6.2 Damage to Wood Houses

6.2.1 Objectives of damage survey

A lot of wood buildings were damaged by the 2011 Tohoku earthquake. NILIM and BRI surveyed the damage of wood building starting from March 14, three days after the earthquake occurrence for the purpose of grasping the general image of the damage. Because the disaster by the earthquake occurred in wide areas, we carried out the first survey for multiple times, but cannot grasp the whole aspect of the damage. In this chapter, results of these multiple survey were summarized as basic documents to devise a survey plan in afterward to consider about the damage cause.

6.2.2 The selection of the survey area and the outline of the survey

The survey area and the reasons of the selection are as follows;
Kurihara city in Miyagi pref. : The seismic intensity 7 was recorded,
Osaki city in Miyagi pref. : As a result of damage survey[6.2-1)], heavy damage was reported,
Sukagawa city in Fukushima pref.: RC buildings were heavily damaged,
Nasu and Yaita cities in Tochigi pref., and Hitachiota and Naka cities in Ibaraki pref. : As a result of damage survey[6.2-1)] by others, damage information has not been reported, at the time of our survey,
Ishinomaki city in Miyagi pref. : Although it was almost included in the inundation area, the selected area of the city was not inundated by the tsunami, and,
Joso and Ryugasaki cities in Ibaraki pref. : There was damage information and they are located close to NILIM and BRI.

The locations of the surveyed cities and towns are shown in Fig. 6.2-1, and the schedules of the survey are shown in table 6.2-1.

Table 6.2-1 Schedules of survey.

Month/Day	Surveyed area
3/14～16	Kurihara and Sendai in Miyagi prefecture
3/23	Joso and Ryugasaki in Ibaraki prefecture
3/24～25	Sukagawa in Fukushima prefecture and Nasu and Yaita in Tochigi prefecture
3/25	Hitachiota, Naka, and Mito in Ibaraki prefecture
4/21	Hitachiota and Naka in Ibaraki prefecture
4/27～29	Osaki, Misato, and Ishinomaki in Miyagi prefecture

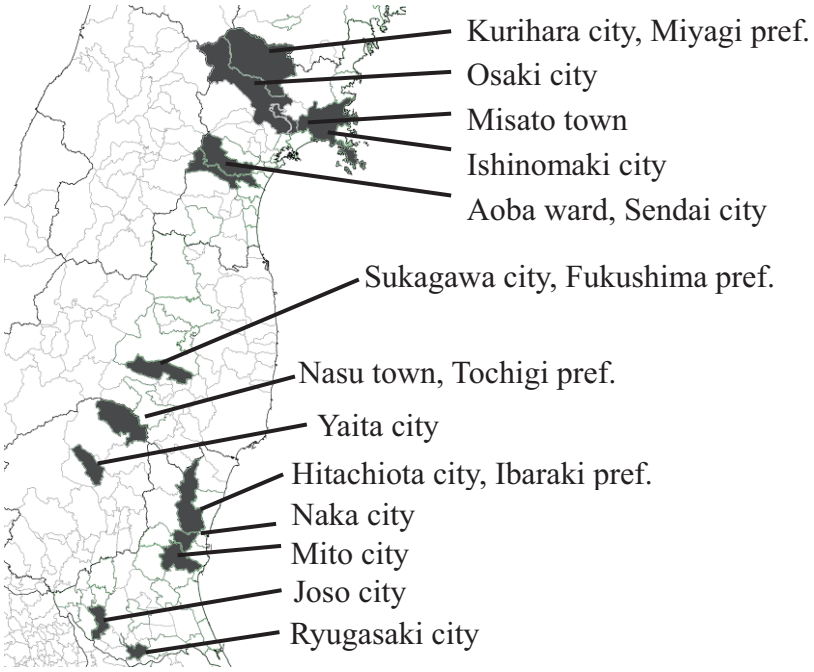


Fig. 6.2-1 Locations of surveyed cities and towns.

6.2.3 Results of the survey

(1) Kurihara city, Miyagi prefecture

According to the Kurihara city office, Miyagi where seismic intensity 7 was recorded, post-earthquake quick inspection of damaged buildings was conducted for 590 wood houses (excluding warehouses) in greatly damaged areas: Wakayanagi-Kawakita (139), Wakayanagi-Kawaminami (246), Wakayanagi-Fukuoka (80), Semine (187), Kurikoma-Sakurada (70), as of March 15. Location of these places is shown in Fig. 6.2-2. Unsafe wood houses in danger, wood houses with limited entry and inspected (safe) wood houses accounted for 18%, 29% and 54% of the total, respectively. The number of collapsed houses was only one, and the number of completely

Fig.6.2-2 Surveyed areas in Kurihara city

destroyed houses and almost-destroyed houses were 42. The ground conditions in Wakayanagi and KurikomaSakurada are poor, and most of the houses in the north and south side of Wakayanagi, KurikomaSakurada and Semine had age of about 30 to 40 years. On the other hand, since the ground conditions are good near the city office, structural damage was not observed in the city office.

K-NET Kurihara Tsukidate (MYG004 : Instrumental seismic intensity 6.6) is set up on the hillock 3m higher (by eye measurement) than south of parking lot of Kurihara lyceum. There was a possibility of the amplification of earthquake motions (Photo 6.2-1). In Wakayanagi district, the ground was bad and sand boil due to liquefaction was observed (Photo 6.2-2). Damage to houses caused by ground transformation (Photo 6.2-3) and damage to houses with store were also observed (Photo 6.2-4).

A large residual deformation was observed in the longitudinal direction in the large-scale wood building used as a movie theatre then renovated to a factory (Photos 6.2-5, 6.2-6)

According to the observation of overturning of tombstones in three places in Wakayanagi district, the ratio of overturning was from 10% to 40%, and it seemed that there were a lot of overturnings in north to south direction (Photo 6.2-7).

In Kurikomasakurada district, collapse of work hut, drop of the mud plasters of Nagaya-mon gates (Photo 6.2-8), damage of plastered storehouses were observed, but any heavy damage in house was not observed.

The Seismograph of Kurikoma (JMA seismic intensity 6-) is set up on the parking lot in the west of “Michinoku-Densokan（Photo 6.2-9）”. From the exterior damage investigation, damage was not observed in “Michinoku-Densokan” and Kurikoma Branch office (Glulam frame structure: Photo 6.2-10).

Photo 6.2-1 K-NET KuriharaTsukidate

Photo 6.2-2 Sand boil due to liquefaction

Photo 6.2-3 Damage of houses caused by ground transformation

Photo 6.2-4 Damage of houses with store

Photo 6.2-5 Large-scale wood building renovated to a factory

Photo 6.2-6 Inside of the building shown in Photo 6.2-5

Photo 6.2-7 Overturning of tombstones

Photo 6.2-8 Drop of mud plasters of Nagaya-mon gate (Kurikomasakurada)

Photo 6.2-9 Seismograph of Kurikoma

Photo 6.2-10 Kurikoma Branch office (Glulam frame structure)

(2) Osaki city, Miyagi prefecture

According to the Osaki city office, it was informed that the damage concentrated in the neighbourhood of the city office and the northwest of JR Freight Company Furukawa Station, as shown in Fig. 6.2-3. In the other areas, it was informed that there was damage on building along the old main road in Furukawa-Araya, but damage on buildings in the mountain region including Naruko district and so on, had not been reported.

Heavy damage including the collapse of houses was confirmed on the way to the northwest of JR Freight Company Furukawa Station from the Osaki city office. Besides the damage reported by the other institutions[6.2-2)], a largely deformed house, a damaged house with store, a partially collapsed house, and so on were observed.

For example, warehouse with the mud walls renovated as store or gallery (Photo 6.2-11) was damaged heavily or slightly. There was the one whose roof system with roof tiles collapsed and fell down, as shown in Photo 6.2-12. In the area of these warehouses, there was a Japanese traditional post and beam construction house with large deformation (Photo 6.2-13) which was renovated as a store. On the opposite side of this house, there was the house with store (Photo 6.2-14) with story shear deformation whose exterior mortar came off and wood lath under the mortar near the opening of the ventilation fan was deteriorated and attacked by termites, as shown in Photo 6.2-15. Such damage was confirmed in the other buildings. Most of these damage occurred along a small river, except for a few case, and it was considered that the soft ground near the river might amplify the earthquake ground motion.

Seismograph at JMA Furukawa (Photo 6.2-16) which recorded seismic intensity 6+ was located in the northeast corner of the Mikkamachi park. There were the former school buildings around it. One of them was not almost damaged (Photo 6.2-17), while the other was damaged on roof tiles and exterior mortar without story drift. In addition to them, a rare damage example (Photo 6.2-18) that only the 2nd story collapsed was observed. On the other hand, a wood school building (Photo 6.2-19) in the west of the Osaki city office seemed not to be damaged in the appearance. Besides these, the house with store with large story drift in 1st story (Photo 6.2-20), those with large story drift in 2nd story (Photo 6.2-21), and 1-story wood house with large story drift caused by the land liquefaction were observed.

In the northwest of JR Freight Company Furukawa Station, a collapsed steel frame building, an RC structure apartment house with rocking drift caused by the land deformation, and a temple building (Photo 6.2-22) with large story deformation were observed.

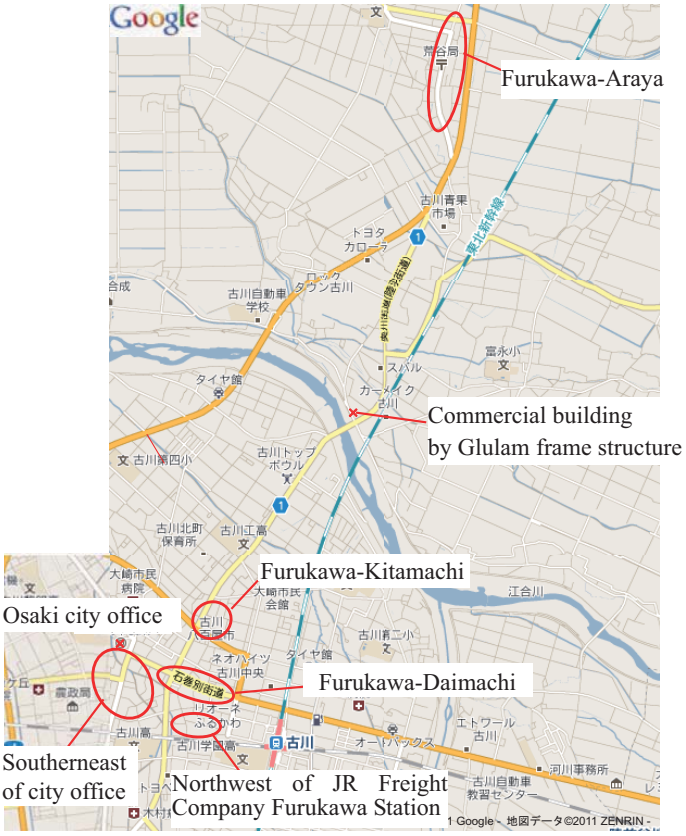


Fig. 6.2-3 Surveyed areas in Osaki city

Photo 6.2-11 Warehouse with mud walls damaged heavily or slightly

Photo 6.2-12 Warehouse with mud walls whose roof system with roof tiles fell down

Photo 6.2-13 Damaged Japanese traditional house with large story deformation

Photo 6.2-14 House with store with large story deformation

Photo 6.2-15 Deterioration in building of Photo 6.2-14

Photo 6.2-16 JMA seismic station at Furukawa (Seismic Intensity 6+)

Photo 6.2-17 School building suffering damage on roof tiles and exterior walls

Photo 6.2-18 School building whose 2nd story collapsed

Photo 6.2-19 Seemingly slightly damaged School building

Photo 6.2-20 House with store with large story deformation

Photo 6.2-21 House with store with 2nd story drift more than that of 1st story

Photo 6.2-22 Heavily damaged temple building

(3) Misato town, Miyagi

According to the Misato town office, the number of damaged structure was shown in table 6.2-2. There were a lot of damaged structures in Nakazone and Hirabari of Kogota area in this town.

Table 6.2-2 Number of damaged structures in Misato town as of April 28

Damage		Kogota area	Nango area	Total
Residential	Fully destroyed	60	17	77
	Half destroyed	243	70	313
	Partially destroyed	1,577	307	1,884
Non-residential		1,193	232	1,425

In Hirabari of Kogota area, there were a lot of wood houses which tilted largely in the east-west direction along the Eaigawa river (Photo 6.2-23). Photo 6.2-24 shows the wood house which leans to the fence. Most of the tombstones in this area fell toward in the east-west direction (Photo 6.2-25). Photo 6.2-26 shows the tilted wood house of

which two-story might have been extended. In the southern side of Eaigawa river, there were log house without damage (Photo 6.2-27), wood house which tilted largely at first story (Photo 6.2-28) and tilted shrine building (Photo 6.2-29).

In Nango area, ground deformation was observed in the branch town office (Photo 6.2-30), but there were few damaged houses. Photo 6.2-31 shows the tilted wood house in Nango area. The structures in this area were damaged in a certain level during the 2003 northern Miyagi prefecture earthquake. There is a possibility that damaged buildings were retrofitted or rebuilt after the 2003 earthquake, because structures in this area seemed to be new.

Photo 6.2-23 Largely tilted house

Photo 6.2-24 Collapsed wood house

Photo 6.2-25 Tombstones in Hirabari

Photo 6.2-26 Tilted two-story house

Photo 6.2-27 Log house without damage

Photo 6.2-28 Largely tilted wood house

Photo 6.2-29 Damaged shrine

Photo 6.2-30 Ground deformation in Nango branch town office

Photo 6.2-31 Heavily damaged house

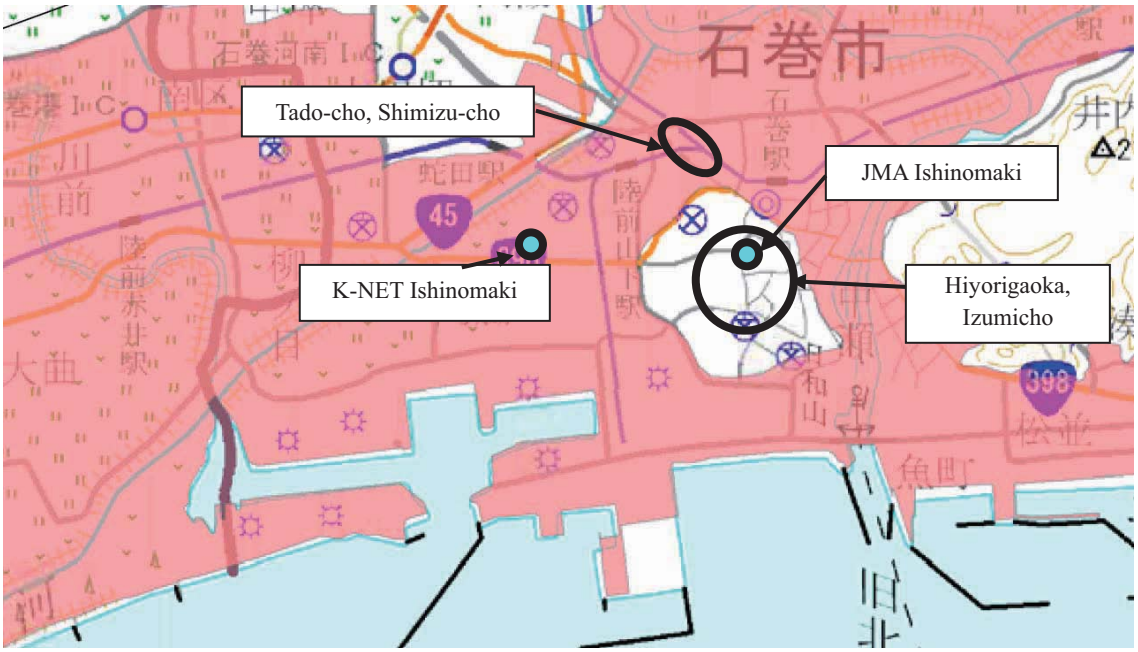
Photo 6.2-32 Inside of the house in Photo 6.2-31

(4) Ishinomaki city, Miyagi prefecture

Hiyorigaoka and Izumi-cho in Ishinomaki city are located on a hill (max. Altitude, 56.4m) at the western side of Kyu-kitakami river, almost all of the buildings are residence without public facilities (Photo 6.2-33). There were not heavily damaged wood houses and a few wood houses of which roof tile damaged (Photo 6.2-34).

Tado-cho and Shimizu-cho are located at the northern side of Hiyorigaoka hill and the area inundated by the tsunami according to the information[6.2-5)] of GSI (Fig. 6.2-4). There are a lot of low-rise wood houses with store which have big opening along the street between Ishinomaki-kaido and Ishinomaki-betsukaido street. The inundation depth estimated by the trace was 80-150cm. The inhabitant said that the fluid velocity of the tsunami was very slow and the inundation depth increased like flood. So it was estimated that the damage of the buildings was caused by the earthquake motion.

On the both sides of the street, there were collapsed wood house by earthquake (Photo 6.2-35) and tilted wood house with store (Photo 6.2-36). It was estimated that the wood houses with store which have less seismic elements at the first story were heavily damaged.



Colored area: inundated area

Fig. 6.2-4 GSI Inundation area map of Ishinomaki city [6.2-5)]

Photo 6.2-33 Appearance of Izumicho

Photo 6.2-34 Damaged roof tile in Hiyorigaoka

Photo 6.2-35 Collapsed wood house

Photo 6.2-36 Tilted wood house with store

(5) Sendai city in Miyagi prefecture

According to the Tohoku Regional Bureau, Ministry of Land, Infrastructure Transport and Tourism and Aoba ward office, Sendai city, the regions, where post-earthquake quick inspection of damaged buildings was conducted, were Asahigaoka 1, 2, 3, 4 chome(2, 250), Oritate 4, 5, 6 chome (470), Kaigamori 1 chome (400), Seikaen 1, 2chome (540) in Aoba ward, and Higashikuromatsu, Kuromatsu 1 chome and 3 chome in Izumi ward and so on. Location of those places was shown in Fig.6.2-5.

From the results of investigations on Oritate and Seikaen where the damage of the houses were serious, it was found that almost all of the damage of house were caused by ground transformation. Moreover, ground transformation caused retaining wall collapse (Photo 6.2-37, 6.2-38), landslide and damage of houses (Photo 6.2-39). On the other hand, there were some sloping lands in Kaigamori and Asahigaoka where the number of damage of retaining wall was minor, and damage of roof tile, collapse of concrete block wall and outer wall were observed. In Komatsujima, Aoba ward, drop off the mortar wall and damage of columns and biodeterioration by termites were observed in the house with store (Photo 6.2-40). Moreover, the house with large residual deformation on the 1st floor was observed (Photo 6.2-41). In Mukaiyama, Taihaku ward, collapse of a Japanese-style hotel was observed because of the sudden fall of stone of hillback (Photo

6.2-42, 6.2-43).

Fig. 6.2-5 Observation points in Sendai city
(◯:observation completed, ◌: not completed)

Photo 6.2-37 Damage of retaining wall and houses（Oritate, Aoba ward）

Photo 6.2-38 Damage of house in Photo 6.2-37

Photo 6.2-39 Damage of house caused by the ground transformation (Oritate)

Photo 6.2-40 Drop off the mortar wall (Komatsujima)

Photo 6.2-41 House with large residual deformation (Komatsujima)

Photo 6.2-42 Collapse of Japanese-style hotel (Mukaiyama)

Photo 6.2-43 Hillback of the hotel

(6) Sukagawa city, Fukushima prefecture

According to the Sukagawa city office, it was said that the damage of buildings was concentrated on around the city office at Hachiman-machi, Kaji-machi and Minami-machi. The post-earthquake quick inspection of damaged buildings (Table 6.2-3) was conducted only around the city office and finished by March 24.

There was a little damage on the upper timber construction of wood houses, and the damage of several residential lands was reported in the east part of the city. A lot of Japanese traditional warehouse with wood structural members and mud walls were built and left at present because Sukagawa city prospered as a merchant town. A lot of warehouses with mud wall and stone built about 30 years ago suffered heavy damage.

A lot of damaged wood houses were observed around the collapsed RC structure building. Examples are as follows: the failed exterior mortar wall of the 2nd floor in a house with store (Photo 6.2-44), deterioration and damage by Reticulitermes on a part of structural member and wood lath of exterior mortar wall (Photo 6.2-45), a wood house whose stair hall was removed and collapsed (Photo 6.2-46), and so on.

The wood warehouses with mud wall were heavily damaged near the hotel with the window glass broken. For example, the warehouses which deformed much (Photo 6.2-47) and whose roof system collapsed (Photo 6.2-48) were observed. A few wood houses with roof tiles damaged (*e.g.* Photo 6.2-49) were found. On the other hand, roof tiles of temple gate (called as "*Sanmon*") were damaged, while the main hall of the

temple was not so damaged (Photo 6.2-50 and 51). The sand eruptions caused by the soil liquefaction and the damage on the roof tiles were seen here and there in Minami-machi, Sukagawa city. In addition, on the web site of the city, the collapsed house was reported (Photo 6.2-52, From the city website).

Another collapsed building with uncertain structural type was found (Photo 6.2-53). According to the damage overview seen from the east of Minami-machi (Photo 6.2-54), it was observed that the wood houses with roof covered temporarily with blue vinyl sheet which was guessed to be damaged to roof tiles were relatively many.

Table 6.2-3 Results of Post-earthquake quick inspection of damaged buildings in Sukagawa city as of March 24

Structural type	Checked number	Unsafe	Limited Entry	Inspected
Timber	1,023	245	315	463
Steel	188	51	44	93
Reinforced concrete	73	25	16	32
Total	1,284	321	375	588
Ratio	100 %	25.0 %	29.2 %	45.8 %

Photo 6.2-44 Fallen mortar of wall (Wood house with store)

Photo 6.2-45 Deterioration and damage due to termite on column and wood lath of exterior mortar

Photo 6.2-46 Collapsed stair hall

Photo 6.2-47 Failed warehouse with mud wall

Photo 6.2-48 Fallen roof of warehouse with mud wall

Photo 6.2-49 Damage of roof tile

Photo 6.2-50 Minor damage of temple gate

Photo 6.2-51 No damage on main hall of temple

Photo 6.2-52 Collapsed wood house at Minami-machi (From Sukagawa city website)

Photo 6.2-53 Collapsed building (Unknown structure type)

Photo 6.2-54 Damage overview from the east of Minami-machi (Many roofs covered with blue vinyl sheet)

(7) Nasu town, Tochigi prefecture

According to the Nasu town office, the post-earthquake quick inspection of damaged buildings had not been carried out. The primary damage survey was conducted only by the town officials. With the survey, 32 wood houses were found totally collapsed.

It was said that the damage on buildings was concentrated in the area of Nishi-Ohkubo near the town office, although there was no collapsed wood house. It was reported that there was little damage in Nasu-kogen highland area in the west of national road route 4. On the other hand, it was said that damage on many wood houses were found in Toyohara-Otsu area where many cottages built on slope lands.

The damaged houses were in the area of Shio-akutsu, Chausu, Hoshibata, Akiyamasawa, Nigashimuro, Yanome, Higashi-Iwasaki, Numanoi, Hongo, Nishizaka, Ishizumi, Muronoi etc. and most of them were developed as residential lands. The locations of surveyed areas are shown in Fig. 6.2-6.

The stone-built warehouse was heavily damaged near the town office (Photo 6.2-55). The exterior stonewall of the former post office was failed (Photo 6.2-56).

Toyohara-Otsu area is in the north of Nasu town, and cottages are built along the path on slightly elevated hills. The movement and collapse of the wood deck (Photo 6.2-57) and collapse of the stone exterior were often observed. Several damages on wood houses caused by the slope land or the embankment were observed. The damage on the wood house due to large ground deformation caused by the earthquake motion was also found (Photo 6.2-58). It was confirmed that the metal fasteners were installed in the column end joint and the brace end joint of this house. (Photo 6.2-59). Besides the story drift, crack of concrete foundation (Photo 6.2-60), crack and loss of the exterior siding board, broken window glass, and failed ceiling of eaves (Photo 6.2-61) were observed.

In Nishi-Ohkubo area, several wood houses whose exterior mortar wall in the 1st floor was almost failed were found (Photo 6.2-62). And, the wood house with large story drift (Photo 6.2-63) and the other one damaged due to deformation of the residential land (Photo 6.2-64) were found.

Photo 6.2-55 Damage of stone-built warehouses

Photo 6.2-56 Damage of an old post office

Fig. 6.2-6 Surveyed area in Nasu town

Photo 6.2-57 Damage of wood deck in Toyohara-Otsu, Nasu town

Photo 6.2-58 Heavily damaged wood house

Photo 6.2-59 Metal fastener at the end of column and brace

Photo 6.2-60 Crack of foundation

Photo 6.2-61 Failed ceiling of eave

Photo 6.2-62 Damage of exterior mortar wall

Photo 6.2-63 Wood house with large story drift

Photo 6.2-64 Damaged house due to deformation of residential land

(8) Yaita city, Tochigi

According to the Yaita city office, the post-earthquake quick inspection of damaged buildings was limited to the houses at the request of residents and all houses in evacuation zone due to deformation of the residential land. By March 23, 108 buildings (including 3 buildings, such as stone warehouse, which couldn't be evaluated) were surveyed by the post-earthquake quick inspection of damaged buildings. The numbers of "Unsafe", "Limited Entry" and "Inspected" were 40, 42 and 23, respectively.

Evacuation was announced officially to the east of Lobin-city due to the deformation of the residential land. It was said that many damage were observed in the

northeast area of Narita-Happy-Highland, Arai, Hariu, and Koshiwata where development was made by sharpening slope lands and filling up swamps. The locations of the above areas are shown in Fig. 6.2-7.

In Lobin-city (Photo 6.2-65), cracks of fence and retaining wall, caving of road bed, ups and downs of the residential land (Photo 6.2-66) and cracks of the foundation concrete (Photo 6.2-67) were often observed. In addition, damage on the roof tile, especially top of the roof, and collapsed concrete block fences were observed.

Narita-Happy-Highland located at the north of Lobin-city was a developed residential land. Most of the damage on buildings was due to the deformation of the residential land. A wood house with 1/10 radian shear deformation (Photo 6.2-68) was found.

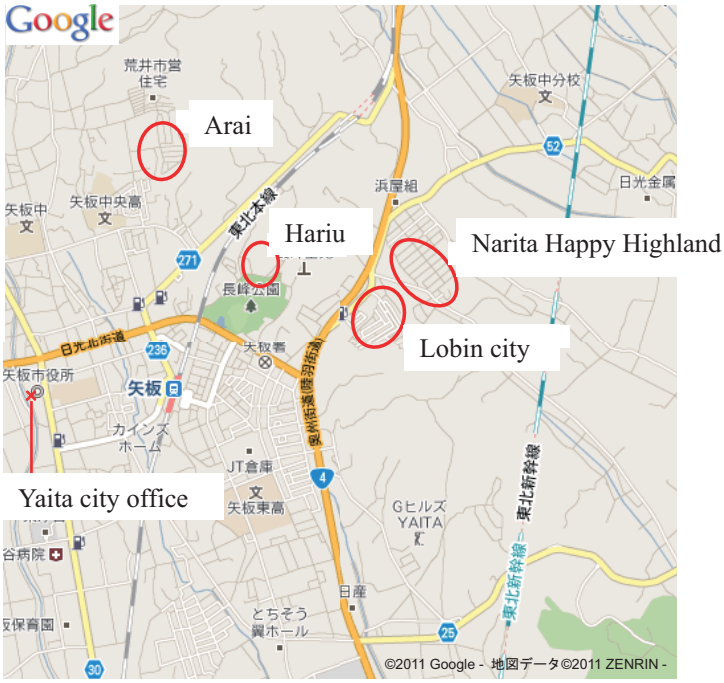


Fig. 6.2-7 Research area in Yaita city

Photo 6.2-65 No damaged houses at Lobin-city area

Photo 6.2-66 Ups and downs of residential land

Photo 6.2-67 Crack of foundation

Photo 6.2-68 Wood house with large shear deformation

(9) Hitachiohta city, Ibaraki prefecture

According to the post-earthquake quick inspection of damaged buildings, the number of “Unsafe” was 199, “Limited Entry” was 549 and “Inspected” was 574 in the city. The number of “Unsafe” was 87, “Limited entry” was 235 and “Inspected” was 97 in the Matsuzaka-cho. There were a lot of damaged buildings at the Kanasago area (Matsuzaka-cho and Nakano) in the Kujigawa river basin. Hitachiohta city office had made the hazard map that considers the subduction-zone earthquake. The seismic intensity was from 5+ to 6- at the Kujigawa river basin area.

There were a lot of damaged fence made by the Ohyaishi stone. A collapsed farm type house was observed (Photo 6.2-69, 6.2-70). The mortar plastered wall finish of the wood house at the land filled paddy field fell down (Photo 6.2-71).

Photo 6.2-69 Collapsed wood house

Photo 6.2-70 Breakage of entrance part.

Photo 6.2-71 Falling down of mortar plastered wall

(10) Naka city, Ibaraki prefecture

Naka city is surrounded by the Nakagawa river and the Kujigawa river and the center of the city is located on the plateau. A lot of damaged buildings were located at the Kujigawa river basin. The number of totally collapsed houses was 4 at Kadobe-shimogawara, 1 at Motoyonezaki as of March 25. By the post-earthquake quick inspection of damaged buildings, the number of "Unsafe" was 88. The damage information was reported at Kadobeakutsu and Urizura.

At Kadobe-shimogawara in Naka city, there were a lot of collapsed barns (Photo 6.2-72) and heavily damaged nagayamon gates (Photo 6.2-73). A damaged house with store was observed (Photo 6.2-74). A lot of collapsed barns were observed at Kadobe-akutsu.

A two story wood house with mortar finish collapsed at the urban area of Urizura in Naka city (Photo 6.2-75).

At the wood gymnasium (Photo 6.2-76, Photo 6.2-77) with curved glue laminated timber built in 1985-1989 in Urizura, buckling and tensile failure of the steel braces, the breakages of the foundation concrete at the brace joint were observed (Photo 6.2-78). At the wood school building (Photo 6.2-79), the slip of wood braces (Photo 6.2-80), the deformation of steel roof plate, wood flooring and interior material due to the contact with the stairway made by reinforced concrete were observed.

Photo 6.2-72 Collapsed nagayamon gate (Kadobe)

Photo 6.2-73 Tilted nagayamon gate (Kadobe)

Photo 6.2-74 Damaged house with store (Kadobe)

Photo 6.2-75 Collapsed house (Urizura)

Photo 6.2-76 Wood gymnasium

Photo 6.2-77 Inside of the gymnasium

Photo 6.2-78 Breakage of the foundation concrete

Photo 6.2-79 Wood school building

Photo 6.2-80 Slip of the wood brace

(11) Mito city, Ibaraki prefecture

According to the Mito city office, the number of totally collapsed building was 34 (residential 2, non-residential 32), half destroyed building, 66 (residential 34, non-residential 32) as of March 25.

The damaged buildings were mainly located around the city hall and in Motomachi, Yoshinuma-cho, Aoyagi-cho, Yanagawa-cho, Kamikochi-cho, Taya-cho, Joto and Sannomaru. The number of the collapsed residential house was two at Motomachi.

In the southern part of the Mito railway station, the ground settlement occurred

and the gap between the high-rise building and ground was observed. This area had been a part of the Senbako lake and was developed as residential land in 1965-1974. The ground settlement was also observed at the city hall and the entry to the building was restricted.

There was a heavily damaged Nagayamon gate at Yoshinuma-cho (Photo 6.2-81). The damaged barns were observed at Aoyagi-cho, Yanagawa-cho, Taya-cho (Photo 6.2-82).

Photo 6.2-81 Heavily damaged Nagayamon gate (Yoshinuma-cho)

Photo 6.2-82 Damaged barn (Aoyagi-cho)

(12) Joso city, Ibaraki prefecture

According to the Joso city office, Ibaraki prefecture, structural damage was not observed for houses. An announcement of collapsed house immediately after the earthquake, was the damage to a wood hut in a resting place. The house built in the side of Lake of crescent was inclined because of the soil liquefaction (Photo 6.2-83, 6.2-84). Although there were several inclined houses because of the soil liquefaction, a lot of damage to the roof tile were observed, and it seemed that the ratio of the damage of the roof tile was comparatively high.

Photo 6.2-83 Damage of resting place (Joja-machi, offered by Joso city office)

Photo 6.2-84 Damage of ground near the resting place（offered by Joso city office）

(13) Ryugasaki city, Ibaraki prefecture

According to the Ryugasaki city office, Ibaraki prefecture, structural damage was not observed in houses, and information about collapsed house immediately after the earthquake, was the damage of barn in the Takasu-cho. The post-earthquake quick inspection of damaged buildings was conducted for 58 wood houses based on the request from the citizens. According to the department, unsafe wood houses in danger and wood houses with limited entry accounted for 12, and 29 respectively. Most of the damage of houses was damage of roof tile and outside wall. There was no damage due to inclination of structural building frame. Though 6 houses and 1 barn were judged as partial collapse, the sites of those buildings were not located in concentrated specific region. The surrounding of the city office and JR Sanuki station are old urban areas, grounds of those areas are low and weak, and have a lot of damage of the roadbed. On the other hand, two new towns in the east and the west areas in the city are located on the hill, the ground is sound, and the damage of houses was not reported. Sand eruption by soil liquefaction was partly observed in the Takasu-cho area.

6.2.4 Conclusions

From the damage survey on the wood houses due to ground motion in Kurihara city, Osaki city, Misato town, Ishinomaki city, Sendai city in Miyagi prefecture, Sukagawa city in Fukushima, Nasu town, Yaita city in Tochigi prefecture, and Hitachiota city, Naka city, Mito city, Joso city, Ryugasaki city in Ibaraki prefectue, the followings were summarized.

1) The damage on many wood houses due to ground motion was confirmed in Osaki city in Miyagi prefecture, Sukagawa city in Fukushima prefecture, Nasu town in Tochigi prefecture, and Hitachiota city and Naka city in Ibaraki prefecture.
2) Although the seismic intensity 7 was recorded in Kurihara city, Miyagi prefecture, it was observed that the damage on wood houses was minor.
3) The heavy damage on wood houses caused by the failures of residential land was confirmed in Sendai city, Miyagi prefecture, and Yaita city, Tochigi prefecture. The number of wood houses suffering such damage was quite large.
4) The damage of the roof tile in Fukushima and Ibaraki prefectures seemed much larger than that in Miyagi prefecture where large earthquakes occurred frequently.
5) The possibility that the ground motion was amplified on the land filled up from swampland or rice field, even if the residential land did not fail, was suggested in Kurihara city, Osaki city in Miyagi prefecture, Nasu town in Tochigi prefecture, Hitachiota city, Naka city, Joso city, Ryugasaki city in Ibaraki prefecture, and so on.
6) In Osaki city, several rare damage examples that residual story deformation of 2nd floor was larger than that of 1st floor were confirmed.

The selected houses will be surveyed in detail and each damage cause will be discussed in future, based on the results of the damage summary of the above-mentioned wood houses.

References

6.2-1) Masato MOTOSAKA：The 2011 Off The Pacific Coast of Tohoku Earthquake - Quick Report of The Damage Survey - http://japonism.org/wp-content/uploads/2011/04/motosaka-report.pdf

6.2-2) Naohito KAWAI：Quick Report of Damage Survey on Buildings Due to The 2011 Off The Pacific Coast of Tohoku Earthquake by Kogakuin University Survey Team for Wood Buildings, Quick Report of Damage Summary Survey in Osaki City and Ichinoseki City on April 11. (draft), non-publication document.

6.2-3) The Japan Wood Research Society: (non-publication document)

6.2-4) NILIM and BRI：Quick Report of The Field Survey and Research on “The 2011 off The Pacific coast of Tohoku Earthquake” http://www.nilim.go.jp/lab/bbg/saigai/h15miyagi/chousa.pdf

6.2-5) Geographical Survey Institute: Figure of inundation range general condition http://www.gsi.go.jp/common/000059847.pdf