

The 2011 Off the Pacific Coast of Tohoku Earthquake
- Quick Investigation Report on Earthquake Damage on Buildings -

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(Translation by Shunsuke Otani, University of Tokyo)

March 12, Saturday, Preliminary Investigation

1. Investigation Team Members

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2. Investigation Route

Faculty of Engineering, Tohoku University - Narita-machi, Wakabayashi-ku - Municipal Office,
Wakabayashi-ku - Minami-Koizumi Elementary School, Wakabayashi-ku (DCRC Observation Station) -
Yamato-machi, Wakabayashi-ku - Oroshi-machi District, Wakabayashi-ku - Takasago, Miyagino-ku
(condominium buidlings, Miyagi Yume Messe, Mitsui Outlet Mall, Naga-machi Koriyama Municipal
Apartment Buildings, Taihaku-ku (see Fig. 1).



Fig. 1: Investigation Route (March 12, Saturday)

3. Outline of Observed Damage

3.1 Division of Engineering and Human Environment Research Building

Four corner columns in the third story suffered heavy damage in the Human Environment Research Building (Nine-story non-full web Steel Encased Reinforced Concrete Building), in which 1,040 Gal. acceleration was measured in NS direction on the ninth floor during the 1978 Miyagi-ken Oki Earthquake; the intensity of floor motion was felt larger this time. The earthquake observation for structural health monitoring is carried out in the first, fifth and ninth floors by the Disaster Control Research Center, Tohoku University. The Building Research Institute, Tsukuba, measured the strong motion by SMAC-MD instruments, and they retrieved the records from the instruments on March 16. The records are now analyzed.

The damage of the east end walls is shown in Photos 1 and 2. The base of the third story columns in the east and west end walls suffered heavy damage due to high axial forces caused by the overturning moment. Non-full web steel element was exposed and buckled in a steel encased reinforced concrete column, and longitudinal reinforcement was either fractured or buckled (Photo 3). After the failure at column bases, the rocking vibration of the building must have occurred. Exposed longitudinal reinforcement at the base of damaged columns revealed new fracture by this earthquake and old fracture of rusted reinforcement by the previous earthquake.



Photo 1: Damage of end walls from roof of the adjacent building

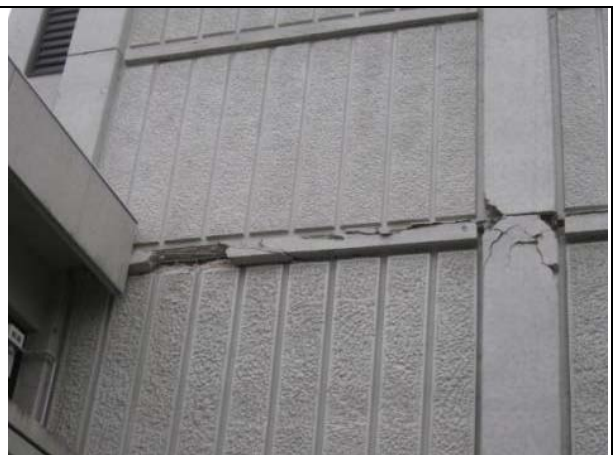


Photo 2: Damage of end walls from the ground



Photo 3: Damage of north-east corner column



Photo 4: Damage of south-east corner column

The penthouse of the Department of Electrical Engineering Building No.1 was damaged and elevators could not be operated.

3.2 Yamato-machi area of Wakabayashi-ku

The information of building damage was obtained at the disaster headquarter of Wakabayashi Municipal Office. The penthouse of a six-story reinforced concrete building tilted in Narita-machi (Photo 5); the building did not show any other damage.



Photo 5: A tilted penthouse of a six-story reinforced concrete condominium building

Three-story reinforced concrete building collapsed in the second story in Yamato-machi 5-chome (Photos

6 and 7), probably caused by torsional oscillation.



Photo 6: Collapse in the second story of a three-story reinforced concrete building in Yamato-machi 5-chome.



Photo 7: Collapse in the second story

X-shaped shear cracks were observed in non-structural walls facing the hall way from second to nine stories in a fourteen-story reinforced concrete condominium building sold in 1981, Yamato-machi 5-chome (Photo 8); no such damage was observed in the first story (pilotti: soft first-story) and 13 and 14th stories. Doors are not located in the non-structural walls and could be opened.



Photo 8 (a) A 14-story reinforced concrete building



Photo 8 (b): Damage of non-structural walls in the hall way

Along the Shinterakouji in Yamato-machi 5-chome, exterior wall finishing fell from a two-story steel construction (Photo 9) and roofing materials fell from a two-story steel building (Photo 10); poor detailing of connection between the finishing and structural members (Photo 11).



Photo 9: Exterior finishing fell from a two-story steel building



Photo 10: Fall of roofing materials from a two-story steel building



Photo 11: Detail of fastener (anchor) of fallen ALC exterior wall

3.3 Oroshi-machi, Wakabayashi-ku

The Oroshi-machi area, Wakabayashi-ku, was severely damaged by the 1978 Miyagi-ken Oki Earthquake. According to the Sendai Oroshisho Center (Association of 280 retailer companies), two buildings collapsed in this area.

The first-story of a two-story reinforced concrete building collapsed in Oroshim-machi 2-chome (Photo

12); the first story is box wall construction, and the second-story is moment-resisting frame construction. The first story failed in the weak (out of plane) direction of the walls, and second-story columns failed in shear.



Photo 12: Collapse of a two-story reinforced concrete building in Oroshi-machi 2-chome, Wakabayashi-ku

A part of the first story of a three-story reinforced concrete building collapsed in Oroshi-machi 3-chome (Photo 13); the diameter of plain longitudinal reinforcement was 19 mm, and tie reinforcement of diameter 9 mm at 250 mm on centers. The core of the building suffered slight damage, but the building was twisted by eccentricity and exterior columns failed in shear.



Photo 13: Collapse of a three-story reinforced concrete building in Oroshi-machi 3-chome, Wakabayashi-ku

Many exterior curtain walls were observed to fall in Oroshi-machi (Photo 14). Concrete block fences were overturned in many locations (Photo 15).



Photo 14: Fall of exterior curtain walls in steel construction



Photo 15: Overturned concrete block fences in Oroshi-machi, Wakabayashi-ku

3.4 High-rise Condominium Buildings in Takasago, Miyagino-ku

This high-rise condominium buildings suffered damage in pile foundation during the 1978 Miyagi-ken Oki Earthquake. There are two buildings. A building located normal to Route 45, suffered slight structural damage although non-structural partitions failed in shear; no tilting was observed in this building. A building facing to Route 45 showed tilting in the short direction (confirmed on March 12) although the

damage in the upper stories appeared light; non-structural exterior walls showed shear cracking in the longitudinal direction; the tilting rotation was observed in the short direction and the residual lateral displacement at the 14-th floor was estimated to be 400 mm by visual observation. The first floor indicating inclination; the pile might be damaged. The investigation team told the occupants that further detailed investigation might be necessary. The occupants by their own method monitored the separation of the expansion joints, and the tilting is reported to increase (March 15). The damage in piles is suspected.



Photo 16: Condominium buildings in Takasago, Miyagino-ku



Photo 17: Shear failure of non-structural exterior walls



Photo 18: Expansion joint between two buildings (left on March 12, and right on March 16)



Photo 19: Damage at the base of a first-story column

3.5 Neighborhood of Mitsui Outlet Mall and Miyagi Yume Messe

Tsunami water reached 1.0 m high in a large shopping mall, Mitsui Outlet. Some cars were floated and moved in the parking area by the tsunami wave. However, water did not go into shops. No vibration damage is observed in the buildings (Photos 20 and 21).



Photo 20: The parking area of the Mitsui Outlet shopping mall

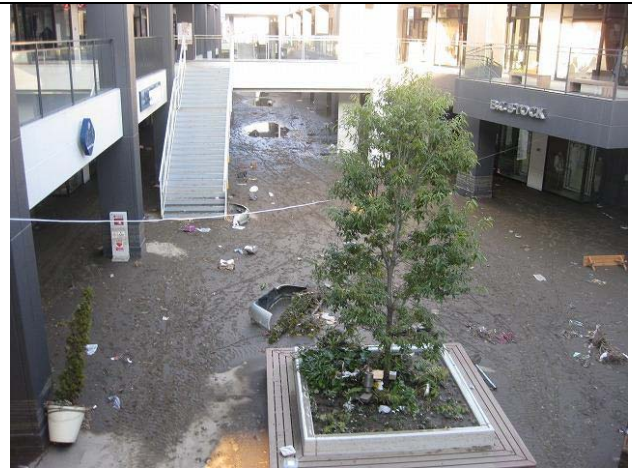


Photo 21: Damage of the Mitsui Outlet Mall building by the tsunami (Second floor deck)

Some cars were floated and moved into the exhibition hall of Miyagi Yume Messe, and broke exterior glasses (Photos 22 and 23). No damage of the building was observed caused by the vibration of the earthquake.



Photo 22: Damage of Miyagi Yume Messe by tsunami



Photo 23: Cars were carried into the exhibition building by tsunami wave

It was not possible to visit residential areas of Gamoh area due to heavy damage by tsunami (Photo 24).



Photo 24: Damage of Gamoh residential area due to tsunamis

3.6 Nagamachi Kohriyama Municipal Apartment Building, Taihaku-ku

A 11-story reinforced concrete condominium building, which tilted attributable to the damage in piles after the 1978 Miyagi-ken Oki Earthquake, suffered no damage. The 11-story reinforced concrete building normal to the longitudinal building showed the trace of rocking motion, and cracking was observed in the ground along the base, no residual displacement was observed at the expansion joint; no inclination of the building was detected (Photo 25). The damage in piles appeared slight if any.



Photo 25: Kohriyama Municipal Apartment Building
in Nagamachi, Taihaku-ku

Preliminary Investigation on March 13, 2011

1. Investigation Team Members

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2. Route

The team started the Tohoku University Campus and visited the places below;

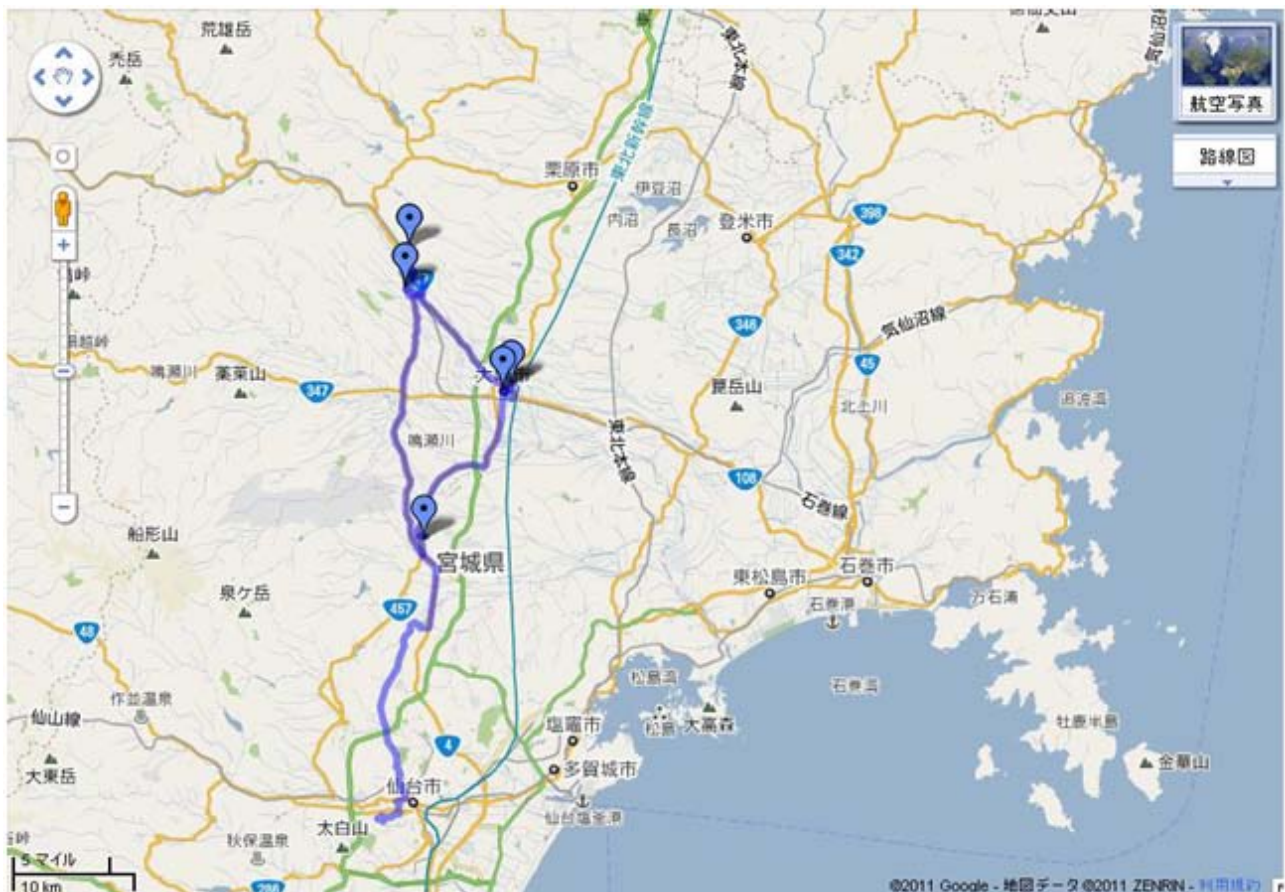


Fig. 1 Route and points of Preliminary Investigation

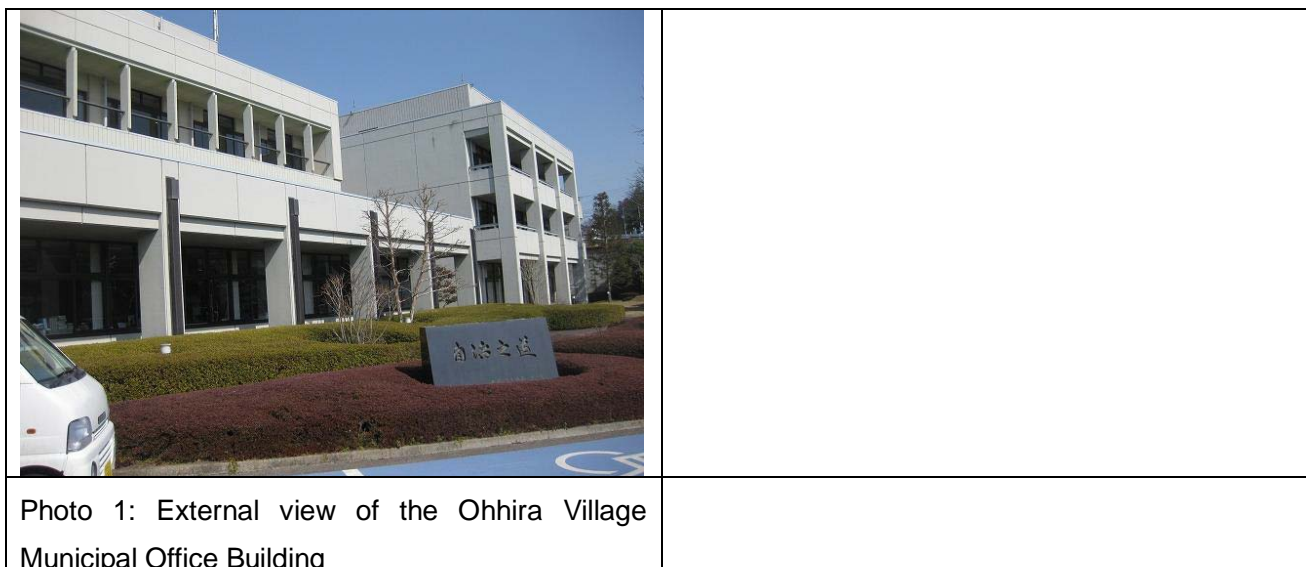
3. Observed Damage

3.1 Tohoku University, Prefectural Route 264, National Route 4 and to Ohhira Village Municipal Office

Fall of external walls were observed along the route, but no serious structural damage was observed.

3.2 Ohhira Village Municipal Office at 1:00 pm

Seismic intensity (Japan Meteorological Agency Scale, JMA scale) of higher 6 was measured by the municipal intensity instrument. The municipal office is in a two-story reinforced concrete building (Photo 1); no major cracks were observed. No serious damage has been reported in the village.



3.3 Ohhira Village Municipal Building, National Route 4, Kounosu Intersection

Damage of roof tiles, fall of external walls were observed but no serious structural damage.

3.4 Kounosu Intersection to Osaki City Municipal Office Building

First-story collapse of residential buildings were seen here and there; the damage is serious. Even in those buildings without collapse, serious damage was observed such as fall of external walls.



3.4 Ohasaki City Municipal Building and surrounding area

There are old houses used for combination of shop and residence, and godowns (storehouse made of mud walls) in Furukawa Mikka-machi and Nanoka-machi near the Ohsaki City Municipal Building. Many of these houses collapsed. The Furukawa No.1 Elementary School of two-story timber construction was prohibited to enter due to possible collapse during aftershocks. A seismic intensity instrument at Mikka-machi recoded the ground shaking of intensity higher 6 (JMA intensity scale).



Photo 4: Ohsaki City Municipal Building



Photo 5: Ohsaki City Municipal Furukawa No.1 Elementary School (two-story timber construction)



Photo 6: Ohsaki City Municipal Furukawa No.1 Elementary School



Fig. 7: Collapse of a Godown, adjacent to Ohsaki City Municipal Building



Photo 8: A tilted two-story house for combined use for shop and residence



Photo 9: Collapse of a two-story house for combined use for shop and residence

There is a 11-story reinforced concrete hotel in front of Furukawa Station. No structural damage in the super structure is observed, but the tilting of the building is observed probably due to ground movement (Photos 10 and 11).



Photo 10: Tilting of a 11-story reinforced concrete hotel building



Photo 11: Boundary of foundation and ground at the base of the 11-story reinforced concrete hotel building

3.5 Furukawa Fire Station (K-NET strong motion observation station) and Maeda-machi area of Ohsaki City

Damage of roof tiles was observed in a few houses, but not serious damage,

3.6 Furukawa Fire Station, National Route 108, National Route 47, Iwade-yama area and Iwadeyama High School

Damage of roof tiles was observed in a very limited number of houses, but not serious damage, In the Iwadeyama High School, ground fissure was observed along the scarcement of f the building (Photo 12), but no serious structural damage was detected.



Photo 12: Ground cracking along the periphery of the building	
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3.6 Yuhbi-kan Historical Building

The Yuhbi-kan, a traditional farm house with thatch roof, collapsed completely in Iwade-district of Ohsaki City.



Photo 13: Collapse of the Yuhbi-kan in the back of the picture	
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3.7 Ohsaki city Municipal Kaminome Elementary School


The Kaminome Elementary School building suffered serious damage in the 2008 Iwate- Miyagi Inland Earthquake. The damage was repaired and steel braces were used for retrofit. No damage was observed in this earthquake.



Photo 14: Overview of Uenome Elementary School (No damage)	
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3.8 Kaminome Elementary School, National Route 47, National Route 457, and Nakaniida area

No structural damage was observed from Kaminome Elementary School to National Route 457. In the urban area of Kami-machi Nakaniida District, many external non-structural walls fell from a three-story steel commercial building.

	
Photo 15: Fall of external non-structural walls from a three-story steel commercial building	

3.9 Nakaniida area, National Route 457, National Route 4, to Tohoku University

No special damage is observed to report.