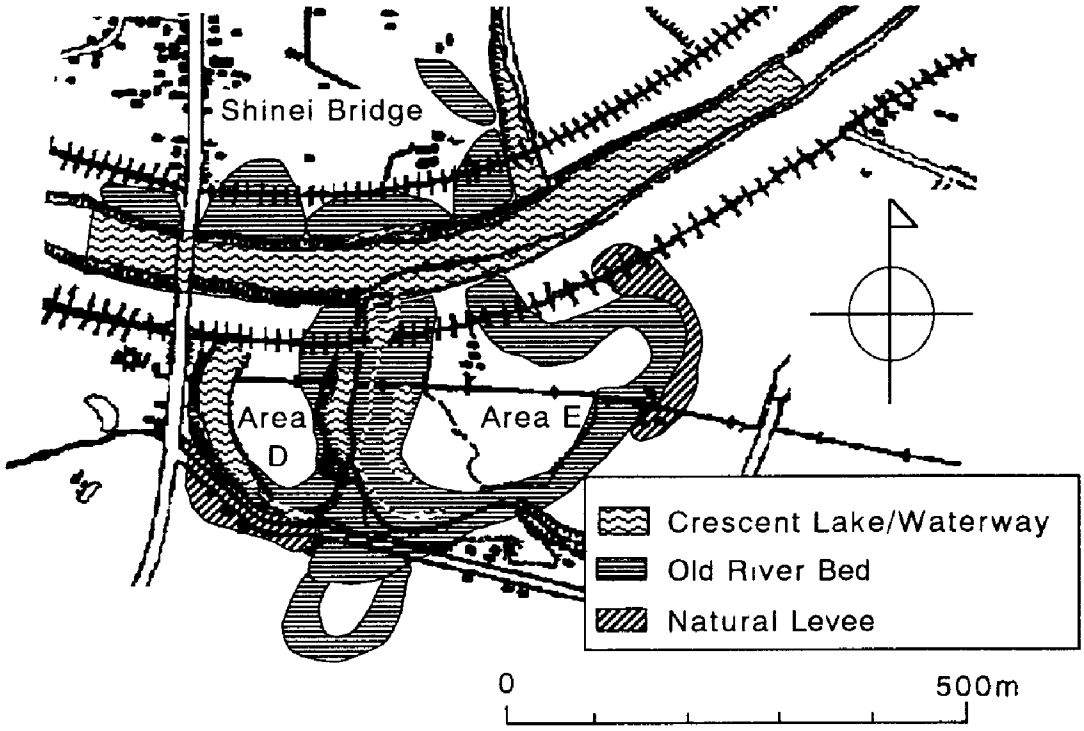


Figure 11 Old and Present River Channels Interpreted by Photograph Taken at 1948 in Aichi Area (Area A and E)

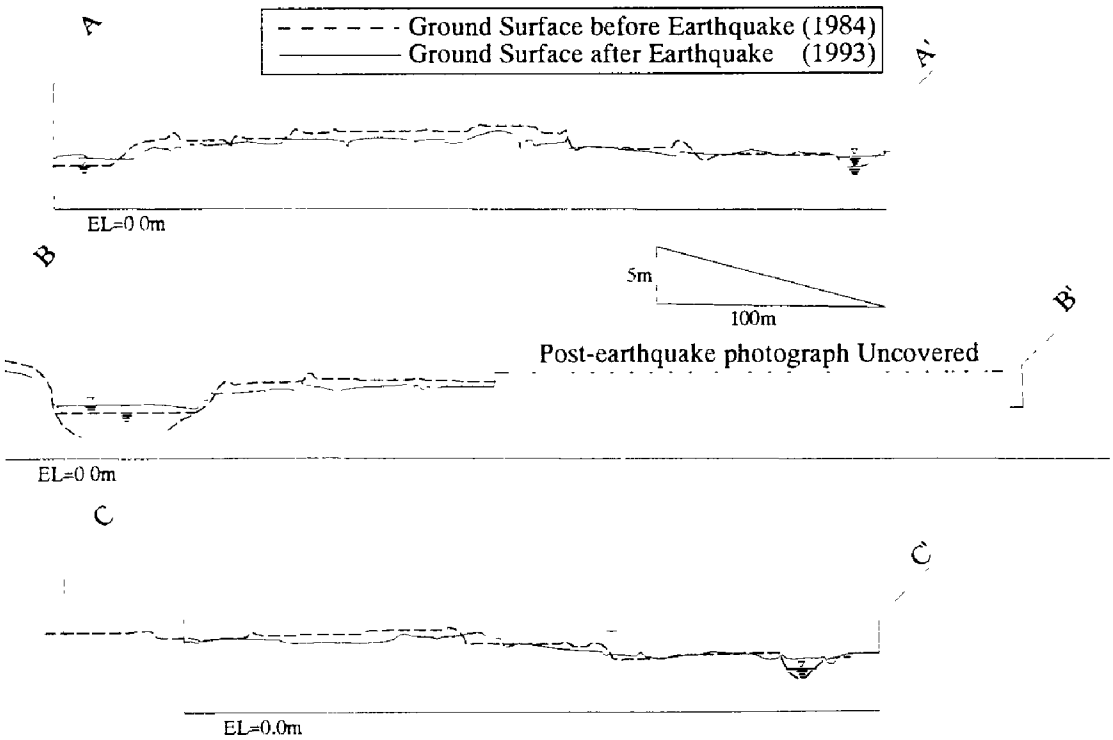
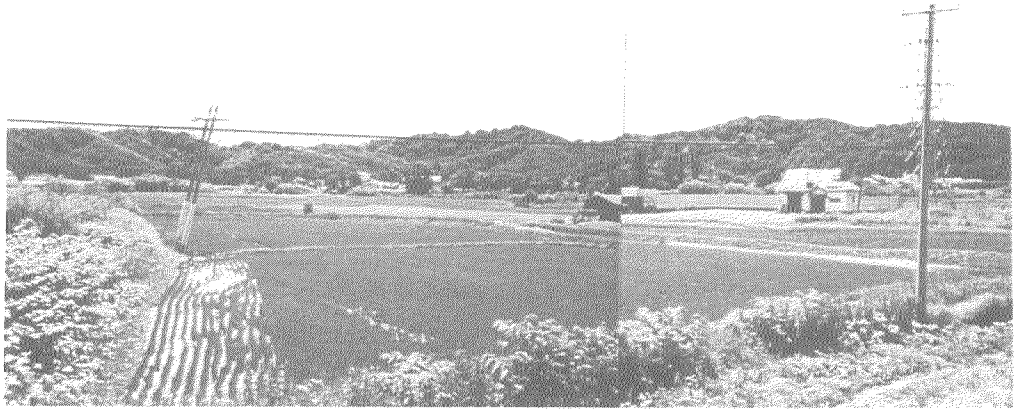
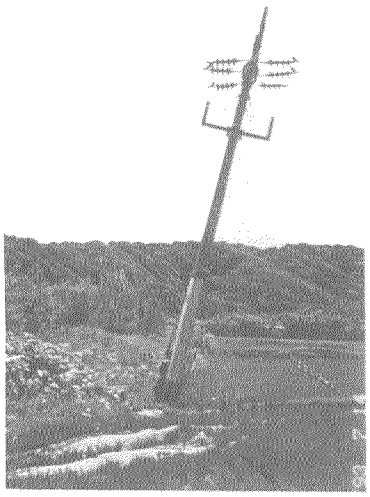


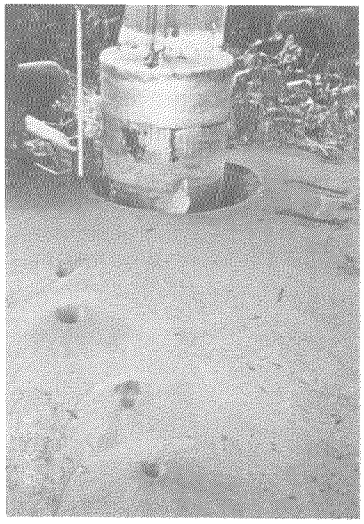
Figure 12 Measured Cross-Sections of Surfaces. Before (1984) and After(1993) the Earthquake (Locations of the Cross-sections are Shown in Fig. 10)



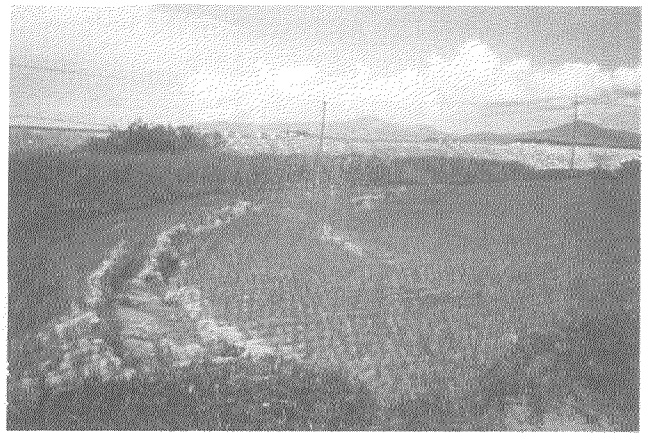
(a) Settlement and Tilting of Electric Pylon (One of Two Pylons, Gate-shaped, Settled and Tiltied in the Center of the Photo)



(b) Tilting of Electric Pylon



(c) Sand Boil from a Leg of Electric Pylon with four legs



(d) Fissures

(e) Fissures and Sand Boils

Photo 13 Ground Deformations and Damage to Electric Poles in Aichi Area (Area D)

of these profiles follow the surface lines prior to the earthquake shown in Figure 12.

Figure 13 demonstrates that the strata of this area consist mainly of surface soil, upper clay layer, upper sandy soil layer (As-1), lower sandy soil layer (As-2) and lower clay layer. The upper sandy soil layer (As-1) lies underneath the upper clay layer at 1m to 5m from the ground surface and is extremely loose with N value of 1 to 4. The lower sandy layer (As-2) of somewhat hard with N value of approximately 10 appears. Ground water table is approximately 2 meters. (Soil survey was conducted in March 1994 and the water table at the moment of the earthquake could have been different from this.) Properties of the sandy soil layers (As-1 and As-2) are summarized as follows.

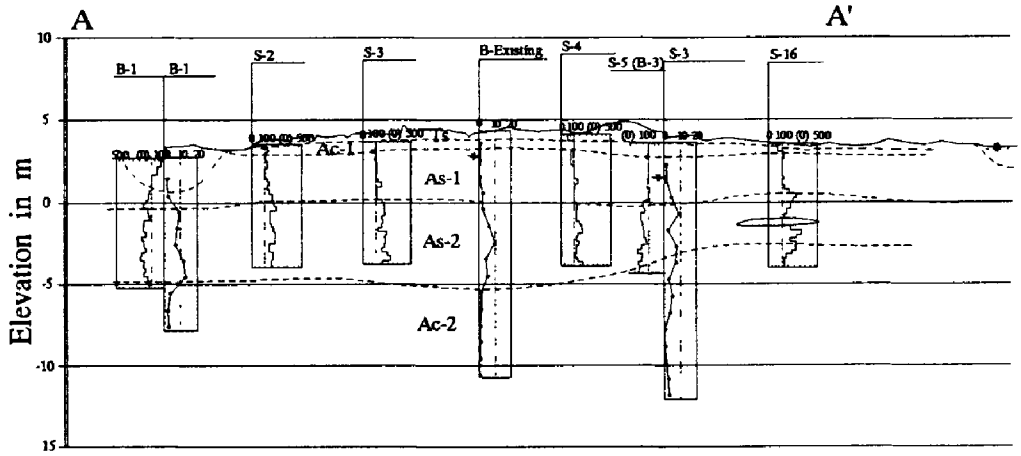
The upper sandy soil layer As-1 consists of sandy soil with much varied micro-fine sand, fine sand, and coarse sand with colors of brown-gray whose base is distributed around the sea level (elevation H= 0 m). This much-varied sandy soil is distributed in the entire region of Area D with the layer thickness of 2.0 $\sim$ 4.0 m. Mixtures include silt and small gravel in some spots while mica pieces are mixed in overall in large quantities. N values are very low: N= 1 $\sim$ 4, and average N is 2. Sws values, number of half revolution/m by sounding Nsw 0 $\sim$ 40, and average Nsw=10 $\sim$ 20.

The property values of this layer is summarized in Table 1 with those of As-2. The grain size distribution curves are shown in Figure 14 (a). This soil can be described as clean sandy soil with uniform grain diameter of uniformity coefficient (Uc) 2.5 $\sim$ 4.0 with fine grain content of over 95%. This sandy soil layer underneath the water table is thought to have liquefied completely.

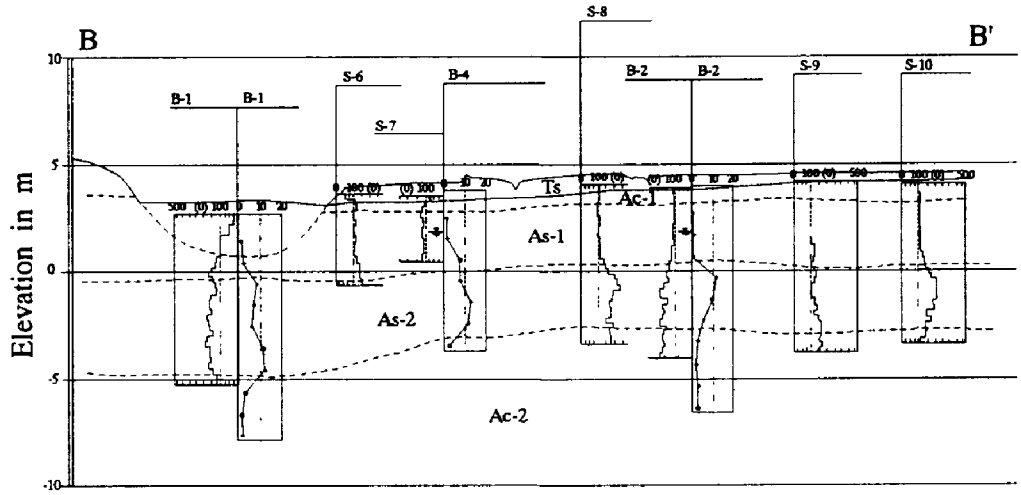
The lower sandy soil layer As-2 is predominantly sandy soil mixed with gravel of dark grey distributed mostly around H= 0 $\sim$ -5.0 m. This layer is distributed 3.0 $\sim$ 5.0 m thick under As-1 layer in the entire area investigated. The grain size distribution curves of this soil are shown in Fig. 14 (b). Gravel is mainly circular/semi circular with diameter ϕ 2 $\sim$ 5 mm, max. ϕ = 10 mm approximately with a higher rate of mixture in top layer and lower rate of mixture in the bottom. The sand diameter varies from small to fine. More silt mixture is found in lower parts, forming silty sand. It is soft sandy soil whose N values are 3 $\sim$ 13, average N $\fallingdotseq$ 7. Nsw is 15 $\sim$ 80, with the average of Nsw $\fallingdotseq$ 50 while Nsw $\fallingdotseq$ 100 is obtained in spots with high gravel content.

Table 1 Property Values of Sandy Soil Layers

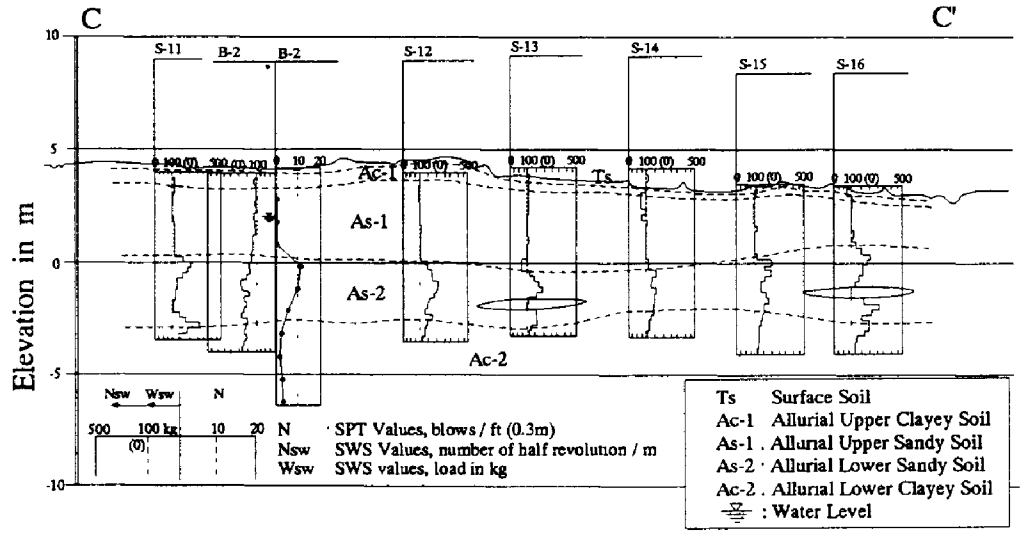
Property	As-1	As-2
Density of soil grain ρ_s (g/m^3)	2.70	2.68$\sim$2.73
Natural water content Wn (%)	25 $\sim$ 30	27
Grain soil test fine grains (F)	95% or more	15$\sim$55%
Uniformity coefficient (Uc)	2.6 $\sim$ 3.6	2.7$\sim$17.6



(a) A - A'

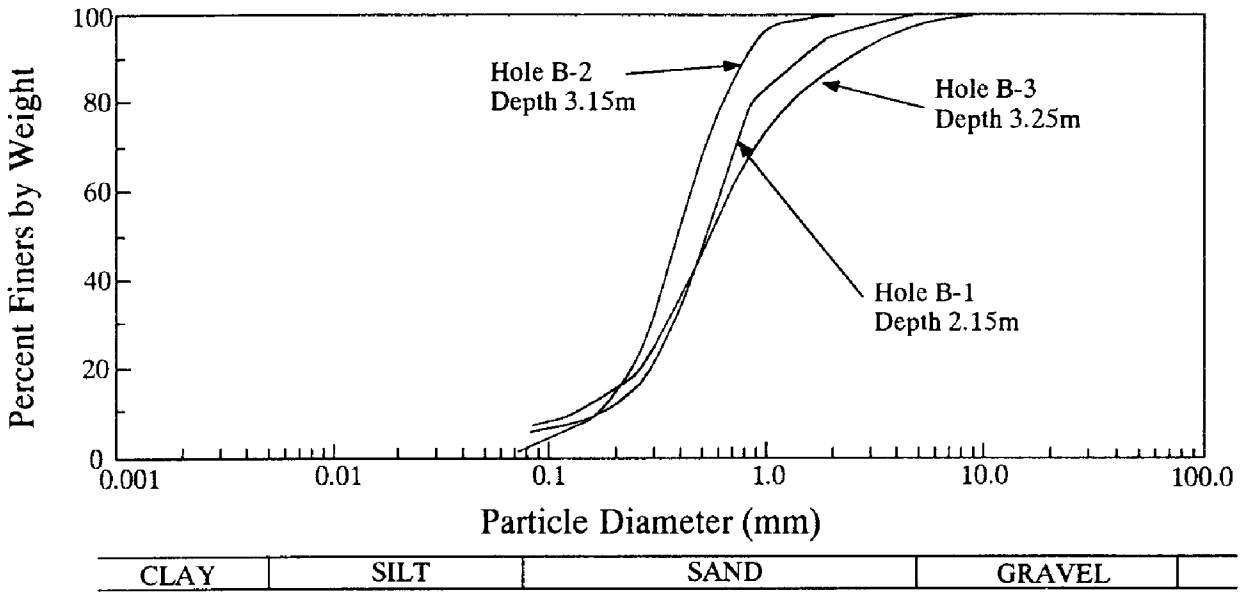


(b) B - B'

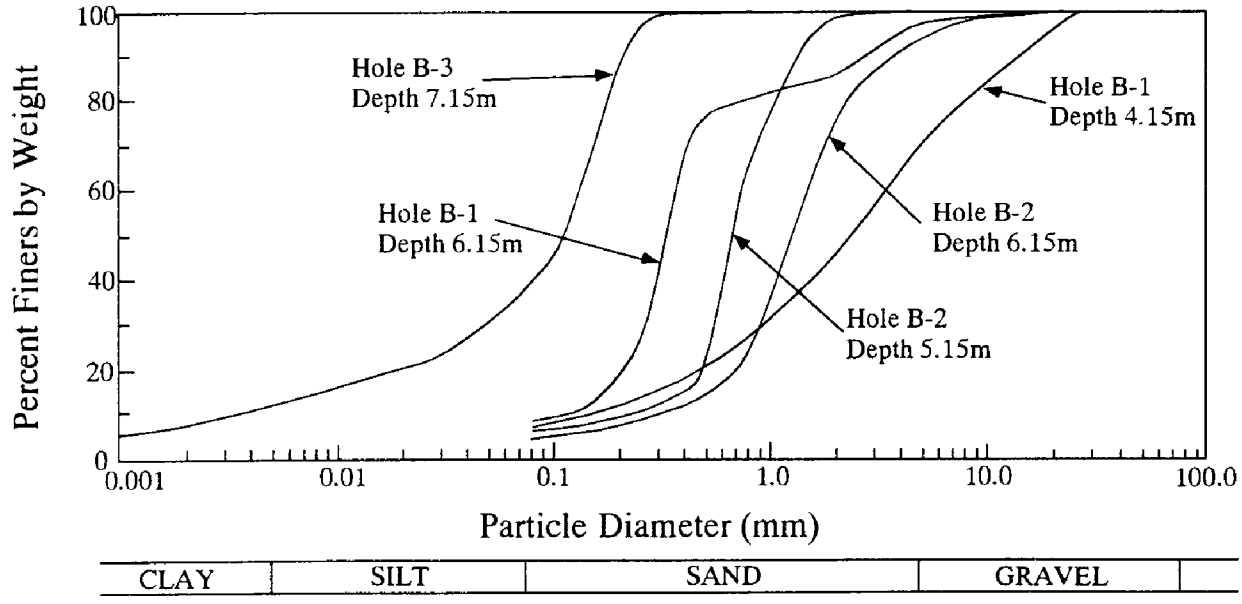


(c) C - C'

Figure 13 Soil Profiles in Aichi Area (Area D) at Cross-sections in Fig.10



(a) A_{S-1}



(b) A_{S-2}

Figure 14 Grain Size Distribution Curves from Sand Layers at Aichi Area
(Boring Hole B-1, B-2 and B-3)

CONCLUSION

Identification of ground deformation by means of aerial photos and measurement of ground displacements were undertaken for the basin area of the Shiribeshi-toshibetsu River where liquefaction and accompanying lateral spreading occurred during the 1993 Hokkaido-nansei-oki Earthquake. The result showed that severe liquefaction occurred inside the meandering of the old river beds, still present today as crescent lakes or waterways, while displacements in the horizontal direction was at most 2 to 3 meters toward the crescent lakes or waterways of the old river bed.

Soil investigations were conducted by boring and sounding in the areas where ground deformation is noteworthy. It is presumed from the result that the very loose sandy soil layer existing one meters below the ground surface with thickness of 2 to 4 meters liquefied completely. The lower sandy soil layer distributed under this very loose layer 3 to 5 meters thick contains fine grains and gravel with average N value of 7, and it is not known at the present whether it liquefied or not.

This present article was compiled based on the results obtained from the early stages of the research project of the river basin area of the Shiribeshi-toshibetsu River and the description contained mainly the facts so far discovered. Currently, continued efforts of ground investigation, strength tests of sandy soil layers and the investigation of damages to the farm lands, houses, water pipes and electric power facilities are in progress, and we intend to specify the liquefied layers and study the relationships between the thickness of liquefied layer, permanent ground displacements both horizontal and vertical, as well as the relationship between the ground deformation and the damages to buried pipes and structures.

ACKNOWLEDGMENTS

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REFERENCES

1) Michio Hirano and Yasuyuki Shimizu : Damage to River Embankments, Reconnaissance Report of the Damage Caused by the 1993 Hokkaido-nansei-oki Earthquake (in Japanese), Earthquake Engineering Committee, Japan Society of Civil Engineers, Sept. 1993, 21 - 24.

2) Yutaka Nakamura, Kenji Tomita, Muneyuki Tamogami, Kazutoshi Hidaka, Jun Saita and Shinji Sato : Strong Accelerations and Damage of the 1993 Hokkaido Nansei-Oki Earthquake (QuickReport), JR Earthquake Information No.19b, Railway Technical Research Institute, July 1993.

3) Japan Road Association : Specification for Highway Bridges Part V Earthquake Resistant Design (in Japanese), Feb. 1990.

4) Yutaka Nakamura, Jun Saita and Muneyuki Tamogami : Results of Strong Motion Observation on Kushiro-Oki Earthquake and Hokkaido Nansei-Oki Earthquake by Alarm Seismometers, RTRI Report, Railway Technical Research Institute, Vol. 8, No. 5, May 1994, 1 - 6.

5) Masanori Hamada, Susumu Yasuda, Ryoji Isoyama and Katsutoshi Emoto : Study on Liquefaction Induced Permanent Ground Displacements, Association for the development of Earthquake Prediction, Nov. 1986.