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SEISMIC MICROZONATION IN ADRA AND BERJA TOWN OF ALMERIA, SPAIN

BY

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ABSTRACT

In this paper, it is shown some fundamental maps to use seismic microzonation for a little town, Adra of Almeria in Spain which affected lately two earthquakes. The authors have surveyed on damages caused by two quakes happened in 1993 and 1994, and we have estimated on the ground dynamic characteristics by microtremor observation and seismic intensity distribution by a questionnaire survey .
Predominant frequencies evaluated by microtremor were very good corelated with the deference of surface geology in the survey area. In the soft soil area, predominant frequencies were low, and in hard area hifh frequencies.
The damages, the dynamic characteristics and seismic intensity distribution, have been correlated so we can suggested that the microzoning in the study area will be able to complete sufficiently by using the methods in this research and the already clasification geological map.

KEYWORDS

Earthquake, Earthquake disaster, Seismic microzonation, Microtremor, Seismic intensity distribution, Spain, Andalucia, Adra town

RESEARCH OBJECTS

In historical view point, Andalucia in Spain is one of the earthquake active regions in Europe. In December of 1993 and January of 1994, two earthquakes hit Adra, Berja and a some towns around, and the quakes damaged many houses and buildings with severe cracks. So practical research of seismic disaster prevention is

requested by the people of the region.
From 1992 year, Andalucia Institute of Geology and Seismic Disaster Prevention have studied on the seismicmicrozonation in Granada city as a fundamental study for seismic disaster prevention in Andalucia with a Japanese research group, as an international research project between Spain and Japan.
This research has been down as part of the international project, to clear the relationships between earthquake damages and effects of surface geology in each sites.
Most important object of this study is to get the basic data for seismic microzonation in the target area and to prepare for making useful zoning maps.

OUTLINE OF THIS RESEARCH

Methodology

We used the followings methods in this study: 1)Reconnaissance survey of the damage caused by two earthquakes; 2)Microtremor observation of the ground; 3)High density seismic intensity distribution survey by questionnaire method; 4)Using and verification the prepared surface geology map with the government of the town.

Members of This Research Group and Target Study Area

This research has been down with coordination from the following members: Dr.Kazuoh SEO from Tokyo Institute of Technology who is the leader of the Japanese side of the international project, Dr.Takahisa ENOMOTO from Kanagawa University in Japan, and the authors of this paper.
Target area in this research are the towns Adra and Berja in Province of Almeria, Spain, mainly Adra town that has been affected by the two earthquakes mentioned.

SEISMIC ACTIVITY

Historical Earthquake and Estimated Isoseismal Map

Historically, the coastal area of Mediterranean Sea in Spain has been frequently affected by severe earthquakes. Fig.1 is an isoseismal map of the return period estimated for 500 years in Spain.(IGN). The target area of this study is estimated to be the highest intensity zone in Spain.

Two Earthquake Happened in December 1993 and January 1994

Data of the earthquakes is following;

	Berja-Adra Earthquake	Balerma Earthquake
Date	1993.12.23 15:29	1994.1.4. 09:03
Epicenter	36.79N 3.07W	36.63N 2.84W
Depth	9.9 km	2.0 km
Magnitude	5.0	4.9
Max.Intensity	MSK 7	MSK 7

Isoseismal maps for two earthquakes are shown in Fig.2 and 3. (IAGPS). The Berja-Adra earthquake shows a wider high intensity area than the Balerma Earthquake.

The general tendencies of damage caused by two earthquakes are shear cracking of brick walls in unengineered buildings, peeling of dressed materials of brick walls, but the damage does not reach destruction. Adra town was the area most affected by the earthquakes. Adra is located in the most southern part the hypocentral area of the Berja-Adra Earthquake, and it is away about ten km from the epicenter of Balerma Earthquake.

Reinforced apartment housings with about 4 to 5 floors located in the coastal area of the town were damaged with the types damage mentioned previously.

Berja is away in a the northerly direction and is located at the northern end of the of the Berja-Adra Earthquake.

Newly constructed reinforced apartment housings with 3 to 4 floors that are located in the bottom area of little circular valley of the town, were damaged.

SEISMICMICROZONATION IN ADRA TOWN

Profile of Adra and Geological Map of the Town

Adra is located along the Mediterranean coast, and it has a little fishing port in south part of the town and wide agricultural land in north and south-east of the area. The population of the town is about twenty thousand.

Civil Protection in Adra has made some zoning maps of the town. One of them is a geological zoning map, and it is shown in Fig.4. According to the map, Adra town is classified in 3 geological types, soft soil condition, middle soil and hard soil condition.

Microtremor Observation of Ground Surface

Stations of microtremor observation have been set up on the cross points of a grid and they were divided by 100 m in horizontally and 100 m vertically on a map scaled at 1/20,000.

Two sets of equipment were used and the natural period of seismometers was set 1 second. Each observation time is 3 minutes.

Predominant period distribution of horizontal shear waves by Nakamura's Method (Nakamura 1986) in Fig. 5 shows us that long period zone coincides with soft soil zone in Fig.4. The hard and middle soil zone show short periods although in some places in the hard soil zone long period are shown.
Damaged buildings are located in middle soil zone where show predominant periods 0.30 sec to 0.39 sec. The natural periods of the buildings may be the same periods as the periods for the ground, but we have to study on the buildings to make sure of this.

Seismic Intensity Distribution Evaluated by Questionnaire Survey

A questionnaire survey to evaluate seismic intensity during the two earthquakes was down by the direct hearing method in Adra town. Questionnaire sheets had been used for the 1989, Loma Prieta EQ. in USA, the 1990 Luson EQ. in Philippines and for others.
Survey sites are shown in Fig.6 and about 2 or 3 questionnaires were carried out by the employees of Civil Protection in Adra. By estimated Seismic Intensity, the average seismic intensities in the town due to two earthquakes were about 7.0 in MM Intensity Scale. These average values correspond very well to the Seismic Intensity 7.0 in MSK Intensity Scale in Fig.2 and Fig.3. The distributions of the intensity are shown Fig.6 and Fig.7. By these, it is shown that seismic intensity distribution due to the December 23,1993 EQ. is concerned with geological conditions, because the intensity of the nearer sites of soft soil condition shows greater intensities. But in the case of the January 4,1994 EQ. was not clearly concerned with soil conditions.

Seismic Microzoning in Adra

The ground dynamic characteristic is able to be classified from the result of predominant period distribution obtained by microtremor observation well, and it is corresponding to regional division considered the ground condition in Adra. As a result, the predominant period in the region of each ground condition became very clear.

Also, according to the seismic intensity distribution survey, especially, in the case of the 1993 December earthquake, it was shown that higher seismic intensities were distributed in comparatively soft ground region correspond to above-mentioned ground condition, and then the difference of seismic intensity distribution between hard ground condition and soft condition was very clear.

There are a lot of small scale valley which develop and open in the alluvial fan, the hard ground region which extends to the northern part of Adra. The change of the predominant period and seismic intensity distribution in this region are thought to be influenced by a minute change in the ground condition by means of existence of these small valleys.
Any way, the microzoning in Adra will be able to complete sufficiently by using the above -mentioned already classified regional division according to ground condition and a little bit detailed considering of distributed small valleys in alluvial fan develop to northern part of the town.

CONCLUSIONS

The followings are conclusions reached in this research:

1. It is surmised by this study that the damages caused by the latest two earthquakes are affected by surface ground conditions.
2. Geological map proposed by Civil Protection of Adra town government with 3 types soil conditions is useful for judgment using ground soil condition.
3. By microtremor observation, the authors show a predominant periods distribution map. It will be useful to consider the damages caused the two earthquakes and to estimate future damages with the data from buildings.
4. Using questionnaire survey, the seismic intensity distribution due to the Berja-Adra Earthquake was found to be related to soil condition. But the case of Balerma Earthquake is affected by different tendencies.

Analysis of data of microtremor not yet finished on this stage. An evaluation of the amplification characteristics of the surface geology is needed with an analysis of microtremor data.
The data of buildings are necessary to evaluate the seismic vulnerability of the town.
However with the help of this study, the authors have an insight in order to make seismic microzonation in this town which does not have sufficient soil data.

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3)Nakamura,Y., Ueno,M:A Simple Estimation Method of Dynamic Characteristics of Subsoil, Proceedings of Seventh Japan Earthquake Engineering Symposium(in Japanese), 1986,pp 265-270

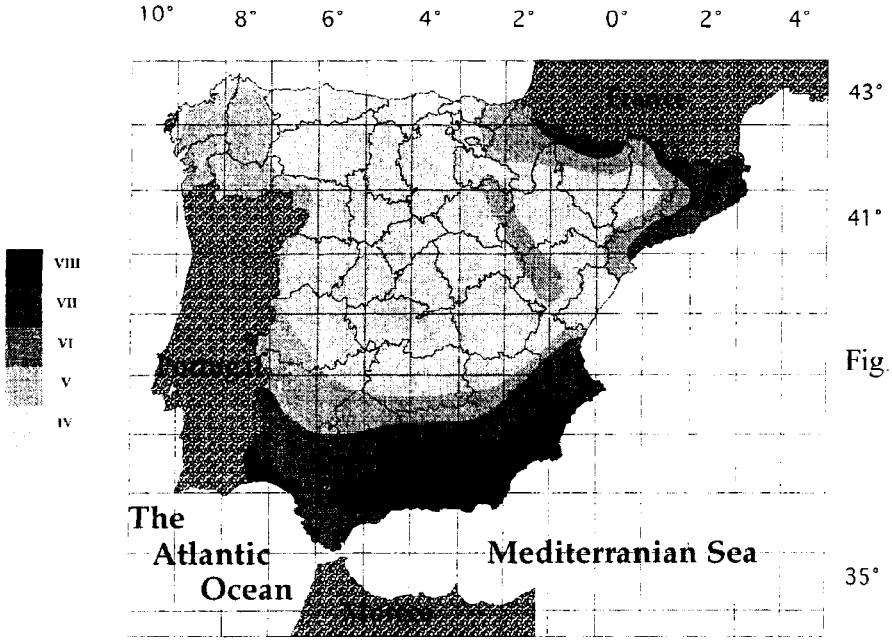

Fig. 1 Estimated Iso-seismal Map of Spain in 500 Years Return Period

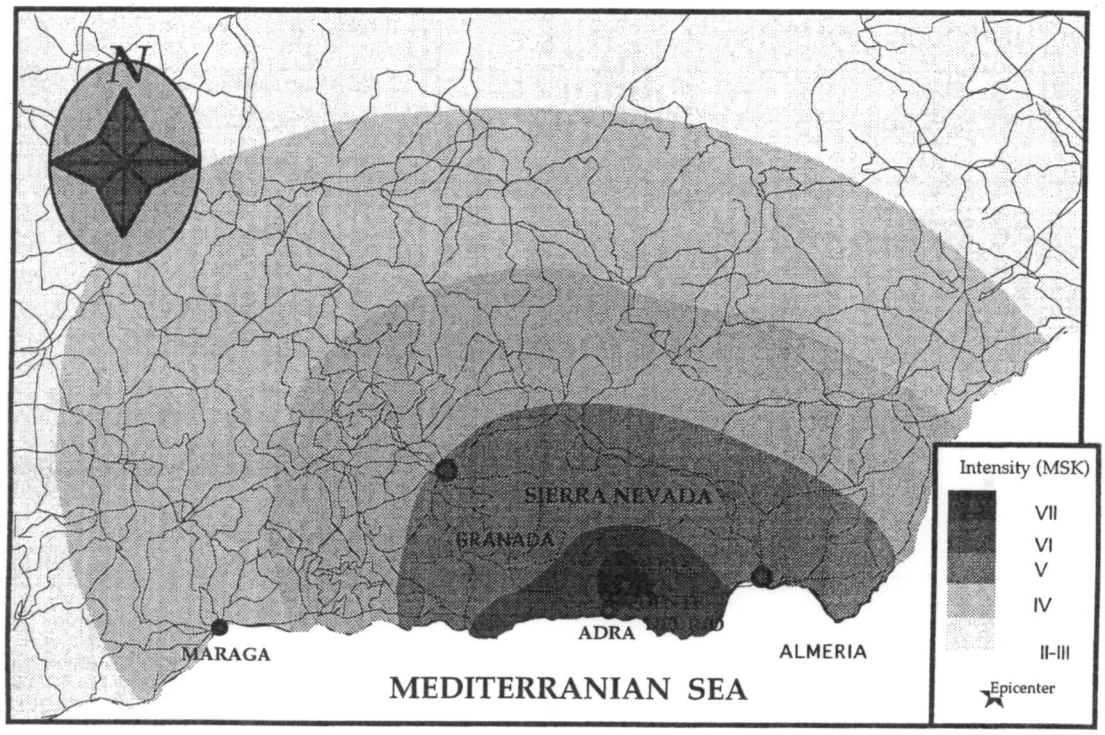

Fig. 2 Iso-seismal Map Caused by the 1993 Berja-Adra Earthquake(after IAGPA)

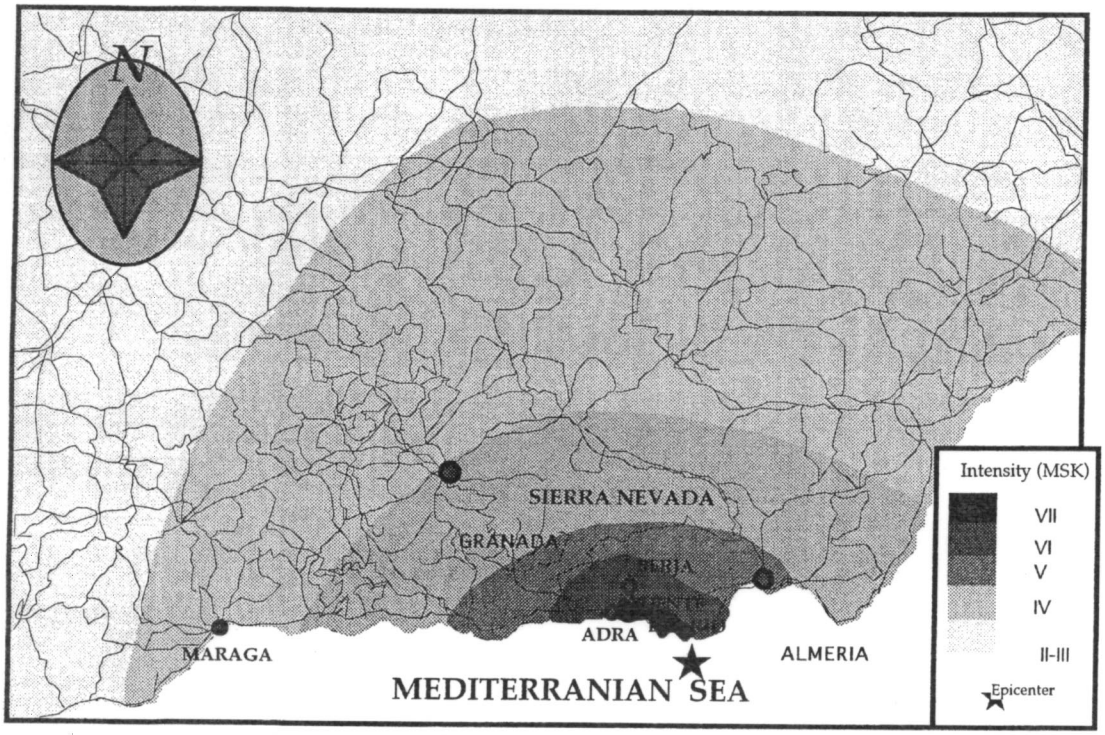

Fig. 3 Iso-seismal Map Caused by the 1994 Balerma Earthquake(after IAGPA)

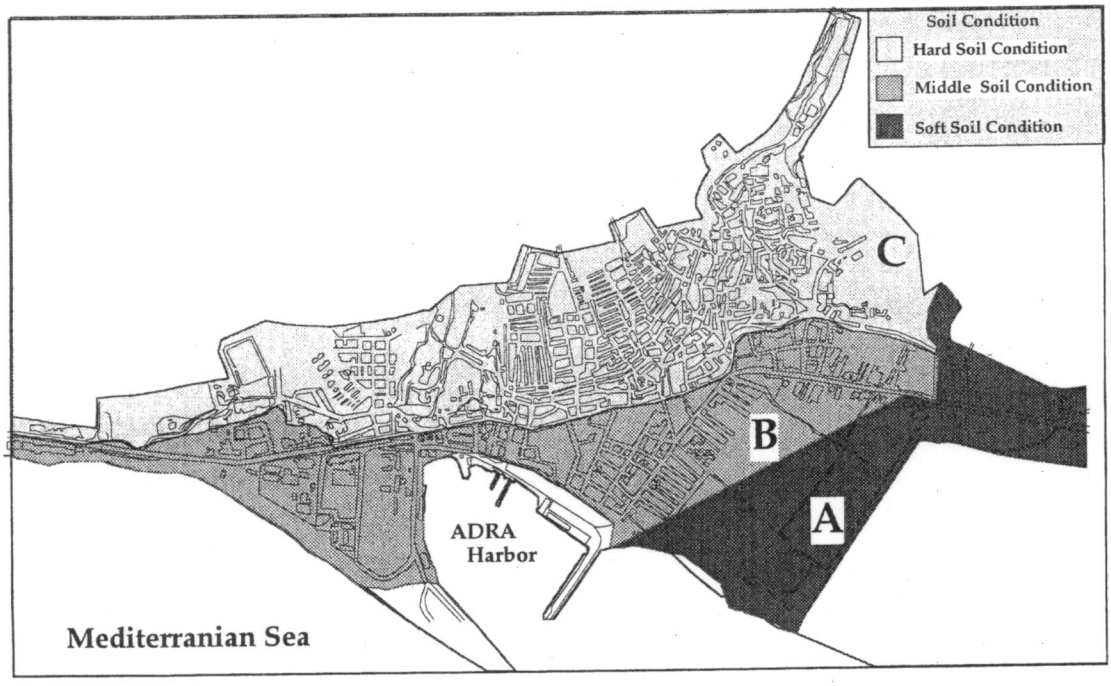

Fig. 4 Surface Soil Condition Map in Adra made by Civil Protection of Adra

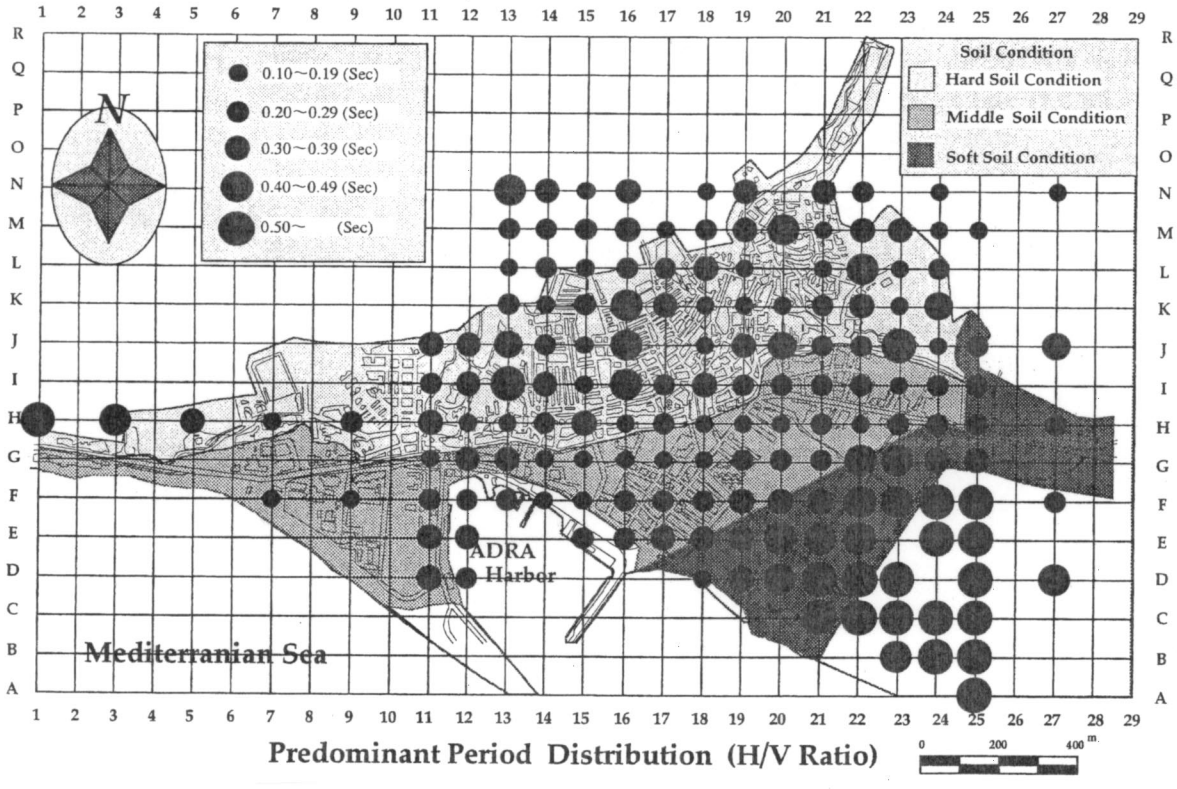

Fig. 5 Predominant Period Distribution in Adra evaluated by Microtremor

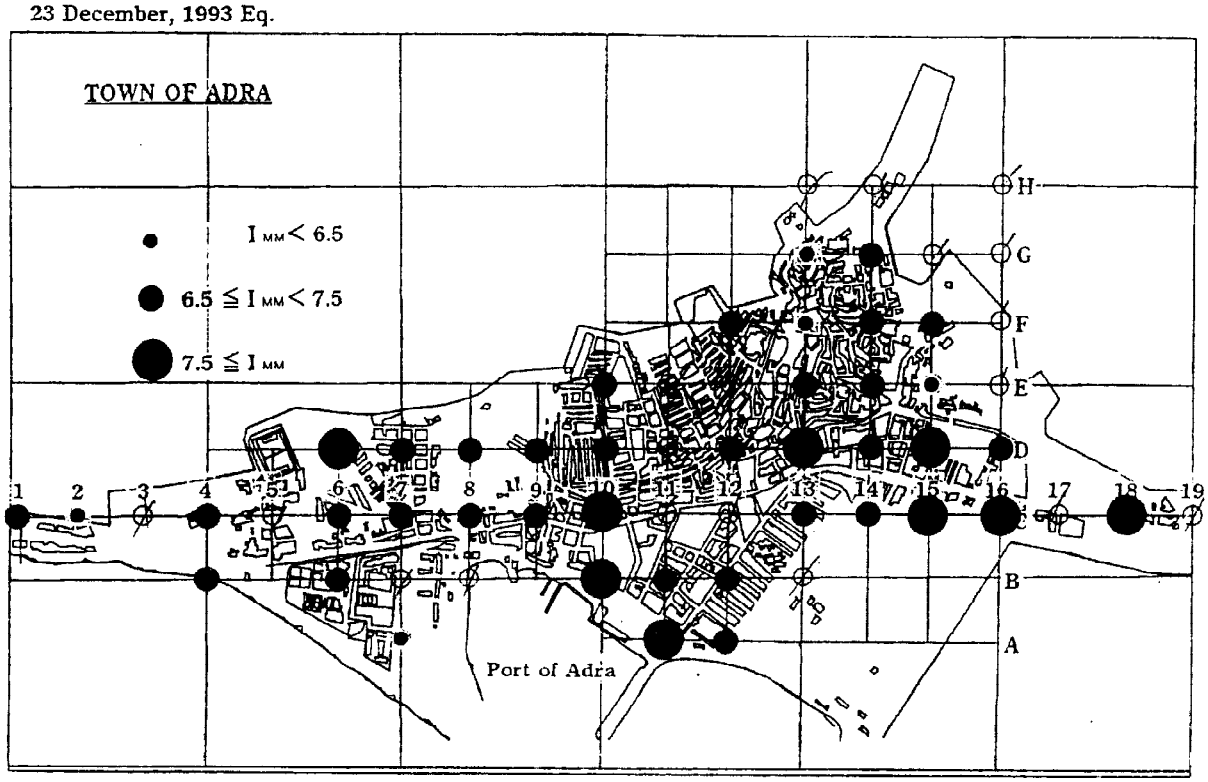

Fig. 6 Seismic Intensity Distribution During the 1993 Berja-Adra Earthquake Estimated by Questionnaire Survey

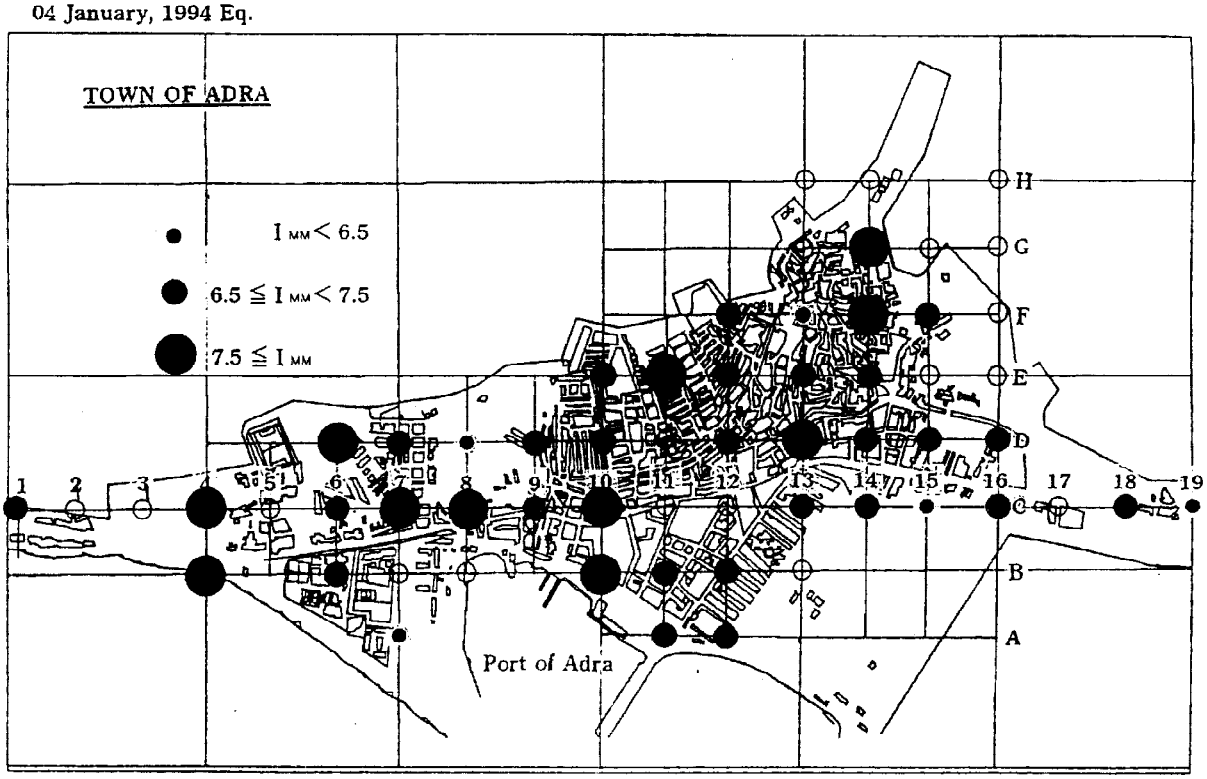

Fig. 7 Seismic Intensity Distribution During the 1994 Balerma Earthquake Estimated by Questionnaire Survey