CHARACTERISTIC OF SEISMIC GROUND MOTION AND BUILDING DAMAGE DURING THE 1997 NORTHWEST KAGOSHIMA EARTHQUAKE

M MIYAZAKI[1], S SHIRINASHIHAMA[2], S UMEDA[3] And T AKIYOSHI[4]

SUMMARY

From March to May in 1997, seismic activity became intense in the northwestern area of Kagoshima Prefecture in Japan. Since then relatively large two earthquakes of the magnitude MJMA = 6.5 and 6.3 (in JMA scale) occurred in 26 March and 13 May in 1997, respectively. The series of earthquakes caused serious damages of buildings, roads, and harbor facilities in the epicenter and surrounding regions. We discuss the relational characteristics from distribution data for this study of building damages, especially wooden houses and intensity of seismic ground motions. The data were referred to the surveyed results after the earthquakes and the statistical damage data by the public office of Kagoshima Prefecture et al. The data regarding seismic ground motions were obtained from the K-net (NIED: National Research Institute for Earth Science and Disaster Prevention) strong motion records. As the results for the ground surface, there were instantaneous observed the input horizontal acceleration amplitude are 1G and the velocity amplitude exceeding of 500mm/s near epicentral region, estimating from the strong motion records. The distribution of wooden house damages indicates the strong relation with the estimated fault motion. In the estimated fault region (within about 30km from the hypocenter), the distribution of wooden houses damage agrees well with the high intensity region of acceleration of 0.1- 0.2G and velocity of 100 – 200 mm/s.

INTRODUCTION

On March to May in 1997, two moderate size earthquakes (the magnitude of MJMA = 6.5 and 6.3) were estimated an inland shallowly focused earthquakes occurred and brought various kinds of damages in the northwest part of Kagoshima prefecture in Japan. The earthquake damage investigation were carried out for questionnaire survey of seismic intensity and collection of

[1] *Dept of Architecture, School of Engineering, Kyushu Tokai University, Japan. Email: mmiyazak@ktmail.ktokai-u.jp*
[2] *Technical research institute, TEKKEN CORPRATION, Narita, Japan. Email: shozo-shirinashihama@tekken.co.jp*
[3] *HITACHI ZOSEN CORPORATION, Osaka, Japan. Email: umedashi@omenv.hq.hitachizosen.co.jp*
[4] *Dept of Civil Engineering and Architecture, Kumamoto University, Kumamoto, Japan. Email: akiyoshi@gpo.kumamoto-u.ac.jp*

the damage data in order to make clear the distribution of damaged area and the strength of earthquake motion in epicentral region.

In order to evaluate the strength of earthquake motion on the ground seismic wave data collected using the strong motion records of the K-net [NIED: National Research Institute for Earth Science and Disaster Prevention, Science and Technology Agency]. This paper shows that these exists a strong relation between the distribution of earthquake ground motion and wooden house damages.

Table 1: Seismic parameters of 1997 northwest Kagoshima earthquake

Date Time		1997/03/26 17:31(JST)	1997/04/03 04:33(JST)	1997/04/05 13:24(JST)	1997/5/13 14:38(JST)
Epicenter		130°22' E 31°59' N	130°19' E 31°59' N	130°24' E 31°58' N	130°18' E 31°57' N
Depth		12km	9km	10km	9km
Magnitude M_{JMA} in JMA scale		6.5	5.5	4.9	6.3
Seismic intensity scale of JMA	6(LOWER)				Sendai
	5(UPPER)	Sendai Akune Miyanojyo	Sendai		Miyanojyo
	5(LOWER)		Akune Miyanojyo	Sendai Miyanojyo	Akune

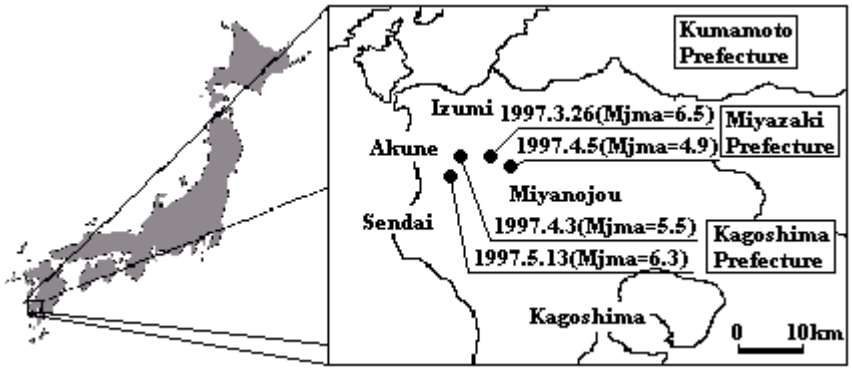


Figure 1: Locations of epicenter of 1997 northwest Kagoshima earthquake(M_{JMA}≧4.9)

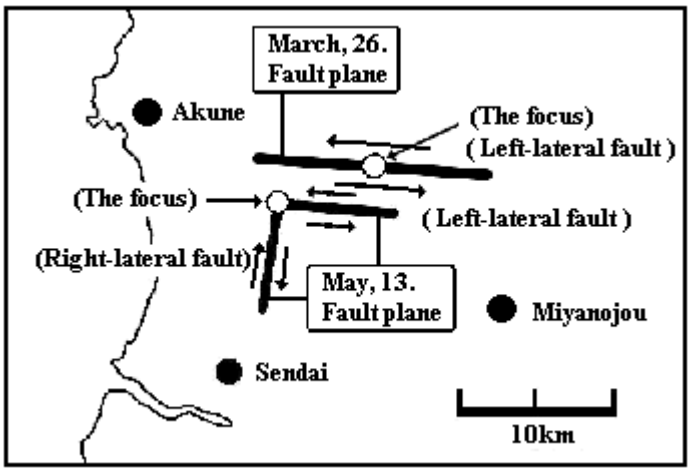
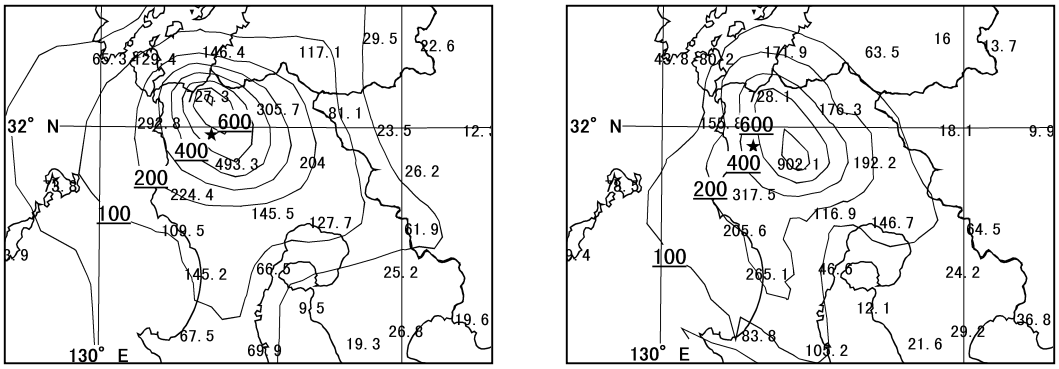
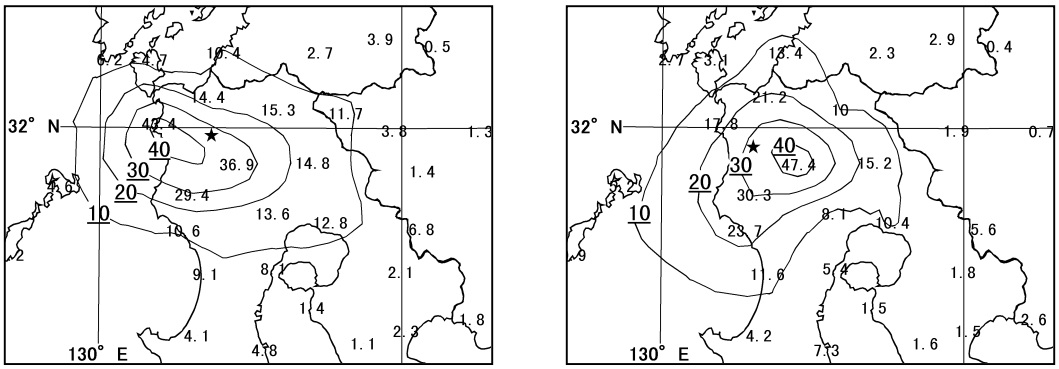


Figure 2: Schematic diagram of earthquake source faults and its fault motion of March 26 and May 13, 1997 northwest Kagoshima earthquake



(a) PGA($\times 10^{-2}$ m/s/s) March 26 1997 (b) PGA($\times 10^{-2}$ m/s/s) May 13 1997



(c) PGV($\times 10^{-2}$ m/s) March 26 1997 (d) PGV($\times 10^{-2}$ m/s) May 13 1997

Figure 3: Distribution map of seismic ground motion of 1997 northwest Kagoshima earthquake

OUTLINE OF THE 1997 NORTHWEST KAGOSHIMA EARTHQUAKE

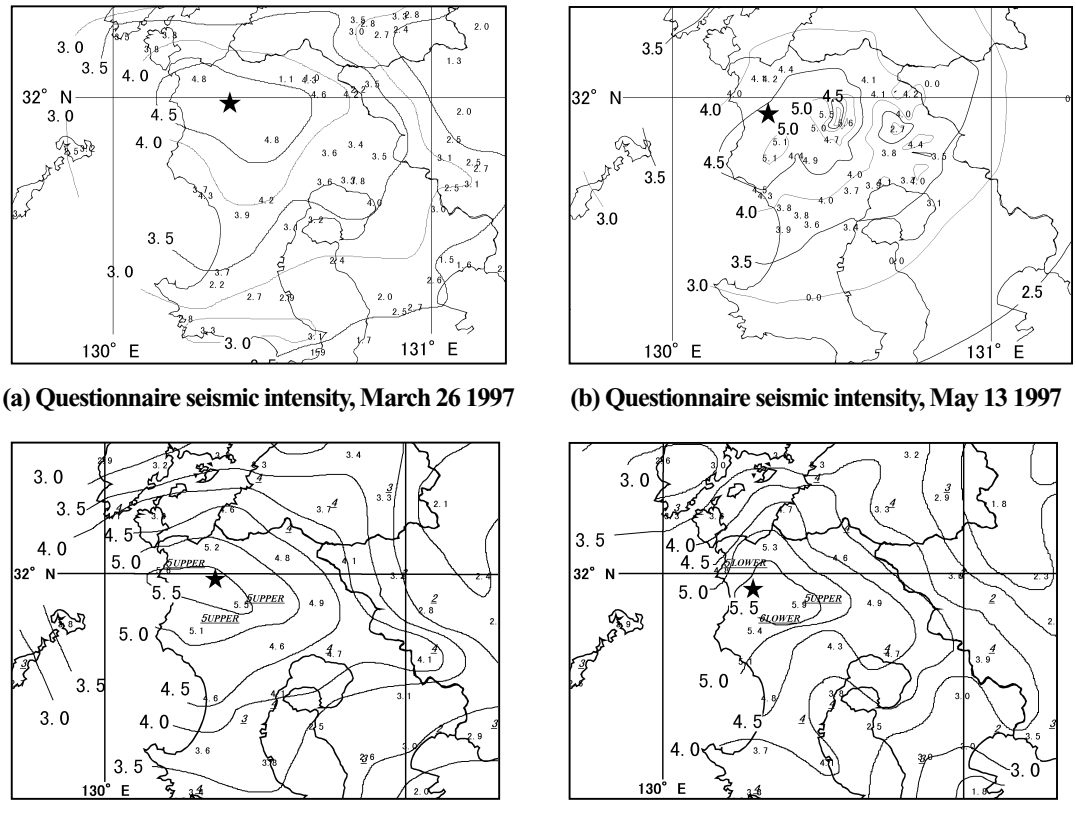
In the northwest part of Kagoshima prefecture, two earthquakes of the magnitude of 6 or more occurred form March to May in 1997, and 13 aftershocks of the magnitude of 4 or more occurred, and earthquake activity became intense. The location of epicenter of earthquakes that causes the earthquake damages are shown in Fig. 1 and these seismic parameters are shown in Table 1 [Japan Meteorological Agency, 1997].

Seismic parameter of the former earthquake of the magnitude of 6.5 that occurred at 17:31 (JST) on March 26 in 1997 is estimated that it would be the left handed strike-slip fault of east and west direction about 12km long and vertical direction about 6km wide from the aftershock distribution and the focal mechanism of mainshock. On the other hand, the latter earthquake of magnitude of 6.3 that occurred at 14:38 (JST) on May 13 in 1997 and aftershocks distributed and moved about 4km places to north from the epicenter of the former earthquake. Especially, the aftershock distributed in the direction of the east and the south from a epicenter. From these aftershock's distribution and the focal mechanism of the mainshocks, occurrence of two faults are estimated as the conjugate relations of L character type (dislocation of the east and west, and the north and south). The faults were observed to move the east and west, and the north and south direction about 12km long, 5km wide [Hashida,1997, Shimizu *et al*.,1997]. Fig. 2 shows each earthquake's source fault and its fault motion.

Among these earthquakes, severe strong motion records were observed at many observation points by the Kyoshin-net (K-net). As shown in Fig. 3 that distribution of peak horizontal ground acceleration (PGA) and peak horizontal ground velocity (PGV) at source region. This PGV was obtained by integration of PGA. The PGA values of the former earthquake are 7.27m/s/s with Izumi, 4.34m/s/s with Miyanojyo, 2.93m/s/s with Akune, 2.11m/s/s with Sendai, and the latter earthquake are 9.02m/s/s with Miyanojyo, 7.28m/s/s with Izumi, 3.00m/s/s with Sendai, 1.56m/s/s with Akune. As the results, there can be seen a close

relation between the local appearance of accelerations and the fault, that the energy radiation takes a large value in the vertical direction to the fault. The PGVs of more than 0.3m/s appears with Akune and Miyanojyo for the former earthquake and with Miyanojyo and Sendai for the latter earthquake seem to be accepted that reflected destruction due to the fault.

After the earthquake, a questionnaire survey [Ohta *et al.*,1972] was carried out in order to estimate the accurate seismic intensity and make the seismic microzoning map of the northwest part of Kagoshima prefecture. From the survey answers, the seismic intensities at contour maps were plotted by means of a series of computation and JMA seismic intensity maps as shown in Fig. 4, respectively. Questionnaire seismic intensity map agrees approximately with the JMA seismic intensity map.



(a) Questionnaire seismic intensity, March 26 1997 **(b) Questionnaire seismic intensity, May 13 1997**

(c) JMA seismic intensity, March 26 1997 **(d) JMA seismic intensity, May 13 1997**

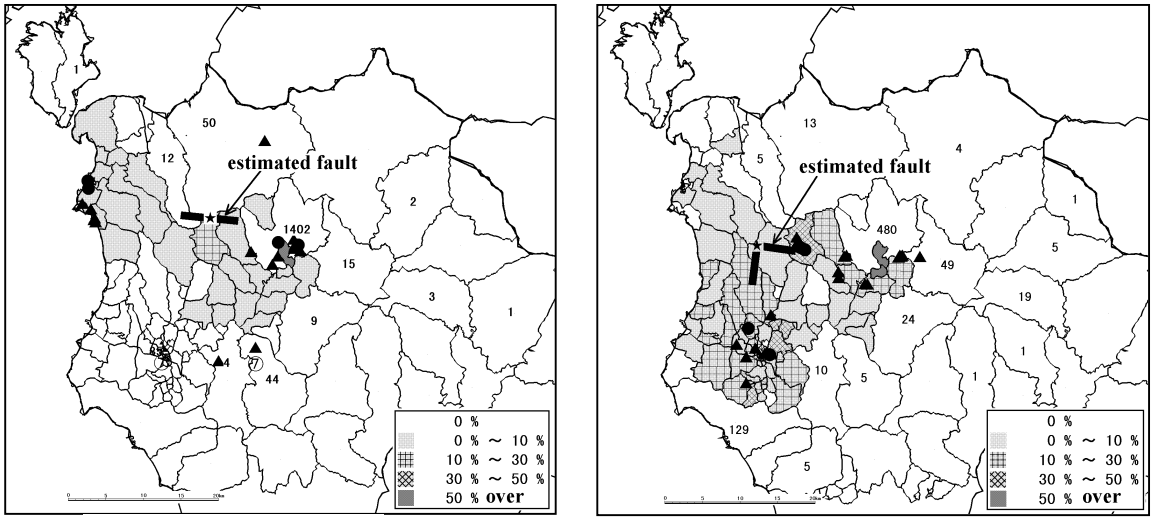
Figure 4: Questionnaire seismic intensity and JMA seismic intensity maps

THE DISTRIBUTION CHARACTERISTICS OF WOODEN HOUSES DAMAGE

During three month quakes including two major earthquakes, the severe damage occurred to many buildings, e.g., school buildings of reinforced concrete which depended on regional characteristics. So the investigation was concentrated to the damage distribution in the focal regions and its around. On the basis of the earthquake damage data collected in each city, towns and villages at Kagoshima prefecture, the number, conditions and distribution of house (residential buildings) damages were considered.

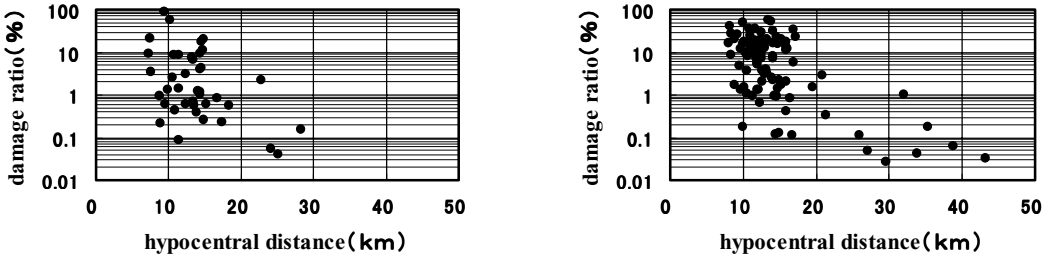
Most damages were observed in one- or two-story residential buildings of wood. After the degree of damage, collapse, half collapse, partial damage, investigated by Kagoshima prefecture, 99% of the damage total number are partial damage, some broken glass, cracked wall and fall of roof tiles [Shirinashihama, Miyazaki and Umeda., 1998]. In Fig. 5 showing the distributions of damage ratio of wooden houses for villages. The damage ratio of wooden houses is estimated as the number

of total damage data divided by the number of houses in the area. Collapse and half collapse buildings were observed closely to the epicenter and extension line of estimated the earthquake fault. To consider the causes of house damages, these old buildings should also be taken into consideration the weakness of the foundation., e.g., almost building not anchored to foundations.



(a) March 26 to April 9 1997 **(b) May 13 1997**

Figure 5: Distribution map of damage wooden houses of the 1997 northwest Kagoshima earthquake Solid circles denote the collapse point and triangles denote the half collapse point from the field surveyed in this study, the number indicate the damaged data which unknown the houses number in the area.



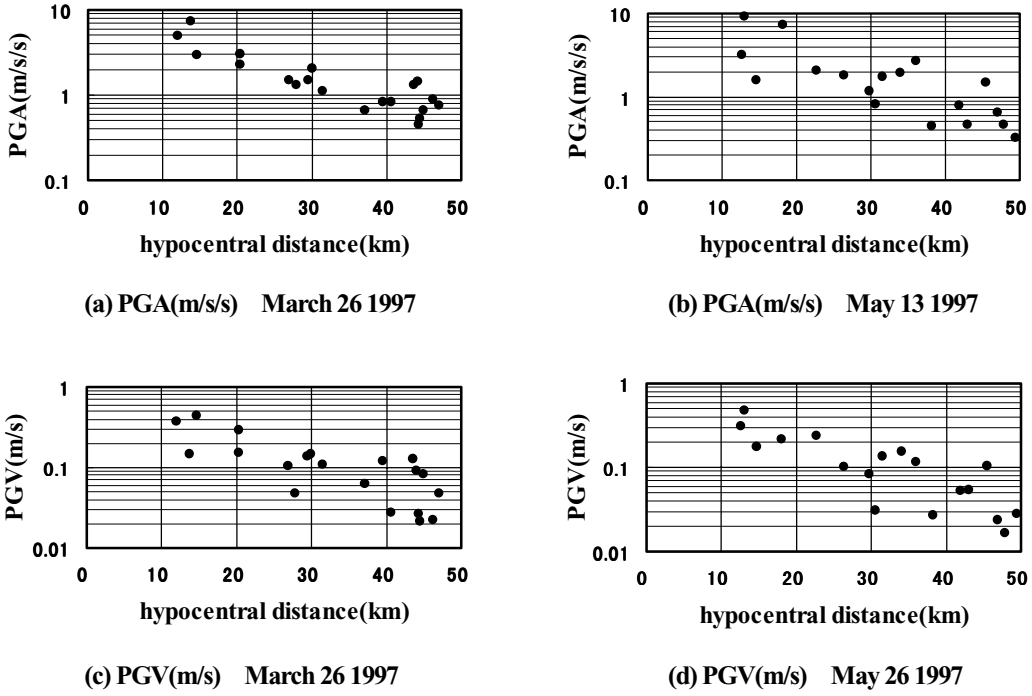
(a) March 26 1997 **(b) May 13 1997**

Figure 6: Attenuation of damage ratio of wooden house with hypocentral distance of 1997 northwest Kagoshima earthquake.

High damage ratio can be seen in the east, west and southeastern area near the epicenter the former earthquake. On the other hand, in the south and north sides, there is a little damage ratio except the focal region. This tendency is corresponds to the characteristic of instrumentally observed earthquake ground motions (see Fig. 3). It would be noted that it was distribution and the damage degree of houses will be explained by the factor such as magnitude of earthquake, epicenter position and aftershock distribution.

RELATIONS BETWEEN THE WOODEN HOUSE DAMAGE AND EARTHQUAKE GROUND MOTION

According to the damage investigation of major earthquake, it is well known that the correlation between PGV and building



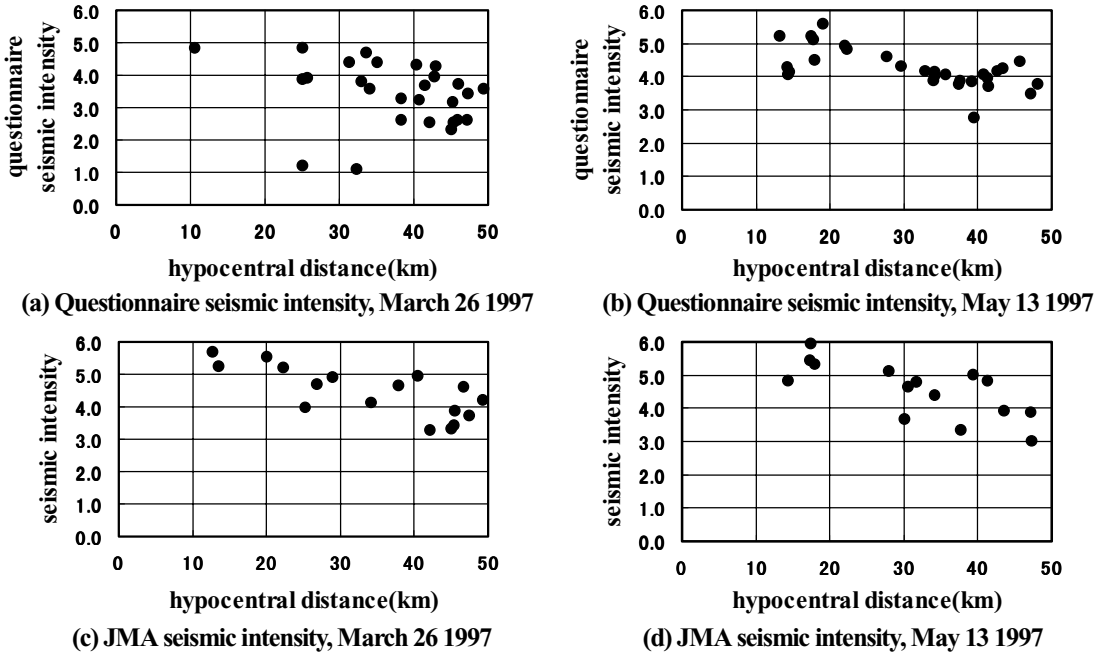
(a) PGA(m/s/s) March 26 1997

(b) PGA(m/s/s) May 13 1997

(c) PGV(m/s) March 26 1997

(d) PGV(m/s) May 26 1997

Figure 7: Attenuation of seismic ground motion severity with hypocentral distance of 1997 northwest Kagoshima earthquake



(a) Questionnaire seismic intensity, March 26 1997

(b) Questionnaire seismic intensity, May 13 1997

(c) JMA seismic intensity, March 26 1997

(d) JMA seismic intensity, May 13 1997

Figure 8: Attenuation of questionnaire seismic intensity and JMA seismic intensity with hypocentral distance of 1997 northwest Kagoshima earthquake

damage is high. But for the moderate size earthquake, detailed investigation can not be expected because of a few strong motion records. So comparison was made between the peak values (PGA and PGV) due to the strong motion records by K-net and the damage ratio of wooden houses using an empirical horizontal attenuation formula due to the hypocentral distance.

In use of the formula, the hypocentral distance which normally are defined as the shortest distance from the estimated fault to K-net observation point, is assumed to be the distance from the fault to the center of large section of a villages.

The relationship between the damage ratios and the hypocentral distance is shown in Fig. 6, and the relationship between the severity of shaking (for PGA and PGV) and the hypocentral distance is shown in Fig. 7. The area where the damage ratios of wooden house exceeds 0.1% located at 30 km with the hypocentral distance. The severity of shaking for the hypocentral distance of 30km, is estimated PGA of 1 - 2m/s/s, PGV of 0.1 - 0.2m/s, for each earthquake. And it is estimated that the ground motion would exceed 10m/s/s and 0.5m/s the highest area due to damage ratios, near the epicenter regions.

From a purpose to make clear the relationship between earthquake damages and seismic intensities using questionnaire surveyed seismic intensities. The questionnaire (surveyed) seismic intensities totalized every an area and use a value averaged simply. The relationship between questionnaire surveyed and JMA seismic intensity and the hypocentral distance is shown in Fig. 8, respectively. It is the hypocentral distance of 30km to occurred of wooden houses damage, a seismic intensity is about 4.5. This value of 4.5 is lower than value of 5 in seismic intensity scale of the JMA and it is predicted that the house damage occurred.

CONCLUSIONS

In this paper the strong relationship between the intensity severity of earthquakes and damage ratio of wooden houses at sites are shown for the 1997 Northwest Kagoshima earthquake. The results obtained are summarized as follows:

(1)The distribution of wooden house damage corresponds attenuating of the estimated fault motion.

(2)The wooden houses suffered some damage within the hypocentral distance of about 30 km, and by the excitation of 1m/s/s - 2m/s/s (PGA), 0.1 - 0.2m/s (PGV) which was almost close to the expected intensities by the empirical attenuation formula.

(3)Extreme large acceleration and velocity exceeding about 1G (10m/s/s) (PGA) and 0.5m/s (PGV) at some locations near epicenter region is needed of the consideration of special amplification of to the site soil deposits.

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