Characteristics and Damage Investigation of 1993 Hokkaido Nansei-oki Earthquake

Takahiro Iwatate *, Yoshihiro Sawada **, Daiei Inoue **, and You Sakamoto ***

ABSTRACT

This paper describes the characteristics and earthquake damage of 1993 Hokkaido Nansei-oki Earthquake(M=7.8) by the recorded strong motion accelerograms and damage investigations performed a few days later the earthquake by CRIEPI researchers. The main results imply that: (1) About 80 aftershock records including maximum acceleration of 190 gal were obtained by CRIEPI s temporary observation system in Okushiri island. (2) The tsunami left the run-up height more than 15m along the coast of Okushiri island,particularly more than 30 m at local point. (3) Many houses and civil engineering structures(breakwater, wharfs and etc.) along the coast of Okushiri island were suffered heavy damages from tsunami. (4) Lots of slope failure occurred at Okushiri island. (5) Earthquake has been resulted damages on ground and civil engineering structures(road,raiway, embedded pipes and etc.) which were constructed on(in) soft alluvial deposits, due to the liquefaction of loose sandy deposits. (6) The permanent displacements(Max. 160cm) of the surface ground occurred in the soft alluvial deposit. (7) Volcanic coarse-grained soil liquefied with a wide range at Akaigawa district,resulting in differential settlement of houses. The cause of the liquefaction occurrence of the gravelly soil was verified by the various soil tests. (8) Though the electric power distribution facilities were suffered some damage from tsunami,the facilities were promptly restored.

1 INTRODUCTION

The Hokkaido Nansei-oki Earthquake of 7.8 magnitude occurred at the southern part of the Hokkaido island and its adjacent Okushiri island at 22:17 12 th July 1993, whose seismic center was 34 km in depth. This earthquake has been resulted to the damages on the ground including slope failure, and liquefaction and civil engineering structures(roads, embedded pipes and etc.). The tsunami accompanied by the earthquake brought heavy damage to the Okushiri island and the west coast of Hokkaido.

The damage investigations due to the earthquake motion and the tsunami as well as after shock observation were carried out a few days later the earthquake by CRIEPI researchers.

This paper describes the characteristics of the earthquake by the observation data and earthquake damages on the ground(liquefaction and slope failure) and, civil engineering structures(houses, roads, wharfs and etc.) and electric facilities by means of field survey due to liquefaction and tsumani(Iwatate 1993). Moreover to examine the the permanent displacement of the ground surface occurred at the soft alluvial deposit and the liquefaction of volcanic coarse-grained soil at the Akaigawa district by means of field survey and soil tests.

2 HOKKAIDO NANSEI-OKI EARTHQUAKE

2.1 Earthquake Element

According to Japan Meteorological Agency (JMA), thus earthquake was of magnitude 7.8 and the hypocenter was located 42° 47' N, 139° 12' E with focal depth was 34 km(Table 1). This earthquake is the biggest size which occurred in Japan sea of Hokkaido region. Fig.1 shows the map of seismic intensities by JMA, and the intensity of the region near the epicenter was V. This earthquake were caused by the collision between Eurasian Plate and North-American Plate as shown in Fig.2.

---

* Professor of Tokyo Metropolotan University,Japan

** Central Research Institute of Electric Power Industry(CRIEPI)Japan

*** Hokkaido Electric Power Company Inc.,Japan

Judging from the after shock distribution, the size of earthquake fault were estimated 100 km of NS x 50 km of EW,and stress drop,average slip was estimated about 60 bars and 4 m, respectively as shown in Table 2.

In this particular event, the earthquake indicated a complicated rapture process, and the rupture has started from the north side of the fault to the south side with velocity about 3 km/s.

2.2 Earthquake Observation

(1) Observation Stations

CRIEPI has about 50 strong earthquake observation stations that are located on rock outcrops in mainly the circum-Pacific seismic zone of Japan in order to research the input motion on bedrock (Yajima 1991). Among these stations,the earthquake data of main shock were recorded at the 4 stations(SRN, KUJ, FRF and KMS)located at Tohoku region(Fig.3). And, in order to examine the characteristics of the earthquake motion minutely, two temporary stations near the epicenter for after shock were constructed on the outcrop at Okushiri island(OKS) and Setana-cho(SET) of the west coast of Hokkaido.

(2) Earthquake Observation Data

・ Main Shock

1) Fig.4 shows three-component accelerograms at SRN station which is located 257 km far from the epicenter . The maximum values were 10.3gal(NS component), 9.9gal(EW component), and 7.9gal(UD component), respectively. And Fig.5 shows the Fourier amplitude spectrum, power spectral density, absolute acceleration response spectra, and pseudo velocity response spectra of NS component .

2) Fig.6 shows the three-component accelerogram at JMA Sutsu station(SUT)which is located 69 km far from the epicenter, and the maximum accelerations were 216gal(NS component), 202 gal(EW component), and 51 gal(UD component), respectively.

・ After Shock

1) About 80 after shock events were recorded at OKS and SET stations. The maximum one(M=6.5) occurred at 04:42 8 th August. Fig.7 shows the three-component accelerogram of this earthquake observed at OKS station. The maximum accelerations were 95 gal(NS component),189 gal(EW component), and 65 gal(UD component), respectively. And the Fourier amplitude spectrum, power spectral density, absolute acceleration response spectra, and pseudo velocity response spectra of NS component are shown in Fig.8.

Fig.9 shows the relations between the observed maximum accelerations of the these stations to hypocentral distance. The acceleration values were almost same those predicted from some empirical acceleration-attenuation formula except for the SUT data.

3 TSUNAMI

(1) Characteristics of Tsunami

The tsunami accompanied by the earthquake brought heavy damage to Okushiri island and west coast of Hokkaido. In Okushiri island ,the tsunami left the run- up height more than 15 m along the coast,particularly more than 30 m at local point which is the highest value in 20 th century in Japan, as shown in Fig.10,11.

The tsunami was diffracted and refracted around this island with concentrating the energy at the shoal of the coast.

(2) Damage of Tsunami

Photo 1 shows the overveiw of the damages at Aonae area in Okushiri island. Many houses and harvor facilities (breakwater, wharfs) were suffered heavy damage from tunami and fire. Photo 2 shows the broken breakwater of Okushiri harbor, and Photo 3 shows the damage of the embankment of the coast of Taiseicho in Hokkaido.

4 EARTHQUAKE DAMAGE (Fig.10,11)

Table 3 shows the summary the earthquake damages of houses,civil engineering structures compared to the other past earthquakes with same magnitude. The damages of structures of this earthquake were concentrated in the

Okushiri island and east cast of Hokkaido due to tsunai and the liquefaction of the ground. And lots of slope failure occurred in Okushiri island. The sum of the damage cost of this earthquake was about twice larger than that of Kushiro-oki earthquake,and more than two hundred people died. The main damages show as follows.

(1) Electric Power Facilities

Table 4 shows the summary of the damages of electric power facilities, and Table 5 shows the damages of electric power distribution facilities. In Hokkaido island, Hokkaido electric company has 1 nuclear power station(Tomari), and 3 thermal power stations of the area near epicenter. The damages of the facilities of these power stations were very little,but the electric power distribution facilities were suffered some damages in Kita-hiyama district. From these damages, the electric power supply were cut off in Kitahiyama district, but about 5 hours after the outage was almost restored. On the other hand, in Okushiri island,though the electric power distribution facilities(cable, pole) were suffered severe damages with the electric supply cut off from tsunami as shown in Fig.12. But the emergency electric sources were promptly recovered, and 4 days after the outage was almost restored.

(2) Slope Failure

Lots of slope failure(about 400 points)occurred along the coast of Okushiri island. These failures were classified into 4 types, that is, shallow-seated sliding, deep-seated sliding,landslide and rockfall. In particular, the most of slope failure was the shallow seated sliding with repeated phenomena(more than 80%) and the sliding part of the slope was consisted of fairly efforescented rocks. Photo 4 shows the slope failures of Okushiri island comparison between the before earthquake(a) and after earthquake(b). The slope failure were tremondously increased by the earthquake. And Photo 5 shows the large deep sliding at the back of the Okushiri port. In this case, 37 people died.

(3) Liquefaction

The liquefaction of the ground with loose sand deposits were occurred with wide range along the No. 5 road (from Oshamanbe to Yagumo) and Kitahiyama district, resulting the manholes,gasoline oil-tanks and agricultural culvert built-up as shown Photo 6,7. And ground displacements also occurred at the ground of Nakanosawa elementary school as shown in Photo 8. Fig.13 shows the measured permanent displacement of the ground. The maximum value was about 160 cm resulting the damages of broken piles of the school houses and the fallen concrete walls. But, at the part of compacted alluvial deposit of the ground, the permanent displacement was very little and the backnet for baseball and the plant trees were useful to protect the lateral flow of the liquefied soil.

(4) Damage of roads

Most of damaged roads were constructed on soft alluvial deposits,such as National Highway No.5(from Oshamanbe to Yagumo),Kitahiyama district along the Rishibetu-river. The collapsed embankments,differential settlements and caving in roadbed were occurred as shown in Photo 9. The main cause of them may be liquefaction of loose sand deposits by strong earthquake motions.

(5) Liquefaction of Gravelly Debris Avalanche Deposit

Vocanic coarse-grained soil liquefied with wide range at Aki-gawa district in Mori town near the Ohonuma lake,resulting in differential settlements of houses.

It is rare case that gravelly ground is liquefied and often used for foundation on ground of electric power facilities because of its high stability against liquefaction, so CRIEPI has conducted further site investigations with geological survey,PS-logging, large penetration tests, elastic wave exploration tests, in-situ freeze sampling and some laboratory tests in order to clarify the liquefaction occurrence of the site(Tanaka 1994).

The test results imply that : ① The age of organic soil layers which sandwich the gravally soil deposits,was found about 2000 years. ② According to the results of PS-logging,the average of shear wave velocity of the ground shallower than depth of 7 m is about 100m/s which is very small value for a gravelly soil as shown in Fig.14. ③ The value of shear wave velocity of the ground measured by the refraction method was approximately equal to those by PS-logging.

On the base of these test results and estimated ground surface acceleration values, liquefaction susceptibility of the ground was examined by a practical method. And from the test results ,the cause of the liquefaction occurrence at the site has been verified.

5 CONCLUSION

(1) Hokkaido Nansei-oki earthquake was the biggest one occured in Japan sea of Hokkaido region, and it were caused by the collision between Eurasian Plate and North American Plate.
(2) CRIEPI obtained about 80 earthquake data on the outcrop near the epicenter by the after shock observations. The maximum acceleration was 189gal(NS-component).
(3) The tsunami left the run-up height more than 15 m along the coast of Okushiri-island particularly more than 30 m at local point.
(4) Many houses and civil engineering structures(wharfs, breakwaters) along the cost of Okushiri island and the east coast of Hokkaido were suffered severe damages from tsunami, and though electric power distribution facilities also suffered severe damages from tsunami, the facilities were promptly restored.
(5) Lots of slope failures were occurred along the coast Okushiri island. The most of slope failure was the shallow-seated sliding and the sliding part of the slop was consisted of fairly efforescented rocks.
(6) This earthquake has been resulted the heavy damage on the ground and civil engineering structures(roads, railway embankments and etc.) constructed on (in) soft alluvial deposit due to the liquefaction.
(7) The permanent displacements(Max.160 cm)occurred in soft ground of Nakanosawa elementary school resulting the damage of the piles of school houses.
(8) Volcanic coase-graind soil liquefied with a wide range at Akaigawa district,resulting in differential settlement of houses. The cause of the liquefaction occurrance of the site has been verified by the soil tests.

REFERENCE

- Iwatate T., Sawada Y, Inoue D.and etc.(1993)
  Characteristics and Damage Investigation of 1993 Hokkaido Nansei-oki Earthquake
  Abiko Research Laboratory Report No.U93028 (in Japanese)
- Yajima,H.(1991)
  Strong Motion Earthquake Records of CRIEPI earthquake observation network
  CRIEPI Report No.U90058 (in Japanese)
- Tanaka,Y.(1994)
  Investigation of Causes of Liquefaction of Gravelly Debris Avalanche Deposit occurred during Hokkaido Nansei-oki Earthquake of July 12,1993(Part 1)
  Abiko Research Laboratory Report No.U94007(in Japanese)

Table 1 Earthquake Elements

(1)Origin Time	:1993.07.12. 22h17m(JST=9hours+UT)
(2)Location Name	:Off south-west coast of Hokkaido
(3)Hypocenter	:Longitude 42° 47'N
	Latitude 139° 12'E
	Depth H=34km
(4)Size	:M_{JMA}=7.8
(5)Seismic Intensities by JMA :	
V	:Otaru,Fukaura,Suttsu,Esashi
IV	:Aomori,Muroran,Tomakomai,Mutsu,Kutchan,Hakodate
III	:Rumoi,Sapporo,Hachinohe,Akita,Obihiro,Iwamizawa, Haboro
II	:Asahikawa,Wakkanai,Shinjo,Morioka,Sakata,Urakawa
I	:Yamagata,Abashiri,Miyako,Kushiro,Onahama,Niigata, Ofunato,Wajima,Omu,Hiroo,Sendai

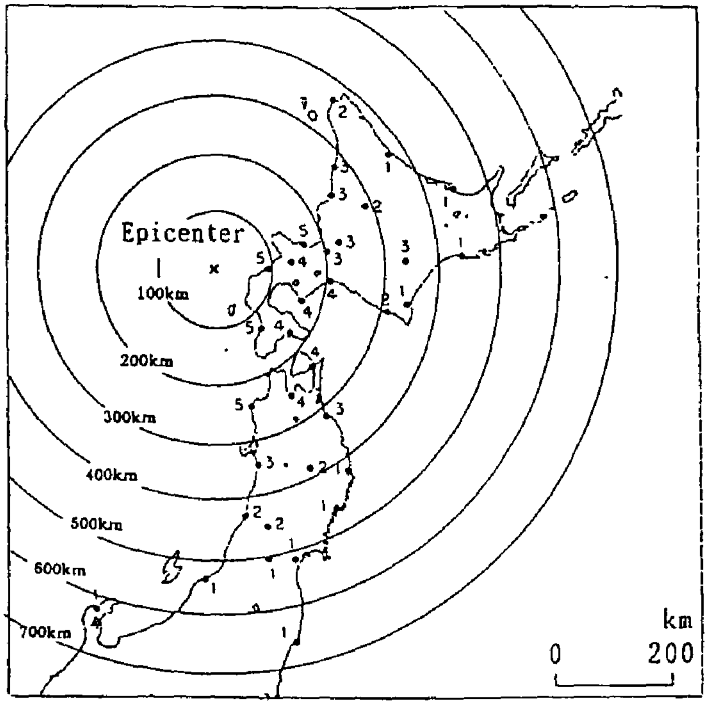

Fig. 1 Map of Seismic Intensity by JMA

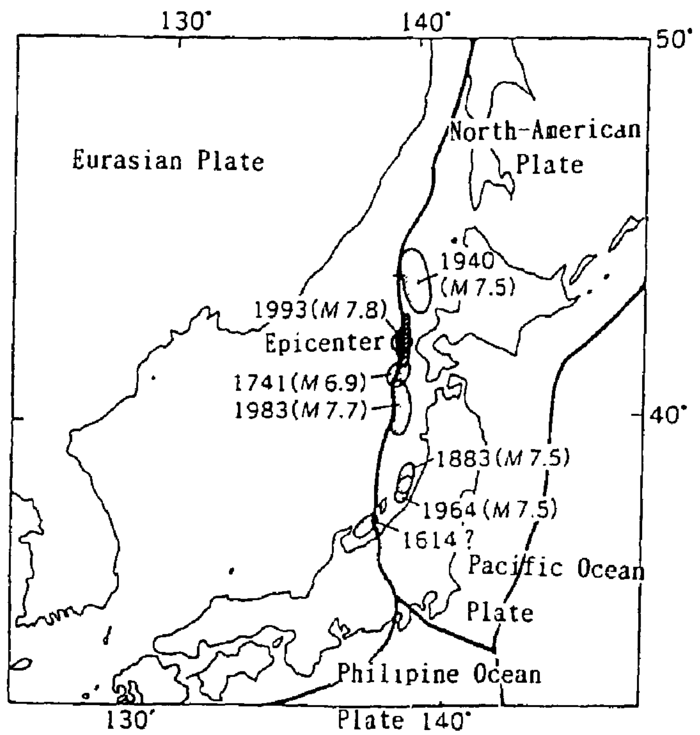

Fig. 2 Seimic Regions of Big Earthquakes occurred in in Japan Sea of Hokkaido Region

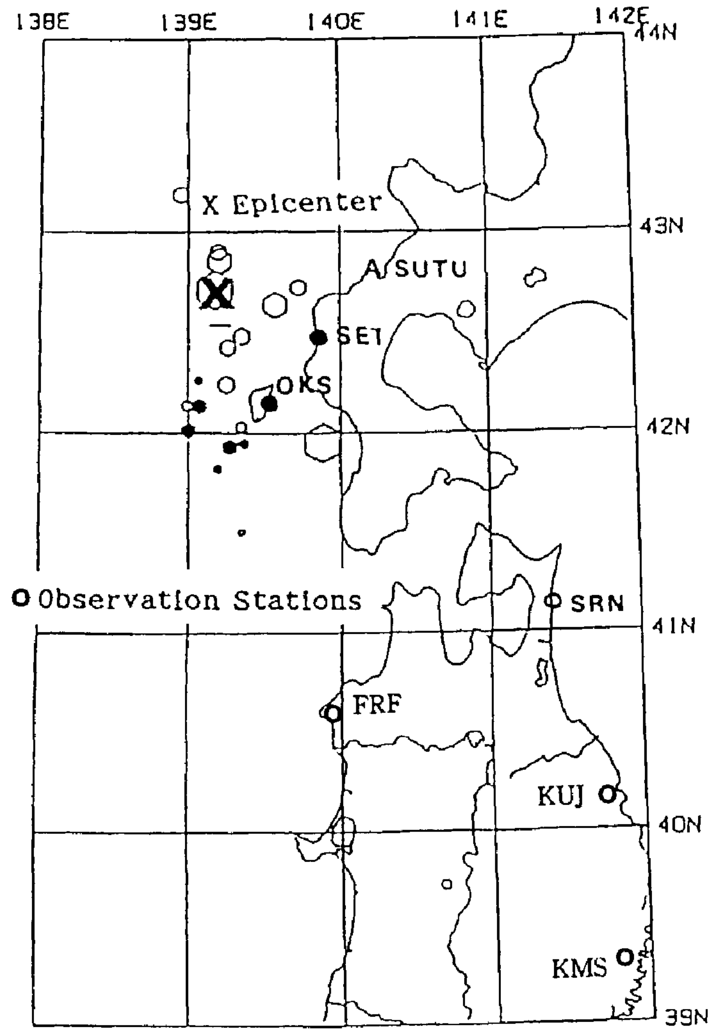

Fig. 3 Observatin Stations of CRIEPI

Table 2 The Source Parameter of The Main Shock

Origin Time	Fault Size (km)	Seismic Moment (dyne·cm)	Stress Drop (bar)	Average Slip (m)
1993, July, 12 22:17	100(NS) x 50(EW)	4.2×10^{27}	60	4.0

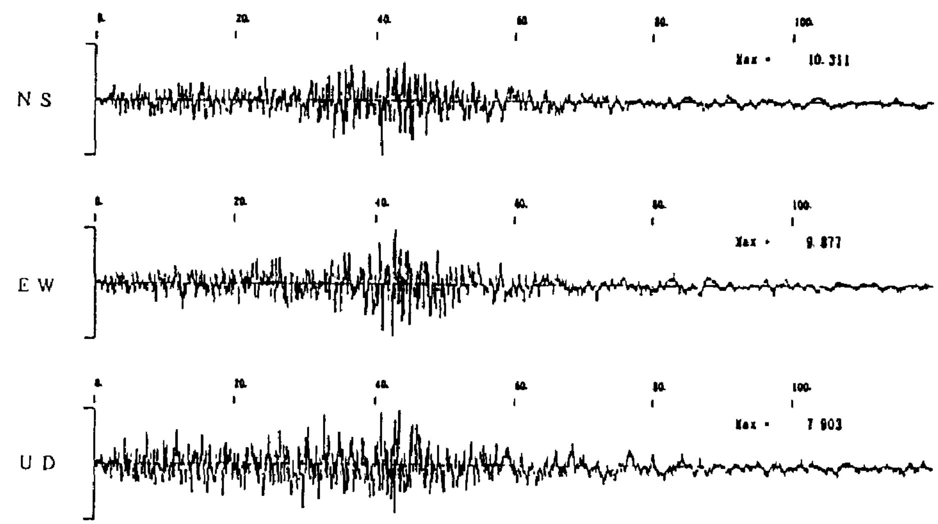

Fig 4 Observation Accelerograms at CRIEPI's SRN Station

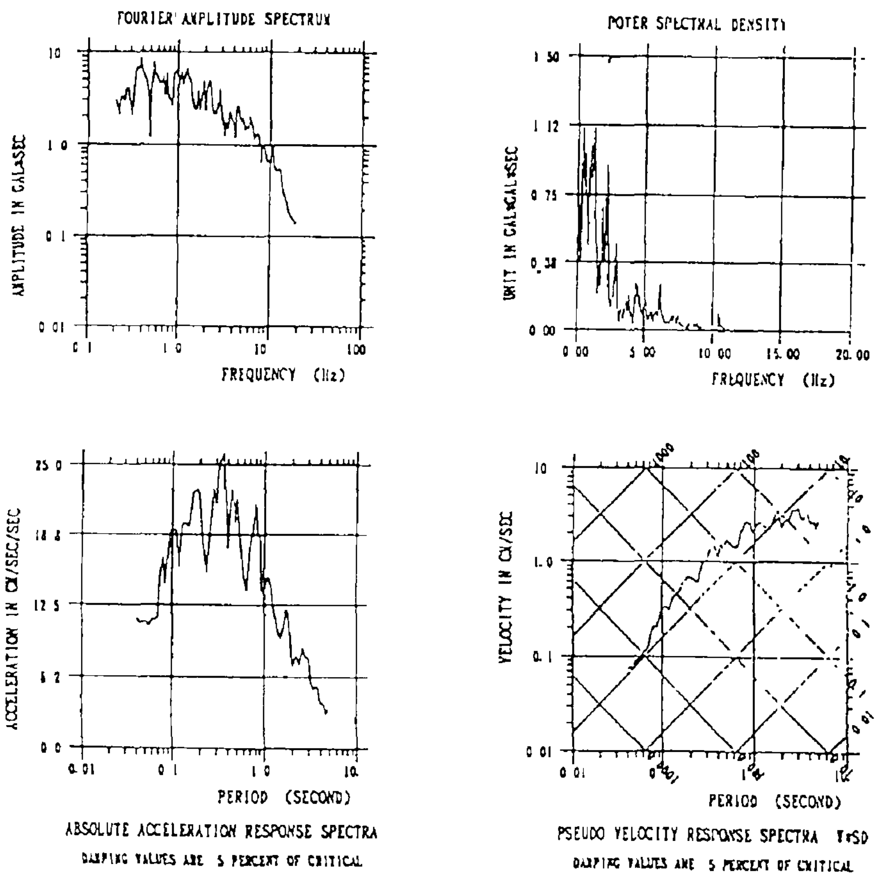

Fig. 5 Fourier Amplitude Spectrum, Power Spectral Density, Absolute Acceleration Response Spectra and Pseudo Velocity Resonse Spectra of SRN Data (NS-component)

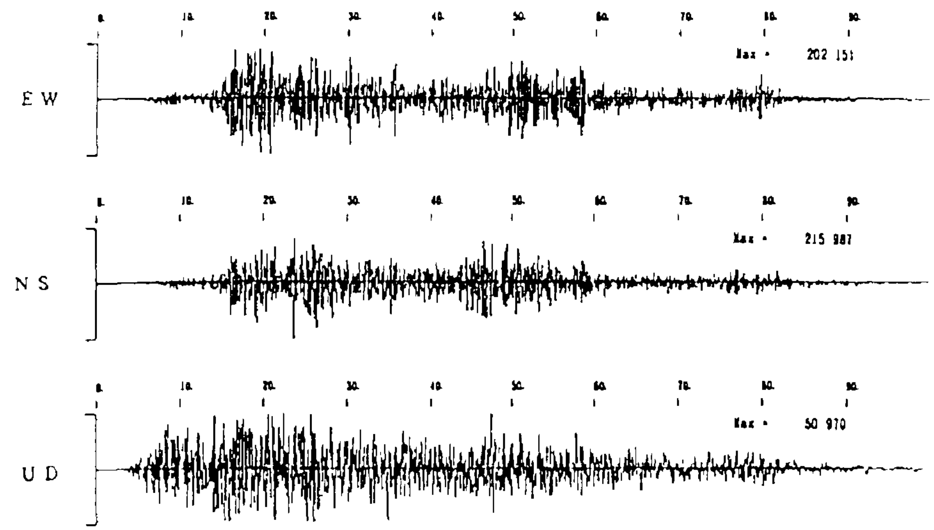

Fig. 6 Observation Accelerograms at JMA Sutu Station (Main Shock)

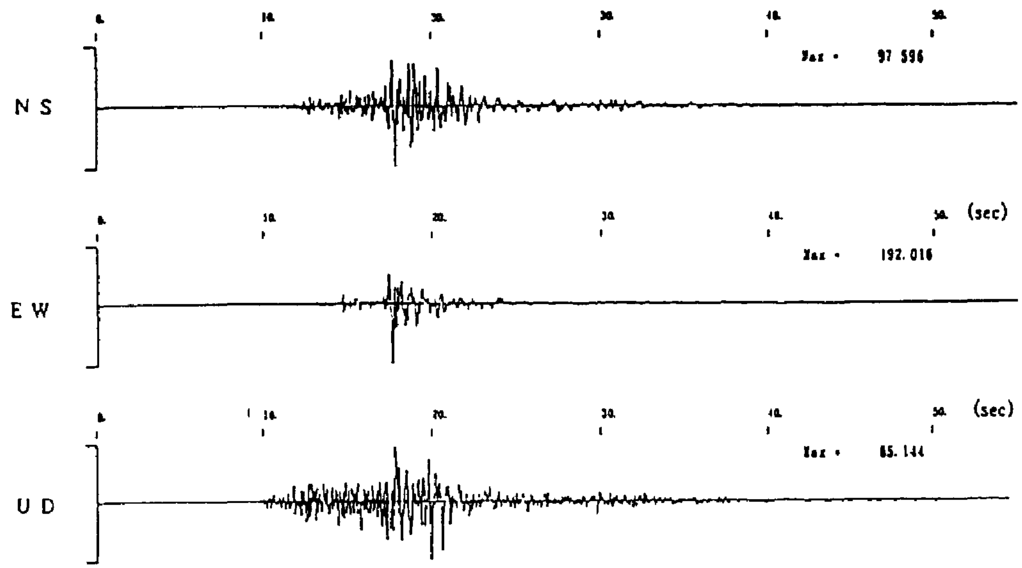

Fig. 7 Observation Accelerograms at CRIEPI' OKS Station

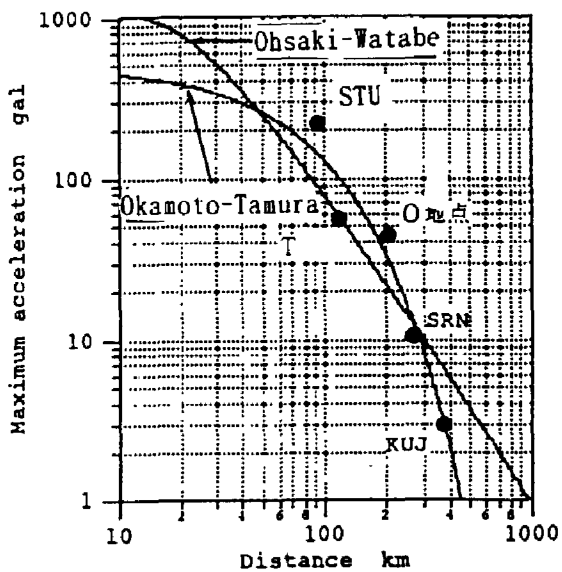

Fig. 9 The Relations between the Observed Maximum Accelerations to Hypocentral Distance

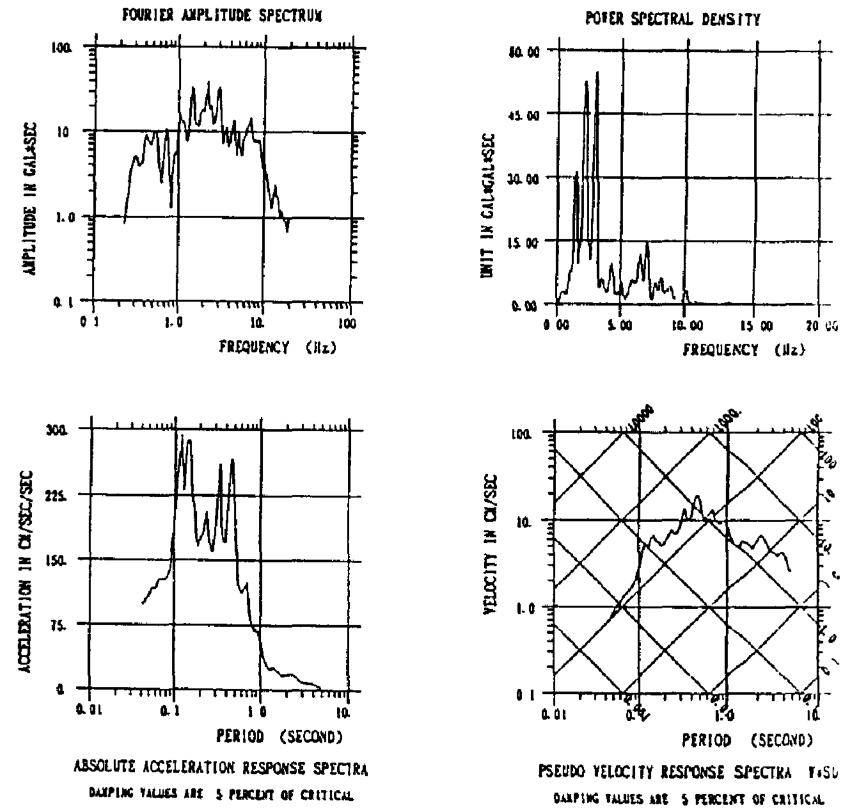

Fig. 8 Fourier Amplitude Spectrum. Power Spectral Density, Absolute Acceleration Response Spectra and Pseudo Velocity Resonse Spectra of OKS Data (NS-component)

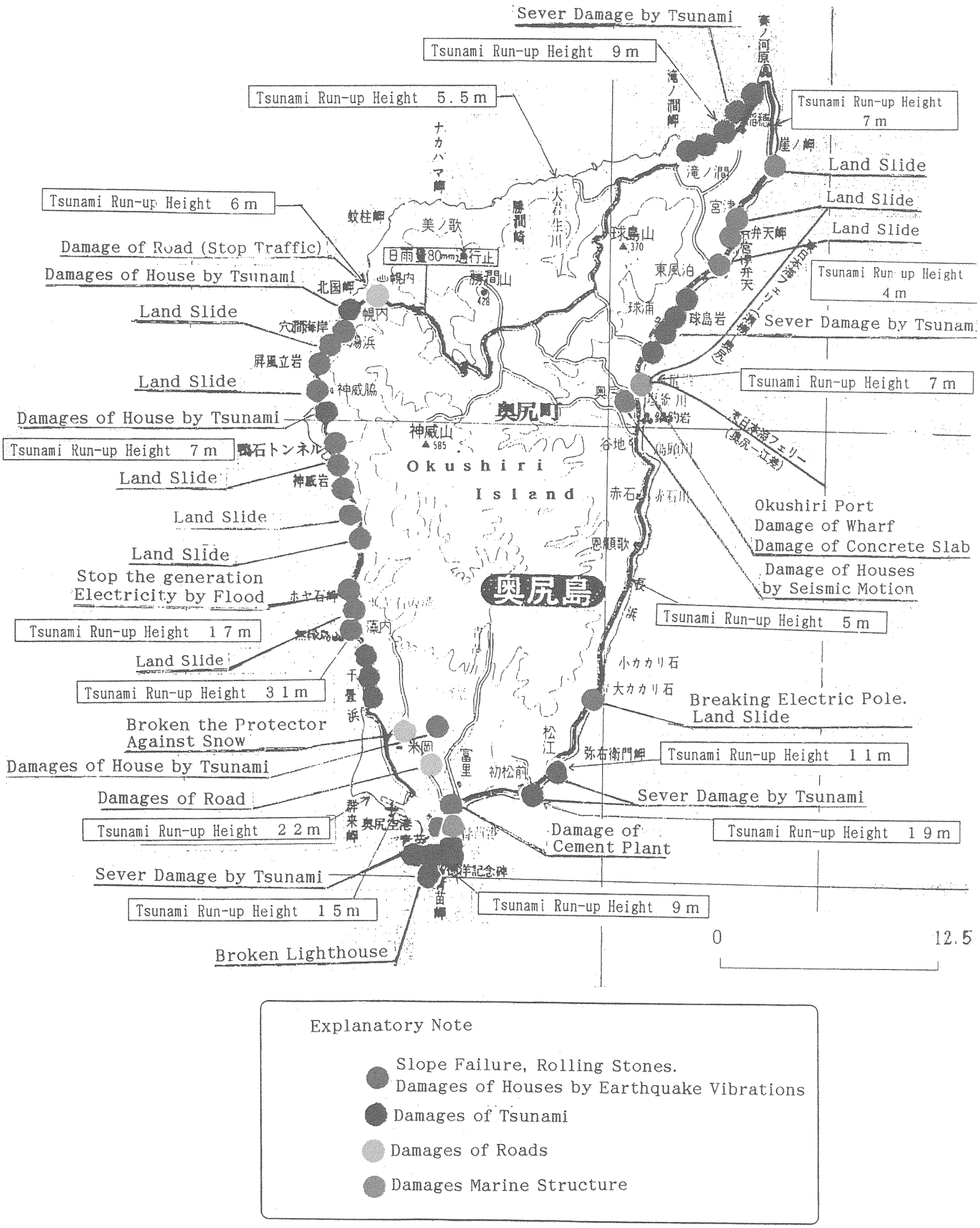

Fig. 10 Earthquake Damage of Okushiri island

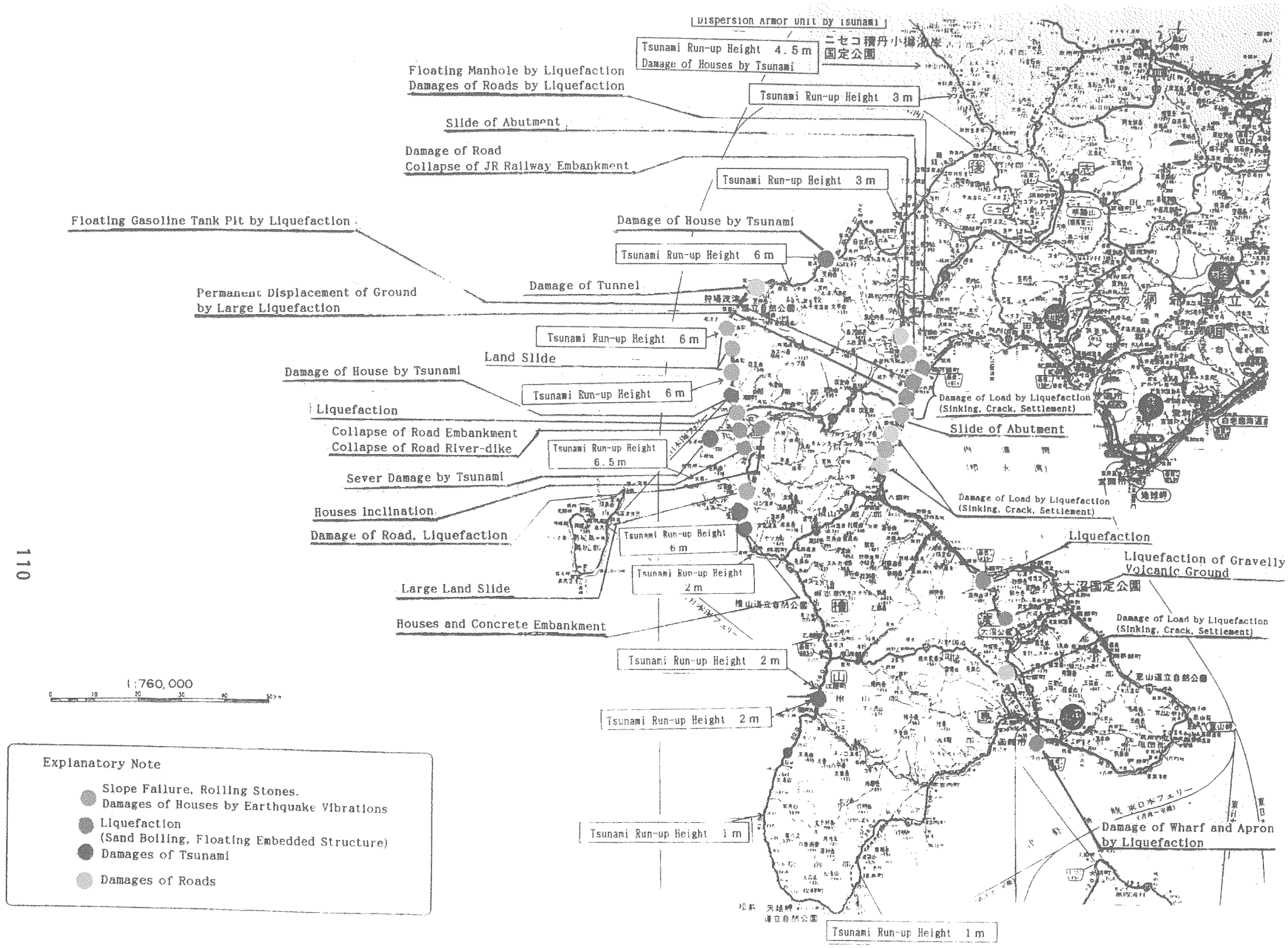

Fig. 10 Earthquake Damage of Hokkaido island

Table 3 Summary of Hokkaido nansei-oki Earthquake Damages compared to the other Earthquake Damages with same magnitude(1993/8/16)

Event	Origin Magnitude Date	Amount of Damage	Human Damage Death Injured Missing	Damage of houses	Damage of Civil Engineering Structures
Hokkaido Nansei-oki	1993 07 12 M7.8	100.7billions	201 305 29	3947	1167
Kushiro-oki	1993 01 15 M7.8	53.1billions	1 927 0	4466	1993
Nihonkai Chyubu	1983 05 26 M7 7	164 billions	104 324	11061	2226

Table 4 Earthquake Damages of Elecrtic Equipments

Equipments	Damage Pattern
1.Power plant	
• Mori(Geo-Thermal:50MW)	Leaking insulting oil for pipes of actuater
• Shiriuchi(Oil:350MW)	Short -circuit of EP Damage of support tower for chimney
• Okushiri(Internal-combustion:3.2MW)	Damage of feul pipelines
• Hoya-ishikawa(Hydraulic:0.17MW)	The generator was submerged by Tsunami
2 Transmission line	
• 33KV(Matsumae-Line)	Broken porcelain component(1)
• 33KV(Toshima-Tohbetsu-Line)	Broken porcelain component(2)
• 33KV(Setana-Line and etc)	Inclined the pale(14)
• 33KV(Hiyama-Line)	Displacement of the base of Iron Tower(3)
3.Substation	
• Ohno	Broken of the part of 187KV Arrester Crack of retaining wall
• Kamiiso	Broken poclain of 72KV Gas-breaker Breaking Jumper
• Oshamanbe	Broken porclain and Leaking insulting of oil
• Fukushima	Broken porclain of 72KV switch

Table 5 Damage of Electlic Power Distribution Facilities

Equipment	Hakodate Area	Okushiri Area	Muroran Area	Otaru Area	Iwamisawa Area	Total
1.Pole	572	278		7		857
2.Cable	27	659		4		690
3 Transformer	633	96	18	57	1	805
4.A Breake and Make Switch	3	11	2		1	17