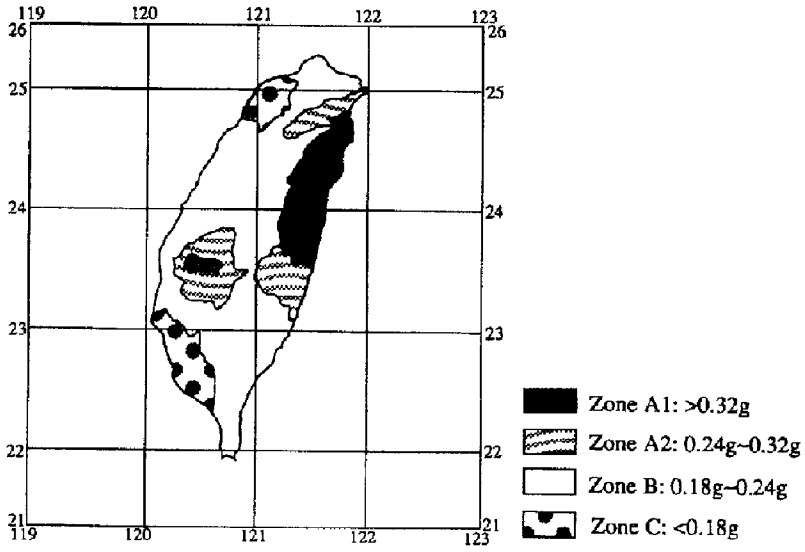

Figure 5: Seismic zoning map of Taiwan

In the future the earthquake resistance research that will be implemented to mitigate seismic hazard will concentrate on the seismic zoning of geotechnical hazard. This research will include these three items: zoning for soil liquefaction, zoning for slope failure, and zoning for ground motions. It is believed that earthquake resistance research and prevention capability will increase with the strengthening of governmental financial support in such work.

4 EARTHQUAKE RELIEF AND ITS ROLE IN SEISMIC HAZARD REDUCTION

The basic policy of seismic hazard relief in Taiwan is to keep the organization of disaster relief affairs under the administrative authorities, and to use the army and police forces and professional relief teams. Since the beginning, damage due to earthquake in Taiwan has not been so serious as compared to that in other countries. The relief experiences accumulated over the years are very limited. The Taiwan government feels that the effort on seismic hazard management should focus on large cities and on civil engineering projects such as high-rise buildings, power plants, dams and bridges. However, from a scientific point of view, to maximize the efficiency of disaster reduction, many problems should be solved, including the problems of science, organization, personal training, etc. For this reason, disaster reduction must be system engineering based on a unified information system. We need to establish an information system that could transfer information regarding seismic disaster prevention to the leadership of the country and to the relevant departments.

5 SUGGESTIONS FOR SEISMIC HAZARD REDUCTION

Based on the above mentioned discussion on seismic hazard, there are six major disaster-mitigation measures: monitoring and survey, forecasting, resistance, prevention, rescue and relief. Reduction of earthquake damage, emergency preparation and social reaction are joint responsibility of a series of departments. With the coordination of the government at all levels, disasters can be mitigated. The government's function in reducing earthquake disaster/natural disasters is to make full use of existing knowledge and technology to mitigate disasters through coordinated action. The government should closely combine science and technology with disaster reduction. At the present stage, the organization for reduction of earthquake disasters in this area has been established and classified into three levels: national, provincial, and district and county. The local government department will take most of the responsibility for prevention and relief work.

Taiwan, being a disaster-prone country, has a long history of post-disaster management; but the experience is related mainly to floods and typhoons. A more refined arrangement for disaster management, especially on seismic disaster management, must be re-designed. Those functions would be to prepare a national plan for disaster preparedness together with national and district level for disaster management. Figure 6 shows the proposed institutional arrangement for disaster management in Taiwan.

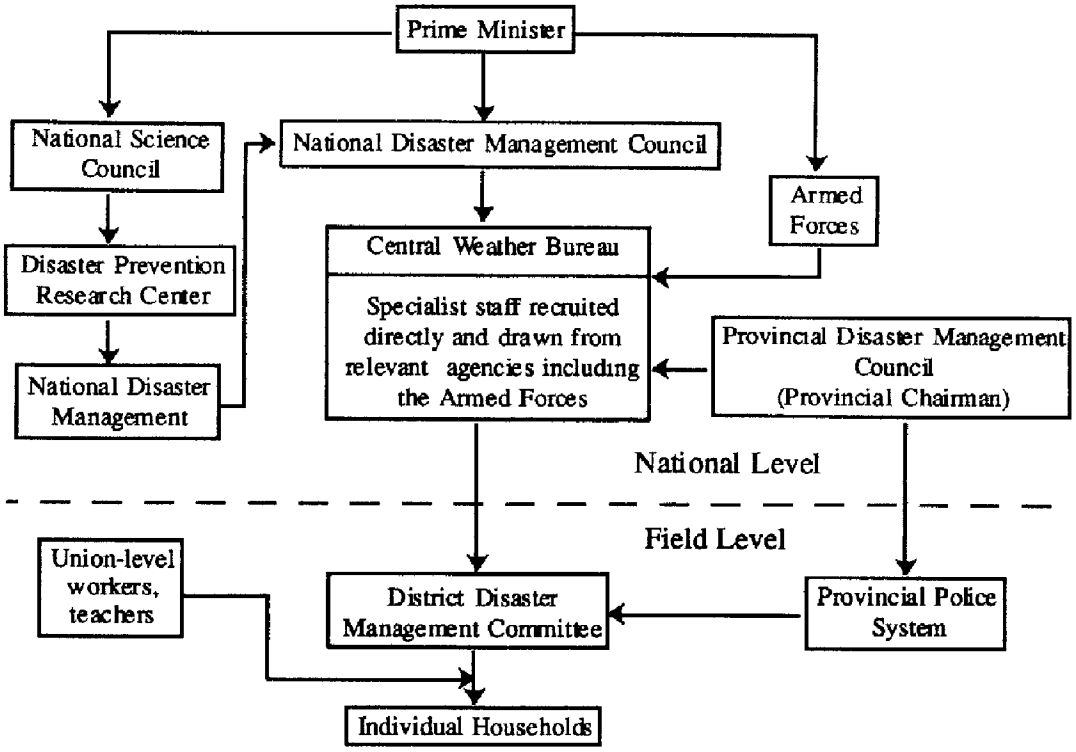

Figure 6: Proposed institutional arrangement for disaster management in Taiwan

6 ACTIONS RECOMMENDED UNDER WSSI

(1) Establish networks for flow of earthquake related information -- exchange of data and results of recent investigations on earthquake-related problems in each country.

(2) Establish the system for emergency disaster activities -- raise awareness among government and decision-makers, public and engineering communities.

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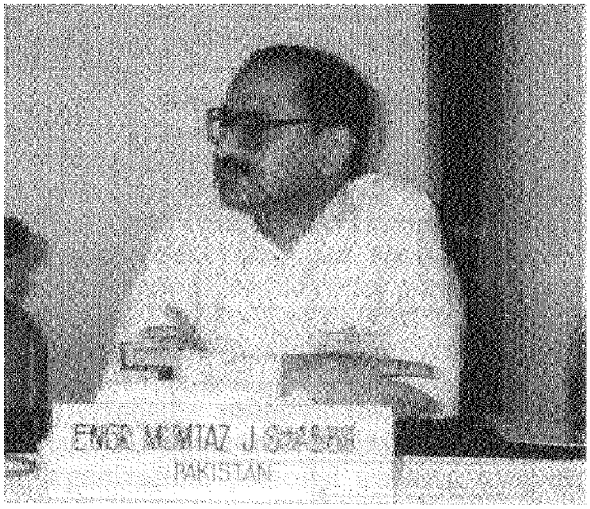

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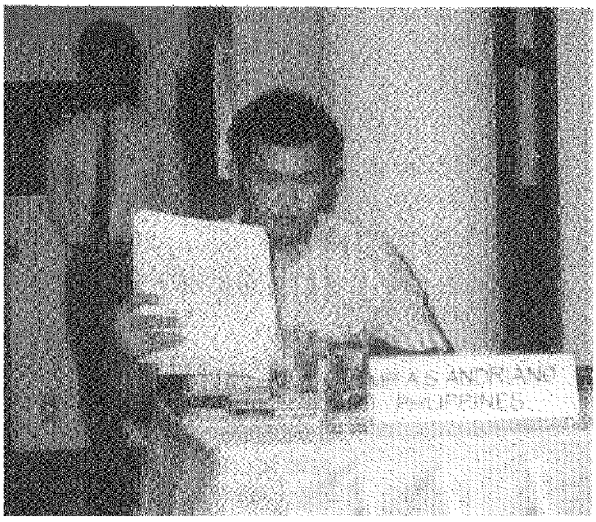

A. S. Andriano (Philippines), who was taking the ADPC training course at AIT, participated in the workshop instead of Dr. Punongbayan.