Paper No. 1258. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3
11 WCEE

THE STRUCTURAL DAMAGE NEAR ACTIVE FAULTS IN HYOUGOKEN NANBU EARTHQUAKE

YAO, Shintaro, MURAYAMA, Kyohei, SUGA, Masanori,
NISHIDA, Kazuhiko and KUSUMI, Harushige

Faculty of Engineering, KANSAI University,
Suita, Osaka, 564 JAPAN.

ABSTRACT

This paper presents the general formation of the seismic intensity distribution for the earthquake directly above the focus, based on the survey of the disaster region of Hyougoken Nanbu Earthquake. The survey was continued from February to December in 1995, especially regarding the relation between the structural damages and the existence of faults from various point of view.

The quite important formulation to give the seismic intensity for the earthquake directly above the focus is concluded.

. KEYWORDS

Seismic movement , seismic intensity , active fault , pseudo seismic fault , disaster region , strong disaster belt

INTRODUCTION

In order to find the characteristics of the actual seismic ground movements of Hyogoken Nanbu (South Hyogo) Earthquake at the disaster region, the earthquake sites of Kobe and Nishinomiya city including so called " The Strong Disaster Belt ", were surveyed for several months. For this survey, we recorded the damage of several kinds of structures such as reinforced concrete buildings, roads, buried pipes and so on. On the result of this research, we could find some quite important characteristics of the seismic ground motion in the disaster region of the earthquake directly above the focus.

THE SURVEY OF THE STRUCTURAL DAMAGES

The state of the damages of the reinforced concrete (RC) structures, of which the strength is clearly estimated compared with wooden houses etc., is shown in Fig.1. The estimated seismic intensity I_k is defined as follows. (Yao et al. 1995)

I_K = 7 : many R.C. structures are destroyed and over turned.
6 : main structural members of R.C. structures are cracked.
5 : many non-structural members of R.C. structures are damaged.
4 : R.C. structures are hair cracked.

The results of more detailed survey in Nishinomiya area are shown in Fig.2 - Fig.5. Fig.2 shows the distribution of damages of RC structures in I_k. Fig3. shows the distribution of damages of all kinds of buildings including old wooden houses. Here N_D indicate the degree of the number of all kind of damaged buildings. N_D=7 shows that almost all old wooden houses are destroyed. Fig.4 shows the distribution of damages of sewer pipes which were placed in around 3 meters depth. Here L_D shows the total length in meters of damaged sewer pipes per one block in the map. The ground structure of Nishinomiya area could be got from the boring data as shown in Fig.5.

In this earthquake, we can recognize so called Strong Disaster Belt from Suma to Nishinomiya with 27 km length, also find more seriously damaged spots up to 2 km square to be called "Disaster Spots".

Among these spots, there are three large ones with most heavy destruction in Nagata, Sannomiya and Higashinada area. While in Higashinada Spot, most houses are carried down to north, in Nagata area this direction shows south . On the other hand, Sannomiya Spot had no directional tendency in destruction (Murayama et. al. 1995, Takemura et. al. 1995)

In Nagata and Higashinada area, many cars have jumped and moved to each same direction when the vertical movement had come upon this earthquake . Moreover, the vertical shock pulses are said to have come over 4 times, while at the mountain side (including Sannomiya Spot) no more than two shock pulse-waves have been observed.

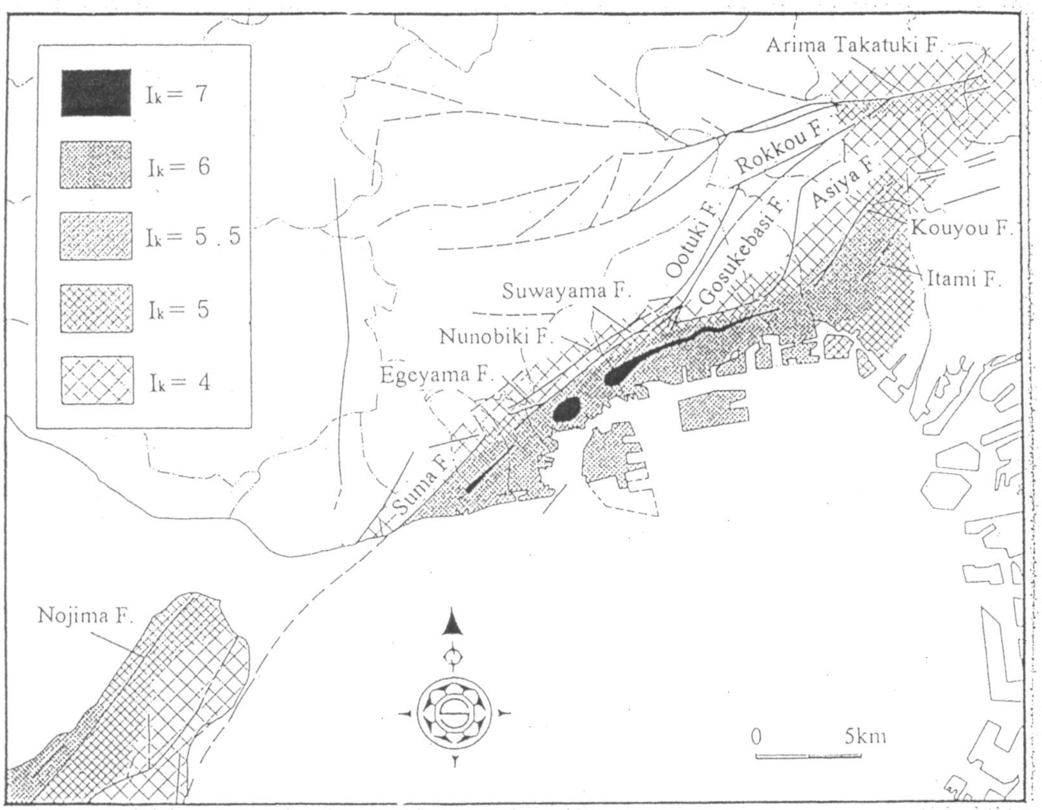

Fig.1 The distribution of I_K in the entire disaster region

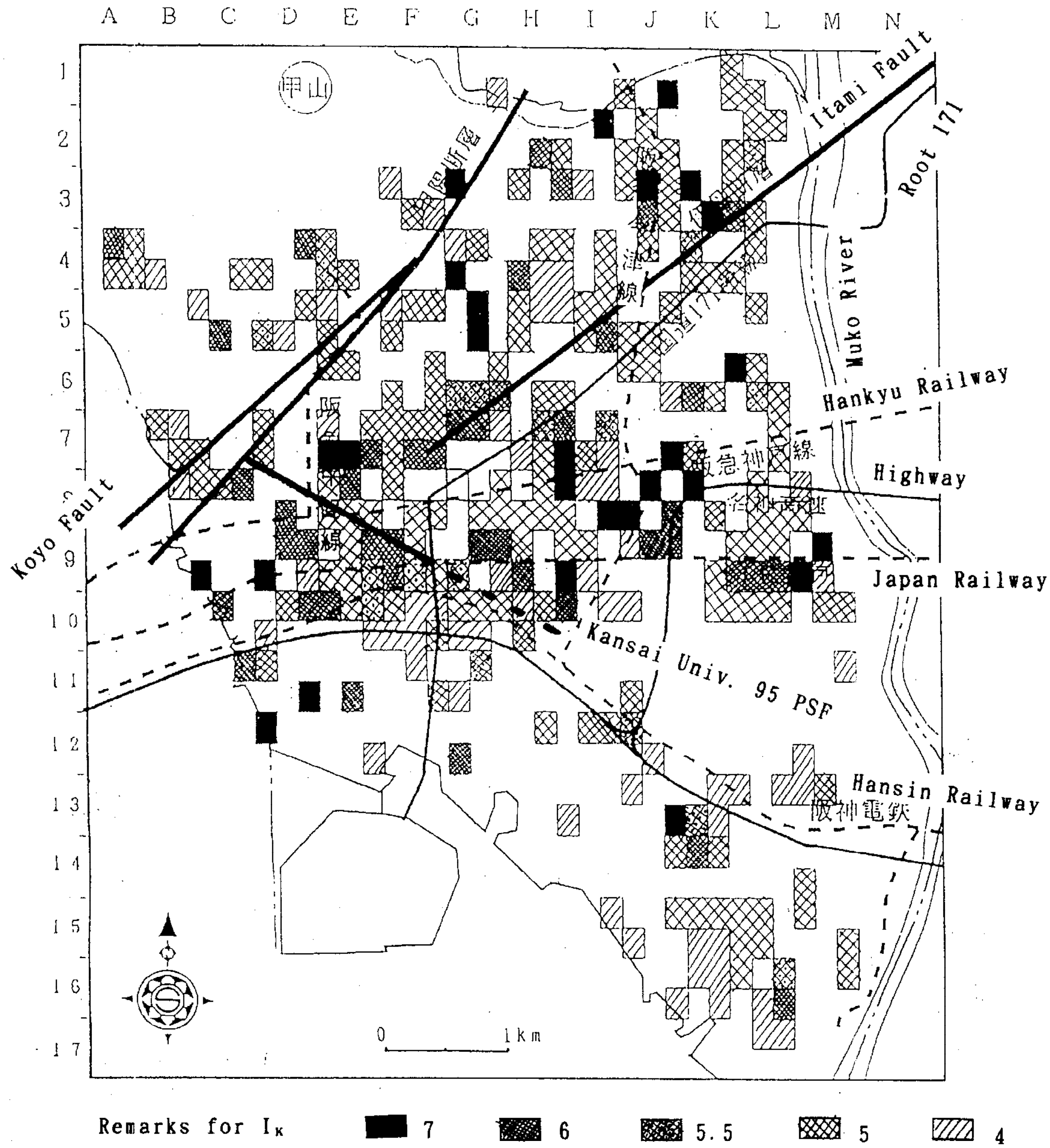

Fig.2 The distribution of I_K in Nishinomiya city area

THREE KINDS OF FAULTS IN THE DISASTER REGION ; SGF, CMF, PSF

As a technical word, "faults" are used in a kind of confusion. Then, in this study we define the following three categories of faults, The first one is Seismic Generating Faults (SGF), which at first make seismic waves originally at the seismic center, the second one is Co-Movement Faults (CMF) , which move by their own tectonic energy triggered by the seismic wave caused by SGF and the last one is Pseudo Seismic Faults (PSF), which is formed not by their own energy but by the large seismic waves from SGF and by the compressive ground displacement triggered by SGF and CMF.

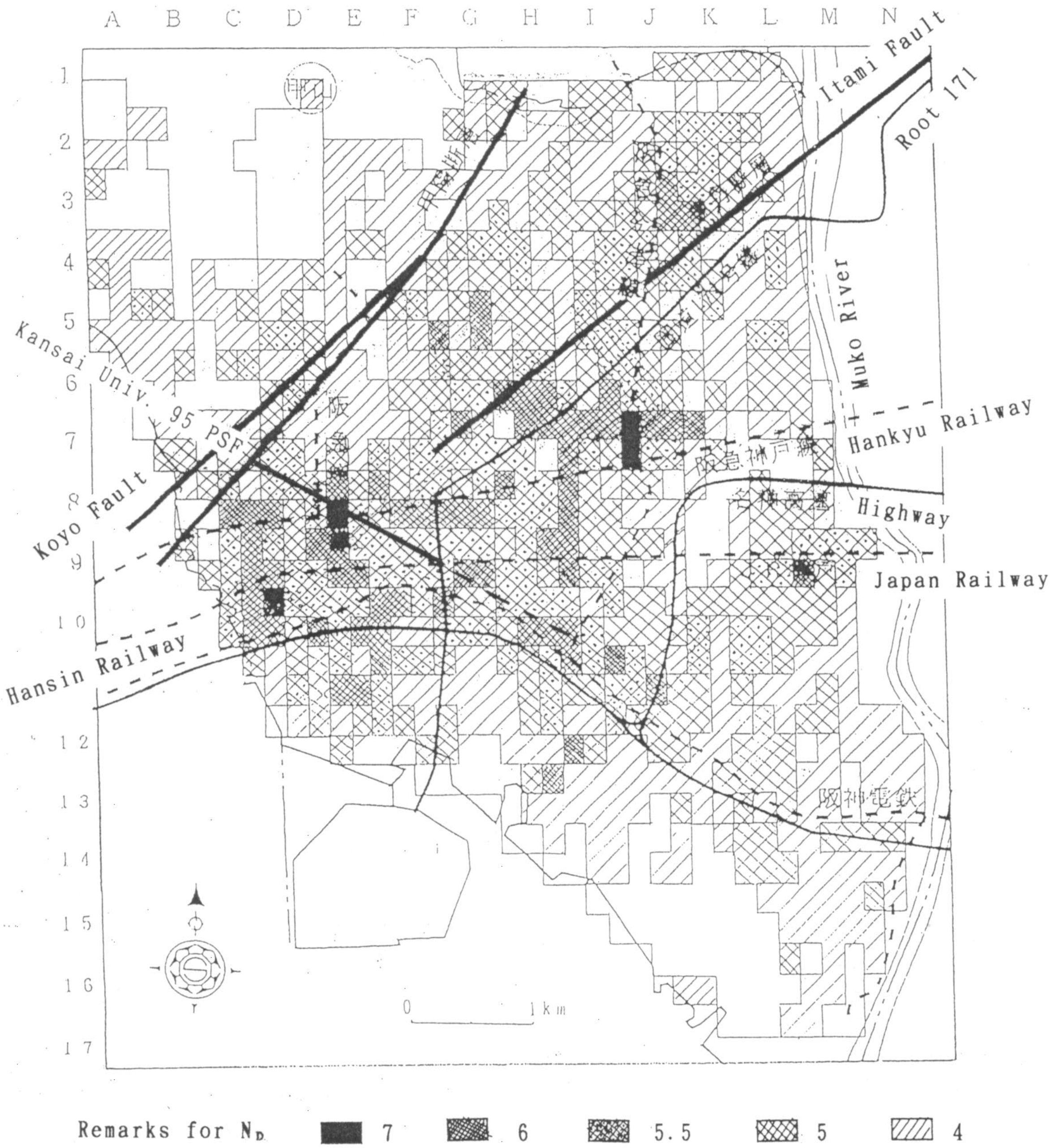

Fig.3 The distribution of N_D in Nishinomiya city area

SGF and CMF usually move for the several times during geological age and sometimes printed in geological maps. The biggest difference between them is whether it generates enough large waves to cause other CMF and over about 8 km depth . Nojima fault in Awagi island which is reported not to make enormous seismic waves should be called a CMF in our definition. PSF is a completely new concept in this paper. By a large earthquake as this South Hyogo one, large cracks with horizontal-slip are seen sometimes even in the city. They are thought to be extended only in the surface strata, but sometimes they tear up buildings all the same as CMF. For example, a large RC structure in Higashinada area has been completely teared up and moved by this type of fault. Though SGF and CMF are set in special tectonic points and sometimes printed in geological maps, PSF will be put at some places especially in soft ground including cities like Kobe or Nishinomiya.

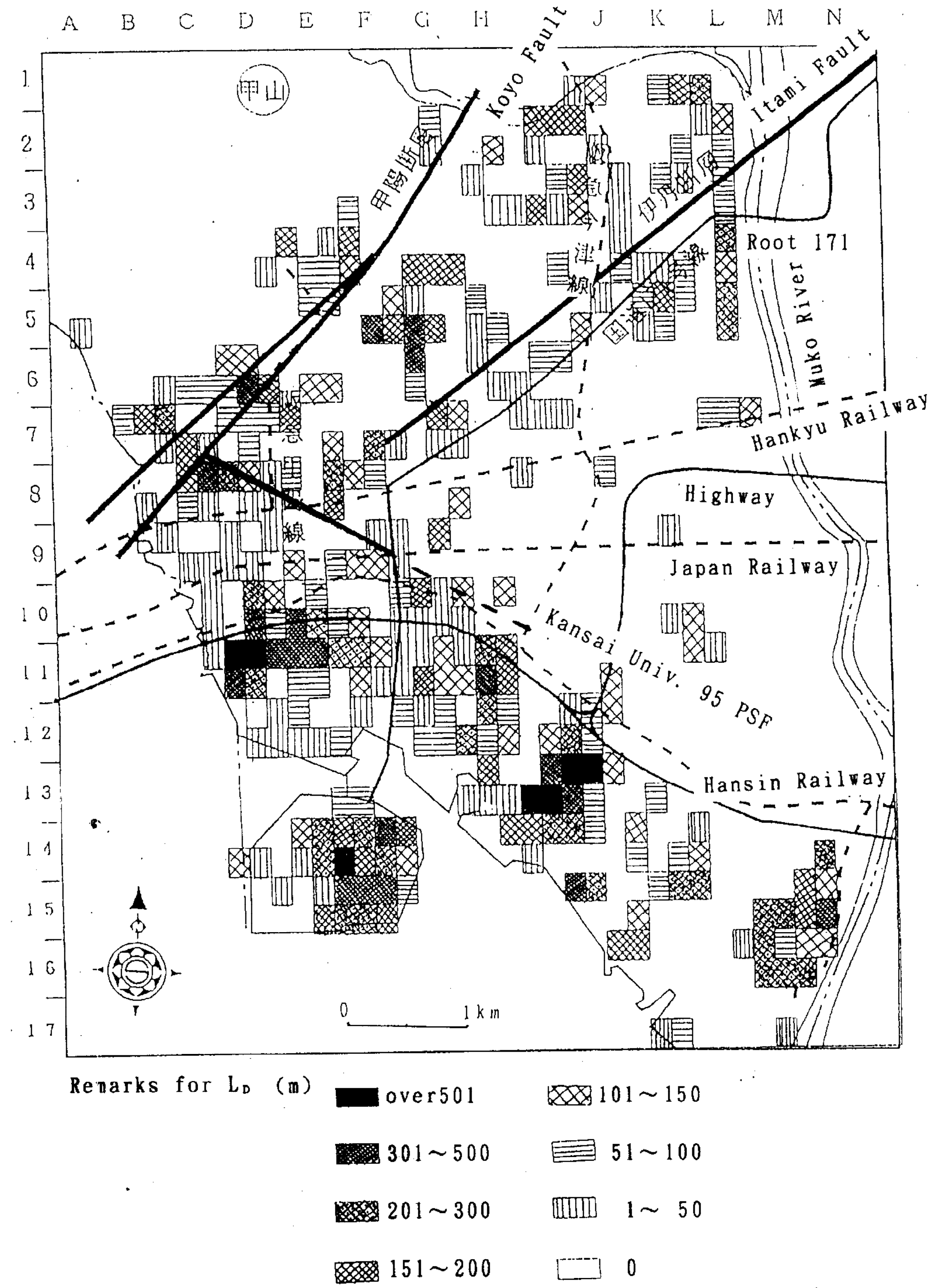

Fig.4 The distribution of L_D in Nishinomiya city area

THE RELATIONS BETWEEN THE SEISMIC INTENSITY AND THE FAULTS

The relative locations of the seismic intensity and the faults in Nishinomiya area are illustratively shown in Fig.6 by referring to Fig.2 - Fig.5. Two strong disaster belts can be recognized about 1km far from and paralleled to each Koyo and Itami fault in Fig.2. These two strong disaster faults are shown by the symbol W_f in Fig.6.

But in Fig.3, these two belts can not be recognized, because there are many destroyed wooden houses around Itami fault. This disaster belt around Itami fault is shown in Fig.6 by the symbol F.

This fact means that the seismic intensity in the region of W_f is larger than that in the region of F. The PSF which was named "Kansai Univ. 95 PSF" was found at the south of Koyo and Itami fault as shown in Fig.6. Also around this PSF, many wooden houses were destroyed. Around Koyo fault, the damages of buried pipes are remarkable. These disaster belts are shown in Fig.6 as F.

At the surface of the soft ground, Koyo fault showed right handed slide and Itami fault and Kansai Univ. 95 PSF showed left handed slide. These facts suggest that the ground surface layer is compressed in East-West direction as soon as the earthquake arose, and the surface layer of the ground block between Koyo and Itami faults was shaken and moved to south.

Other locations of damage distributions are characterized by the local regional ground structure conditions. The location of W_f can be considered to be formed by the reflected waves from the concerned rock face of the fault.

The mechanism of this phenomena are going to be recognized by the model shaking tests in the Yao' s laboratory. (Inoue , T and Omura , K 1996)

Almost the same situation can be seen in other areas as Kobe and Takarazuka.

In Fig. 6 at the locations of W_f , the seismic intensity increased about 0.5 - 1 in I_K, and at the locations of F, it suggested the increase of about 0.5 in I_K. In the crossing area of W_f and F, I_K became additively large.

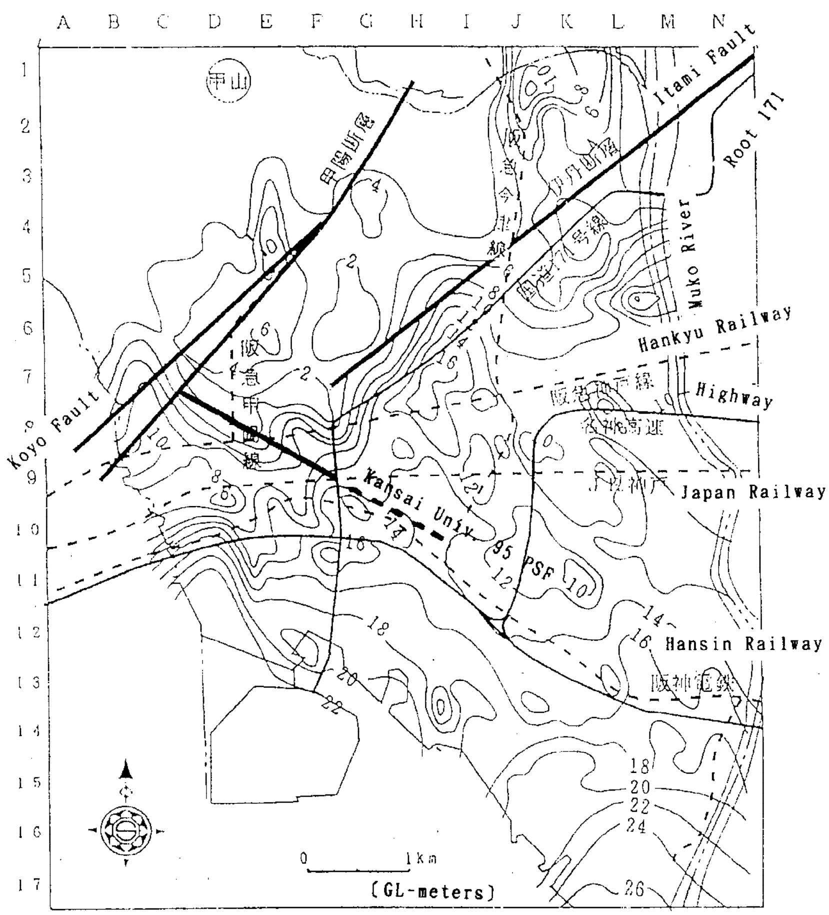

Fig.5 Contours of the botom of alluvial deposit

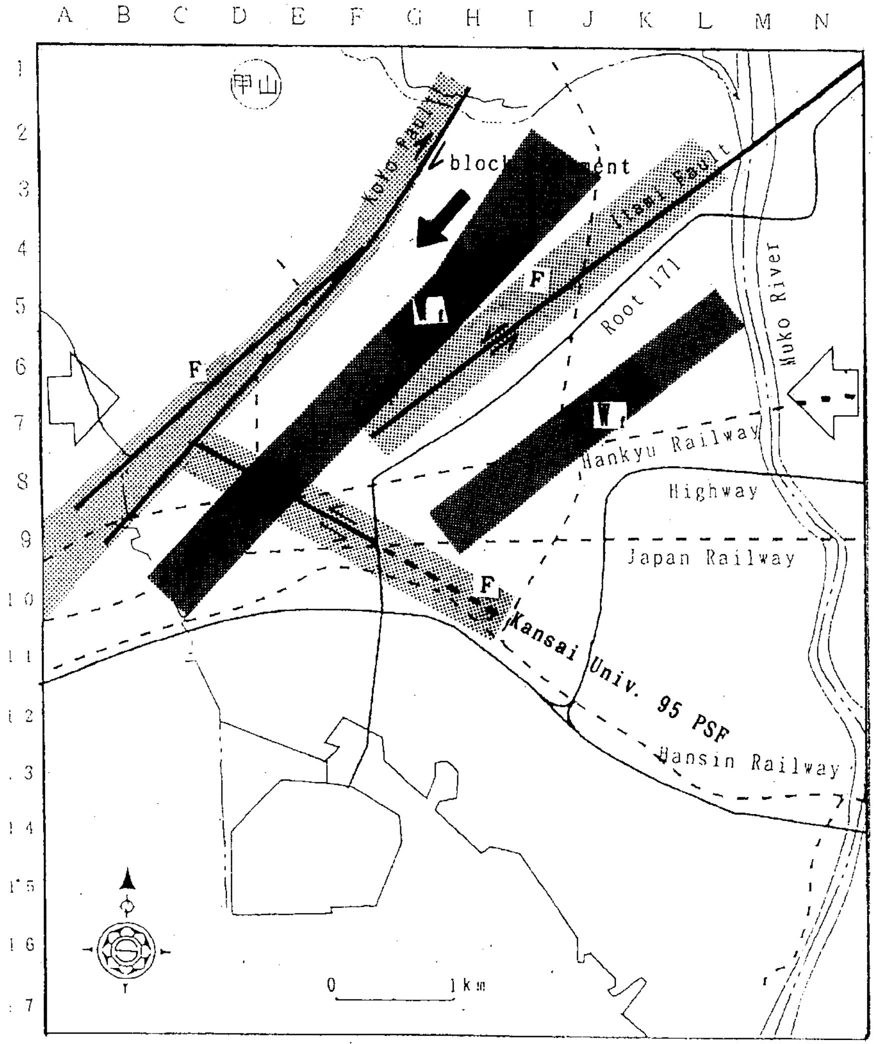

Fig.6 Faults - Seismic Intensity Relation

THE FORMATION WHICH GIVES THE SEISMIC MOVEMENT IN THE DISASTER REGION

As the result of above mentioned facts, the following formation for the seismic movements in the disaster region is concluded by Yao as follows.

$$TW = W + F$$

$$W = W_R + W_f + W_m$$

$$= (1+f+m)\, W_R$$

where

- TW : total seismic movement at the concerned place
- W : seismic movement transferred from SGF
- F : seismic movement caused by the shearing strain of fracture of the ground at the vicinity of PSF or CMF
- W_R : seismic movement at the surface of the base bed rock
- $W_f = f \cdot W_R$: seismic movement caused by the reflected waves from the rock face of near fault
- $W_m = m \cdot W_R$: increase of the seismic movement amplified by the local regional ground structure condition

All the components in the above formulation should have both horizontal and vertical components including the vertical shock waves.

CONCLUDING REMARKS

By observing the damages of classified structures, specified distributions of the seismic movements and the relations with the existence of the faults could be revealed. PSF was newly found and its contribution to the damages of structures is newly estimated as F. The strong disaster belts of W_f were recognized also in Nishinomiya area. The formation to estimate the seismic movement for the earthquake directly above the focus is newly concluded.

ACKNOWLEDGMENT

The great efforts of the students of Kansai University, Mr. K. Sugii, Mr. S. Kato, Mr. T. Tadano, Mr. T. Nakai and Mr. N. Morishima to be engaged in the earthquake site surveying and the offer of materials about the earthquake from Nishinomiya city office should be greatly appreciated.

Finally the authors should pay respect for the aptitude directions by the director general, honorary professor, Y.Yokoo of Japan General Building Research Corporation.

REFERENCES

Inoue, T and Omura, K (1996), The model shaking test of the sediments considering the rock face effects of the fault. A graduation thesis of Kansai University (in Japan)

Murayama, K. (1995), What destroyed Kobe? -On the research of small faults and ground in Kobe city -, the proceeding of symposium on the great Hansin-Awaji Earthquake and its geo-environments, Geological society of Japan P49-54, (in Japanese)

Takemura, A. et al. (1995), Collapsed directions of wooden houses by the Hyougo Nanbu Earthquake, the proceeding of symposium on the great Hansin-Awaji Earthquake and its geo-environments, Geological society of Japan P181-186 (in Japanese)

Yao, S. et al. (1995) Hyougoken Nanbu Earthquake-Structural damage and aseismic design method near active fault (Part I)-, summaries of Tech.Papers of Annual Meeting, A. I. J. Aug. 1995 (in Japanese)