

6.5 Damage to Residential Land

6.5.1 Introduction

The outline of damage situations associated with liquefaction in the alluvial plain area along the Tone River on the border between Ibaraki and Chiba prefectures and in Urayasu city, Chiba prefecture is reported. Furthermore the outline of damage situations of developed housing areas in Miyagi and Fukushima prefectures is also reported.

6.5.2 Damage due to Liquefaction in alluvial plain area along Tone River

Damage associated with liquefaction has occurred in the same areas as in the areas where liquefaction had been reported in the past earthquakes, such as abandoned river channel, back marsh and reclaimed paddy field. This section describes the damage situations in Nishishiro, Inashiki city, Hinode, Itako city and Kamisu city in Ibaraki prefecture. Liquefaction damage in Nishishiro, Inashiki city and Hinode, Itako city had been reported in the 1987 East Off Chiba Prefecture earthquake.

(1) Nishishiro, Inashiki city, Ibaraki prefecture

Large-scale and extensive damage occurred within the area of 500 m by 500 m that route 51 of national highway and the Yokotone River on the east of the road enclose. Route 11 of prefectural road was closed to vehicles, and sand boiling, large-scale road upheaval or severe fissure that was associated with liquefaction were seen mainly along the road. As a ground deformation, the ground subsided up to about 40 cm, and lateral displacement was up to about 1 m. An automobile was buried in boiled sand to the extent of a half of height of their tires.

Finishes of the sidewalks around a large-scale commercial establishment along Route 11 were scattered. The subsidence of the surrounding ground was about 40 cm, and the settlement of the facility itself was slight. The commercial building was tilted about 0.7/100 in the longitudinal direction. The pile foundation of the building was observed from an opening between surrounding fissures (Photo 6.5-1).



Photo 6.5-1 Situations around the commercial building and state of pile head

A boiled sand was seen everywhere on the roads or sites also in surrounding residential area. A house constructed on an embankment was tilted to an adjacent warehouse with sand boiling. An angle of tilting was 5.0/100 (Photo 6.5-2).

(2) Hinode, Itako city, Ibaraki prefecture

In Hinode, large-scale damage occurred in the area of about 200 m by 200 m along the Hitachi-tone River. Boiled sand, uplift of buried structures, and subsidence or tilting of utility poles, which were caused by liquefaction, were seen everywhere on the site. Many houses facing to the road subsided 20 to 30 cm from the front sidewalk (Photo 6.5-3). Foundation cracks or gaps were not observed.



Photo 6.5-2 House tilted 5.0/100

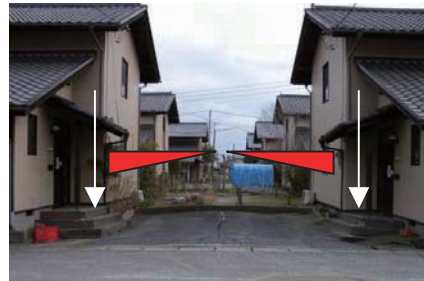


Photo 6.5-3 Subsidence of two houses enclosing vacant land

(3) Kamisu city, Ibaraki prefecture

This section describes the damage situations around Yokose Elementary School, and in Tsutsui, Horiwari and Fukashiba areas.

1) Around Yokose Elementary School

Yokose Elementary School is located about 3 km southeast from the Kamisu city office. The boiled sand by liquefaction was seen on the ground near the school. The ground subsidence was caused about 15 cm of difference in level on the rim of the building, and about 40 cm of difference in level at the outer slope (Photo 6.5-4). The building is supported by pile foundation. The outer slope and stairs were spread foundations, and the differential settlement was caused in this building.

2) Tsutsui area

The types of damage, such as sand boiling, uplift of buried structures, road gaps and subsidence or tilting of utility poles which were caused by liquefaction, occurred in the area of about 300 m by 300 m near Sotonasakaura in the area of Tsutsui that is located in the western part of Kamisu city. Due to damage to residential land, a severe fissure was generated, a house subsided approximately 15 cm from the surrounding

ground and caused about 30 cm of difference in level from the ground (Photo 6.5-5). Cracking or crack fissures on the foundations were not visually observed.

3) Horiwari area

The uplift and the gap caused by site ground subsidence were occurred in the area of about 500 m by 500 m along Route 124 of national highway in Horiwari area that is located in the western part of Kamisu city. Along a street in the center of the area, uplift of the sidewalk or subsidence of the housing site caused a 25 to 30 cm of difference in level, and a side ditch around the house was damaged (Photo 6.5-6). A case where the ground around a house subsided about 15 cm without settlement of the house was observed. It is considered that the lower part of the sidewalk was damaged by the uplift of culverts.

4) Fukashiba area

Fukashiba is located in the western part of Kamisu city and on the opposite side of Horiwai along Route 124. In this area, many houses were damaged due to ground deformation and embankment deformation. Most of the damage patterns of the houses seem to have included their movement, subsidence and tilting without structural damage on their upper structures and foundations (Photo 6.5-7).

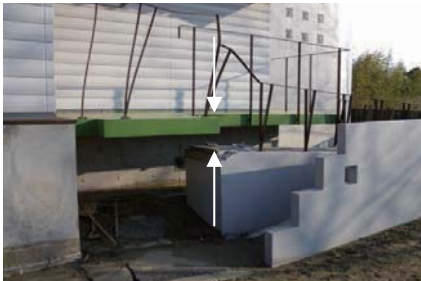


Photo 6.5-4 Slope difference in level



Photo 6.5-5 Crack in the site



Photo 6.5-6 Damage to side ditch



Photo 6.5-7 Damage situations by liquefaction

6.5.3 Damage due to Liquefaction in Urayasu city, Chiba prefecture

Area of reclaimed ground accounts for 3/4 of a total area in Urayasu city at present. The southern part of the city is the area that was developed under a reclamation project using sea sand. In the result, the area consists of soft layers up to GL-40 m. For reference, liquefaction damage was also reported in the 1987 East Off Chiba Prefecture earthquake. The damage situations are given below.

(1) Mihama area

In Mihama, subsidence and tilting were observed in houses that have a dry area in the basement (Photo 6.5-8). An angle of tilting of the house was about 3 degrees. It is considered that the basement was uplifted and another remaining parts of the house was subsided. Around the house, in-site of house was totally covered with boiled sand by liquefaction, and a foundation of fence at site boundary was deformed. In addition, carport in a house was ruptured and moved (Photo 6.5-9). The carport and the house was separated and moved about 50 cm due to the movement of the ground associated with liquefaction.

(2) Benten area

Significant tilting and subsidence of houses were observed at a zone in Benten (Photo 6.5-10). In another zone, the ground subsided by liquefaction, damage to the road that was waved and a 10 cm of difference in level was generated between a side ditch and the road. These types of damage were concentrated on an extension line of the boundary between the sites of tilted houses. Inhabitants told us that there was an old river on a straight line where the damage was concentrated.



Photo 6.5-8 Tilted house



Photo 6.5-9 Moved carport



Photo 6.5-10 Settled and tilted house

(3) Irifune area

In Irifune, a difference in settlement between adjacent buildings on spread and pile foundations was observed. The building on spread foundation settled about 35 cm from the front sidewalk, while the case of building on pile foundation was about 30 cm of difference in level from the front sidewalk (Photo 6.5-11).

(4) Hinode area

In Hinode, the ground subsidence was observed (Photo 6.5-12). This building is considered to have a pile foundation. A relative gap between the building and ground was about 50 cm. Building lifeline was damaged due to ground subsidence and displacement.



Photo 6.5-11 Difference in damage due to support mechanisms



Photo 6.5-12 Building with subsidence of surrounding ground

6.5.4 Damage to Developed Housing Area

The damage investigation for developed housing area was conducted in several areas of Miyagi, Fukushima and Tochigi prefectures, while only the damage in Miyagi and Fukushima prefectures is reported in this section.

(1) 5-chome, Oritate, Aoba-ku, Sendai city, Miyagi prefecture

In one corner of a large-scale housing area, where a slope in the N-NE direction had been developed, ground deformation due to sliding of the reclaimed area by banking to the slope direction, and damage to the retaining walls due to ground deformation were often observed (Photo 6.5-13). Houses on the site were recognized to have different damage patterns, such as movement, subsidence and tilting without structural damage, severe structural deformation and fractured foundation.

(2) 2-chome, Aoyama and 4-chome, Midorigaoka, Taihaku-ku, Sendai city, Miyagi prefecture

This area is located at one corner of the large-scale housing area where a hill was developed. Ground deformation due to sliding of the reclaimed area by banking to the slope direction, and damage to the retaining walls due to ground deformation, were often observed. The damaged area in 4-chome, Midorigaoka during the 2011 Tohoku earthquake was almost same as that during the 1978 Miyagi-oki earthquake. The land in 2-chome, Aoyama is wavier than in 4-chome, Midorigaoka. Near the zone of 2-chome, Aoyama, large-scale sliding of the embankment occurred (Photo 6.5-14). In this zone, large deformation and damage were seen on both of upper structures and foundations of houses in the housing area. In other places with embankment sliding, deformation and damage to upper structures of houses were observed, but it seemed that there was limited significant damage to foundations. In 2-chome, Aoyama, a retaining wall for the housing area with a height of over 5 m was damaged.



Photo 6.5-13 Damage to retaining wall and house due to sliding and ground deformation



Photo 6.5-14 Group of houses damaged due to sliding and ground deformation

(3) 1-chome, Futabagaoka, Aoba-ku, Sendai city, Miyagi prefecture

This area is located at one corner of a large-scale housing area where a slope in the eastern direction was developed. The area suffered ground deformation due to sliding of the reclaimed area by banking to the slope direction. Large structural deformation (Photo 6.5-15) was relatively often seen in houses in the area, but houses without structural damage were sporadically observed. In addition, a gap between the house foundation and surrounding ground that was caused by ground subsidence and transformation, and damage to the lifeline, were observed. Damage to a retaining wall in the area was hardly seen, while traces of flaking and falling of block fences on the upper part of the wall were sporadically observed.

(4) 1 to 2-chome, Midorigaoka, Shiroishi city, Miyagi prefecture

This is a housing area where a hill was developed. Fissures on the slope of the hill and near the top of the hill, and damage to housing foundations and retaining walls due to deformation of the reclaimed area by banking, were observed in the area. The slope in 1-chome, Midorigaoka had been significantly collapsed under the 1978 Miyagi-oki earthquake. A level of ground deformation on the slope under the 2011 Tohoku earthquake was lower than that during the 1978 earthquake. Near the top of the hill, ground deformation of the reclaimed area by banking caused fracture of the embankment retaining wall, damage to house foundations (Photo 6.5-16) and push-out of the retaining wall on embankment.



Photo 6.5-15 Damage to houses due to sliding and ground deformation



Photo 6.5-16 Houses damaged near the top of hill

(5) Shimomiyamae, Aohara, Yamamoto Town, Watari-gun, Miyagi prefecture

This is a housing area where a hill was developed. Land sliding of the slope at the end of the hill, and ground deformation that seemed to be related with the sliding were observed. This ground deformation caused serious damage to houses. In the result, some houses were in a state of sliding on the slope of the hill (Photo 6.5-17). On the other hand, there was no ground deformation in a house located in the flat part of the hill, while paper sliding doors on the first-story of the house were only broken during the earthquake.

(6) Numanoue, Fushigami, Fukushima city, Fukushima prefecture

This area is located at one corner of a large-scale housing area where a hill was developed. The result of investigation was revealed ground deformation due to land sliding on the slope of the hill. This ground deformation caused serious damage to houses. In the result, several houses were in a state of sliding on the slope of the hill (Photo 6.5-18). On the other hand, houses near the top of the hill suffered only damage associated with slight deformation of the reclaimed area by banking.



Photo 6.5-17 Fracture of embankment retaining wall and houses tilting due to land sliding on the slope of hill end



Photo 6.5-18 Land sliding of slope on the southwest of hill and sliding houses

6.5.5 Conclusions

The outline of the damage situations in the investigate scope is as follows.

(1) Damage due to liquefaction:

In the alluvial plain area of the Tone River and the coastal area of Tokyo Bay, extensive damage such as sand boiling or ground deformation associated with liquefaction was confirmed. Heavily tilted houses were seen, while cracks or fissures on the foundations were not observed.

(2) Damage to developed housing area:

Severe damage with ground deformation such as slope sliding was observed mainly in the elevated and developed housing area (particularly marginal part of development). In several areas, ground deformation occurred again in the developed area that had been affected by the past earthquakes.