Damage investigation of 2019 the Off the Yamagata Prefecture earthquake, M_J6.7

Yukiko KOJIMA[1], Takaaki IKEDA[2], Takumi MATSUMOTO[3] and Atsuya MINAGAWA[4]

[1]Member of JSCE, Assistant professor, Dept. of Civil engineering, National Institute of Technology, Nagaoka College
(888, Nishikatakaimachi, Nagaoka, Niigata 940-0817, Japan)
E-mail: y_kojima@nagaoka-ct.ac.jp
[2]Member of JSCE, Professor, Dept. of Civil and Environmental engineering, Nagaoka University of Technology
(1603-1, Kami-Tomioka, Nagaoka, Niigata 940-2188, Japan)
E-mail: ikeda@vos.nagaokaut.ac.jp
[3]Graduate student, Dept. of Civil and Environmental engineering, Nagaoka University of Technology
(1603-1, Kami-Tomioka, Nagaoka, Niigata 940-2188, Japan)
E-mail: s163310@stn.nagaokaut.ac.jp
[4]Graduate student, Dept. of Civil and Environmental engineering, Nagaoka University of Technology
(1603-1, Kami-Tomioka, Nagaoka, Niigata 940-2188, Japan)
E-mail: s173277@stn.nagaokaut.ac.jp

Key Facts
- Hazard Type: Earthquake
- Date of the disaster: June 18th, 2019
- Location of the survey: Murakami City, Niigata Prefecture, Tsuruoka City, Yamagata Prefecture
- Date of the field survey (if any): June 20th, 2019
- Survey tools (if any): Digital camera, Map, GPS
- Key findings:
  (1) Seismic intensity 6+ was observed in this earthquake, but there was no major damage.
  (2) Main damage was tile roof damage of wooden houses.
  (3) Damage situation of tile roof was different even in a narrow area

Key Words: *Off the Yamagata Prefecture earthquake, Earthquake damage investigation, tile roof, Aerial photograph, Site amplification characteristics*

1. INTRODUCTION

At 22:22 on June 18th, 2019 the M_J 6.7 (magnitude determined by Japan Meteorological Agency, JMA), earthquake occurred in the offshore of the Yamagata Prefecture, Japan. The hypocenter of the earthquake was located at 38.6N, 139.5E with its depth of 14km (**Fig.1**). Maximum seismic intensity 6+ (JMA scale) was observed at Fuya station, Murakami City, Niigata Prefecture and seismic intensity 6- observed at Atsumigawa, Tsuruoka City, Yamagata Prefecture[1)] (**Fig.2**). This earthquake occurred in the strain concentration zone along the East Japan sea margin, and faulting type was estimated reverse fault type with a compression axis in the WNW-ESE direction[2)]. The earthquake caused tsunami, maximum height was 11cm[1)].

The authors conducted a quick survey in the affected area on June 20th, two days after the earthquake. There were three purposes for this survey. The first one was to grasp a whole damage and situation. The second was to confirm relation between damage and geotechnical condition. The last one was to compare earthquake damage of this earthquake with the damage of 1964 Niigata earthquake (M_J 7.5), Japan. We investigated damaged area at northern part of Niigata Prefecture by the 1964 Niigata earthquake[3)], but we could not find any damage.

The damage at the near source area was minor though the observed seismic intensity was up to 6+. However, even minor damage, there was a difference in damage depending on the location. This report summarized the damage situation and distribution based on the quick survey.

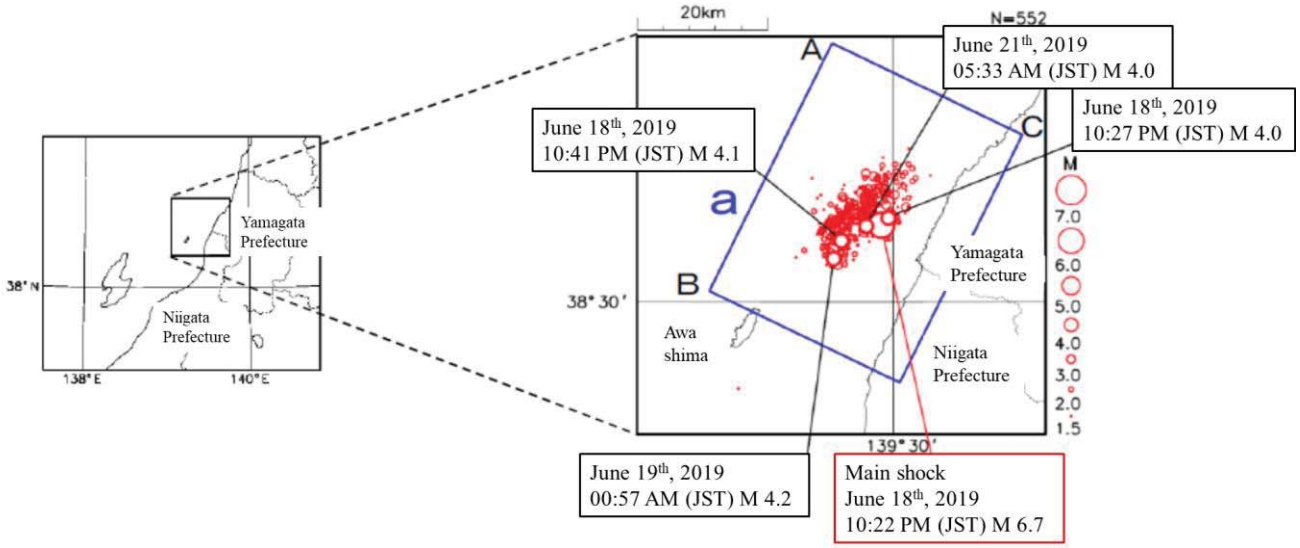


Fig.1 Location of epicenter and aftershocks distribution (June 18th-30th,2019, depth= 0-30 km, $M_j \geqq 1.5$) based on JMA[1].

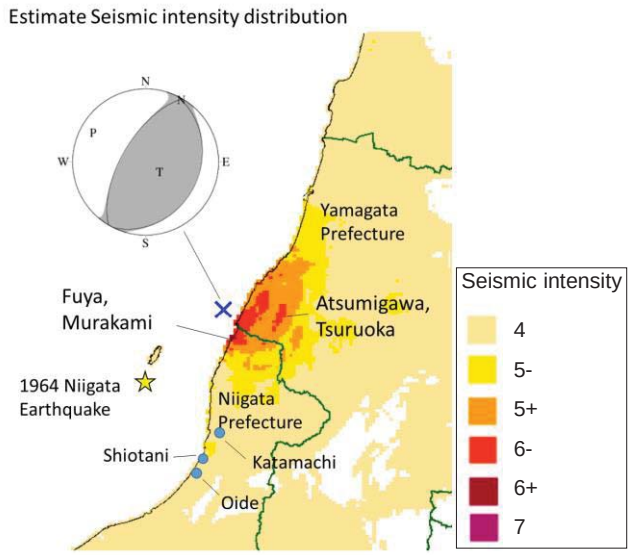


Fig.2 Seismic intensity distribution and focal mechanism [1),2)].

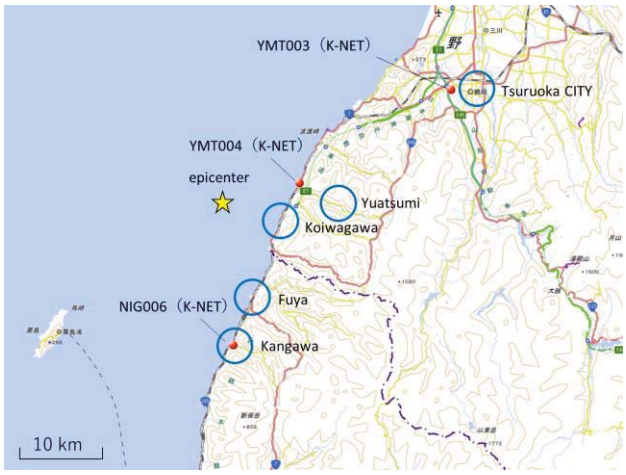


Fig.3 Location of seismic station and target area of damage investigation (blue circles). The base map is a reproduction of the Digital Topographical Map 25000 published by Geospatial Information Authority of Japan[4)]

2. OUTLINE OF EARTHQUAKE AND DAMAGE

(1) Ground motion

Fig.3 shows location of seismic station[5)] which have been installed near source area. There are K-NET Atsumi (YMT004), K-NET Tsuruoka (YMT003) and K-NET Kangawa (NIG006). The closest seismic station to the epicenter is YMT004, and hypocentral distance is about 10 km.

Figs.4-6 shows the acceleration waveforms and acceleration response spectra at each seismic station. The response spectra in this report, were calculated for a damping factor of 0.05.

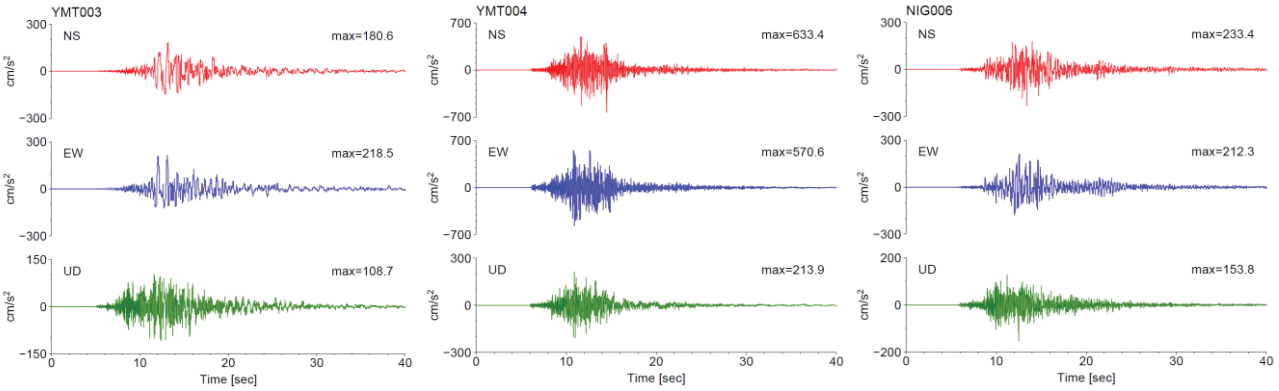
In YMT004 which is the closest station from the epicenter, maximum horizontal acceleration reached 633.4 cm/s^2. The duration time of the principal motion was about eight seconds. The acceleration response spectra have a large amplitude at a short period range, and it exceeded 2,000 cm/s^2 at a period range of 0.1s to 0.2s. At NIG006 and YMT003 whose hypocentral distances are longer than YMT004, the maximum acceleration was about 1/3 of the YMT004. The maximum acceleration spectra are smaller than YMT004. However, the acceleration response spectra at a period range of 0.3s to 1.5s were larger than YMT004. According to the soil boring log of K-NET, hard base which has SPT-N value more than 50 appeared at G.L.-3m. On the other hand, hard base of YMT003 and NIG006 appeared at deeper than G.L.-17m. The ground motions might be affected by ground characteristics.

(2) Summary of damage

This earthquake caused damage with 43 injured persons (9 serious injuries, 34 minor injuries). Fur-

thermore, 36 houses were partially destroyed and 1,245 were partially damaged[6]. Housing damage is concentrated in Yamagata and Niigata Prefectures. Fortunately, there was no major damage such as a house collapse. The damage of Fuya area, where seismic intensity 6+ was observed, was minor.

Because there was a rock fall near the Kobo tunnel of Route 345, Route 345 was closed for three days[7]. Minor slope failure occurred at development land near Fuya seismic station. Liquefaction occurred at the parking lot of Tsuruoka City. However, the range of the liquefaction was restrictive. Occurrence of liquefaction has been reported in Shonai City[8], too.



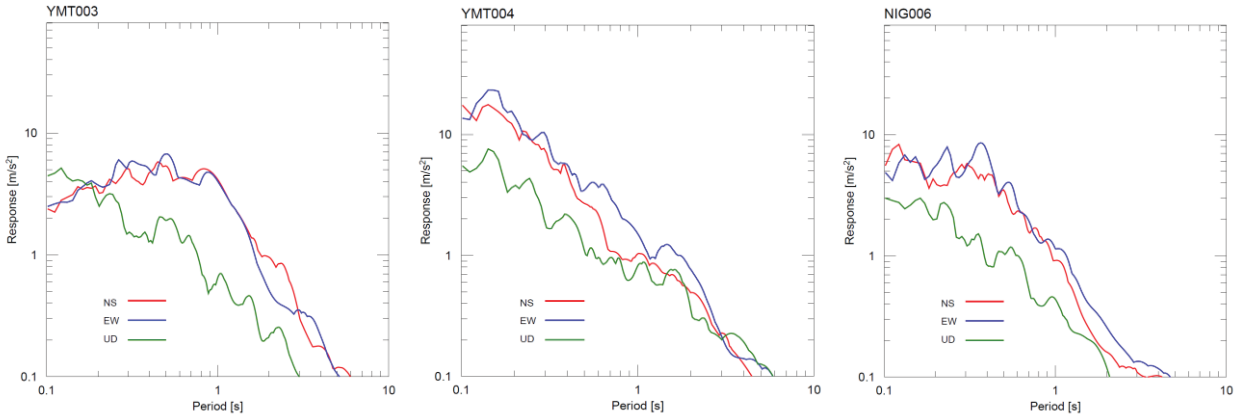


Fig.4 Observed acceleration wave-forms and acceleration response spectra (h=0.05) of YMT003.

Fig.5 Observed acceleration wave-forms and acceleration response spectra (h=0.05) of YMT004.

Fig.6 Observed acceleration wave-forms and acceleration response spectra (h=0.05) of NIG006.

Photo 1 The seismic station of NIG006 that observed seismic intensity 5- (N38.45075, E139.496175).

Photo 2 Slightly damage of the roof tile on the wooden house in Kangawa area (N38.451535, E139.496093).

3. DAMAGE INVESTIGATION

We conducted a damage investigation in the affected area on June 20th, two days after the earthquake. First, we investigated at Oide area, Shiotani area and Katamachi area. In these areas, many geotechnical damages such as liquefaction and liquefaction induced road subsidence have been reported in the 1964 Niigata earthquake[3]. Location of these areas and epicenter of the 1964 Niigata earthquake are shown in **Fig.2**. However, we could not find any damage.

We conducted a detailed survey along a coastline of Japan sea from Murakami City, Niigata Prefecture to Tsuruoka City, Yamagata Prefecture. In this report, we describe housing damage mainly at five sites of Kangawa area, Fuya area, Koiwagawa area, Yuatsumi area and Tsuruoka area. Locations of these investigation sites are shown in **Fig. 3**.

Photo 3 Fuya station that observed seismic intensity 6+ (N38.514105, E139.534208).

(1) Kangawa, Murakami City, Niigata Prefecture

Kangawa is located in the south of our investigation area. Seismic station of NIG006 has been installed at corner of Kangawa purification center. Hypocentral distance is about 17 km. **Photo 1** shows NIG006.

Observed acceleration waveforms and acceleration response spectra are shown in **Fig. 6**. Peak ground acceleration (PGA) of horizontal components were greater than 200cm/s^2. Calculated seismic intensity was 5- by observation records. Acceleration response spectra reached 800cm/s^2 at a period range of about 0.1s to 0.5s.

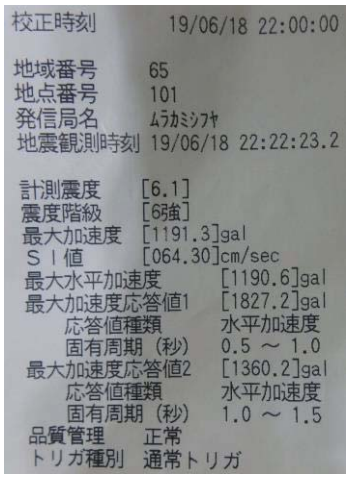
We confirmed minor damage of tiled roof a little far from NIG006. **Photo 2** shows damage of tiled roof. But, there were no major damage around NIG006 as far as we investigated.

(2) Fuya, Murakami City, Niigata Prefecture

Fuya is located in the river mouth of the Ohkawa river. JMA instrumental seismic intensity meter has been installed at Sanpoku branch second office of Murakami City. **Photo 3** shows situation of Fuya station. A building of a one-storied house seen on the further side of the Fuya station is the Sanpoku branch main office. There is no major damage as far as we investigated.

According to the result of instrumental seismic intensity meter, a seismic intensity of 6.1 and a PGA of 1191.3cm/s^2 were observed. **Photo 4** shows result of instrumental seismic intensity meter. All of these values are the maximum in this earthquake.

Photo 5 shows aerial photograph around Fuya station by UAV which was taken on the 21st of June, 2019. Red color circle indicates Fuya station. Serious damage such as total collapse of house is not seen in **Photo 5**. The building and housing near Fuya station were no major damaged. Furthermore, there were no



Last correction	19/06/18 22:00:00
District Number	65
Location Number	101
Name of Station	Fuya, Murakami City
Record Time	19/06/18 22:22:23.2
Instrumental Seismic Intensity	6.1
Seismic Intensity Scale	6+
Max. Acceleration	1191.3 gal
Spectral Intensity	64.30 cm/sec
Max. Horizontal Acceleration	1190.6 gal
Max. Response Acceleration (1)	1827.2 gal
Response Index	Horizontal acceleration
Period Range	0.5 sec – 1.0 sec
Max. Response Acceleration (2)	1360.2 gal
Response Index	Horizontal acceleration
Period Range	1.0 sec – 1.5 sec
Quality	Normal
Trigger	Normal

Photo 4 Result of instrumental seismic intensity meter at Fuya station.

Photo 5 UAV photograph around Fuya seismic station on June 21st, 2019 where seismic intensity 6+ was observed. Red circle mark indicates seismic station (N38.514137, E139.534167).

Photo 6 Slope failure of development land in near Fuya station (N38.513557, E139.534312).

Photo 8 Damage of exterior building material of old wooden house in Fuya area (N38.516733, E139.534405).

Photo 7 Damage of the tiled roof in Fuya area (N38.516572, E139.533605).

Photo 9 Tiled of the block fence without reinforcement in Fuya area (N38.514325, E139.53343).

damages in traffic lights and illumination poles. Minor slope failure of development land which was constructed by filling, occurred in near Fuya station. **Photo 6** shows situation of slope failure.

Typical minor damages in Fuya area are shown in **Photo 7**, **Photo 8** and **Photo 9**. **Photo 7** is damage of tiled roof on the wooden house. Some roof tiles are slid off from their original position. **Photo 8** is damage of exterior building material of old wooden house. A part of the outer wall dropped and an emergency safety evaluation result of caution posted on the entrance door. **Photo 9** means tiled of the block fence with no reinforcement.

We attempt damage estimation of housing by UAV photograph which was taken on the 21st of June, 2019. Target area is plain part of Fuya area. The house covered with a blue sheet was counted as a damage house in this research. As a result, the number of target houses were 799 houses. Among them, it was confirmed that 21 houses were able to directly identify the damage of the tiled roof, and 53 houses were using blue sheets. Accordingly, it is thought that 9.3% of the housings were damaged. Three days after the earthquake occurred, 28.4% of housing the did not cover blue sheets, even if the roof was damaged.

(3) Koiwagawa, Tsuruoka City, Yamagata Prefecture

Koiwagawa area is located most close to epicenter. Main damage is tiled roof of wooden house. Many tiled roofs were damaged and covered with blue sheets for protecting rain. **Photo 10** shows damage situation of Koiwagawa area. Some of damage house has been repaired.

In the cemetery on the hill of elevation 30 m, many tombstones fell down. There are small scale slope failures. The damage causes are regarded as slope failure or amplification of the ground motion by the slope. **Photo 11** shows damage of cemetery. We discuss the tiled roof damage in next chapter in detailed.

(4) Yuatsumi, Tsuruoka City, Yamagata Prefecture

We investigated around Atsumi Onsen area along the Atsumi gawa river. The roof of a few housing was damaged. **Photo 12** shows damage of roof. From the position of the blue sheet, it is thought that the damage of the tile occurred at the upper part of the roof. Seismic station of YMT004, which observed intense ground motion with PGA>600cm/s^2, has been installed at a distance of 1.6 km west from the investigation area (**Fig.3**). Damage of Yuatsumi area is small for an observation record. The ground motion observed in this district was strong, but the damage was minor.

(5) Tsuruoka City, Yamagata Prefecture

Tsuruoka City is the second largest city in Yam-

Photo 10 Damage situation of Koiwagawa area (N38.589305, E139.56581).

Photo 11 Damage of tombstone at Koiwagawa (N38.589553, E139.565355).

Photo 12 Damage of the tiled roof at Yuatsumi area (N38.615022, E139.60404).

agata Prefecture. There are many housings and buildings and civil structures including the lifeline system. However, damage of Tsuruoka area was small and limited. Confirmed damages were soil liquefaction and roof collapse of Sumo ring.

Soil liquefaction occurred at a parking space of the near Tsuruoka railway station. **Photo 13** shows soil liquefaction. There are many sand boils in parking space, but liquefaction occurred in a part of the parking space. Houses around liquefied parking space were no damage (see **Photo 13**). In this investigation, we were not able to find soil liquefaction in other site of Tsuruoka area. Soil liquefaction has been confirmed Sakata City, 15 km north of the Tsuruoka area[8].

Roof collapse of Sumo ring occurred at Oizumi Elementary School in Shiroyama, Tsuruoka City. **Photo 14** shows damage situation. The damage was not seen in a school building and the near housings. YMT003 is located in two kilometers west from Oizumi Elemantary School. Seismic intensity 5+ and PGA more than 180cm/s^2 were observed. But damage of near seismic station is not reported.

4. DISCUSSION

Seismic intensity of 6+ was observed in this earthquake, but the damage was minor. However, even minor damage, there was a difference in damage depending on the location.

Koiwagawa area had a lot of roof damaged houses. **Fig.7** shows location of around Koiwagawa area. Wasada area and Oiwagawa area are located in north side and south side of Koiwagawa area respectively. We calculated a damage rate of the roof tile at three areas using an aerial photograph which were taken on June 20th and June 26th[9]. The fundamental evaluation method of the damage rate is using the same procedure as Fuya area. Because resolution of aerial photograph was insufficient, we judged the housing damage from only a blue sheet on the roof.

Photo 15 - 17 shows aerial photographs of Koiwagawa area, Wasada area and Oiwagawa area respectively. These aerial photographs were taken on June 26th. Many blue sheets are seen in Koiwagawa area. On the other hand, there are few blue sheets in Wasada area and Oiwagawa area. **Table 1** shows the results of roof damage evaluation by aerial photograph. In Koiwagawa area, 58 housings, about 30% of the target housing, were damaged. At the time of the field survey, some tiled roofs were repaired. Therefore, it is considered that actual number of damaged houses was greater than estimated. On the other hand, evaluated damage ratios of Wasada area and Oiwagawa area are 0.99% and 2.59% respectively. These values are clearly lower than Koiwagawa area.

Photo 13 Multiple sand boils by liquefaction at Tsuruoka area (N38.738543, E139.836162).

Photo 14 The roof of the Sumo ring in Oizumi Elementary School which collapsed (N38.615, E139.604167).

Fig.7 Location of the detailed investigation areas (Wasada area, Koiwagawa area and Oiwagawa area). The base map is a reproduction of the Digital Topographical Map 25000 published by Geospatial Information Authority of Japan[4]

Photo 15 Aerial photograph in Koiwagawa area on June 26th, 2019[9] (N38.5893, E139.5658).

Photo 16 Aerial photograph in Wasada area on June 26th, 2019[9] (N38.5740, E139.5564).

Photo 17 Aerial photograph in Oiwagawa area on June 26th, 2019[9] (N38.6084, E139.5758).

Because the hypocentral distance of Koiwagawa area, Oiwagawa area and Wasada area is about the same, it was thought that input motion level to engineering base is also same. However, Koiwagawa area was damaged heavier than other areas. These results mean that the site effect of Koiwagawa area is different from other sites. Furthermore, according to the aerial photograph of Koiwagawa area (**Photo 15**), most of the damaged houses are located in the center of the area. From this result, it is estimated that the site amplification characteristics of Koiwagawa area is different by location. Detailed ground investigation is necessary to elucidate these results.

Table 1 Percentage of buildings with damaged tiled roofs in the target area.

Area	Koiwagawa	Oiwagawa	Wasada
Number of buildings（houses）	203	101	193
Number of blue sheet buildings（houses）	58	1	5
Percentage of blue sheet buildings（%）	28.57	0.99	2.59

5. SUMMARY

The authors conducted a damage investigation of the off Yamagata Prefecture earthquake on June 18th, 2019. The following results were obtained.

1) Seismic intensity of 6+ was observed at Fuya station, but the damage was minor.
2) In other near source areas, the damage was also minor and the main damage was tiled roof damage of wooden house.
3) We can evaluate a damage rate for tiled roofs using an aerial photograph.
4) The damage rate of roof tile at Koiwagawa area was the highest among the damaged area.
5) Oiwagawa and Wasada area were close to Koiwagawa area, but the damage rates were different from Koiwagawa area. The site amplification characteristics in the Koiwagawa area was considered to be different from other sites.

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