AN ESTIMATION OF STRONG MOTIONS IN THE DAMAGED AREAS FOR THE RECENT DESTRUCTIVE EARTHQUAKE IN JAPAN USING GROUND MOTION DATA FROM AFTERSHOCK OBSERVATIONS

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ABSTRACT:
The strong motion data on Monzen-machi Town, where is the one of the most severely damaged area, could not be obtained during the Noto Hanto Earthquake in 2007. This area is located near the Hakka-gawa River and the surface geology can be considered. We performed the aftershock observation densely, in order to evluate the site effect experimentally. We found that the site effect on damaged area was recognized higher than that on the non-damaged area and the effects were successfully evaluated quantitatively. In this paper, we estimated the strong motions during the main shock using aftershock motions. The source model for this estimation was calculated with empirical Green's function technique and GA using the data of the aftershock and the main shock provided by K-NET. The estimated motions are significantly high in the short period range, because the non-linear effect was not be considered in this estimation.

KEYWORDS: the Noto Hanto Earthquake in 2007, aftershock observations, empirical Green's function,

1. INTRODUCTION

The Noto Hanto Earthquake in 2007 with an M_{JMA} of 6.8 caused disastrous damage in buildings and civil engineering structures. For example, more than 684 of wooden houses were completely collapsed (Fire and Disaster Management Agency, 2007). Most of the damage was observed in Wajima City and especially the damage on Monzen-machi Town was severed. The seismic intensity at the Monzen Branch Office is 6.4 in the JMA scale, the highest for this earthquake. But strong motions could not be obtained in this area. Some part of surface geology in this area can be classified as soft soil because the Hakka-gawa River flow the through this area. It can be considered that the site amplification expand the damage area. Arai et. al. (2008) said that the site amplification can explain the damage distribution. We performed the aftershock observation densely, in order to evaluate the site effect experimentally. We found that the site effect of damaged area was recognized higher than that on the non-damaged area.

Irikura (1986) said that the strong mtions for the main shock can be synthesized using aftershock motions as empirical Green's function. The strong motions on the damaged area of the 1995 Kobe earthquake were sucessfully reproduced using aftershock motions (Kamae and Irikura, 1997).

In this study, we estimated the strong motions for the main shock of the Noto Hanto Earthquake in 2007 using the ground motion data of the aftershocks.

2. AFTERSHOCK OBSERVATION

Figure 1 shows the staion of the aftershock observation and the epicenters using as the element earthquake. Table 1 shows the specification of these events including the main shock. These information was evaluated by

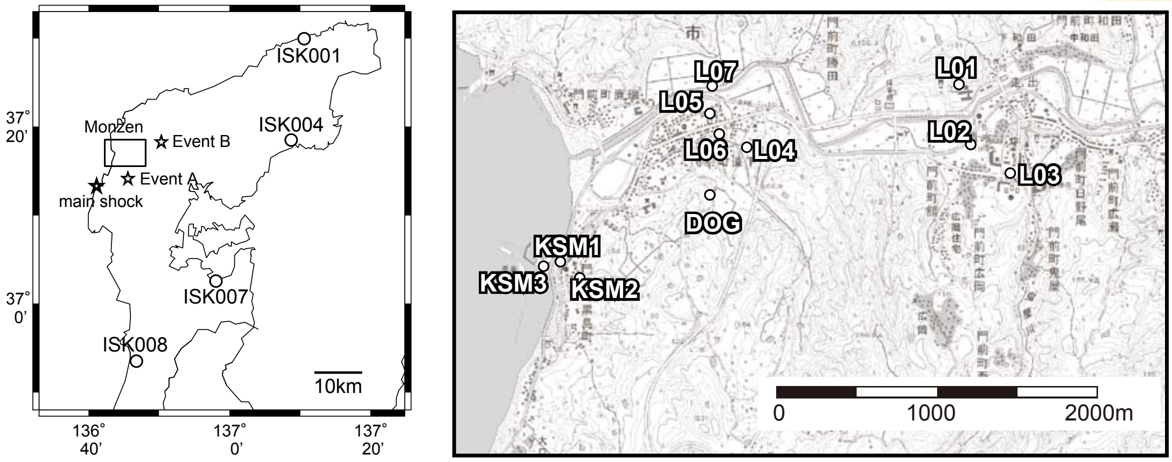

Figure 1 Distribution of Strong Motion Station and Epicenters of the main shock and aftershocks(left),
Location of the Aftershock Observation(right)

Table 1 List of the earthquakes Studied and Source Scaling Parameters

Event	Date	Depth(km)	Mw(M0[Nm])	C	N
A	2007/3/31 8:09	13.5	3.8 (5.83E+14)	0.89	5
B	2007/3/25 18:11	13.4	5.2 (6.22E+16)		
main shock	2007/3/25 9:42	10.7	6.7 (1.36E+19)	0.9	6

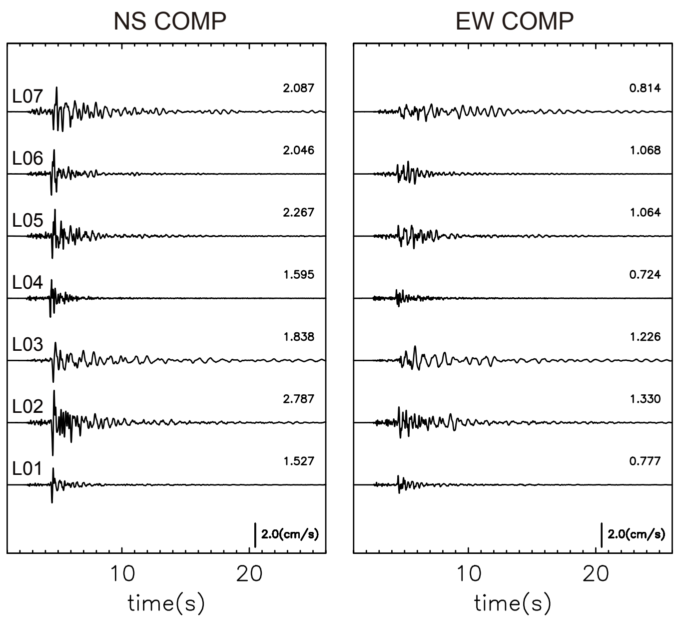

Figure 2 Velocity Waveforms obtained in Monzen Area of Event A

F-net. The event A is the largest event in the appropriate earthquakes which occured near the expected source region of the main shock. The event B occured before the installation and the data could not be obtained. Nevertheless the data of this event are also used for this estimation and to make an inversion to the source model, which will be mentioned below.
Each station was installed in Monzen area and across the Hakka-gawa River and the distances from the other are a couple of hundred meters. Figure 2 shows the velocity waveforms bandpass filtered between 0.5 - 20Hz of the event A. We could not record the earthquake motions of this event at some stations The predominant periods are evaluated between 0.3 and 1.0 second. The amplitudes at the alluvial sites, where are the L02, L03, L05,

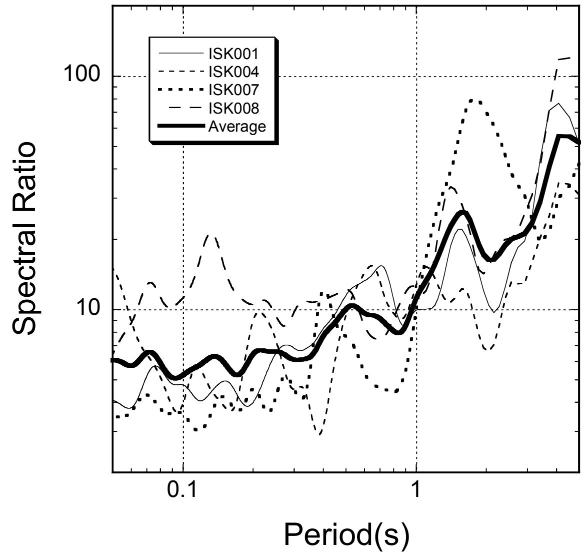

Figure 3 Spectral Ratios of the main shock to the event B.

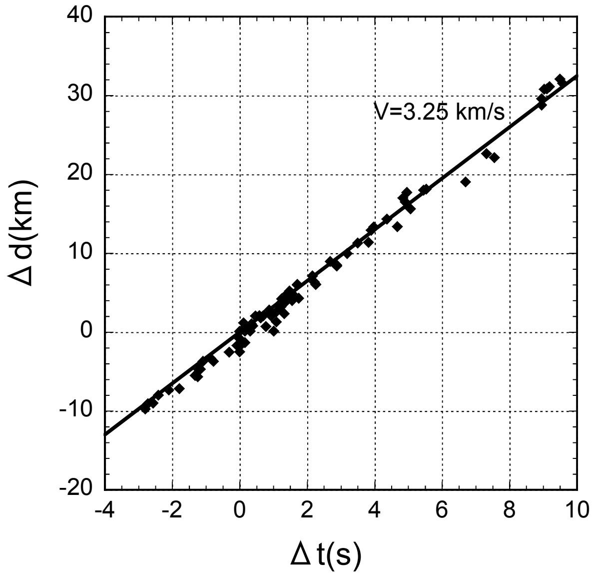

Figure 4 S-wave arrival time and hypocentral distance

L06 and L07, are higher than the hilly sites, where are the L01 and L04, and the later phases at the alluvial sites observed for long duration. This difference of the waveforms implies the difference of the effects of the surface geology. The damage near the site whose predominant period is long is severe.

3. INVERSION FOR SOURCE MODEL

The source model is necessary to estimate the strong motions of the main shock near the source region with the aftershock motions. We used the data of the main shock and aftershocks distributed by the K-NET to make an inversion for the source model. The stations we used for the inversion is shown in Figure 1 and are about 50 km distant from the source region. The data were resampled at 50Hz. The aftershock motions are used as the empirical Green's function and we adopted the filter function which multiplies in synthesization proposed by Irikura *et. al.* (1997). For this technique, the scaling parameters C and N is estimated from the constant levels of accelaration and displacement amplitude spectra of the events with the following the equation

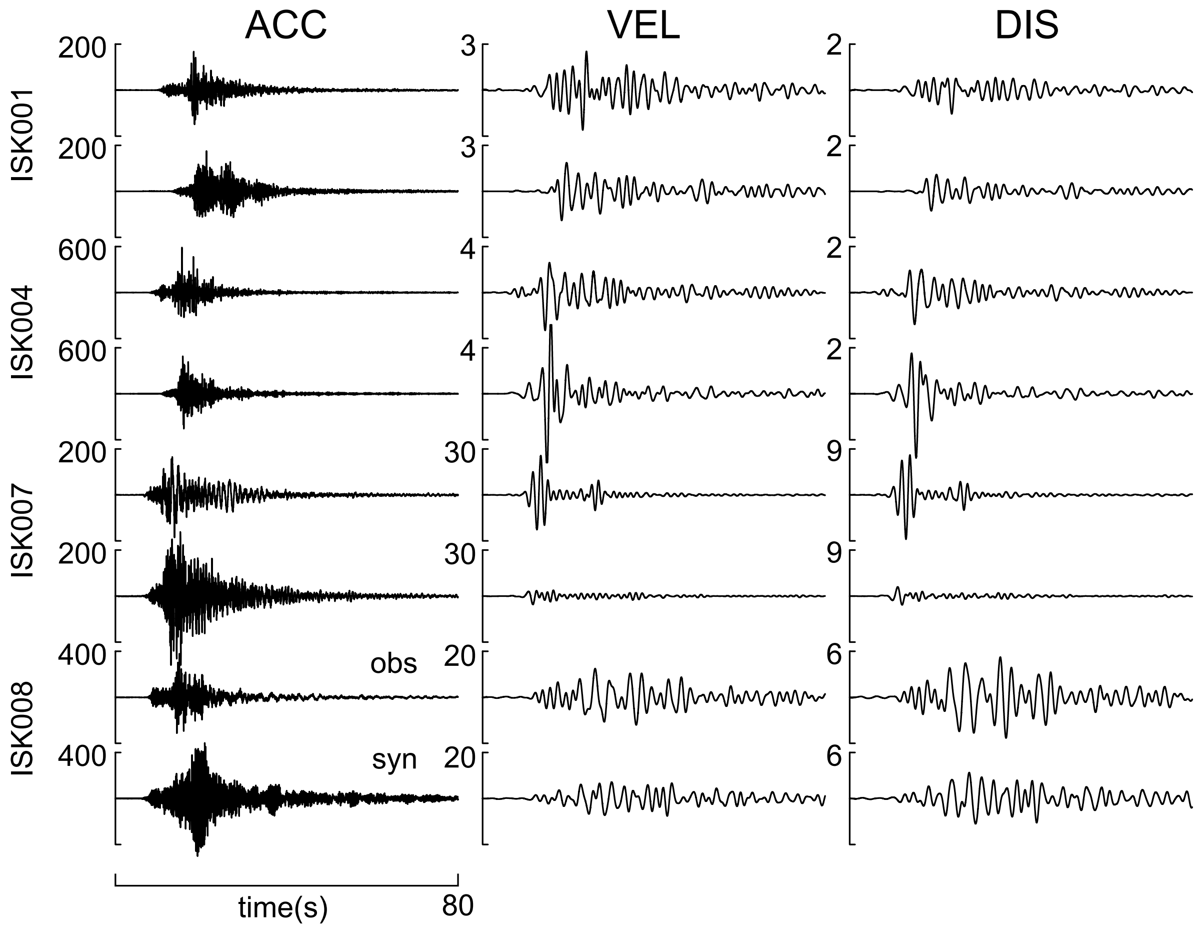

Figure 5 Comparison between waveforms synthesized from event B and observed waveforms of the main shock

$$N = \left(\frac{U_0}{u_0}\right)^{0.5}\left(\frac{a_0}{A_0}\right)^{0.5} \qquad C = \left(\frac{u_0}{U_0}\right)^{0.5}\left(\frac{A_0}{a_0}\right)^{1.5}$$

Where, U_0 and u_0 show the constant levels of the amplitude of the displacement spectra for the large and small events, respectively. A_0 and a_0 indicate the constant levels of the acceleration spectra. Namely, U_0/u_0 and A_0/a_0 mean the constant level of the spectral ratio in the longer period range and the shorter period range, respectively. Figure 3 shows the spectral ratio of the main shock to the event B. The thick line indicate the average of the spectra. In the shorter period range, the flat level can be easily detect but in the longer period range, it is difficult to find it. The seismic moment evaluated by F-net is used for the displacement flat level which means flat level in spectral ratio in the longer period range. The evaluated scaling factor is listed on Table 1. It is difficult to the synthetic the earthquake motions of the main shock from that of the event A, because the difference of the magnitude is large. Therefore, 2 steps are required to estimate the main shock from the event A through the event B.

Since the location of the hypocenter is different from each other, the travel time from the hypocenter is also different. Therefore the time shifting is needed to move the hypocenter. The S-wave arrival time of the aftershocks was picked up to evaluate the apparent velocity to calculate time shifting. Figure 4 shows the relation of the time difference and distance. We evaluate as 3.25 km/s the apparent velocity.

We used Genetic Algorithm (GA) to invert the location of the strong motion generation area (SMGA) proposed by Miyake *et. al.* (2003). In this inversion, unknown parameters representing the location, the trigger point, the size and the rise time were estimated to minimize the residuals of the velocity waveforms filtered 0.2 - 5.0Hz and the acceleration envelop. To take the heterogeneity of the source which cannot be express into account, we tried to invert with 2 SMGAs. To conserve the scaling law, the different scaling factor is required to set, but only the release energy of SMGA is changed in this paper.

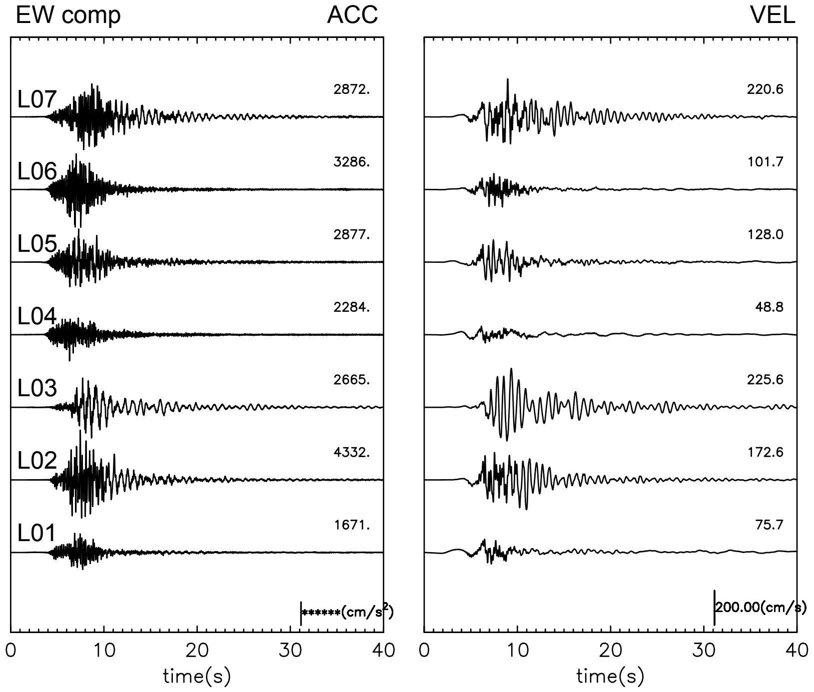

Figure 6 Synthetic Waveforms in Monzen area

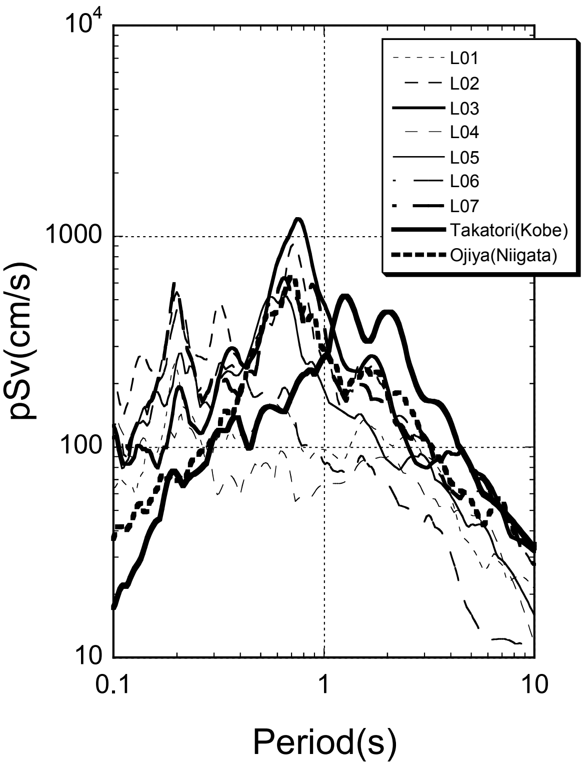

Figure 7 Pseudo Velocity Response Spectra

Figure 5 shows comparison of waveforms between synthetic and observed for the main shock. These synthetic waveforms seem to give a good fit to observed in accelerations, velocities and displaecements except for velocity and displacement at ISK007. The synthetic waveforms of the event B estimated with those of the event A is also good fitting. The inverted SMGA area is consistent with the source model reported by the previous research (Aoi and Sekiguchi, 2007)

4. ESTIMATION OF GROUND MOTION ON DAMAGED AREA

The sources model derived in the previous section are userd for the estimation of the strong motion in Monzen area. The waveforms of the main shock were calculated with the waveforms of the event B synthesized with the observed waveforms of the event A. The estimated velocity waveforms are shown in Figure 6. The amplitudes of strong motions at some points are estimated larger than 200 cm/s and the amplitude at the L03 site is the highest. Figure 7 shows the pseudo velocity response spectra with 5% damping of these synthetic motions. The response is reached to 1000 cm/s and the predominant period can be evaluated to 0.8 second quite similar to those of aftershock motions. The spectral shape is similar to that at the Ojiya station for the Mid Niigata earthquake. The estimated motions are larger in the short period range. From this result, it is easy to understand that the damage in this area was quite severe because the responses are comparable to that at the Ojiya station.
This result is not considered the non-linear effect of the subsurface soil because the amplitudes of the data we used are significantly low comparing to the estimated motions. Therefore, the estimated amplitudes can be considered to be overestimated and the predominant period to be shorter. Nevertheless this result will be a material for the precise estimation taking into account the plastic behavior and the soil information.

5. CONCLUSIONS

We estimated the strong motion of the main shock around the damaged area during the Noto Hanto Earthquake. The responses of these motions are comparable to that during the Kobe earthquake. In the near future, we will evaluate the spatial distribution of the main shock with the microtremors we measured and the non-linear effect with the soil condition.

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