5. Urban Seismic Vulnerability Assessment and Disaster Prevention Measures —— Reviews

We selected six cities, including those in civilized countries, to review seismic vulnerability and safety measures for large urban areas. We reviewed the cases of:

Manila, Philippines
Mexico City, Mexico
Ankara, Turkey
San Francisco, California, U.S.A.
Wellington, New Zealand
Granada, Spain
Tokyo, Japan.

5.1 Manila, Philippines

5.1.1 Profile

The Metro Manila Area, the capital region of the Republic of the Philippines, consists of 17 municipalities (4 cities and 13 towns). The region is a major conurbation carrying a population of 8 million.

According to an earthquake catalog from the 16th century to present, devastating earthquakes struck the Manila area at intervals of 10 to 30 years. Recent major events that occurred near the area were the Luzon earthquake of August 2, 1968 (M7.3) and the Philippine Earthquake of July 16, 1990 (M7.8).

5.1.2 Vulnerability assessment

United Nations Disaster Relief Co-Ordinator, UNDRO, published a report of a Technical Advisory Mission (October 1976 - February 1977). The report, of which contents are shown in the following section, is:

COMPOSITE VULNERABILITY ANALYSIS
A methodology and case study of the Metro Manila Area
(Revised Technical Report)

Office of the United Nations Disaster Relief Co-Ordinator (UNDRO), Geneva, Technical Advisory Mission to the Government of the Philippines, Human Settlement Commission (HSC), 59pp.

The vulnerability assessment was carried out paying attention on earthquakes and floods. The effect of other types of natural hazard, including typhoons, tsunamis, and volcanoes, were briefly mentioned, too.

The seismic vulnerability assessment was carried out only in terms of the spatial distribution of building damage. Toward further development of seismic safety measures, the city may need further information, in the form of a micro-zoning map, concerning the effect of future earthquakes on various urban facilities and socio-economic activities. This task is particularly important and urgent, since an M7 class earthquake is expected to occur on the Marikina fault only 10km away from Manila.

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5.2 Mexico City, Mexico

5.2.1 Study area

Mexico City, the capital of the United States of Mexico, is made up of 16 wards (delegaciones). The city is directly under the jurisdiction of the federal government and usually called DF, or Federal District (Distrito Federal).

ZMCM, or the Metropolitan Zone of the City of Mexico (Zona Metropolitana de la Ciudad de Mexico) is an area that includes Mexico City and its vicinity in which are urbanized municipalities (municipios) in Mexico State. ZMCM forms a single, continuous urban area as a consequence of the rapid growth of urbanized area spreading around DF.

In this review, we focused our attention on DF, instead of ZMCM, due to the limitation of regional data of ZMCM.

5.2.2 Topography and Geology

With an average altitude of 2240m, Mexico City is in the southwest of Mexico Valley (Valle de Mexico). The basin is at the northern edge of the central plateau, which is surrounded by the western and eastern Sierra Madre mountains and a volcanic chain running across the country from east to west.

The northwestern part of the city is on the soft lake deposit, of which bottom deepens towards the east. Several wards to the south of the central part of the city, Coyoacan, Xochimilco, and Tlahuac have similar geological conditions.

5.2.2 Seismicity

Mexico lies on the North American plate, which abuts on the Pacific plate in the west and the Cocos and Caribbean plates in the south. Under active tectonic environment, earthquakes frequently occur in the broad area on the Pacific and in the base of the Yucatan peninsula, most frequently in Oaxaca State.

The Michoacan earthquake of 1985 occurred in the Michoacan seismic gap on the border between Michoacan and Guerrero States, causing a serious disaster in Mexico City. At present, a vast seismic gap still exists near Acapulco on the Pacific coast of Guerrero State.

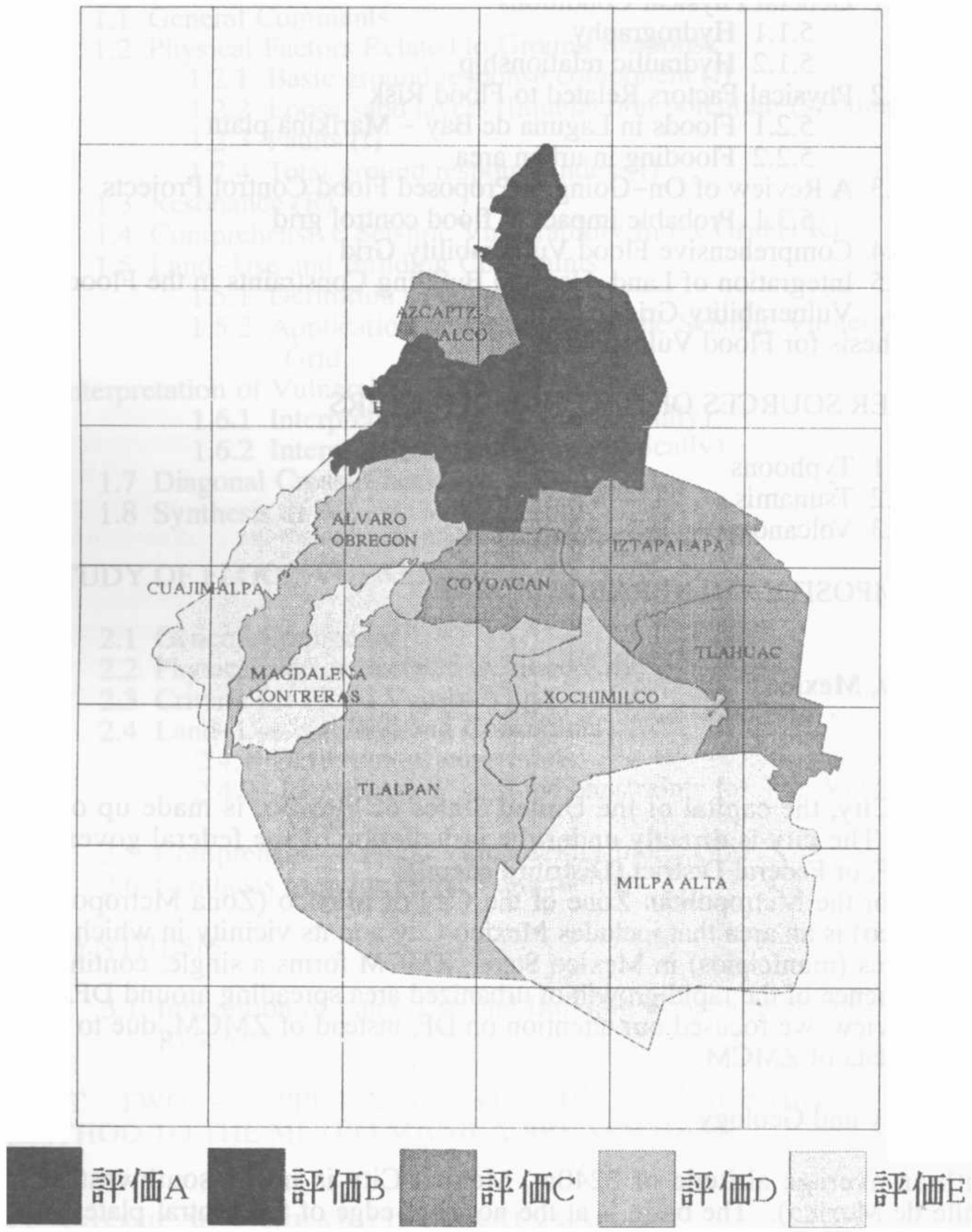

Figure 5.2.1 Macro–scale assessment of vulnerability in Mexico City.

5.2.3 Micro–zoning

A map showing soil classification for the entire Mexico City, a map showing the distribution of soft soil layers for the central part of the city, and a map showing the distribution of damage in past earthquakes were available even prior to the 1985 earthquake.

After the 1985 earthquake, several zoning maps were incorporated into the building regulation. Among those are a zoning map based on the damage to buildings in the 1985 earthquake and a map showing the spatial variation of the predominant period of ground shaking.

5.2.4 Construction type of buildings

According to the 1990 census, there were 1,789,171 dwelling units in the city. Those were classified in terms of the material for floors and walls.

Among the dwellings, 80% have walls of concrete or brick, and 11% of asbestos or galvanized sheets. More than 90% of the dwelling units are non–combustible, and, therefore, the risk of an earthquake–induced–fire is very limited.

5.2.5 Population density

The rate of population growth is remarkably high. The population in 1990 was 4.68 times as large as that in 1940. In the decade between 1980 and 1990, however, the population decreased by almost 600,000. The unusual decrease of population by almost 7% in ten years suggests the saturation of population in the central area. Nevertheless, while the population in the city center rapidly decreased, that in the surrounding area keeps increasing. This implies that people simply moved out into the suburbs within a large urban area of ZMCM.

5.2.6 Risk assessment

On the basis of the regional information motioned above, we figured out risk level for each ward. Carrying out a plain examination, we confirmed that the risk level is the highest in Cuauhtmoc, which lies on the lake deposit and has a large, densely distributed population. A history of frequent earthquake damage indicated the high risk level of the area, too.

5.3 Ankara, Turkey

5.3.1 Macro– and micro–zoning in Turkey

In Turkey, 47 major earthquakes were registered between 1925 and 1984. Among those the most lethal was the Erzincan earthquake of 1939 having a death toll of 32,962. The total number of fatalities in this period was 57,727, with an annual average of 978.

Although there is a long history of earthquake countermeasures, it wasn't until 1945 that the first macro–zoning map was developed. According to the third edition of the macro–zoning map, which was completed in 1972 (Figure 5.3.1), the country was divided into five zones of different seismicity. Zone 1 is the area of the highest seismicity. Zones 1 and 2 carries more than half of the population and more than 70% of the main industrial centers. The concentration of population and industry are distributed in the regions with high seismicity. Ankara has not been subject to any major earthquake damage in the past and, therefore, belongs to Zone 4.

Further revision to those macro–zoning maps is now in progress with international cooperation.

According to UNESCO (1976) and Ergunay and Gulkan (1990), studies on micro–zoning have been conducted since a regal requirement that natural disasters are taken into account in urban and regional planning was issued in 1945. Geological and earthquake engineering data have been used in the inclusion of earthquake disaster since 1968. Geological maps on a scale of 1:5,000 – 1:2,000 were developed.

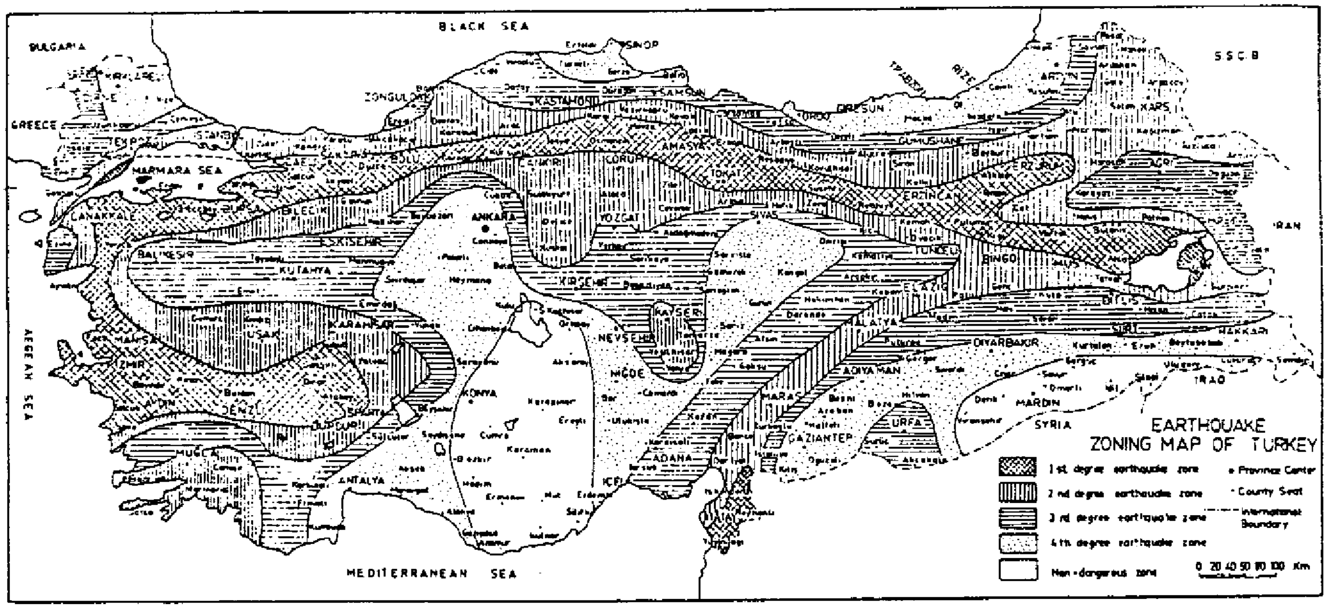

Figure 5.3.1 Earthquake zoning map of Turkey in 1972.

5.3.2 Vulnerability assessment

1) Data

In Turkey, the first national census was carried out in 1927, and the second in 1935. Since then, censuses were conducted once every five years.

Statistics of new buildings, which are compiled on the basis of building permits, are published every year. However, those do not include buildings without a permit, which abound in urban areas. Rollered–out surveys were conducted nationwide in 1970 and 1988 by door–to–door inspection.

Statistics on civil structures and industrial facilities, such as roads, bridges, dams, and power stations are insufficient, and organized data on urban infrastructures are hardly accumulated.

There is serious atmospheric pollution in Ankara. In 1988 data for each district were compiled for the first time to develop new traffic policies. Although such district–by–district data are indispensable to evaluate the local risk levels within the city, the economic situation of the country did not allow further accumulation of detailed data on air quality.

2) Methods

Though mathematical methods of structural analysis are applicable to the damage assessment of modern, engineered structures, those are inappropriate in the damage assessment of traditional, non–engineered structures, such as rural and low–income housing. The difficulty mainly lies in the diversity of structural type and construction material. Damage estimation of traditional buildings, therefore, can be practically done only through statistical approach on the basis of field data from past earthquakes.

The rate of the occurrence of human casualty is considerably different from region to region, even if the earthquake magnitude and the structural type of housing are identical. Eastern Turkey is more susceptible to human loss than the western part. This tendency was explained from the difference in building traditions, including the quality of building material and construction labor.

5.3.3 Topography of Ankara

The topography of Ankara and its vicinity is roughly divided into the following four categories: mountainous area, upland plateau, lowland plateau, and low land. The highest peak in the mountainous area is 1,860m and is composed of volcanic rock and sedimentary rock from the Mesozoic period. The low land is spread over an area of about 2km along the Ankara River at an altitude of 800–850m.

The soil conditions of the Ankara area is good, except the low land. However, almost all housing are located on slopes in the plateau areas, and damage from slope failure could easily occur in earthquakes and heavy rain. Most of the housing without a permit (Gecekondu), which accounts for 70% of dwellings in Ankara, is constructed on steep slopes with only the simplest leveling of construction site.

5.3.4 Urban setting

In Ankara, the urban area was first developed in the bottom of the valley and, in the course of its expansion, spread into the surrounding sloping areas. The urban development of Ankara has proceeded at an amazing pace (Table 5.3.1).

Table 5.3.1
Growth of population and urban area of Ankara

Year	1923	1928	1932	1945	1957	1969	1985
Population	50	74	110	200	478	1,150	2,250
Area	-	300	710	1,900	3,650	13,780	26,900

Units: Population in 1,000 people, Area in ha

The districts with the highest population density are those where poor people live and buildings are constructed without approval. Since those districts stand on steep slopes and have only narrow roads, it is difficult for an automobile to approach the area. The whole area poses difficulties for fire–fighting activities.

Small (one–man), home–based manufacturing businesses are concentrated in the city center and to the north of it. Those areas have a high population density and were occupied by dwellings without permits. Government offices and business establishments such as insurance companies and banks also show a unipolar concentration in the city center.

Coupled with the lack of earthquake resistance in buildings, the urban setting of Ankara is extremely risky to earthquakes. Most of the housing, especially the non–approved developments, including mid– and high–rise buildings, is in danger of collapse in an earthquake. There are many privately–owned, medium–scale buildings in which businesses occupy the first, second, and third floors, while the upper floors are used for housing. Those also pose serious problems objecting earthquake safety.

5.3.5 Required tasks for disaster prevention

We need to stress the following points as major tasks for Ankara. Those were items selected by the author of this article from the national program of Turkey for IDNDR (Ergunay and Gulkan, 1991).

A. Identification of Hazard and Risk

Priority will be given to counter measures intended for reducing earthquake damages during regional and urban planning work.

B. Short–term Protective Measures and Preparedness

Guiding booklets will be prepared so that existing "Provincial–Level Rescue and Relief Plans" will be made more realistic and directry applicable.

C. Long-Term Preventive Measures

1. Revising earthquake resistant design standards
2. Developing earthquake resistant designs for special structures
3. Creating a system for surveying and registering the state of buildings
4. Creating a system for diagnosing the safety (earthquake resistance) of key facilities
5. Strengthening the quality control of concrete and establishing a system for the supply of high quality concrete

There is plenty of evidences that suggest a future disaster in Ankara caused by an earthquake. Since the disaster awareness in Ankara is considerably high, undesirable economic situation of the country seems to be the only problem that prevents the vulnerability reduction in Ankara.

5.4 San Francisco, California, U.S.A.

5.4.1 Introduction

San Francisco is a major city on the west coast of the United States of America with a current population of about 710,000. The city is the principal commercial center of the state of California, as well as a well known tourist destination having many tourists from all over the world.

San Andreas fault, which has a total length of about 1,300 km and high seismic activity, passes by the city. Major earthquakes that recently occurred on this fault system include the San Fernando earthquake of 1971 (M6.5) in the Los Angeles area, the Coalinga earthquake of 1983 (M6.7) in central California, and the Loma Prieta earthquake of 1989 (M7.1) affecting the San Francisco Bay area.

In the Loma Prieta earthquake of 1989, in spite of a large epicentral distance of about 100km, remarkable damage, both in human and material, occurred in the San Francisco Bay area. From this disaster, we once again learned the vulnerability of modern cities to earthquakes.

On the basis of lessons learned from the Loma Prieta earthquake, as well as those from the 1906 San Francisco earthquake, seismic safety projects are currently in progress in San Francisco. The projects are: 1) to identify problems that cause and expand a seismic disaster, 2) to re-evaluate existing seismic safety measures, 3) to assess the seismic risk of the area, and 4) to integrate the results from the above 1) – 3) in the safety and urban plans of the city.

In the following section, we briefly describe the vulnerability assessment for San Francisco, referring a report published by the San Francisco Department of City Planning in 1992 under the title of "Review of Seismic Information." The contents of this report is shown in Section 5.4.3.

5.4.2 Vulnerability Assessment

Seismic hazard assessment and damage estimation were carried out, and the results were incorporated into the master plans for urban planning.

What came to our attention in the hazard assessment is that the location of expected epicenters were specifically given, and the probability of future earthquakes was evaluated quantitatively. Those surveys took place including the area's seismic environment in which earthquakes occur exclusively on the San Andreas fault system. Each fault in the system is precisely located, and, thus, the earthquake conditions for the surveys were rationally give in a deterministic and quantitative manner.

Items of damage estimation were diversely given and similar to those examined in Japanese practice. One of the remarkable aspects of the survey was the estimation of economic loss, macro-scopic though, for the San Francisco Bay area, as well as the San

Francisco area. The economic impact was assessed on the basis of the estimation of physical damage.

The city of San Francisco, in addition to carrying out vulnerability assessment by itself, collected all relevant material derived from the research done by national, state, and local organizations. From the view point of regional earthquake risk assessment for the entire Bay Area, including San Francisco, the material collected by the city is crucial and of relevant help. The material is also useful in conducting mutual aid between local communities in an earthquake disaster. The author of this review article would like to suggest that it is valuable to assess not only earthquake vulnerability for areas of different size but also that for different levels of disaster severity. The development of an emergency response plan on the basis of such assessment is also significant toward the enhancement of regional safety.

5.4.3 Contents of the report

Building Loss Issues for Businesses
Impact on Historic Resources
Macroeconomic Impacts

5.5 Wellington, New Zealand

5.5.1 Basic stance of disaster countermeasures

In New Zealand, the Local Government Amendment Act was revised in 1989, and substantial reorganization of the administrative system was carried out. The country was re-divided into 14 regions, and a regional council was set up for each region. The regional councils were authorized in regional planning, civil defense, coastal planning, and so on. Those authorities previously belonged to the ministries of the national government. The territorial authorities were also reorganized and merged, reducing into 73 bodies. Of the 73 bodies, regions in which more than 50,000 people live, urban areas dominate, and large centers were established were appointed as cities, while the rest as districts. Currently, 14 cities and 59 districts are designated. The Ministry of Civil Defense, to execute the work on a daily basis and authority of the Minister of Civil Defense, has divided the country, which consists of 14 regions, into 4 zones and, for each of the four zones, appointed an executive officer called commissioner.

In New Zealand, the term of "civil defense" is used for disaster safety measures, and the Ministry of Civil defense was established for this object. The civil defense take action in disasters. Police and fire departments still exist, but in major disasters, which traditional emergency services cannot handle, the civil defense are mobilized. While the officer in charge of the civil defense are appointed by law, they are not permanent employees, but citizens that join the organization basically on a voluntary basis in major disasters. This rationale is based on the spirit of "taking responsibility for own safety," which is in complete contrast to the attitude of Japanese people, who leave everything in the hands of the national and local governments.

The activities of the civil defense take their legal pretext from the Civil Defense Act. The law was first enforced in 1962 and was revised several times since then. The presently valid version was enacted in 1983. This does not intend to reduce vulnerability to disasters in advance by, for example, stipulating appropriate land use or architectural standards. The aim of the civil defense is to prevent the spread of casualties in a disaster, to care the injured, and to rescue disaster victims. On the basis of the Civil Defense Act, the central and local governments and the territorial authorities prepared their own civil defense plans, respectively. In comparison with the structure in Japan, the Civil Defense Act has a nature similar to the Disaster Countermeasures Basic Act, while the civil defense plans are the equivalent of regional disaster prevention plans.

Together with the reorganization of the local government system in 1989, the Civil Defense Act was also revised in the same year. This revision basically involved a re-appraisal of the applicability of the law after the alterations to administrative boundaries.

5.5.2 Annual plans for earthquake safety measures

A 7-year Natural Disaster Reduction Plan was started by the Wellington Regional Council in 1988. Its objectives are to raise the levels of safety within regions by clarifying the vulnerability to earthquake disasters in each community. To enhance regional safety, plans as follows were proposed: revision of the land use plan, engineering upgrading of life-lines, amendment of the action plans for the civil defense, revision of the architectural planning standards, and implementation of public education.

First, plans were made to evaluate the type and extent of earthquake disaster expected in each district. The types of earthquake disasters were divided into those caused by ground shaking, displacement of fault lines, liquefaction, slope failure, and tsunamis, and the development of countermeasures against each type was incorporated into the annual plans. A survey into active faults in the whole region was started in the fiscal year of 1988. Announcement of strategy for countermeasures is scheduled in the fiscal year of 1994 (Table 5.5.1). The results of the survey are shown in the form of a micro-zoning map. And, at the same time, studies for the development of countermeasures are carried out, through which strategies for reducing risk down to the acceptable level.

Table 5.5.1
Programme for the Natural Disaster Reduction Plan

Year	Research Programme
1988/1989	Work on active faultlines in Wellington Region.
1990/1991	Research on the tsunami hazard to Wellington Harbour.
	Study on variations in the amplification of ground shaking due to local ground conditions.
	Work on each active faultline including the Ohariu and Wellington faultlines.
1991/1992	Define the ground shaking in Upper Hutt, Wellington, Kapiti and the Wairarapa.
	Further investigate risk mitigation opportunities and the integration of the Natural Disaster Reduction Plan.
	Produce a literature review on the potential impact of earthquakes on the regional economy.
1992/1993	Define the ground damage hazard, including liquefaction.
	Assess the liability aspects of natural hazard management in the Region.
	Develop general policies dealing with seismic hazards for inclusion in the Regional Policy Statement.
1993/1994	Define seismically induced landsliding and locally significant hazards.
	Develop risk mitigation policies and methods for assessing acceptable risk.
1994/1995	Prepare and release a draft for achieving an acceptable level of risk from seismic hazards in the Wellington Region.

After Wellington Regional Council.

5.5.3 Character of the earthquake countermeasures

Studies on seismicity on the basis of research on active faults have revealed that the Wellington area, which has experiences of major earthquakes in the past, has a high likelihood of occurrence of earthquakes in future. However, while it can be said that the Wellington fault is getting closer to its active period, urgent situation is not recognized. Currently, importance is attached to safety policies based on long-term prospects.

The idea of the disaster prevention in New Zealand consists of: 1) avoidance from disasters, 2) rescue by the civil defense, and 3) relief by the national government. These three are especially applicable to the social environment of New Zealand, where population density is low and the "pressure" on construction site is not high. Regarding the idea of "avoiding disasters," land use pattern for areas having earthquake faults was proposed so as to minimize the damage potential. From now on, land use is to be proposed on the basis of seismic micro–zoning maps. Relief for disaster victims by civil defense is traditionally a fundamental idea for disaster safety of this country. Disaster relief by the national government is currently the subject of debate how far the nation takes responsibility in this aspect, particularly in case of enormous disasters. It seems reasonable to manage this problem as a part of welfare.

5.6 Granada, Spain

5.6.1 Seismicity of Spain

The seismic activity in Spain is as high as that in other countries on the Mediterranean, while the region is one of the most seismically active part of the European continent. Table 5.6.1 shows the major destructive earthquakes that affected Spain in the last 500 years.

Table 5.6.1
Major historic earthquakes in Spain over the last 500 years

Year	Affected Area	Damage caused
1396	Tabernes (Valencia)	The town of Tabernes was devastated.
1428	Olot (Gerona)	The town of Olot was devastated.
1504	Carmona (Sevilla)	Many buildings collapsed.
1518	Vera (Almeria)	The town of Vera was destroyed and rebuilt.
1522	Almeria	Most buildings were severely affected. Many buildings collapsed.
1645	Alcoy (Alicante)	Many buildings collapsed. Several towns suffered severe damage.
1680	Malaga	70 people were killed. 20% of dwellings collapsed. 30% of dwellings were not inhabitable. 30% of dwellings suffered severe damage.
1748	Enguera (Valencia)	Many buildings collapsed. The remainder were not inhabitable.
1755	Southwestern Cabo and Southern Vicente	Tsunami. 2,000 people were killed in Spain. Earthquake was felt even in western Europe.
1804	Dalias (Almeria)	300 people were killed. Many villages were affected.
1829	Torrevieja (Alicante)	389 people were killed. Town of Torrevieja was destroyed.
1884	Arenas del Rey	900 people were killed. 4,400 dwellings collapsed. 13,000 dwellings were affected.

Source: Instituto Geografico Nacional, Peligrocidad Sismica en Espana.

5.6.2 Seismic hazard map

Estimated isoseismals were developed with return periods of 100, 500, and 1,000 years. Areas of high intensity are expected in the Mediterranean coast in the south and the northern most part of the country toward the border to France. In the Mediterranean coast area, particularly high intensity is expected in the Granada area.

For the city of Granada, expected intensity on the MSK scale is 7–8 for a return period of 100 years, 8–9 for 500 years, and 9–10 for 1,000 years. A map showing estimated isoseismals for a return period of 500 years appears in Figure 5.6.1.