Sexto Congreso Nacional y Conferencia Internacional de

Geología Ambiental y Ordenación del Territorio

Riesgos Naturales, Ordenación del Territorio y Medio Ambiente

COMITE ORGANIZADOR

D. JOSÉ CHACÓN MONTERO — Presidente
Departamento de Ingeniería Civil
Universidad de Granada

D. JUAN ANTONIO MARTÍN-VIVALDI MARTÍNEZ — Vicepresidente
Consejería de Medio Ambiente. Granada

D. CLEMENTE IRIGARAY FERNÁNDEZ — Secretario
Departamento de Ingeniería Civil
Universidad de Granada

D. JESÚS GARRIDO MANRIQUE — Vicesecretario
Delegación de la Consejería de Obras Públicas y Transportes. Granada

D. MIGUEL VILLALOBOS MEGÍA — Tesorero
Ingemisa. Granada

COMITE CIENTIFICO

D. José Aguilar Ruiz. Universidad de Granada
D. Jesús Beas Torroba. Diputación de Granada
D. José Benavente Herrera. Universidad de Granada
D. Antonio Castillo Martín. Universidad de Granada
D. José Chacón Montero. Universidad de Granada
D. Mario Chica Olmo. Universidad de Granada
D. Luis Cruz Pizarro. Universidad de Granada
D. Javier Cruz San Julián. Universidad de Granada
D.ª Purificación Fenoll Hach-Ali. Universidad de Granada
D. Jesús Garrido Manrique. Delegación de la Consejería de Obras Públicas y Transportes. Granada.
D. Clemente Irigaray Fernández. Universidad de Granada
D. José Linares. CSIC. Granada
D. Carlos López Casado. Universidad de Granada
D. Andrés Maldonado. Universidad de Granada
D. Juan Antonio Martín-Vivaldi Martínez. Consejería de Medio Ambiente. Granada
D. Francisco Ortega Alba. Universidad de Granada
D. Roque Ortiz Silla. Universidad de Murcia
D. Antonio Pulido Bosch. Universidad de Granada
D. José Luis Rosúa Campos. Universidad de Granada
D. Carlos Sanz de Galdeano. Universidad de Granada
D. Mariano Simón Torres. Universidad de Granada
D. Francisco Valle Tendero. Universidad de Granada
D. Francisco Vidal Sánchez. Universidad de Granada
D. Joan Manuel Vilaplana. Universidad de Barcelona
D. Miguel Villalobos Megía. Ingemisa. Granada

INVESTIGATION ON THE UNEQUAL DISTRIBUTION OF DAMAGE DURING THE HANSHIN EARTHQUAKE (KOBE, JAPAN).

Lekkas, E., Kranis, H., Leounakis, M. & Stylianos, P.

University of Athens. Department of Geology. Panepistimioupoli, GR-157 84, Athens Greece.

ABSTRACT

The unequal distribution of the damage observed in a portion of the urban complex of Kobe during the earthquake of January 17, 1995 is described. At first, a brief outline of the geological - tectonic setting of the greater area of Kobe is given, together with the characteristics of the surveyed area. Then, the method of the damage recording and its results are presented in a composite value diagram. The damage caused to the wooden constructions has been divided into four categories. The composite value diagram shows that an important role in the unequal distribution of damage was played by the faults that belong to the reactivated fault zone and intersect the area.

Key words: Damage, Kobe, Hanshin earthquake, Japan.

RESUMEN

Se estudian la desigual distribución de los datos observados en un sector del complejo urbano de Kobe durante el terremoto del 17 de Enero de 1995. En primer lugar se describen, a grandes rasgos, el marco geológico y tectónico del entorno de Kobe junto con las características del área inspeccionada. A continuación se presentan el metodo de registro de daños y sus resultados en un diagrama de valores. Los daños causados en las construcciones de madera se han dividido en cuatro categorías. El diagrama de valores muestra que las fallas pertenecientes a la zona de falla reactivada y que intersectan el área estudiada, jugaron un papel importante en la irregular distribución de los daños.

Palabras clave: Daños, Kobe, terremoto de Hanshin, Japón.

INTRODUCTION

The earthquake of Jan 17, 1995, M=7.2R in Kobe, Japan, also known as Hanshin earthquake caused a multitude of victims and huge material loss. More than 81.000 buildings collapsed or were damaged beyond repair, while the large scale constructions of the city such as highways, quays and all lifelines were virtually destroyed.

The bulk of damage was located in the urban complex of Kobe and more precisely in the central part of the city where every type of building collapsed or suffered considerable damage. Besides, in other areas/suburbs the concomitant geodynamic phenomena such as the landslides and liquefaction locally augmented the observed damage, with the most representative examples the suburb of Nishinomiya and the coastal zone, respectively. In addition the fires that broke out as a result of the burst gas pipes added to, and virtually finished off the devastation in numerous urban blocks.

Given that the destruction that was mainly due to ground liquefaction and landslides was the object of other fields of specialized research, in this paper we shall present certain parameters that led to the unequal distribution of damage and are solely due to the earthquake movement itself and the existing geological - tectonic conditions in the urban complex of Kobe.

It has to be noted that the presented results are the outcome of a first approach pertaining to one only part of the city, given the fact that the overall problem of the intensity and damage distribution calls for a multidisciplinary approach which will be a combination of geological, tectonic, geophysical, seismological, soil-dynamics and urban-structure data.

THE STUDY AREA

As mentioned above, the huge material loss in the urban complex of Kobe were the result of both the seismic motion itself and the concomitant geodynamic phenomena (liquefaction, landslides) as well as the fires that broke out. In order to focus our investigation on the distribution of damage that was attributed directly to the seismic motion and not to other causes (landslides, liquefaction), a location in the city that did not suffer any of these was chosen. In the meantime this area had had not to be completely burnt down. The location that fulfilled those prerequisites lay at the eastern part of the Kobe megalopolis (Fig. 1). It is a narrow, north-northwestern trending zone from the University of Kobe to the coastline. The southern half of the study area is flat with altitudes that do not exceed 20m, while its northern part lies quite higher, at approximately 120m (University of Kobe).

The same location has been by other research groups (Akamatso et al, 1995) in order to give solutions to the same subject using different methodologies and techniques (microtremor evaluation, etc.).

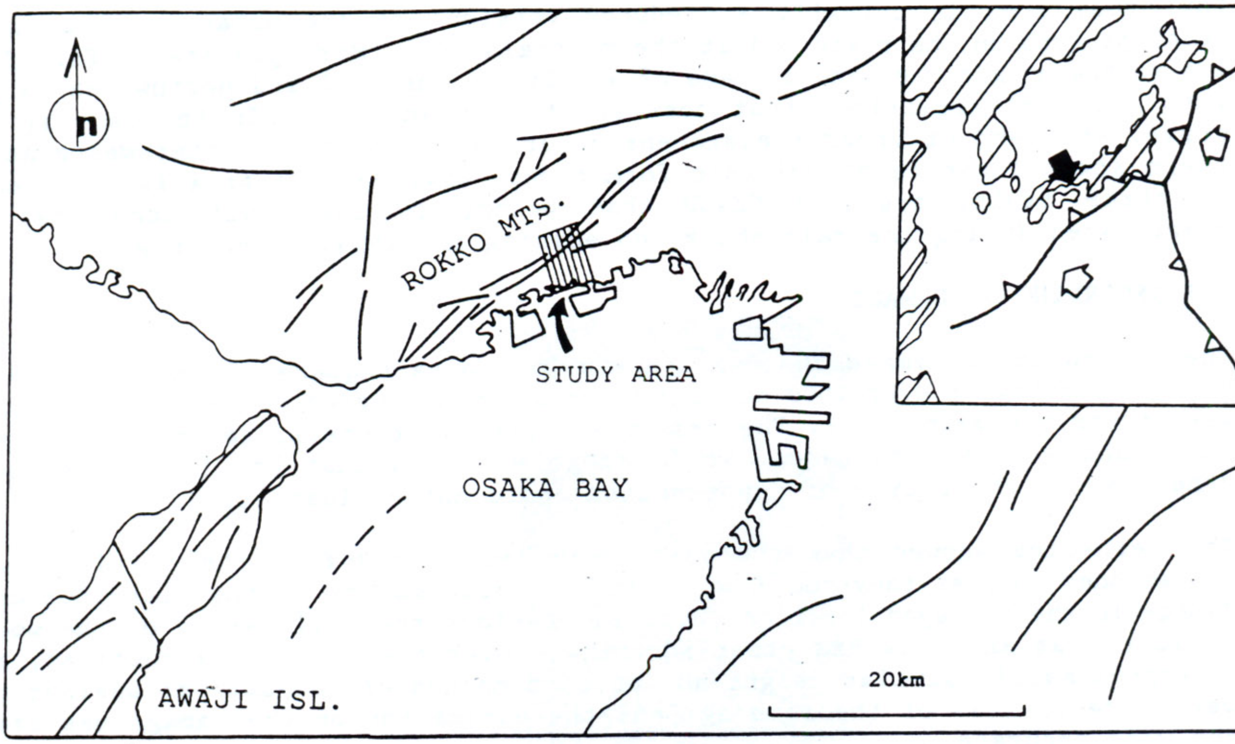
The study area is build up of a variety of structures (steel, reinforced concrete, wooden) but the wooden structures prevail. In addition, the location is intersected by large transportation lines, local or intercity ones, such as Hunkyu line, Yamate Kansen, J. R. Line, Route 2, Hanshin Line, Route 43 and Hanshin Express.

GEOLOGICAL SETTING

The greater area of the urban complex of Kobe is characterised by the presence of a tectonic uplifting block (horst), which is mount Rokko and a downthrown block (graben) which lies to the south of the horst. The horst is built up of Pre-Pliocene formations of volcanic origin mainly, while the graben is filled with Plio-Pleistocene and Holocene formations of considerable thichness (Itihara, 1966, Itihara et al, 1991).

The juxtaposition between the horst and the graben is carried out through a well developed set of active faults (RGAFJ, 1991). These faults have an average NE-SW trend and are of cosedimentary character. They have also created a complex occurrence picture among the Plio-Pleistocene and Holocene formations. Many of the faults are clearly depictable on the ground surface, while others have been covered either by recent deposits or the urban constructions. Some of these in the outskirts of the city of Kobe and on Awaji island were reactivated during the earthquake of Jan 17, 1995, a fact confirmed both by the location of the epicentre and the surficial evidence of earthquake fractures (Fig. 1).

The urban complex of Kobe occupies mainly the coastal plain that corresponds to the northern portion of the downthrown block. It also extends at the southern foot of mount Rokko which is the uplifting block; this fact means that the urban complex is actually crossed by the faults that juxtapose the two blocks. Thus,



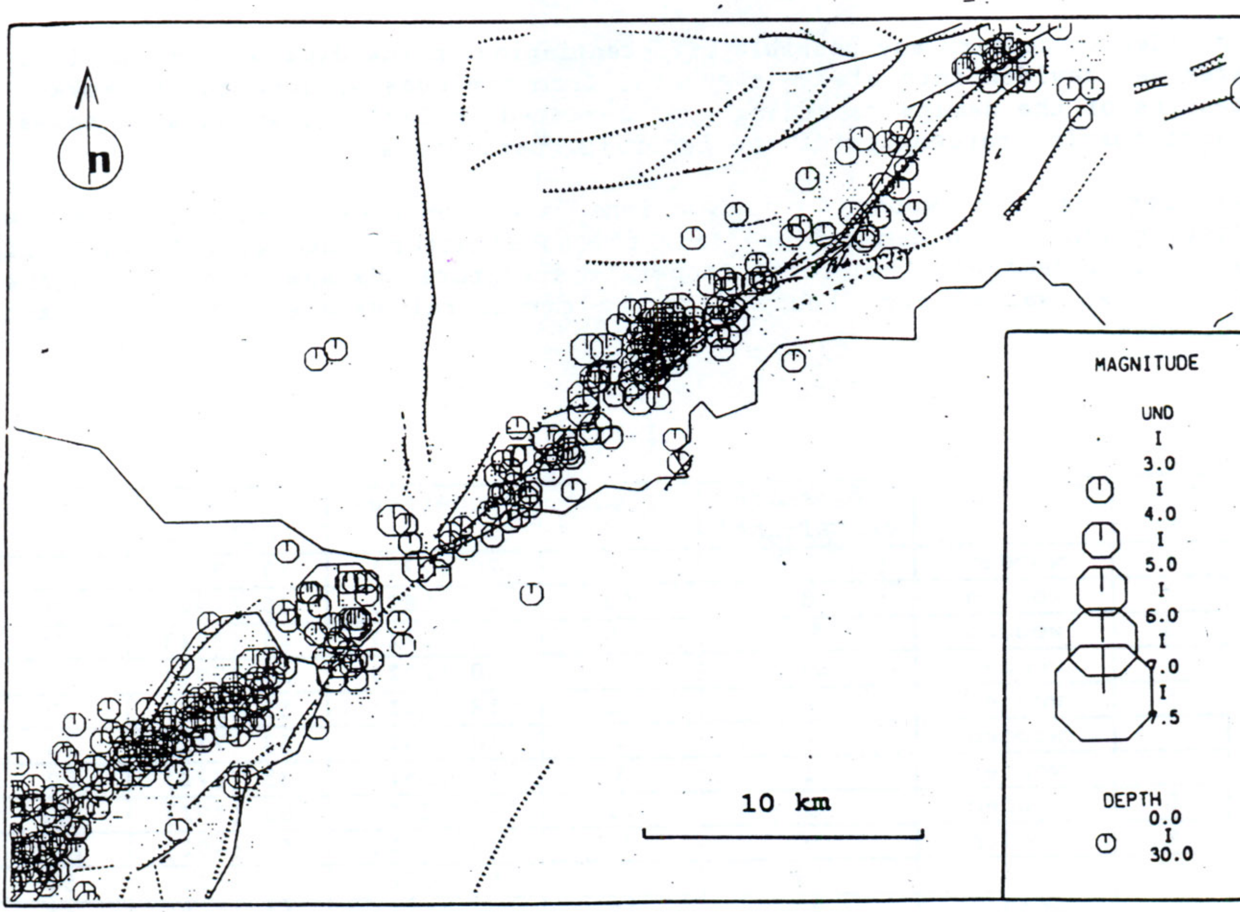


Fig. 1 The survey area, in the urban complex of Kobe (up) and the geographical position of the epicentres of the seismic sequence of January 17, 1995 (down), after JMA (1995).

the study area is actually a "reduced version" of the urban complex, as it develops both on the plain and at the mountain foot. More precisely (Fig. 3) at its southern part the land is made of artificial landfill and northwards we pass into alluvial formations that consist of sand and clay. In the central part gravel and sand of Upper Pleistocene occur, while at the northernwesternn one there are occurences of volcanic formations. Besides, the area is intersected by three faults trending NE-SW that belong to the fault zone that was reactivated during the main shock and ensuing the seismic sequence.

THE RECORDING OF DAMAGE

The recording of damage that was caused by the earthquake of Jan 17, 1995 was done on a total of over 1000 constructions and was carried out approximately one week after the main shock. The area was built up of steel, reinforced concrete (R/C) and wooden structures, while there were few that had been constructed otherwise or their type of construction could not be identified.

The recording showed that the vast majority, over 80% of the buildings were wooden ones so that they could constitute a valid marker of the distribution of damage in the surveyed location (Fig. 2). Besides the utilization of the wooden buildings as an index had other advantages over the other constructions, such as approximately similar height and uniform method of foundation; besides they were more or less of the same age and the estimation on the damage was easier and were accurate.

In order to confirm any possible differentiation in the damage distribution, the area was deviden into eleven segments, from the coastal zone to Mt. Rokko. The results of the damage recording are presented in Table I, which also shows the participation percentage of the recording parameters.

As far as the wooden constructions are concerned, four classes were distinguished: "no damage" or "slight" (no structural damage), "light" (light structural damage), "moderate" (moderate structural damage or severe damage in structural walls) and "heavy" (severe structural damage) or "total/partial collapse".

Table I

Area no.	Structure	"no damage" or "slight"	"light"	"moderate"	"heavy" or collapse	total
1	wooden	5	10	20 (27%)	38 (52%)	73
2	wooden	8	10	21 (28%)	36 (48%)	75
3	wooden	66	35	33 (17%)	66 (33%)	200
4	wooden	20	35	30 (25%)	35 (29%)	120
5	wooden	9	11	18 (20%)	52 (58%)	90
6	wooden	2	2	18 (24%)	53 (71%)	75
7	wooden	1	3	13 (25%)	35 (67%)	52
8	wooden	9	10	22 (22%)	60 (59%)	101
9	wooden	30	25	20 (16%)	50 (40%)	125
10	wooden	19	10	5 (10%)	16 (32%)	50
11	wooden	27	12	6 (10%)	15 (25%)	60

Important damage and collapse in wooden structures cause by the earthquake of January 17, 1995.

Investigation on the unequal distribution of damage during the Hanshin earthquake (Kobe, Japan).

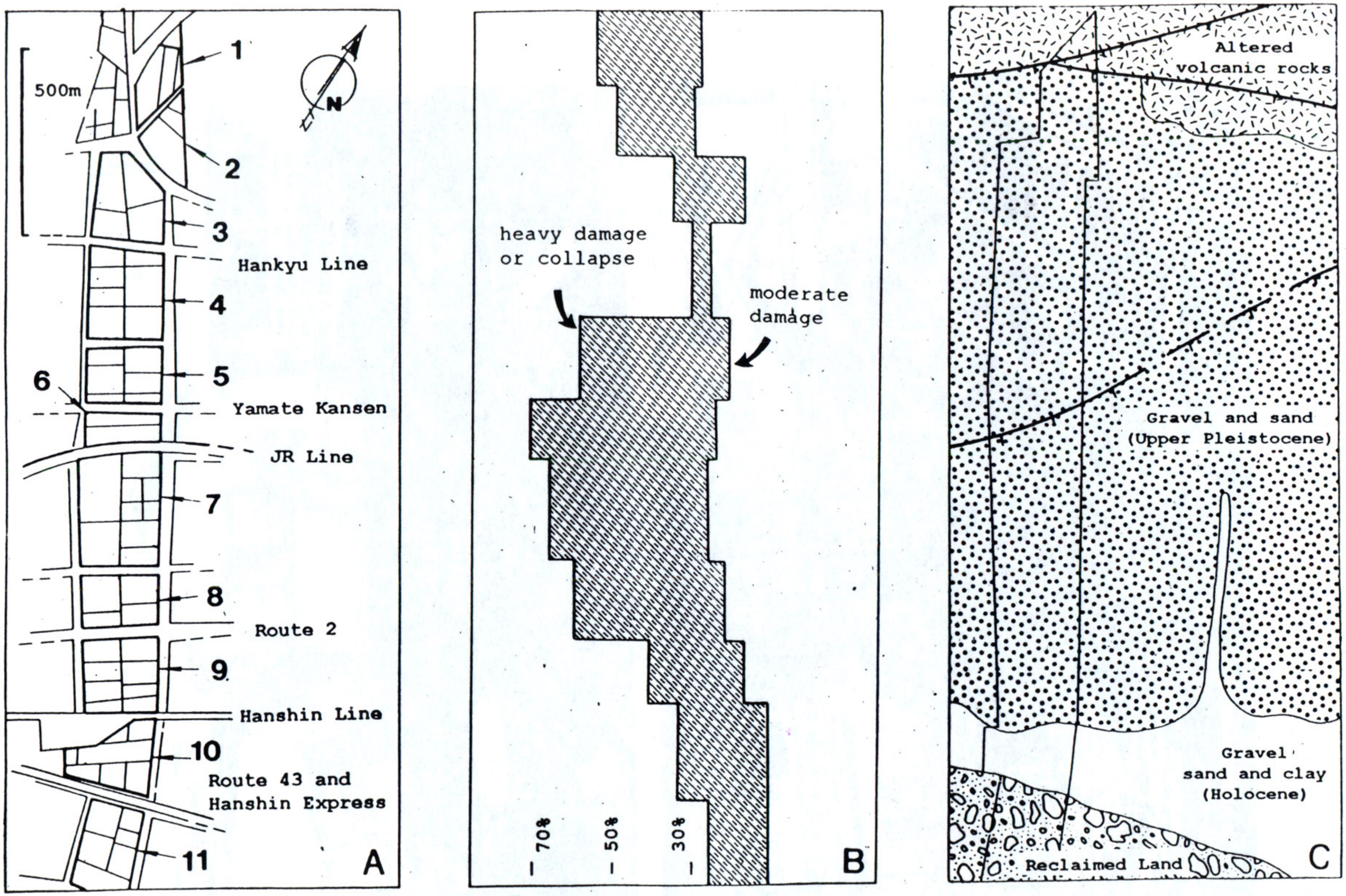


Fig. 3 The sectors that the study area was divided (A), the damage percentage (B) and the geological map of the area (C). The correlation denotes the crucial impact of the faults on the distribution of damage.

EVALUATION OF THE RECORDINGS AND CORRELATION

From the recording data and the subsequent statistic elaboration, the ones that were actually useful are those that give a clear picture of the differentiation of damage so that it is directly correlataable to the existing geological variations and the tectonic conditions.

In particular, the buildings that suffered slight or light damage were not taken into account given the large magnitude of the earthquake that caused even minor damage to every wooden structure. In addition some of this damage is attributed to some negligence of construction failure thus not allowing the correct correlation with the other factors.

The same holds for the buildings that suffered moderate damage despite the slight differentiation in certain parts of the area that appears (Fig. 3); in this case too, a valid correlation could be insecure. However, there is an increase in the damage at the vicinities where faults pass, while there is also a general downward, trend of the damage to the south.

On the contrary, where the damage was "heavy" or "collapse" there is a clear unequal distribution with distinct minima and maxima. Thus, in sectors 1, 2 and 6, 7 the damaged percentage is significantly high and can be attributed to the underlying faults there.

On top of that, in the adjacent sectors (5, 8, 9) there is a gradual decrease which can be ascribed to the larger distance from these faults.

It has to be remarked that there is no lithological differentiation in the Upper Pleistocene formations, which could be held responsible for the abovementioned differentiation of the damage percentage.

Finally, we must draw the attention to the fact that again heading southwards, there is a gradual decrease in the damage percentage (concerning this rery class of damage).

DISCUSSION AND CONCLUSIONS

The study area is a representative part of the urban complex of Kobe. It practically constitutes a "reduced version" and a representative example of the geological setting of the greater area which is characterized by the variety of the geological formations and the presence of an uplifting tectonic block and a downthrown one. These two are juxtaposed by a fault set trending NE-SW. The earthquake of Jan 17, 1995 caused the reactivation of some of the segments of the fault zone, which is turn led to considerable damage.

In the study area, the recording of the damage on wooden constructions that was made showed that there is intense differentiation in certain locations which coincide with fault traces. This fact denotes the crucial impact of the underlying geological structure on the modification of damage distribution. Besides, due to this (impact) no other possibly existing correlation was confirmed between the ground, the geological formations of the foundations and the damage caused.

It has to be noted that relevant correlations have been found on other occasions where the unequale distriibution of damage owes its presence to the existing tectonic features (Lekkas, 1994)

REFERENCES

Akamatso, J., Morikawa, H., Saito, H. & Jido, M. (1995). A relation between disstribution of damages caused by the 1995 southern Hyogo prefecture earthquake annd grounnd vibrational characteristics inferred from microtremors. DPRI, Special Issue, 24-33, Kyoto. Japan.

Itihara, M. (1966). The Osaka Group and the Rokko movements. Chikuy Kagaku, 85-86, 12-18, Tokyo.Japan.

Itihara, M., Yoshikawa, S., Mitamura, M., Mizuno, K. & hayashi, T. (1991) 1:250,000 "Quaternary map of Osaka and adjacent areas, Kinki, Japan. Urban Kubota, n.30. Osaka. Japan *(in Japanese)*

JAPAN METEOROLOGICAL AGENCY. (1995). The Hyogo-ken Nnby eaarthquake sequence epicentre location map. Tokyo. Japan.

Lekkas, E. (1994). Recording of the damage caused by the earthquake of March 23, 1992 at Pirgos, based on the European Macroseismic Scale (EMS) and attempt to correlate it with the geological and geotechnical conditions present. European Seismological Commission, XXIV, General Assembly. Athens. Greece.

THE RESEARCH GROUP FOR ACTIVE FAULTS IN JAPAN. (1991) Active faults in Japan (rev. edition), Univ. of Tokyo press. Tokyo. Japan. *(in Japanese)*