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Measuring the Groundwater Level Using a Hole of the Swedish Weight Sounding Test

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ABSTRACT

This paper introduces the groundwater measurement technique using the Swedish Weight Sounding (SWS) test holes and a foraminate pipe. This new technique has advantages that the steady groundwater level can be measured in a very short time (within the SWS test time in home site ground).The accuracy was found to be satisfactory.

KEY WORDS: Swedish Weight Sounding (SWS) test, Liquefaction, Groundwater level, Foraminate Pipe, Alternating Current (AC) Resistivity sensor

INTRODUCTION

The Swedish Weight Sounding (SWS) test is a simple but popular method for evaluating the ground bearing capacity in home site, and it is required in Japan by law to check the harmful subsidence and displacement of buildings caused by liquefaction due to earthquake.

The authors focused on the groundwater level for the liquefaction evaluation and developed a new measurement technique using the SWS test hole and a foraminate pipe. In this paper, results of in-situ experiments using the new technique are described.

THE POSSIBILITY OF LIQUEFACTION ASSUMED BY GEOGRAPHICAL FEATURES

In Japan, the possibility of liquefaction of the ground surface is classified to three categories such as Large (L), Medium (M), and Small (S). Those are determined by the topographical map and geographical features of the site as shown in Fig.1 and Table 1 (AIJ, 2008). However, since the groundwater level is essential information when considering the possibility of liquefaction, the development of the simple monitoring method is necessary.

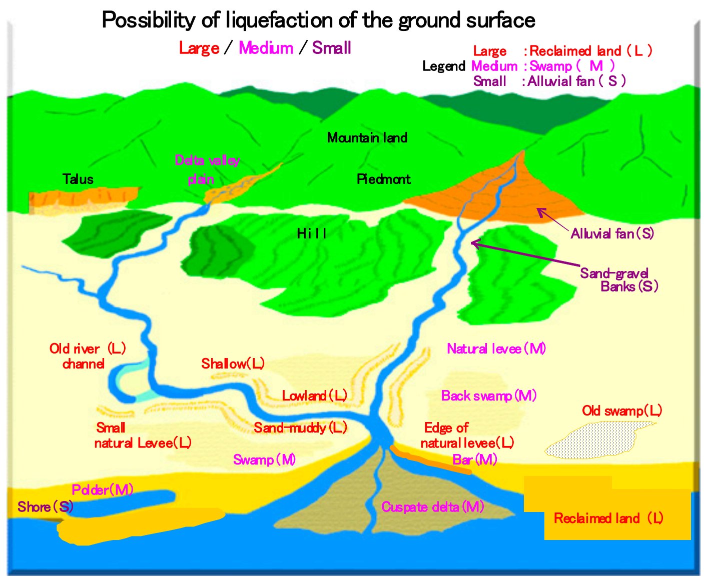

Fig.1 Topographical map

Table 1 Geographical features (AIJ,2008)

Possibility of liquefaction of the ground surface	Geographical features
Large (L)	Edge of natural levee, Small natural Levee, Shallow,Old river channel,Old swamp, Sand-muddy, Gentle in dune, Artificial shore, Low land in dune, Low land, Reclaimed land,Inflow water,Embankment
Medium (M)	Delta valley plain, Alluvial fan of gentle slope, Natural levee, Back swamp, Swamp, Cuspate delta, Bar, Polder
Small (S)	Delta plain of fan type, Alluvial fan, Sand-gravel banks, Dravel bar, Dune, Shore

SIMPLE METHOD FOR LIQUEFACTION JUDGMENT WITH REGARD TO THE GEOGRAPHIC FEATURES FOR MIDDLE LEVEL EARTHQUAKE

(Ground surface acceleration reference value: 150 to 200cm/s^2)

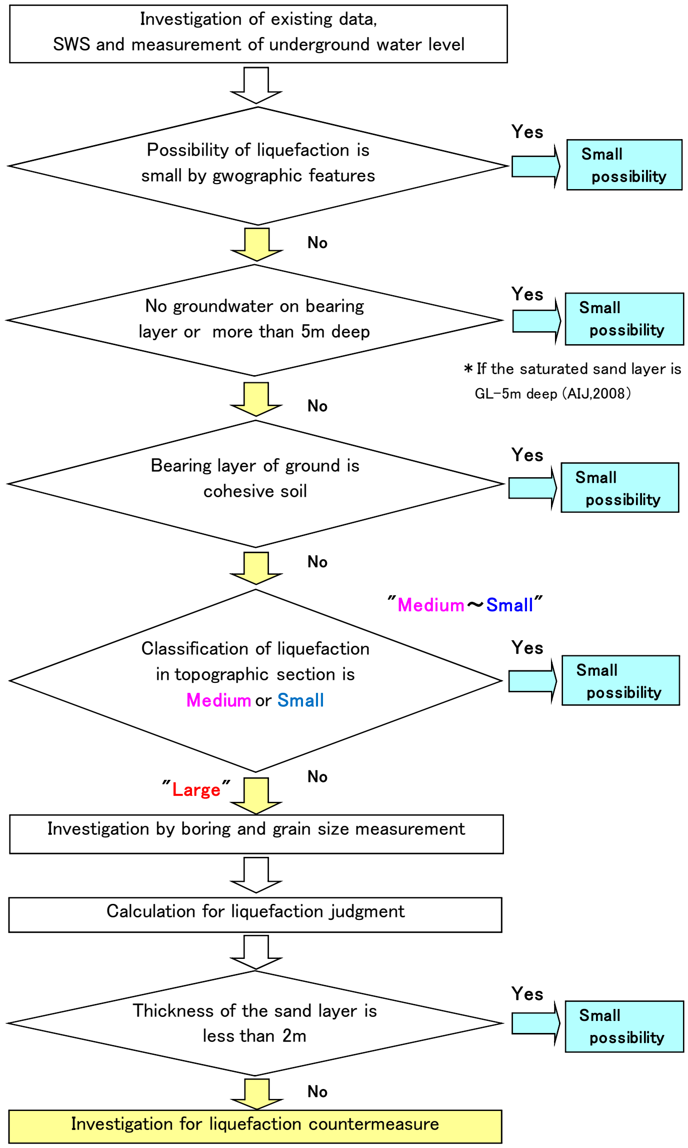

Fig.2 Flow-Chart of liquefaction judgment

METHOD OF MEASURING THE GROUNDWATER LEVEL

As shown in Table 2, measuring the groundwater level using the SWS test hole is not established at present, and it is significant to develop the new technique.

Technique for Measuring the Groundwater Level Using SWS Test Hole

- Penetration and measurement of 10m deep in ground are possible.
-Using the Alternating Current (AC) resistivity sensor, the water level of sand, silt, and clay ground can be measured easily and accurately.
-Accurate ground water level can be measured without water and slurry penetration.

Table 2 Typical results obtained by boring and sounding tests (JGS,2004)

Investigation methods \ Results		Geological structure	Ground condition	Physical property	Chemical property	Groundwater Permeability	Compaction ＊	Consolidation	Strength	Bearing capacity	Deformability
Boring・Sampling		◎	◎	○	○	◎	○	○	○	○	○
Sounding	Standard penetration test		○	○					○	○	
	Portable dynamic cone penetration test		○	○					○	○	
	Swedish weight sounding		○	○		★			○	○	
	Portable cone penetration test		○						○		
	Dutch cone penetration test		○						○		
	Electric cone penetration test		○						○		
	In−situ vane shear test								◎		
	Borehole lateral load test								○		◎

◎:Direct, ○:Indirect, ＊:Unsaturated condition

(★Proposed in this paper)

Photo 1
Overall view of measuring the underground water level

Photo 2
AC sensor with a small diameter cable

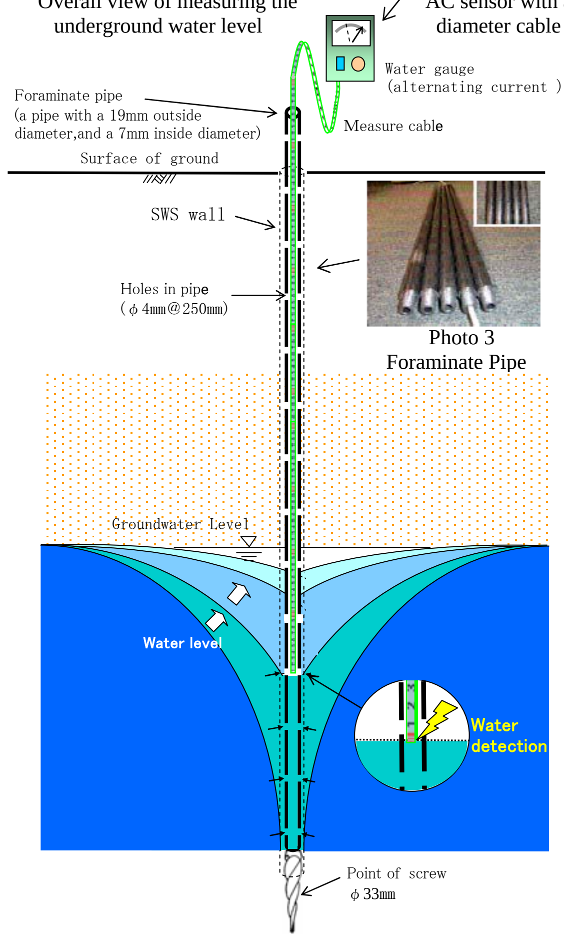

Fig.3 Image of how the AC resistivity sensor works

REASONS FOR USING THE GROUNDWATER LEVEL MONITOR OF AC RESISTIVITY SENSOR

As a diameter of the foraminate pipe is 7mm and so small, the bubble tends to remain in the pipe and may make a mistake for measuring the groundwater level. Additionally, in case of saturated silt ground, sometimes the bubble remains below the groundwater level. In this point of view, minor changes of the groundwater level should be measured accurately when using the foraminate pipe. After several experiments, it was turned out that the Alternating Current (AC) resistivity sensor is more accurate than the Direct Current (DC) resistivity sensor.

G.W.L.
Monitor ------AC signal ---Analog Meter (best for accuracy and readability)
-Digital Meter (inappropriate for readability)
-DC signal ---Analog Meter (inappropriate for accuracy)
-Digital Meter (inappropriate for accuracy)

Photo4 AC resistivity sensor

Direct Current (DC) Resistivity Sensor

In the DC resistivity type, the resistance increases more than 25% in a very short time due to the electrolysis (gas generation) in the electrode. When the electrode is slightly moved in the water, the same phenomenon occurs and the measurement data become unstable.

Ground Water Level Monitor

As the sensitivity control is bad, several errors of the underground water level were observed. In order to measure the minor change of the resistance when reaching the underground water, the analogue meter system with properly adjusted time was found to be effective and appropriate in terms of readability. At present, however, the monitor using the analogue meter system is not available in the market in Japan.

Monitor of Market Product

As the resistance measured by the DC resistivity type is unstable due to the electrolysis, the sensitivity and reliability are not good.

Alternating Current (AC) Resistivity Sensor

In the AC resistivity type, electrolysis does not occur and the sensitivity and reliability are found to be excellent. In order to measure the minor change of underground water level using the foraminate pipe, it is turned out that the AC resistivity sensor is most effective. As such a monitor is not available in the market in Japan, the authors developed the original "Groundwater level monitor of the AC resistivity sensor".

METHOD OF THE IN-SITU EXPERIMENT

Outline of in-situ experiment using the "Groundwater level monitor of the AC resistivity sensor" is shown in Fig.4. The SWS tests at two points of 1m distance from the center point were carried out, and polyvinyl chloride pipes (PVC13; 5mm thickness with holes of φ4mm@250mm) were inserted to observe the underground water level. A few hours later, the steady groundwater level was obtained in the pipes, and the foraminate pipe was inserted as the similar way to the SWS tests in the center point in order to confirm the accuracy of the AC resistivity sensor.

Measurement using the AC resistivity sensor was implemented as soon as the screw point could not penetrate into the soil anymore, and both elapsed time and change of the water level in the foraminate pipe were recorded until recovery of the steady groundwater level was obtained. Measurement of the water level was performed using the AC resistivity sensor with a small diameter cable, which was inserted into the foraminate pipe.

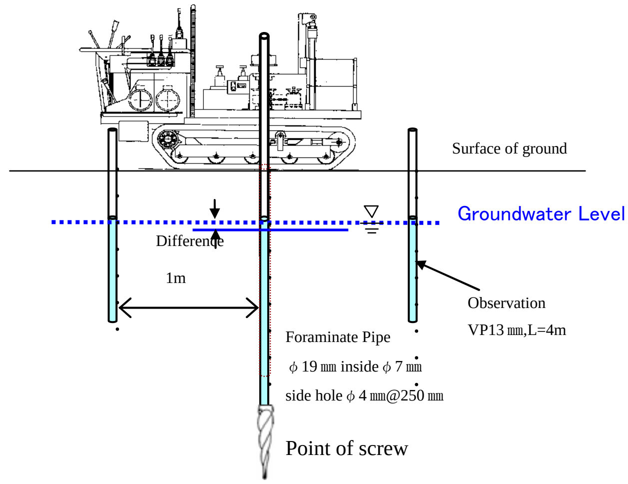

Fig.4 Method of the in-situ experiment

Table 3 Summary of the results obtained from the in-situ experiment

Area	No.	Site	soil classification	Geographical Features	Possibility of Liquefaction	Boring Data	Depths of the G.L.- m	Groundwater level Normal W.L. G.L.- m	Differ Ence ㎝	Settling Time (min)
Touhoku	1	Ohmagari, Miyagi	sandy soil	Lowland	large	–	3.00	1.53	0	25
	2	Higashimatushima, Miyagi	sandy soil	Lowland	large	–	3.20	1.10	1	5
	3	Yamagata, Yamagata	clay	marsh	medium	–	10.00	0.57	0	20
	4	Yabukimachi, Fukushima	granular sand	Lowland	large	○	5.97	2.39	1	15
Hokusintsu	5	Higashi, Niigata	sandy soil	backswamp	medium	–	3.50	3.02	1	1
	6	Komathu, Ishikawa	sandy soil	backswamp	medium	–	10.00	0.57	0	10
Kitakanto	7	Kanuma, Tochigi	clay	marsh	medium	–	10.00	1.84	0	3
	8	Hokota, Ibaraki	clay	marsh	medium	–	10.00	0.53	1	12
Kanto	9	Syoubumachi, Saitama	clay	marsh	medium	–	4.25	1.11	0	3
	10	Souka, Saitama	clay	backswamp	medium	–	10.00	0.67	0	10
	11	Hanamigawa, Chiba	clay	plateau of loam	very small	–	10.00	3.79	0	2
	12	Funabashi, Chiba	granular sand	marsh	medium	○	10.00	0.85	0	3
	13	Higashimurayama, Tokyo	sandy soil	plateau	-	○	2.25	(3.0)	-	-
	14	Hachiouji, Tokyo	sandy soil	hill	-	–	6.00	(9.2)	-	-
	15	Sumida, Tokyo	sandy silt	backswamp	medium	–	10.00	1.30	0	2
	16	Adachi, Tokyo	fine sand～silt	backswamp	medium	○	10.00	0.41	0	15
	17	Edogawa, Tokyo	sandy silt	backswamp	medium	○	8.95	1.12	0	2
	18	Katushika, Tokyo	sandy silt	backswamp	medium	○	10.00	1.23	0	1
Nishikanto	19	Fuefuki, Yamanashi	sandy soil	Lowland	large	–	2.80	2.40	1	5
	20	Fuefuki, Yamanashi	silty sand	Lowland	large	○	5.35	3.99	1	5
Tokai	21	Fujieda, Shizuoka	clay/gravel	alluvial fan	large	–	5.95	0.90	0	3
	22	Hamamatu, Shizuoka	sandy soil	natural levee	medium	vicinity	3.50	1.82	2	15
	23	Ibaraki, Oosaka	sandy silt	backswamp	medium	–	9.75	1.02	0	8
	24	Gifu-shi, Gifu-ken	sandy silt	backswamp	medium	–	7.95	0.62	1	30
Kinki	25	Ibaraki, Oosaka	sandy soil	backswamp	medium	vicinity	4.25	0.40	0	5
Chugoku	26	Kurashiki, Okayama	silty sand	alluvial fan	large	○	10.70	1.12	0	5
	27	Kita, Okayama	sand with clay	alluvial fan	large	vicinity	10.00	1.04	1	5
Kyushu	28	Kurume, Fukuoka	sandy silt	deltaic plain	medium	○	12.75	1.72	4	30
	29	Karatu, Saga	sand～silt	backswamp	medium	○	5.00	1.98	0	3
	30	Maebaru, Fukuoka	sandy soil	backswamp	medium	○	10.00	1.83	0	5
	31	Kumamoto, Kumamoto	silty sand	backswamp	medium	vicinity	10.00	1.28	0	1
	32	Airamachi, Kagoshima	granular sand	Lowland	large	○	9.50	1.11	0	3

※ Soil classification is carried out using datum of borings and rod point conditions.
( ) means assumed water level by wells of vicinity.

RESULTS OF THE IN-SITU EXPERIMENT IN FUKUSHIMA PROVINCE

Fig.5 and Fig.6 show the example of measuring the groundwater level in Fukushima. Soil profile near the groundwater level was sand-gravel and its groundwater level was -2.39m, and it is observed that the settling time of measurement was around 15 minutes.
Fig.7 (a) and Fig.7 (b) show the observed settling time from the in-situ experiments, for those cases that the groundwater levels are (a) less than 1m and (b) more than 1m deep.

From the experiments, in case of sandy soil with more than 1m deep of groundwater level, the average settling time was observed around 10 minutes. On the other hand, in case of low permeability soil such as silt, it is understood that the settling time increases comparing with sandy soil.

Fig.7 (a) and Fig.7 (b) illustrate the relationships between groundwater level and the elapsed time in No.24 (Gifu) and No.28 (Kurume) respectively. In these sites, settling time of more than 30 minutes was necessary as silt soil flowed into the pipe. From the results mentioned above, the settling time in all of the sites was within 30 minutes, and settling time depended on only soil classification and was not influenced by the groundwater level.

An Example of the Result

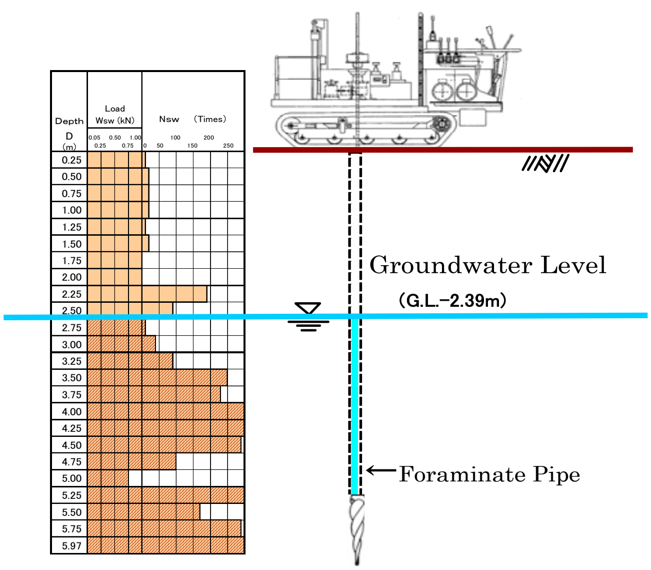

Fig.5 Results of the in-situ experiment in No.4 Fukushima province

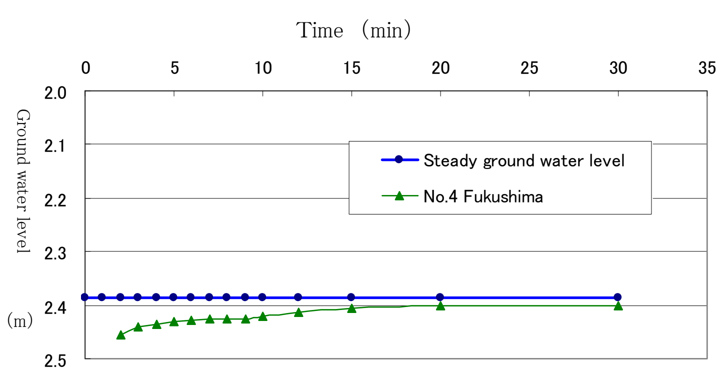

Fig.6 Relationship between G.W.L. and the elapsed time
(No.4 Fukushima province)

Results at Other Sites

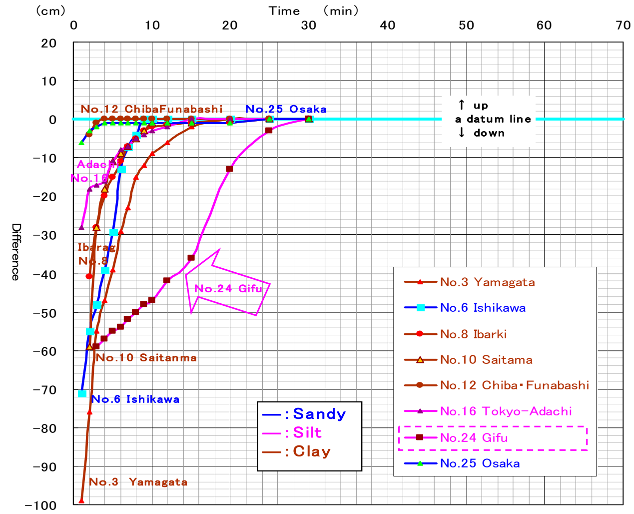

Fig.7 (a) Relationship between G.W.L. and the elapsed time
(Less than GL-1.0m)

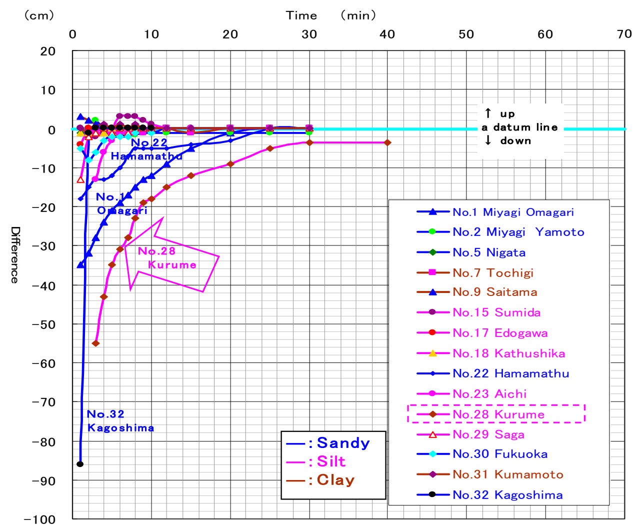

Fig.7 (b) Relationship between G.W.L. and the elapsed time
(More than GL-1.0m)

SUMMARY

The authors developed the groundwater measurement technique using the SWS test holes and a foraminate pipe. This new technique has an advantage that the steady ground water level can be measured in a very short time (within the SWS test time in home site ground).

In the next step, the authors will carry out laboratory tests to investigate the settling time to obtain steady water level for several soil types, especially sandy soil, which may cause liquefaction by the middle level earthquakes.

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