Damage Report on 1994 Sanriku-harukaoki Earthquake

by

Kenji Kabayama [1], Atsushi Mikami [2], Yoshiaki Nakano [3] and Choshiro Tamura [4]

1. Introduction

Northern half part of Japan was shaken by a strong earthquake motion on the evening of December 28, 1994. This earthquake named 1994 Sanriku-harukaoki Earthquake caused significant damage on the northeastern part of the Tohoku district and the southern part of the Hokkaido district. Especially in Hachinohe City where intensity VI on the JMA scale was recorded, severe damage was caused, and two persons were killed by collapse of an R/C building. This area also had been damaged heavily during 1968 Tokachi-oki Earthquake.

A building reconnaissance team consisting of 10 researchers from universities carried out a field survey in Hachinohe City and Misawa City from January 3 to 6, 1995. The team mainly investigated damage to public R/C buildings such as schools and city offices.

A civil engineering reconnaissance team stayed in a suburb of Hachinohe city (Tanesashi-kaigan) from December 28, 1994 to January 1, 1995 and investigated damage to civil engineering facilities.

2. Characteristics of Earthquake

Characteristics of 1994 Sanriku-harukaoki Earthquake are written below. An intensity distribution on the JMA scale is shown in Fig. 1 with epicenters of this earthquake and 1968 Tokachi-oki Earthquake. The maximum ground acceleration recorded at JMA Hachinohe Station was 602 cm/sec^2. Fortunately, this earthquake caused slight tsunami in spite of an ocean type earthquake.

Origin time	: 21h 19m, December 28, 1994
Epicenter	: 143.7° E, 40.4° N (about 200 km offshore from Hachinohe City)
Depth	: 0 km
Magnitude	: 7.5
Peak aftershock	: M6.9, 07h 39m, January 7, 1995

3. Damage to buildings

The building reconnaissance team investigated 75 buildings in Hachinohe City and Misawa City.

1) Graduate Student ; University of Tokyo
2) Research Associate ; Institute of Industrial Science, University of Tokyo
3) Associate Professor ; Institute of Industrial Science, University of Tokyo
4) Professor ; University Research Center, Nihon University

Most of them were public R/C buildings. Numbers of investigated buildings and corresponding damage degree are written below .

Collapse	:	3
Severe damage	:	2
Medium damage	:	5
Slight damage	:	50
No damage	:	15

Hachinohe-higashi High School and two pinball houses in Hachinohe City collapsed as shown in Photos 1 through 6. Photos 1 and 2 show damage to Hachinohe-higashi High School which is a three story R/C building constructed in 1963. Two collapsed pinball houses, referred to as "Pinball House A" and "Pinball House B" hereafter, are three story R/C buildings with a basement. Two persons were killed due to collapse of columns in the first story of "Pinball House A" constructed in 1966 (Photos 3 and 4). Photos 5 and 6 show a front view and interior damage to "Pinball House B" constructed in 1959. Photos 7 through 12 show other structural damage to R/C buildings. Most of these damaged buildings were constructed before the revision of Building Standard Law Enforcement Order in 1971, and few damage was observed in buildings constructed after 1982 in accordance with the current seismic code. Fig. 2 shows the relationship between the year of construction and the damage degree of R/C buildings investigated in Hachinohe City. This is strongly showing that retrofitting of older and vulnerable buildings is the most urgent issue.

It should be noted that damage was again observed in buildings that had been retrofitted following 1968 Tokachi-oki Earthquake as shown in Photos 13 through 16. Photos 13 and 14 show a general view and damage to a column and wall panel at the entrance of Hachinohe City Main Office. The damage was attributed to a poor detailing between an existing column and a new wall element. Photos 15 and 16 show damage to columns in upper story of Hachinohe Technical College. This damage resulted from irregular distribution of strength since the first story that had severe damage during 1968 Tokachi-oki Earthquake had been retrofitted after the event. These results revealed that retrofit detailing and the distribution of strength were key factors in retrofitting buildings.

4. Damage to Civil Engineering Facilities

The civil engineering reconnaissance team investigated railways, roads, bridges, ports and other facilities. Damage to civil engineering facilities amounted to over seven billion yen. Since the damage was so extensive, only a portion of the suffered area could be investigated in a limited time.

Sliding of the embankment for railways occurred on the JR Tohoku-line between Hachinohe and Mutsu-Ichikawa stations. A fill section of about 50 m in length collapsed and a circular failure surface emerged. The rail then became suspended in midair as shown in Photo 17. The height of the fill embankment was about 10 m and the slope about 2 horizontal to 1 vertical. The total volume of the collapsed soil was about 2,600 cubic meters. The line resumed service on January 1, just four days after the collapse, following rushed repairs. Photo 18 shows the reconstruction of the damaged fill on December 31 .

Road damage occurred in the Matsugaoka area in Hachinohe city. A double-lane road at the slope of reclaimed fill broke down due to sliding down of the slope as shown in Photo 19. Some dwelling houses on the top of the hill also sustained severe damage (Photo 20).

Large displacements occurred on the Ohashi bridge and the Hachinohe-Ohashi bridge.

The Ohashi bridge is about 230 m long with 10 piers crossing the Mabuchi river. This bridge is composed of two structurally different bridges; a main bridge and a pedestrian bridge as shown in Photo 21. The main bridge is supported by concrete piers and the pedestrian bridge by steel piers. The bridges were connected with concrete and steel bars at the edges of their piers. Those connections were damaged as shown in Photo 22 due to the difference of response motions between these component bridges. Pier 3 of the main bridge sank and tilted into the Mabuchi river on the upstream side (Photo 23).

The Hachinohe-Ohashi is a bridge of over 1300 m in length (Photo 24). Damage to the steel deck plate of the bridge was found at the joint of the decks above pier 12 (Photo 25). It is suspected that the decks temporarily moved to separate, then the decks came to collision when these deck plates returned to their original positions. Pier 12 supports two different types of girders; an I-type girder and a box-type girder of longer span as shown in Photo 26. It is suspected that the damage occurred due to the different motions of the different types of structures. A handrail of the bridge was expanded about 17 cm in length as shown in Photo 27. A guardrail of the bridge was suspected to be fractured by the large transverse displacements of the bridge(Photo 28).

The Ports of Hachinohe experienced widespread liquefaction (Photo 29). Gravity-type quaywalls displaced laterally by several tens of centimeters toward the sea due to the liquefaction of the fill material behind the walls or by their inertia force (Photo 30).

Acknowledgment

The authors would like to express grateful thanks for the kindness of those who helped in the field surveys and for the courtesy of those who offered precious photographs for this paper.

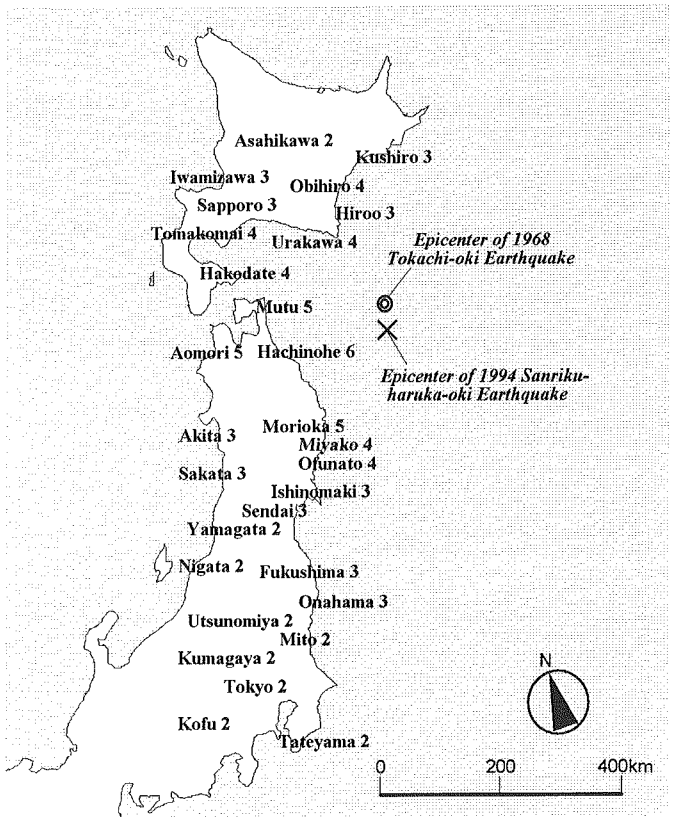

Fig. 1 Intensity distribution on the JMA scale

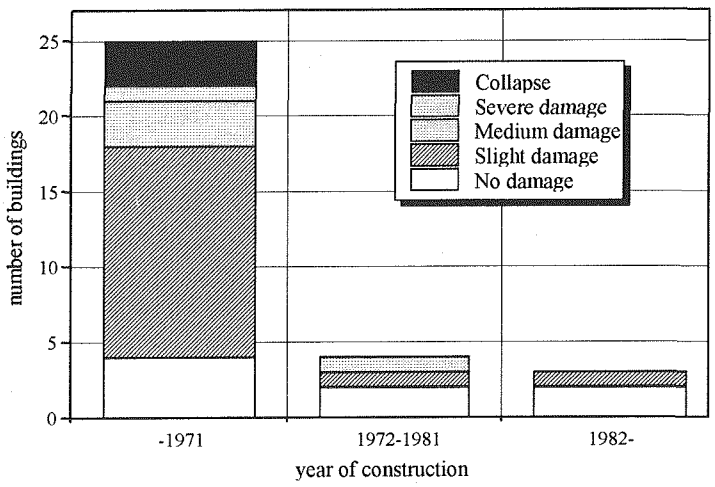

Fig. 2 Relationship between year of construction and damage degree of R/C buildings investigated in Hachinohe City

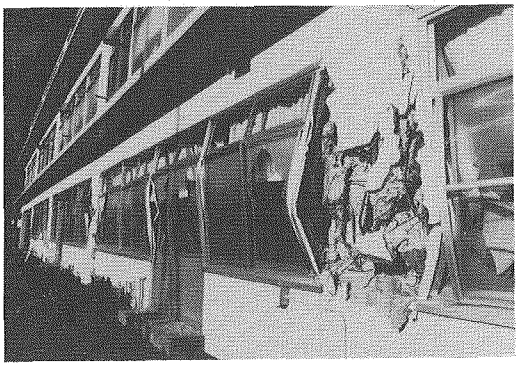

Photo. 1 Collapsed Hachinohe-higashi High School. *(Photo by Daily Tohoku)*

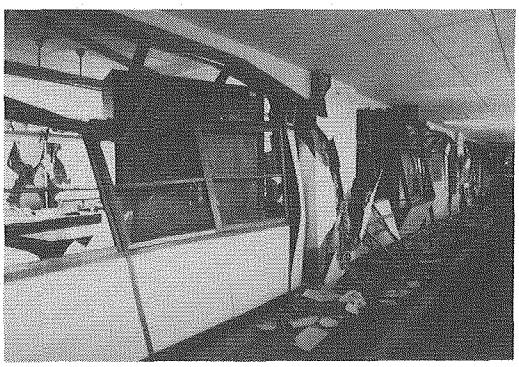

Photo. 2 Interior view of collapsed Hachinohe-higashi High School. *(Photo by Daily Tohoku)*

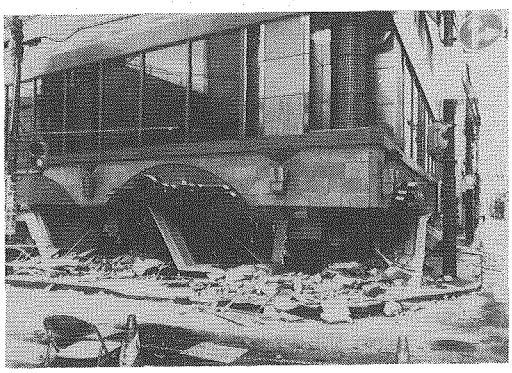

Photo. 3 Collapsed first story of "Pinball House A" in Hachinohe City. *(Photo by Daily Tohoku)*

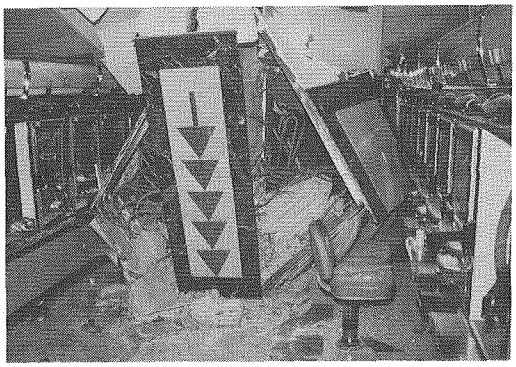

Photo. 4 Collapsed column in the first story of "Pinball House A".

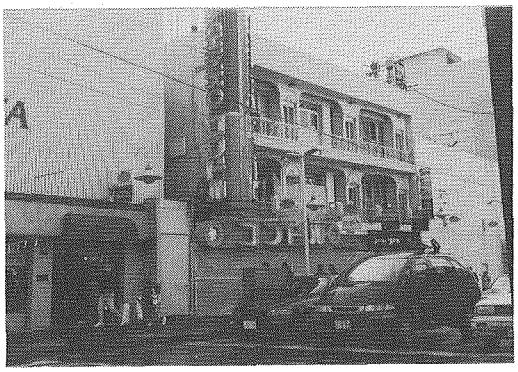

Photo. 5 Front view of "Pinball House B" in Hachinohe City.

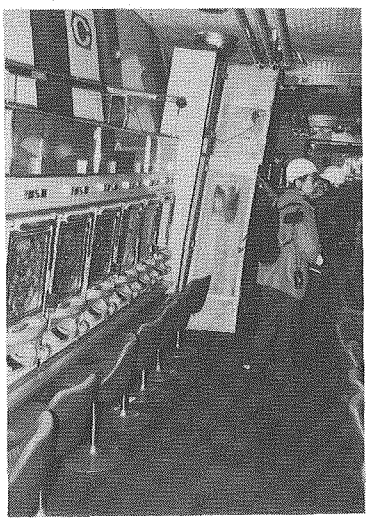

Photo. 6 Interior damage to "Pinball House B".

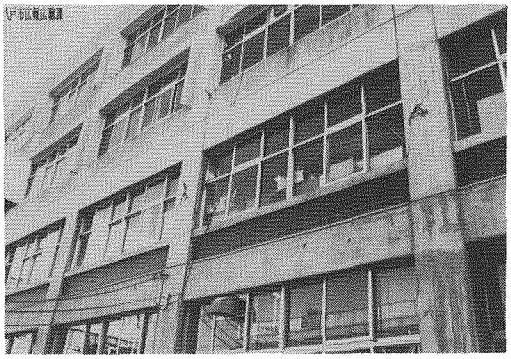

Photo. 7 Shear failure of columns in the second story of Hachinohe City Office Annex.
(Photo by Hachinohe City)

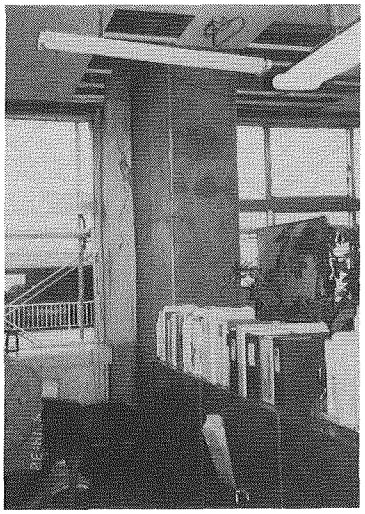

Photo. 8 Added R/C column to support the failed column shown in Photo. 7.

Photo. 9 Damaged show window and collapsed column of Hachinohe Commercial and Industrial Association Office. *(Photo by Daily Tohoku)*

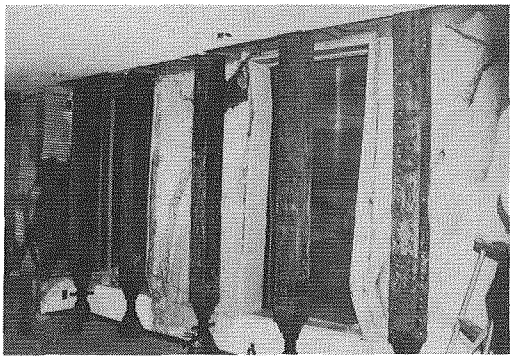

Photo. 10 Temporary retrofit with steel columns to support the second floor in Hachinohe Commercial and Industrial Association Office.
(Photo by Kazuhiro Kitayama, Tokyo Metropolitan University)

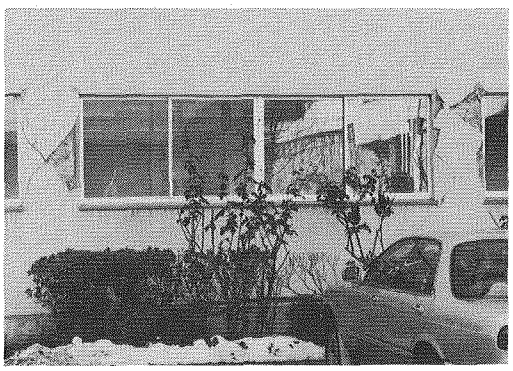

Photo. 11 Severe shear cracks in columns of Chiba-gakuen High School.

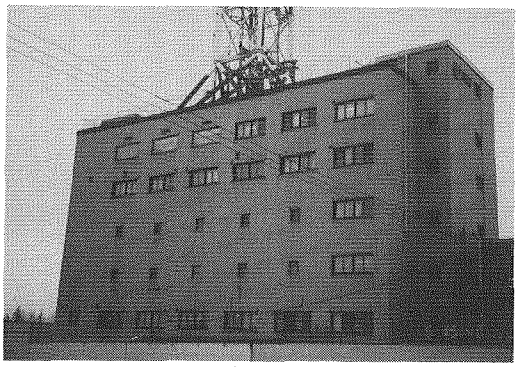

Photo. 12 Shear cracks in columns and walls. Building No. 3 of the NTT Hachinohe Office

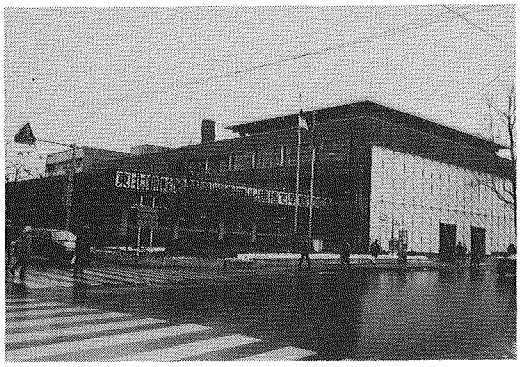

Photo. 13 General view of Hachinohe City Main Office.

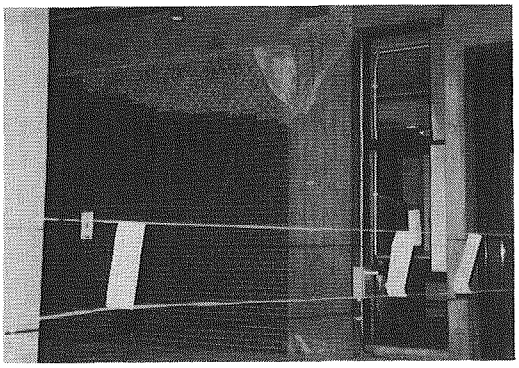

Photo. 14 Damage to a column and wall panel at the entrance. The wall had been installed after 1968 Tokachi-oki Earthquake.

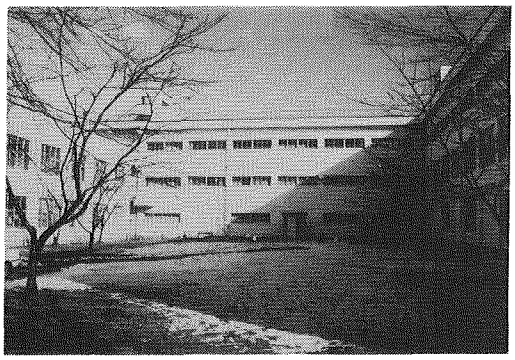

Photo. 15 Damage to Hachinohe Technical College.
(Photo by Sangho Lee, Tokyo Metropolitan University)

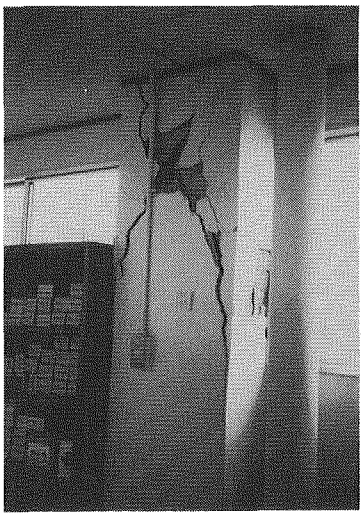

Photo. 16 Shear failure of column at the second story. Shear walls had been installed only in the first story after 1968 Tokachi-oki Earthquake.
(Photo by Masaki Maeda, Yokohama National University)

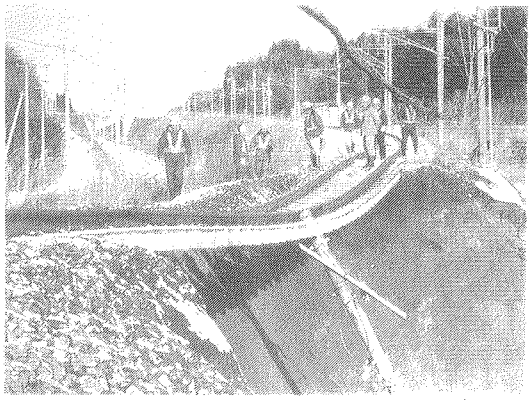

Photo.17 Damage to railways in the Kawaragi area
(Photo by Tooh-Nippo)

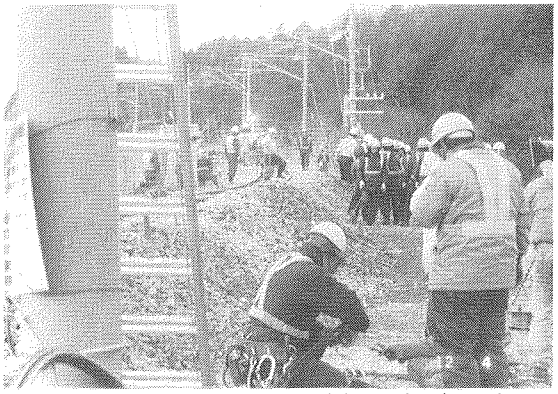

Photo.18 Reconstruction of the embankment

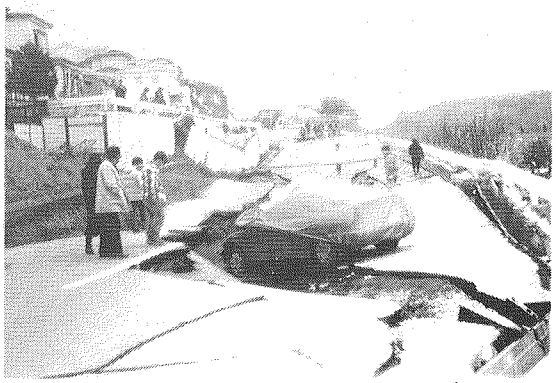

Photo.19 Damage to road in the Matsugaoka area

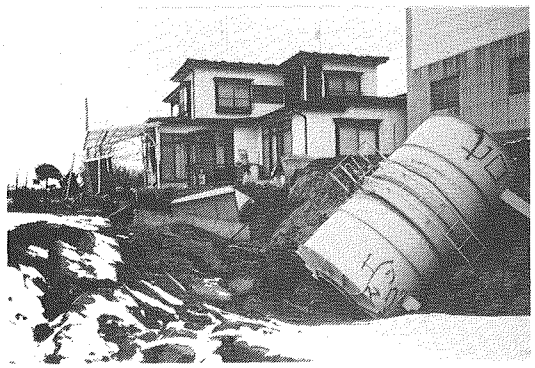

Photo.20 Damage to the reclaimed fill

Photo.21 A complete view of the Ohashi bridge

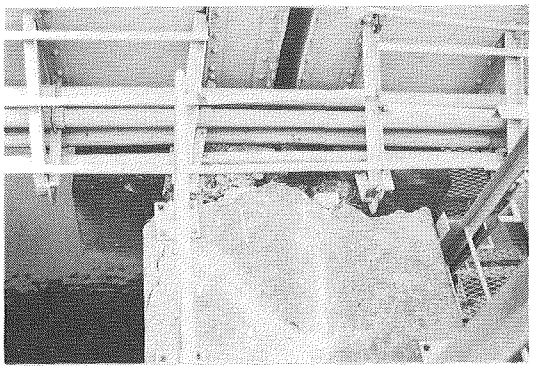

Photo.22 Breakage of the connections between two structurally different bridges

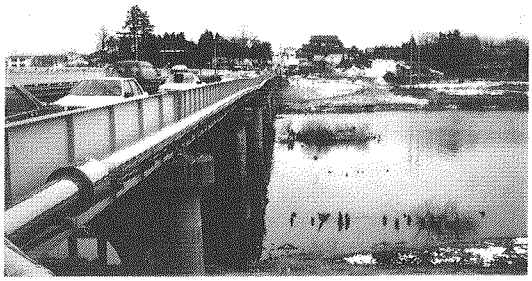

Photo.23 Sunk and tilted pier 3 of the Ohashi bridge

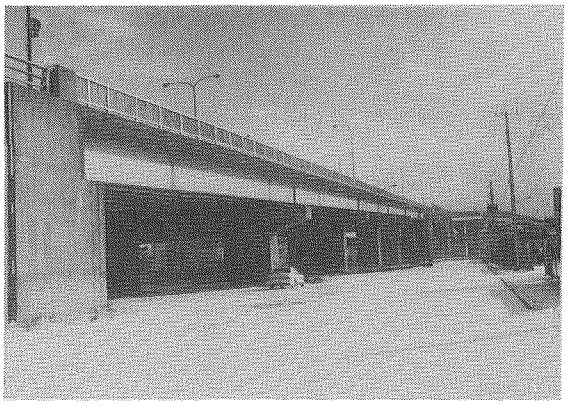

Photo.24 A view of the Hachinohe-Ohashi bridge

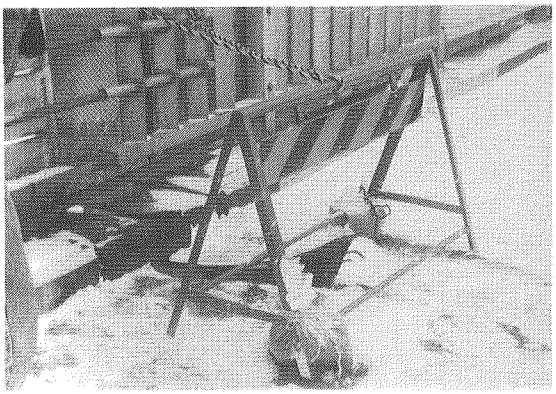

Photo.25 Damage to the steel deck plate of the Hachinohe-Ohashi bridge

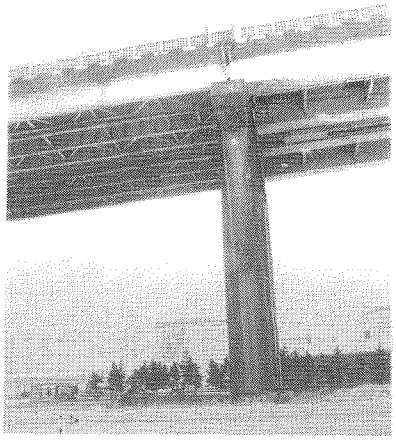

Photo.26 Two different types of girders supported by the pier 12

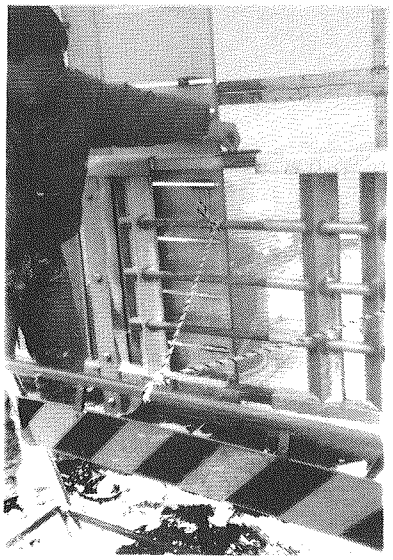

Photo.27 The expanded handrail of the Hachinohe-Ohashi bridge

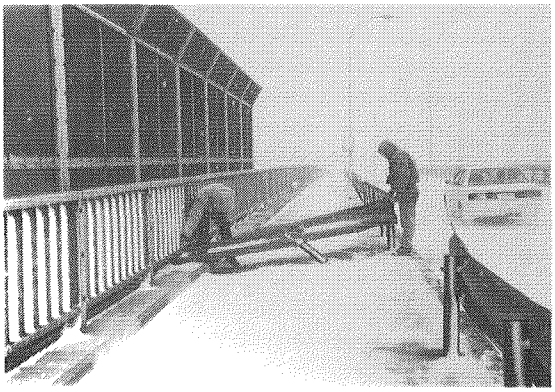

Photo.28 Damage to the guardrail on the Hachinohe-Ohashi bridge

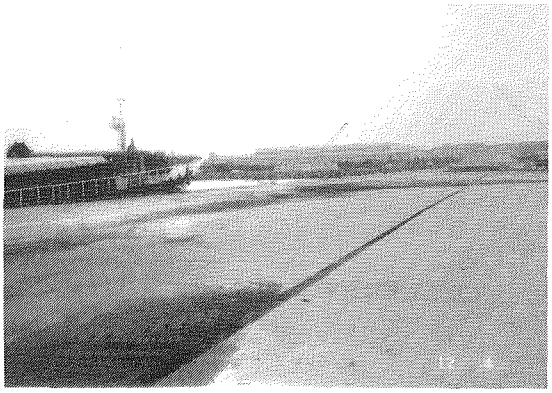

Photo.29 Traces of liquefaction at the Hachinohe port

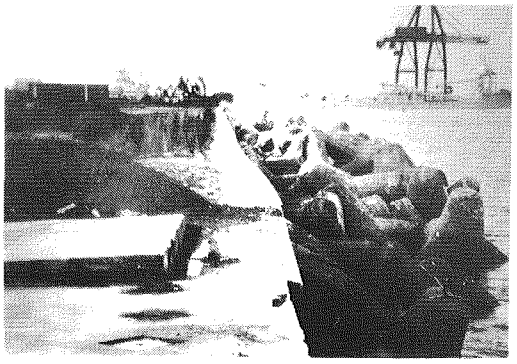

Photo.30 Movement of gravity-type quaywalls at the Hachinohe port