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Sapporo, Japan

Special Lecture
Mechanical behavior and earthquake-induced failures of volcanic soils in Japan

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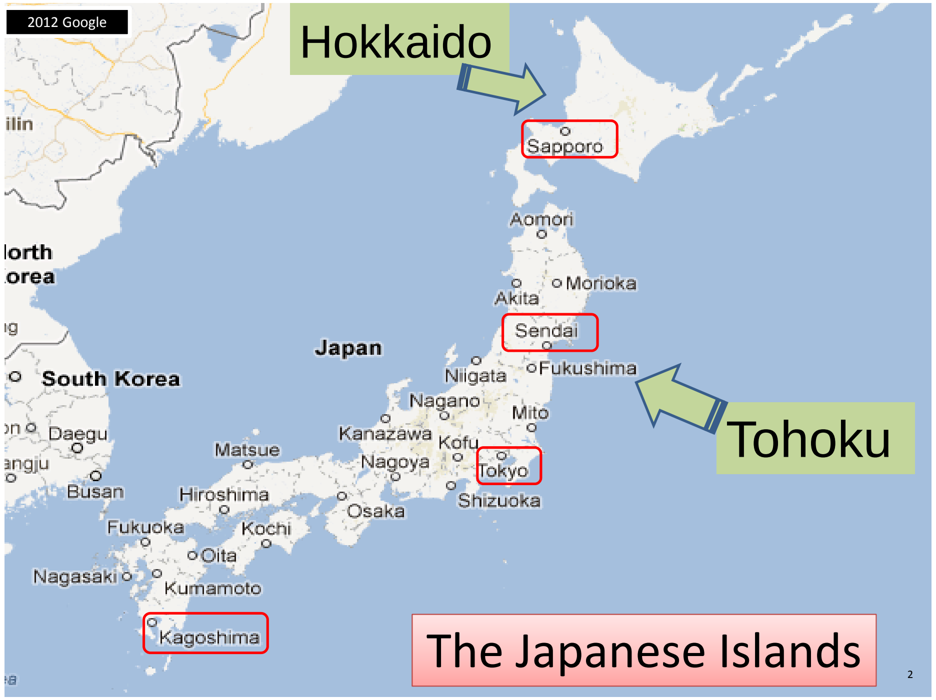
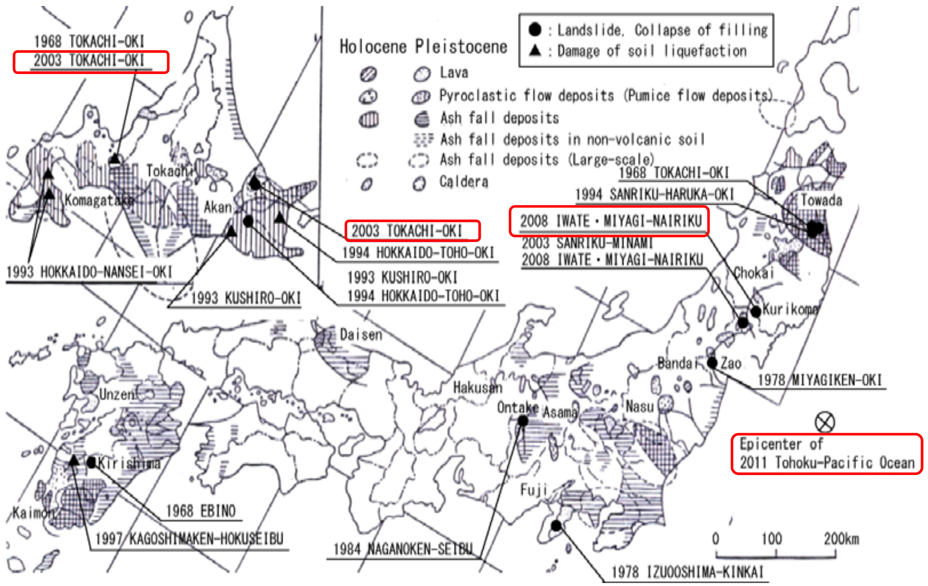


The Japanese Islands

Recent great earthquakes in Japan

Y/M/D	NAME	M
1964.06.16	Niigata	7.5
1968.05.16	Tokachioki	7.9
1973.06.17	Nemuro Peninsula Oki	7.4
1978.01.14	Izu Ooshima Kinkai	7.0
1978.06.12	Miyagiken Oki	7.4
1983.05.26	Nihon Kai Chubu	7.7
1993.01.15	Kushiro Oki	7.8
1993.07.12	Hokkaido Nansei Oki	7.8
1994.10.04	Hokkaido Tohou Oki	8.2
1994.12.28	Sanriku Haruka Oki	7.6
1995.01.17	Hyogoken Nanbu	7.3

Y/M/D	NAME	M
2000.10.06	Tottori Ken Seibu	7.3
2001.03.24	Geiyo	6.7
2003.05.26	Sanriku Minami	7.1
2003.07.26	Miyagiken Hokubu	6.4
2003.09.26	2003Tokachioki	8.0
2004.10.23	Niigata Ken Chuetu	6.8
2005.03.20	Fukuoka Ken Seihou Oki	7.0
2007.03.25	Noto Peninsula	6.9
2007.07.16	Niigata Ken Chuetu Oki	6.8
2008.06.14	Iwate・Miyagi Nairiku	7.2
2011.03.11	Tohoku Pacific	9.0



Volcanic deposits damaged due to recent great earthquakes in Japan

The Great East Japan Earthquake struck Japan on March 11, 2011

(*Tohoku Pacific* * the Japan Meteorological Agency)

Extensive Complex Disaster

Gigantic Earthquake, Gigantic *Tsunami*,
Unexpected accident in Nuclear Plants

Death toll	15,861
Missing	3,018
Disaster-related death*	1,407

on June 13 2012 (the Japanese National police Agency)

Failure of wharf in Port of Onagawa Miyagi Pref.

Minami Sanriku, Miyagi Pref.

Majestic seawall with height of around 10m and length 501m
Tarou, Miyako city, Iwate Pref.

Seawalls constructed
Tarou, Miyako, Iwate Pref.

Seawalls
Tarou, Miyako, Iwate Pref.

Collapse of seawall
Tarou, Miyako, Iwate Pref.

Breakwaters fell down,
Yamada Town, Iwate Pref.

Breakwaters collapsed, Yamada Town, Iwate Pref.


Collapse of new houses due to slope foundation failure in the Aoba-Ku, Sendai City


Foundation soil in Aoba-Ku,Sendai


Situation of town damaged after the tsunami in Arahama, Wakabayashi-Ku, Sendai city

Flooded area due to Tsunami estimated by the Geospatial Information Authority of Japan

Provided by Dr. Yokota , Soil Laboratory, NEXCO Research Center

Tsunami visiting to Sendai International Airport

Japan Coast Guard

Iwate-Miyagi Nairiku Earthquake

June 14 2008
Mw=7.2
Depth 7.77km
N latitude 39° 1.79´
E longitude 140° 52. 84´

Big volcanic mountain area disaster with huge landslide and mud flow caused in northern Japan (Tohoku Area)

Gigantic landslides in Aratosawa Dam induced big mud flow
Iwate-Miyagi Nairiku Earthquake 2008

Head area in the landslide in Aratosawa Dam
Iwate-Miyagi Nairiku Earthquake 2008

Collapse of Matsurube Bridge constructed in the volcanic mountain area
Route 342, National Road Iwate-Miyagi Nairiku Earthquake 2008

Failure of Road constructed on volcanic area
Iwate-Miyagi Nairiku Earthquake 2008

Niigata Earthquake
June 16 1964
Mw=7.5

It was not until 1964 when liquefaction came to be considered seriously by engineers.

Scientific studies on mechanism and prediction of liquefaction as well as remedial measures were properly commenced.

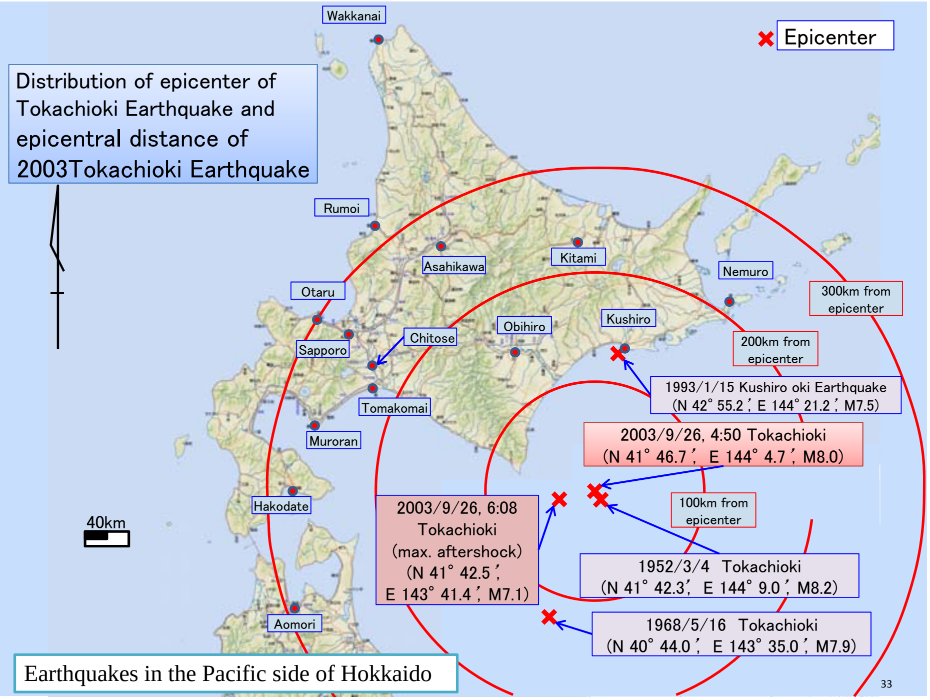
Falling of Showa Bridge due to subsoil liquefaction in Shinano River 1964 Niigata Earthquake

Inclined apartment buildings due to liquefaction 1964 Niigata Earthquake

2003 Tokachioki Earthquake

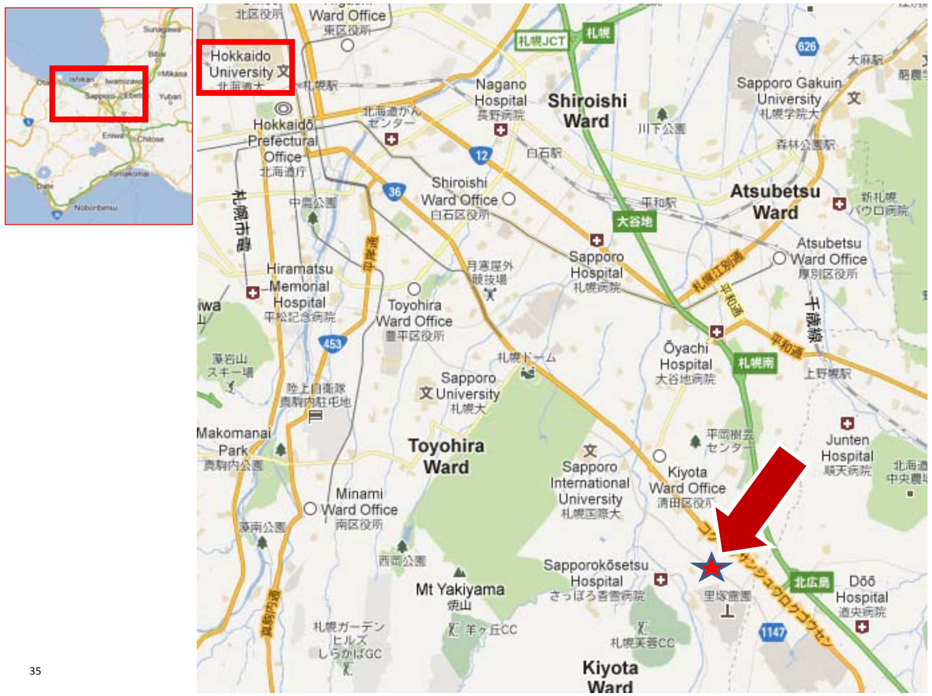
【Main Shock】 4:50AM Sep.26 2003
$Mw = 8.0$
Epicenter: N latitude 41° 46′
E longitude 144° 04′
Depth : 42km

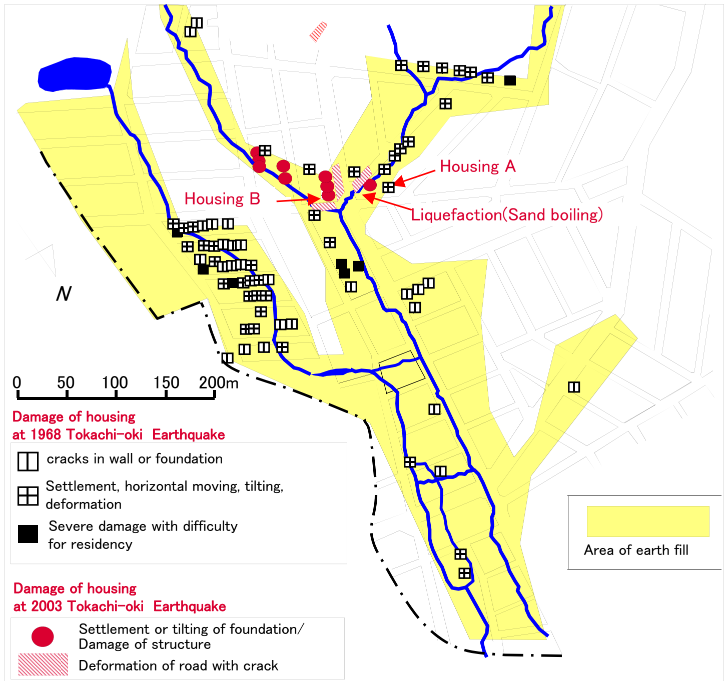
【Aftershock (max)】 6:08AM Sep.26 2003
$Mw = 7.1$
Epicenter: N latitude 41° 42′
E longitude 143° 41′
Depth : 21km

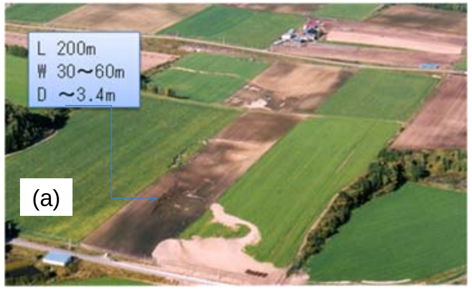


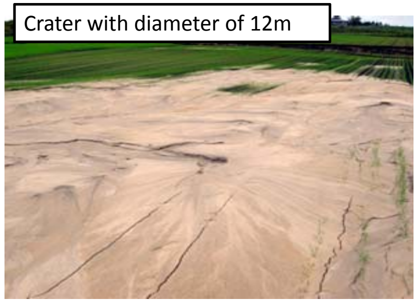
Boiling of volcanic soil (Spfl) at Sapporo City due to 2003 Tokachioki Earthquake: (a) Housing Site, (b) City St.

Collapse of house with tilting angle of 5°

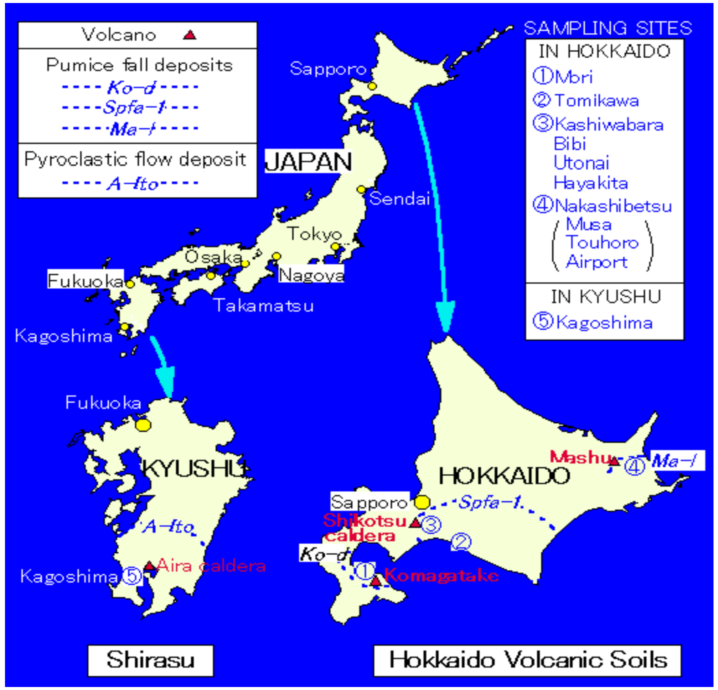


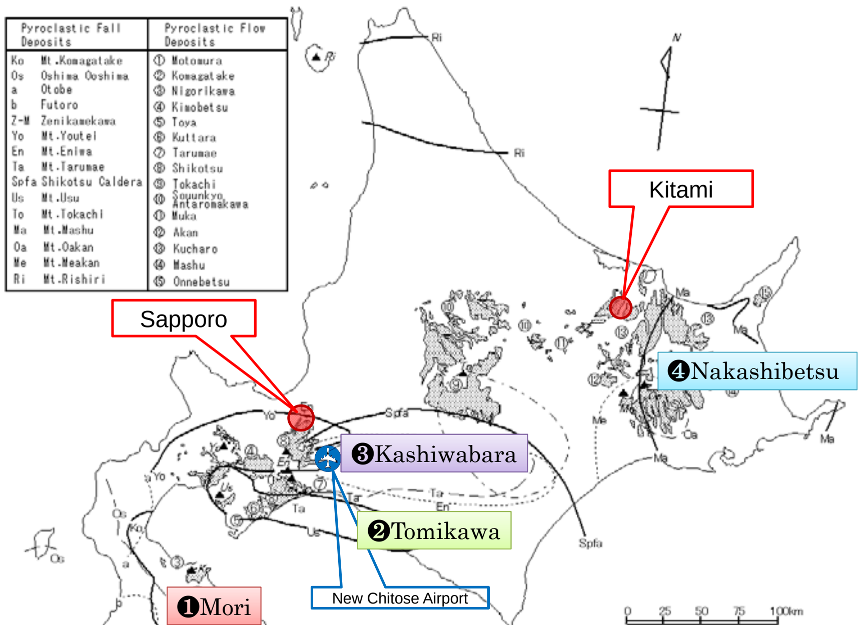






Big liquefaction occurrence of volcanic ground (Kcfl) at Kitami agricultural site due to 2003 Tokachioki Earthquake:
(a) overview of farmland,
(b) subsidence and uplift of farmland induced by liquefaction





Distribution of pyroclastic deposits in Hokkaido and sampling locations of soils discussed

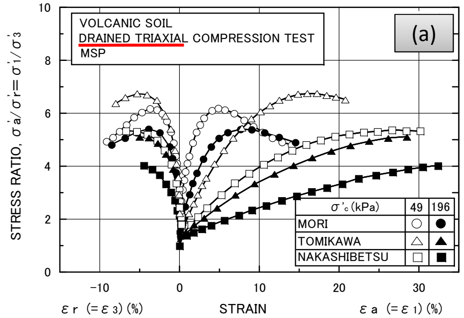
Sample name	ρ_s (g/cm³)	$\rho_{d\ IN\text{-}SITU}$ (g/cm³)	D_{50} (mm)	U_c	F_c (%)
❶Mori	2.82	1.49	0.64	2.3	0.2
❷Tomikawa	2.22	0.49	1.1	2.8	1.0
❸Kashiwabara	2.34	0.53	1.3	3.1	1.3
Bibi	2.28	0.65	1.4	4.0	1.4
❹Nakashibetsu *(Musa)*	2.51	0.41	4.6	5.1	1.6
Touhoro	2.56	0.45	6.6	6.0	2.1
Toyoura sand	2.65	-----	0.18	1.1	—

❶ MORI VOLCANIC SOIL

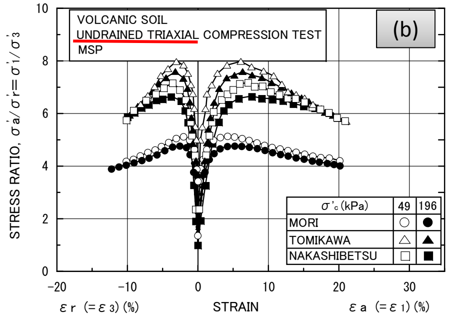
❷ TOMIKAWA VOLCANIC SOIL

❸ KASHIWABARA VOLCANIC SOIL

❹ NAKASHIBETSU VOLCANIC SOIL



(a)Drained condition



(b)Undrained condition

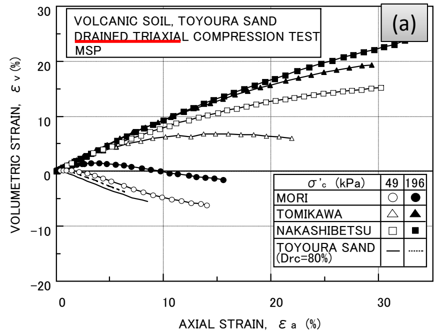
Triaxial stress-strain relationship on Hokkaido Volcanic soils

Sample name	Principal strain ratio $-(\varepsilon_3/\varepsilon_1)_f$			
	σ_c'=49kPa	σ_c'=98kPa	σ_c'=196kPa	σ_c'=392kPa
Mori	0.69	0.48	0.47	0.41
Tomikawa	0.30	0.25	0.17	0.14
Kashiwabara	0.27	0.22	0.17	0.05
Bibi	0.36	0.29	0.24	0.19
Nakashibetsu	0.23	0.18	0.13	0.08
Touhoro	0.23	0.17	0.15	0.13

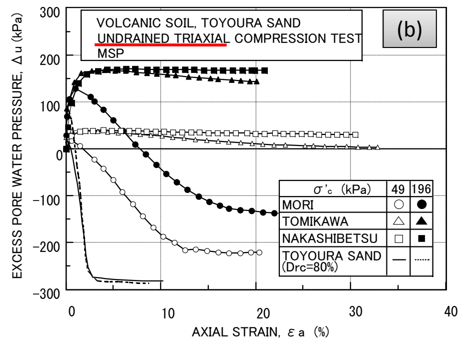
Peculiar deformation behavior of volcanic soils

Principal strain ratio development during triaxial compression

【Volcanic coarse-grained soils, except for Mori volcanic soil come to the failure under the condition for restricting deformation in the radial direction of triaxial specimen】

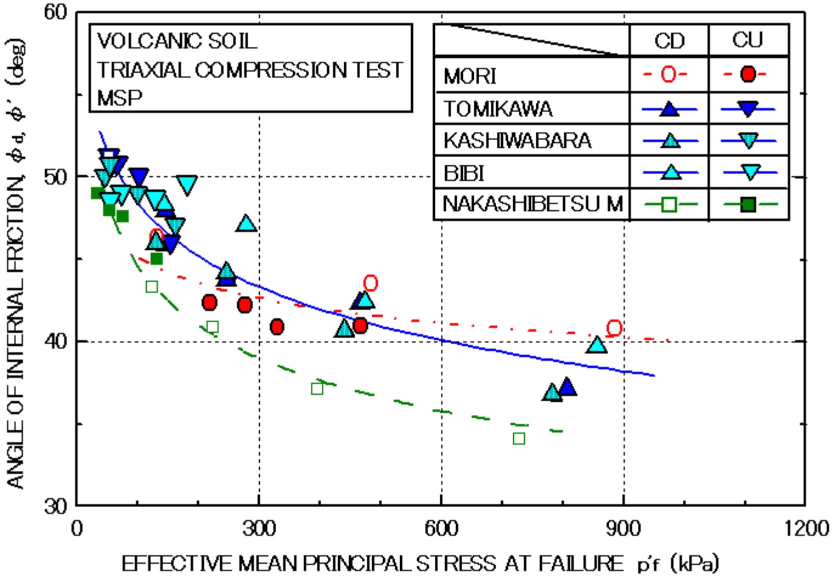


(a)Drained condition

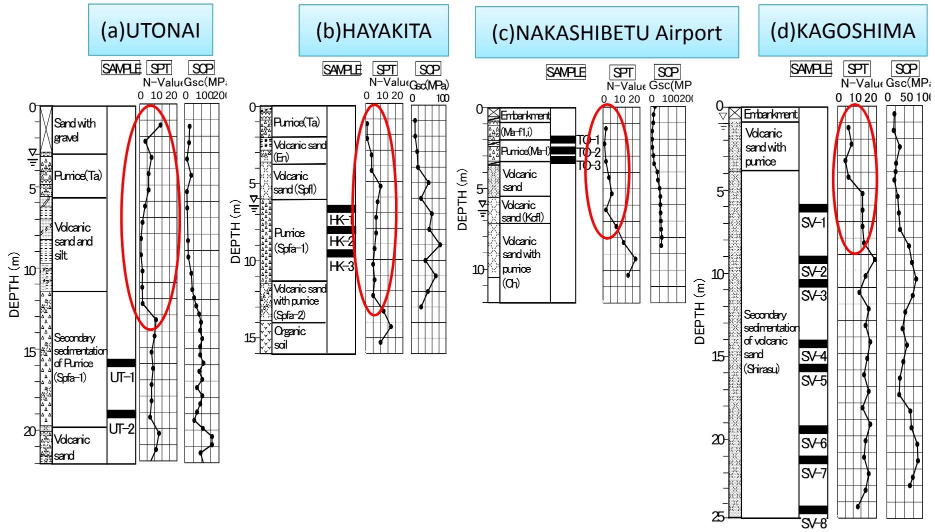


(b)Undrained condition

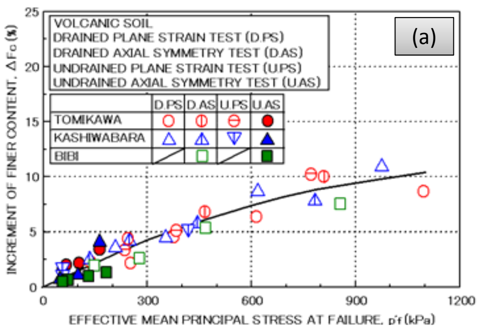
Dilatancy and pore water pressure behavior for Hokkaido Volcanic soils



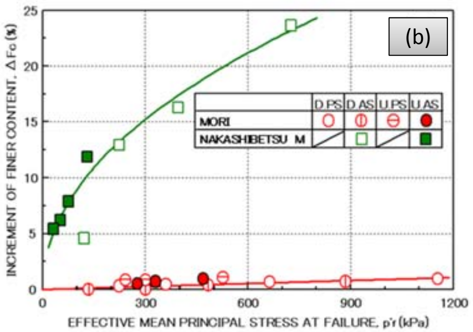
Dependency of ϕ_d and ϕ' on effective mean principal stress



Typical soil profiles and in-situ test results
Hokkaido and Kagoshima, Kyushu

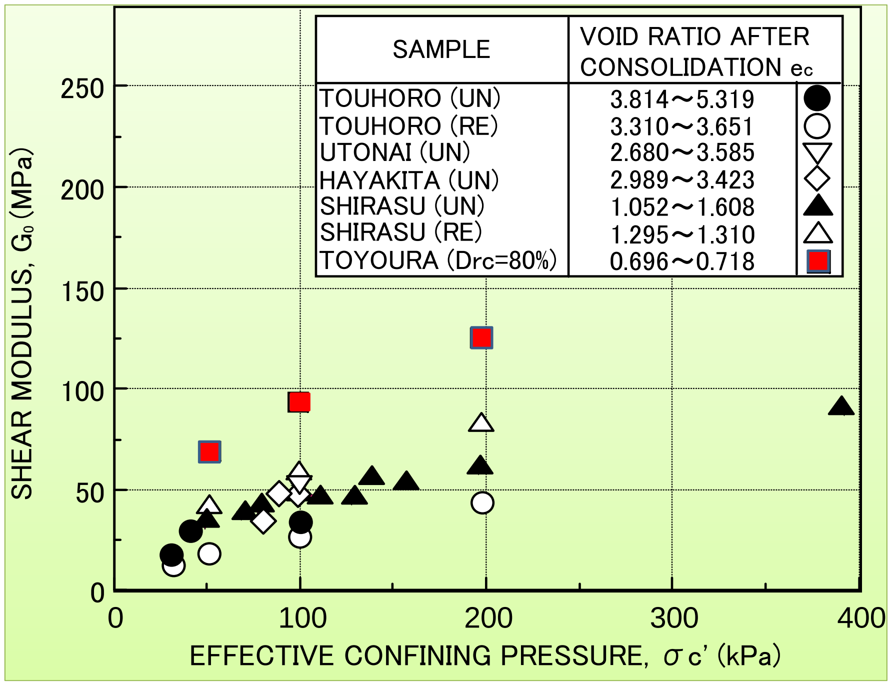


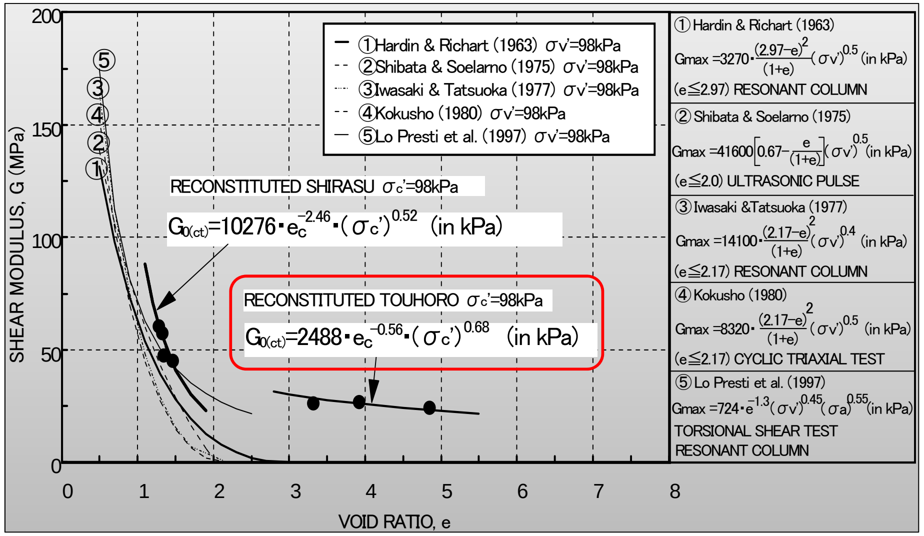
(a) ❷Tomikawa and Kashiwabara
❸Bibi



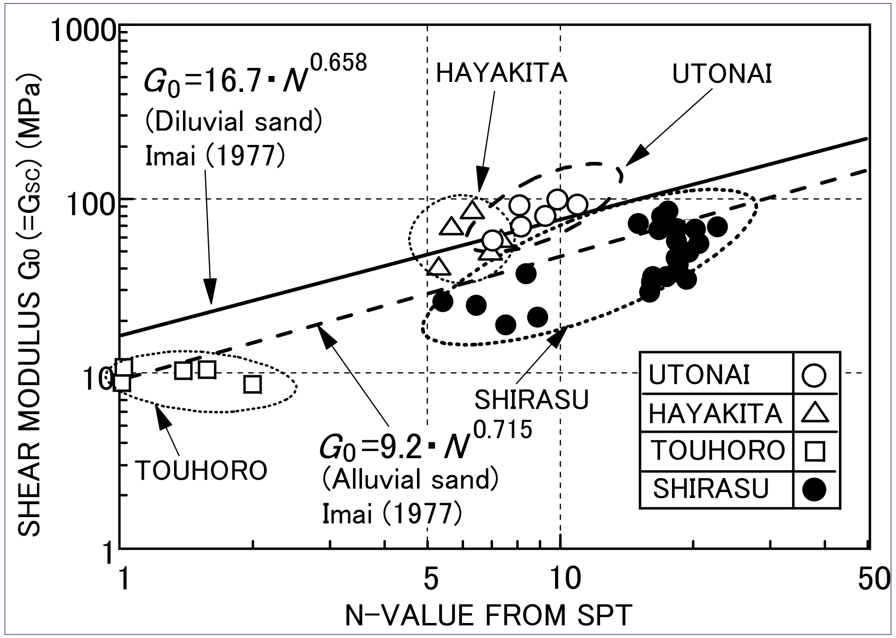
(b)❶Mori
❹Nakashibetsu

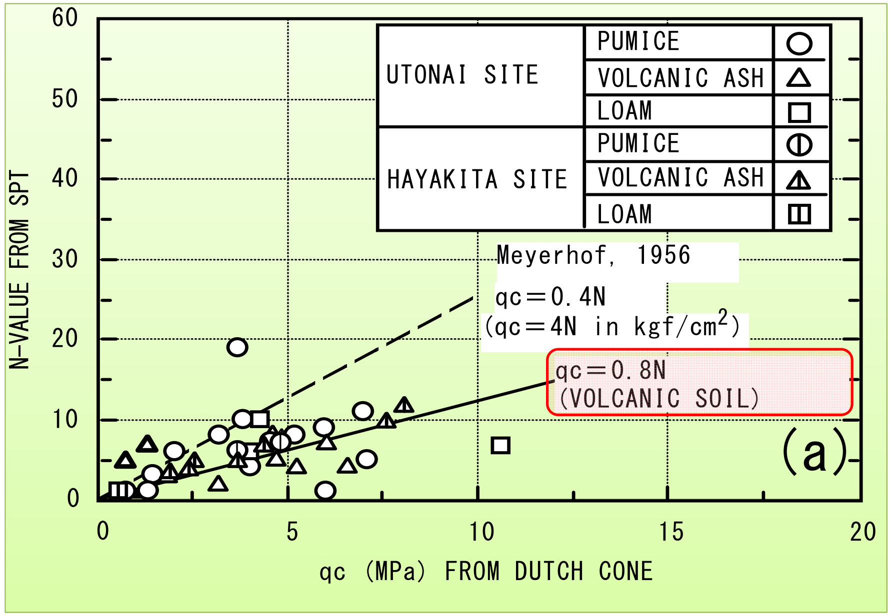
Change in Δ Fc with increase of effective mean principal stress for volcanic soils





Small strain shear modulus G related to void ratio for volcanic soils





Relationships between N value and cone penetration test results

SUMMARY

1. Recent earthquakes-induced damages of volcanic grounds

- Tokachioki Earthquake(1968,2003), Iwate-Miyagi(2008) and the Great East Japan Earthquake(2011) caused ground damages such as liquefaction, extremely huge landslides, debris flows and slope failures. Especially, in the volcanic inland of Tohoku district, gigantic geotechnical damages were induced.
- Earthquake-induced risk such as liquefaction is high in not only sand ground but in volcanic soil ground.
- Occurrence of liquefaction damages was concentrated on the urban areas developed by filling volcanic coarse-grained material.

We must keep in mind that the Japanese archipelago has apparently entered a period of unusually frequent seismic activity.

2. Distribution and engineering characteristics

- Japan has a variety of volcanic ash soils that cause complicated and peculiar geotechnical engineering problems in all the regions of the islands.

- From the laboratory test on such soils,
  #crushing of particles due to consolidation and shearing becomes important.
  #strong contractive behavior in the crushable volcanic soils is mainly attributed to particle crushing due to shear.

- Difference of strength, especially liquefaction potential, between undisturbed and reconstituted volcanic specimens is far bigger than that of usual sand deposits.

This indicates that the in-situ cementation effect on liquefaction strength and shear modulus is important for volcanic soils.

3. Small strain shear behavior

- Shear modulus of volcanic soils can be expressed as a function of confining pressure and void ratio as for the case of usual sand.
- Compared to Toyoura sand and Shirasu, the dependence of shear modulus on void ratio is insignificant in volcanic soils.

This is due to that the void ratio of pumice is extremely high by the existence of many intra-particle voids.

4. In-situ testing on volcanic ground

- In grounds composed of crushable volcanic soils, particle crushing is induced owing to the intrusion of the sampler at the SPT.

This leads to the underestimation of N value for crushable grounds.

Thank you for your kind attention

ありがとう