14 Mar 1991, 10:30 am - 12:30 pm

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Proceedings: Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, March 11-15, 1991, St. Louis, Missouri, Paper No. 3.51

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SYNOPSIS: Permanent ground displacement resulting from the 1964 Niigata Earthquake were studied based on pre- and post-earthquake aerial surveys. In the area along the Shinano River and the Tsusen River, extensive large ground displacements up to about 10 m occurred towards the river, though the ground was almost flat. To ascertain the mechanism of such large ground displacement, several detailed soil investigations were conducted. And it was clarified that the gradient of the ground surface, the gradient of the bottom of the liquefied layer and the thickness of the liquefied layer were main factors affecting to the such large ground displacement.

INTRODUCTION

The authors have conducted measurements of the permanent ground displacements due to liquefaction during the 1983 Nihonkai-Chubu Earthquake in Noshiro City and the 1964 Niigata Earthquake in Niigata City (Hamada et al. 1986). The measurement was conducted on points which are fixed on the ground surface and which can be found in both the pre- and post-earthquake photographs. Manholes, cadastral boundary stones, bases of light poles, corners of drainage channels, etc., were selected. The results showed that large permanent ground displacement up to several meters had occurred in both cities. Especially, extremely large displacement up to 10 m had occurred along the Shinano River in Niigata City. After the study above mentioned, permanent ground displacements at other areas in Niigata City were measured. Moreover, detailed studies on the Ohgata area were conducted. The results of these studies are presented in this paper.

STUDIED AREAS IN NIIGATA CITY

Fig. 1 shows the areas where measurement of the permanent ground displacements, soil investigation and interviewing local residents were conducted. Among these areas, the results in Kawagishi-cho area and Niigata Station area will be shown briefly in the following paragraph because they have already been reported by Hamada et al. (1986). The results in Ohgata area will be shown precisely because detailed studies were conducted in this area.

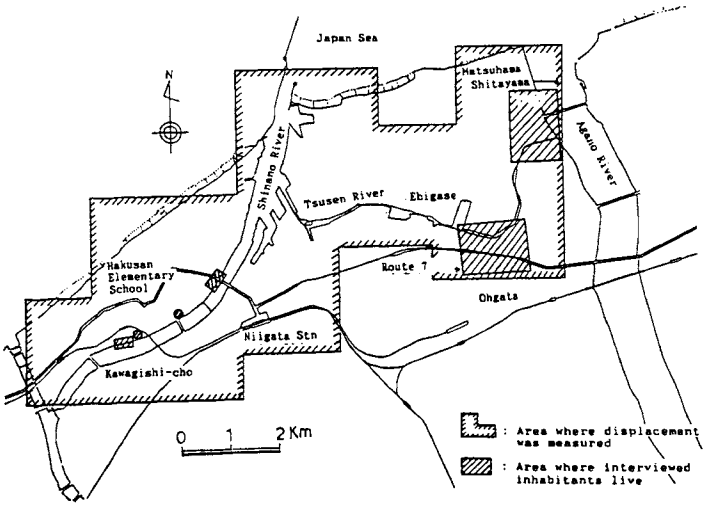

Fig.1 Studied areas of permanent ground displacement in Niigata City

PERMANENT GROUND DISPLACEMENTS IN KAWAGISHI-CHO AND NIIGATA STATION AREAS

Fig. 2 shows the horizontal vectors of the permanent ground displacements in Kawagishi-cho and Niigata Station areas, with the ground failures, such as sand boiling, cracks, subsidences, etc., which were reported by Niigata University. The permanent displacements were much larger on the left bank of the Shinano River from the Showa Bridge to the Hakusan power substation in Kawagishi-cho, and on both banks from the Bandai Bridge to the Yachiyo Bridge. The maximum horizontal displacement was 8.5 m in the proximity of the Hakusan power substation and 8.8 m on the left bank near the Bandai Bridge. The directions of the horizontal vectors of the displacements were almost perpendicular to the river.

The magnitude of the permanent ground displacement in the area near the Niigata Railway Station was 2 to 3 m, smaller than that along the Shinano River, but it is notable that the directions of the displacement was not toward the river but toward the station.

Large permanent ground displacements toward the Shinano river occurred on both banks. From the soil profile in this area, the depth of the liquefied layer increased suddenly toward the river center and the lower boundary face of the liquefied layer was sloped. It can be assumed that the magnitude of the permanent ground displacements depends on the thickness and the inclination of the liquefied layer, and also on the topographical condition of the existing revetment. About 300 m from the river toward Niigata Railway Station, permanent ground displacements of 1 to 2 m occurred in the direction away from the river. The ground surface in this area was almost flat, but the lower boundary face of the liquefied layer was estimated to be sloped with a small gradient of 2-3 % toward Niigata Station. For this reason, the permanent ground displacements in this area might be in the direction away from the river.

MEASURED DISPLACEMENTS IN OHGATA AREA

Fig. 3 shows permanent ground displacements in Ohgata

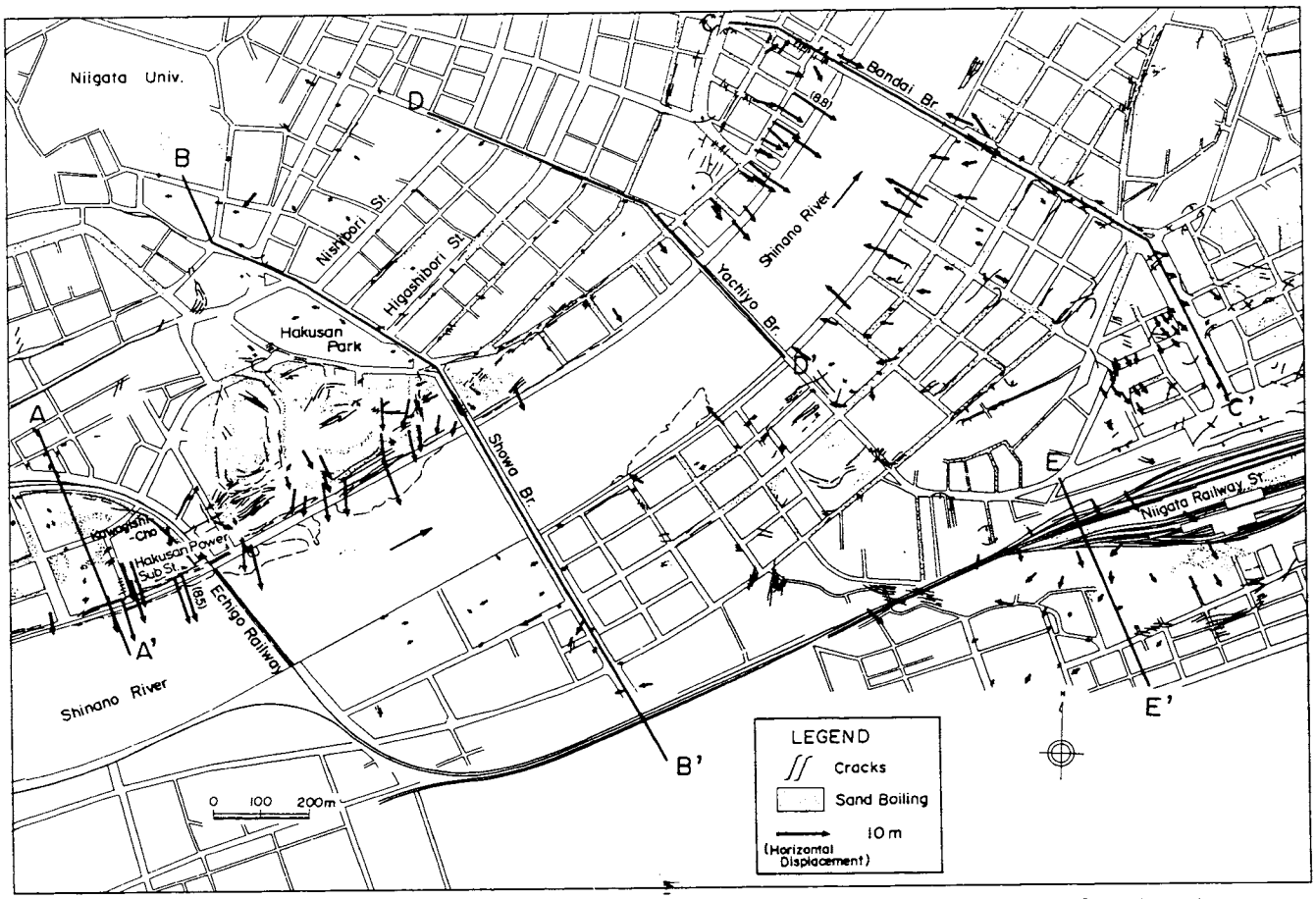

Fig.2 Permanent horizontal ground displacements in Kawagishi-cho and Niigata Station Areas

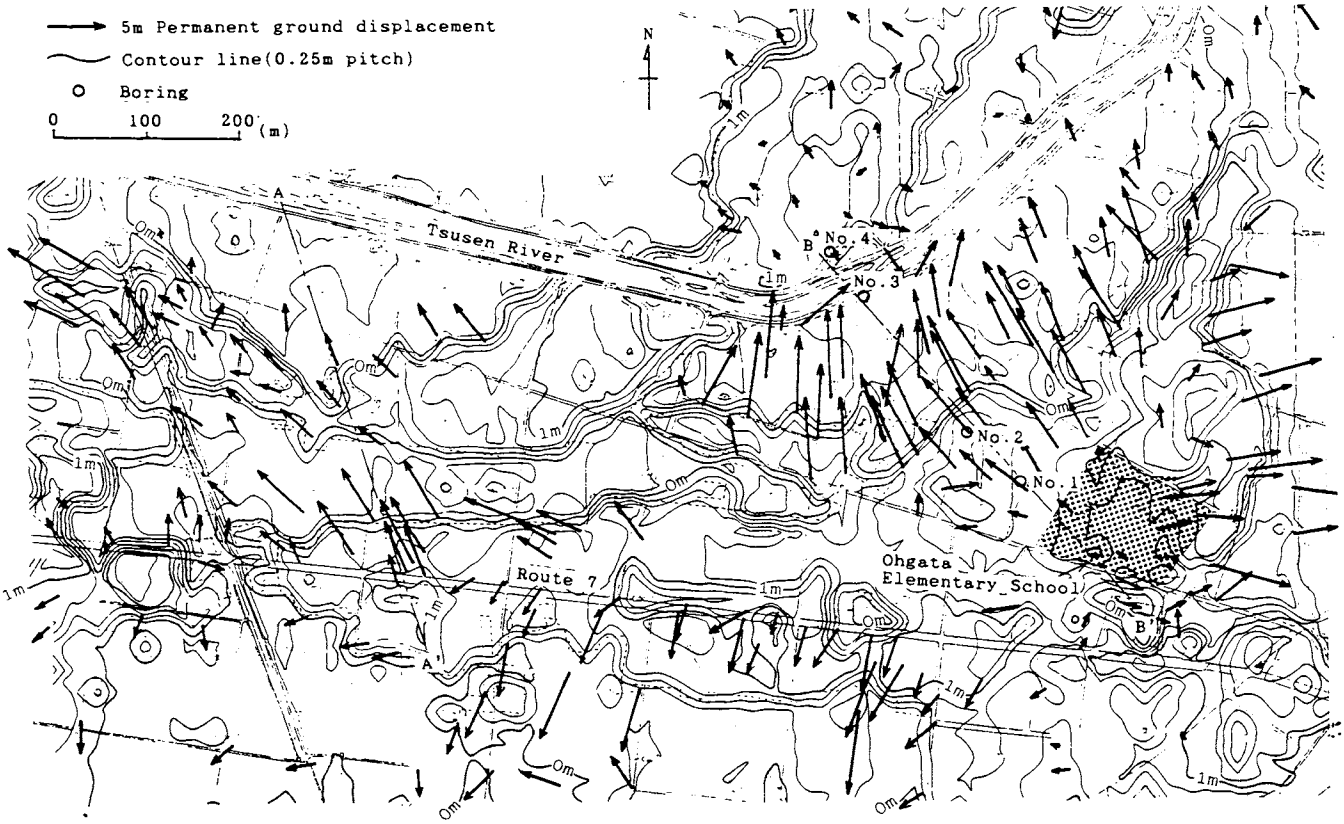

Fig.3 Permanent horizontal displacements and contour lines in Ohgata Area

area. From the schoolyard of Ohgata Elementary School, large permanent ground displacements had occurred in radial direction, with the maximum displacement reaching approximately 10 m. Permanent ground displacements originated from Ohgata Elementary School's yard stretched out for approximately 500 m toward the northwest direction. And the displacements became drastically small when they reached a small creek of about 10 m wide along the Tsusen River.

Many cracks were induced at Ohgata Elementary School, as shown in Fig.4. Schoolhouses were damaged by the cracks. At schoolhouses "b" and "e", floors were torn due to the cracks and passageways waved to and fro. A passage connecting schoolhouses "c" and "d" was torn up to 2 m. One witness said schoolhouse "d" had moved northeast with its foundation ground.

Ground levels at many points before the earthquake were measured using the pre-earthquake aerophotographs, and are also indicated as contour lines with 25 cm pitch, as shown in Fig. 3. The ground surface was almost flat, but a very small highland, of 1.5 m in height, was developed at the south side of the Tsusen River. It can be seen that large permanent ground displacements were concentrated at almost the wedge of the highland. In geomorphological aspect, the highland coincides with a natural levee of the Tsusen River, as shown in Fig. 5.

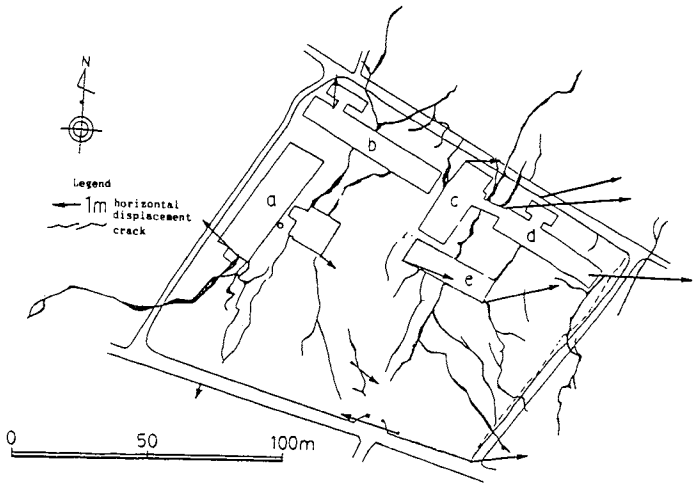

Fig.4 Sites of damaged schoolhouses at Ohgata Elementary School

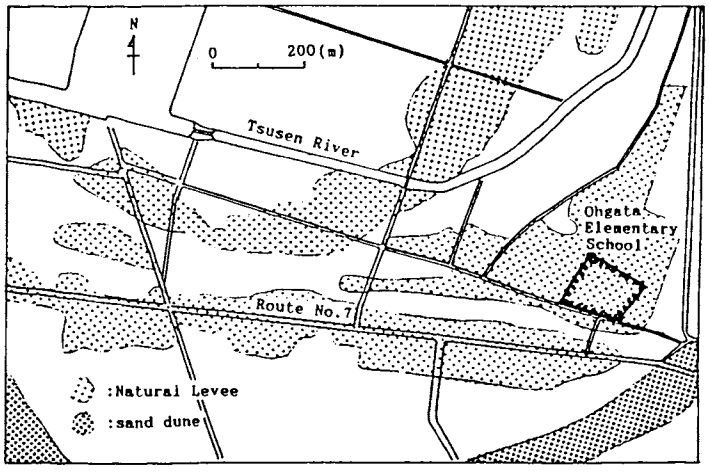

Fig.5 Geomorphological map of Ohgata Area

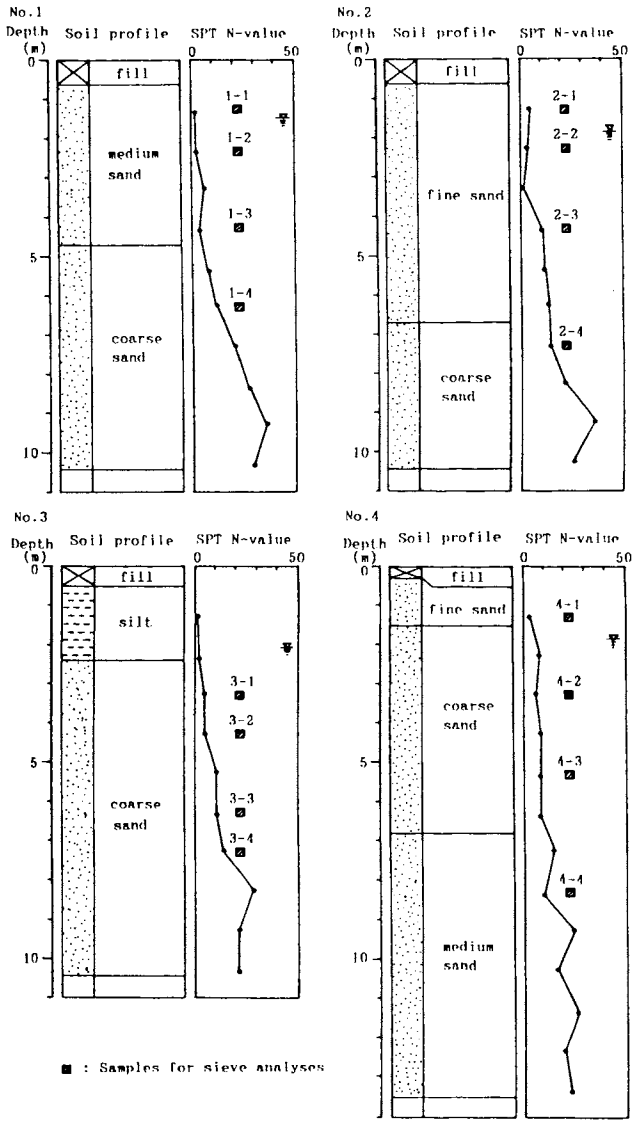

Fig.6 Soil profiles at four sites along B-B' line

SOIL CONDITIONS IN OHGATA AREA

Borings, standard penetration tests, Swedish soundings, dynamic cone tests and measurements of the ground water table were carried out at many sites. Fig. 6 shows the results of these tests conducted at four sites along the B-B' line in Fig.3. As shown in this figure, loose sand layers are deposited from the ground surface to a depth of several meters at all sites. Especially, the upper soil layer up to 4 to 5 m in depth at site 1 and site 2 is very loose. According to the grain-size distribution curves of the loose sands tested at four depths, all sands are very clean and the diameters of the sands at site 1 are smaller than those at site 3 and site 4.

Based on the results of the soil investigations, soil layer profiles along many section lines were estimated. Liquefied soil layers for each section were evaluated by the method proposed by Iwasaki et al.(1978). Fig 7 shows an estimated profile along the B-B' line in Fig.3. In this section, the estimated liquefied layer slopes gently toward the Tsusen River and has a thickness of about 4 m. The ground surface has also slopes gently, the average gradient of the slope being only 0.5 %.

Fig. 8 shows the detailed soil layer profile of the

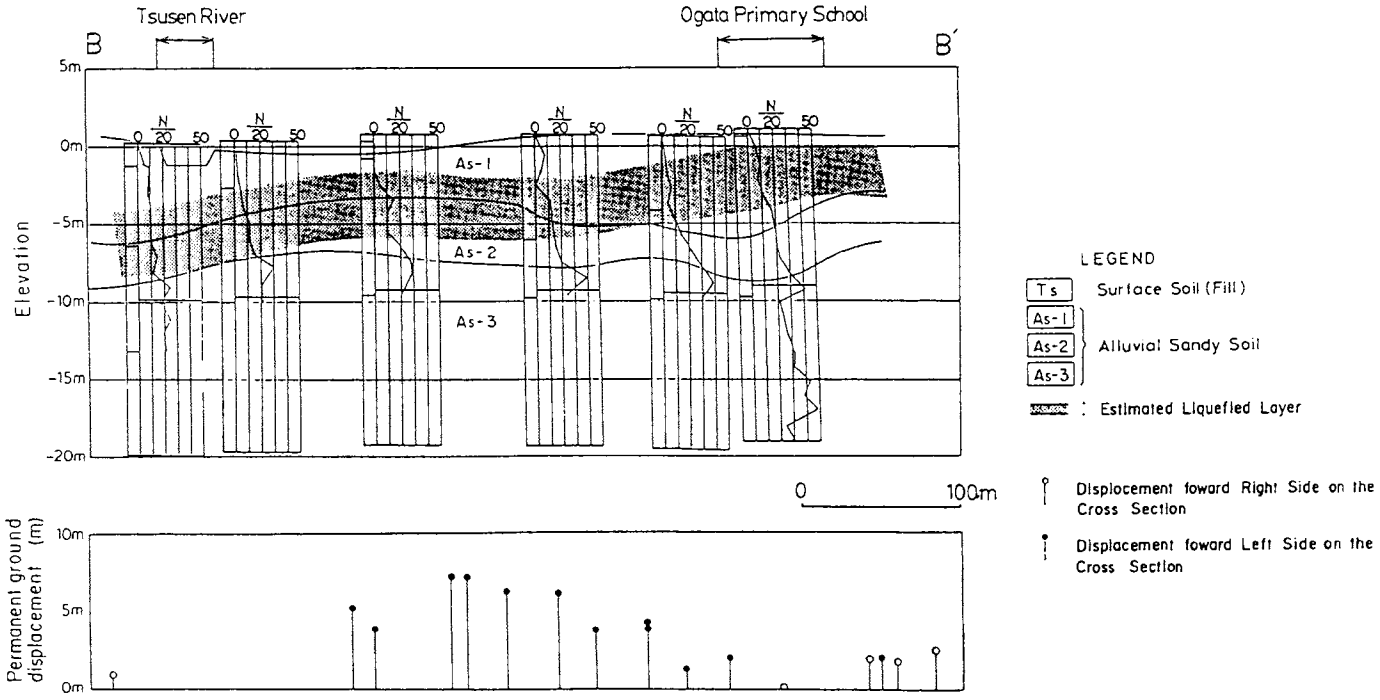

Fig.7 Estimated soil profile and liquefied layer along B-B' line

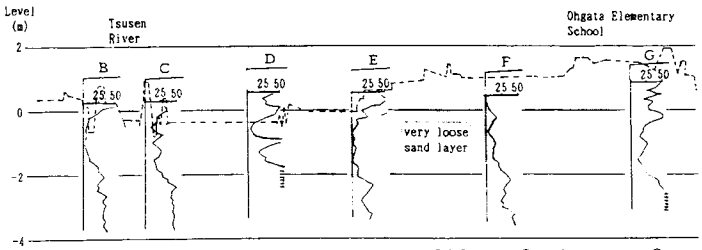

Fig.8 Detailed soil layer profile of the surface layer along B-B' line

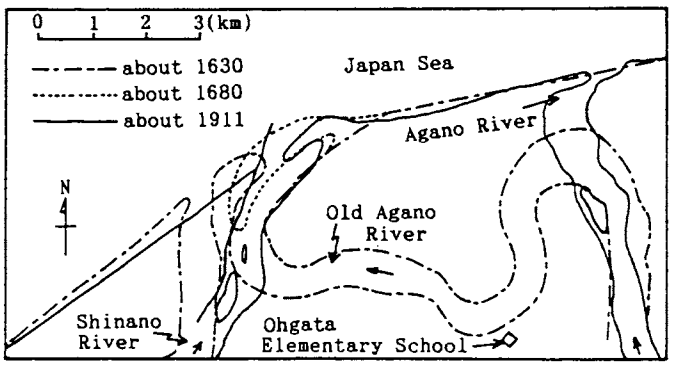

Fig.9 Change of the flow of the Agano River

surface layer along B-B' line judged from the dynamic cone tests. It can be seen that the surface layer up to a depth of about 2 m , within the natural levee, is extremely loose. It may be estimated that this very loose layer contributed to a high incidence of large permanent ground displacements. This very loose sand layer may have been formed for the following reasons: Formerly, the Agano River, a big river, flowed through the present Tsusen River towards the mouth of the Shinano River, as shown in Fig. 9. In the 18th century, the course of the Agano River was changed to empty into the Japan Sea directly, and the volume of water flowing in the Tsusen River decreased. Therefore, the old Tsusen River was probably wider than the present river. The water might have frequently flooded the site of the Ohgata Elementary School. After decreasing the water level, aeolian very loose sand became deposited in the dried area, which might nearly coincide with the area of the natural levee.

CONCLUDING REMARKS

Permanent ground displacements caused by the 1964 Niigata Earthquake were studied. Large displacements were induced along the Shinano River, around the Niigata Station, Ohgata district, etc. The gradient of the ground surface, the gradient of the bottom of the liquefied layer and the thickness of the liquefied layer were main factors affecting to the such large displacement. Moreover, in Ohgata area, the existence of extremely loose sand layer might contribute to a high incidence of large displacement.

ACKNOWLEDGEMENT

This research was conducted by the Japanese team of Japan-U.S. Cooperative Research and Collaboration on liquefaction, large ground deformation and their effects on lifeline facilities. The authors would like to thank each member of the team for their assistance and helpful discussions.

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