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Estimation of liquefaction using Hachinohe geotechnical information and upgrade of that system

*Yutaka HASHIZUME[1)] Naoki OYAMA[2)] and Kenji KANEKO [3)]

[1), 2), 3)] *Department of Civil Engineering, Hachinohe Institute of Technology, Aomori, Japan*
[1)] hashizume@hi-tech.ac.jp

ABSTRACT

In land bordering the Pacific in the Tohoku area and Kanto area of Japan, a lot of liquefaction occurred by The 2011 off the pacific of Tohoku earthquake. There are three principal factors in liquefaction damage. Those are Looseness of sandy soil, Height of groundwater level And Predominance of same soil particle size including Particle size distribution. When we estimate liquefaction risk, geotechnical information is very important data. In Hachinohe area, geotechnical information data base was constructed in 2009. So we can get geotechnical information easily. In this study, we think that estimation liquefaction risk make a remarkable contribution to prevent liquefaction. We estimate liquefaction risk using 2507 measurement sites of boring log from Hachinohe area geotechnical information data base. Then enter the those point on Hachinohe local area map, which shows distribution of liquefaction risk. And we make some comparative calculation which are adopted different seismic intensity.

The last year, The geotechnical information data base system was renewed like that the PL-Value will be calculated automatically, when the boring-log data will be registered.

And the system is changed that anyone can check as a distribution map which was classified by color.

1. INTRODUCTION

Sometimes liquefaction damage in Urayasu Chiba Prefecture by The 2011 off the pacific of Tohoku earthquake was widely reported, Interest in liquefaction is increasing. It is generally known that There are three principal factors in liquefaction damage. Those are Looseness of sandy soil, High groundwater level and Predominance of same soil particle size including particle size distribution. In each case, ground conditions are the main factor. Therefore when we estimate liquefaction risk, geotechnical information is very important data.

On the other hand, in Hachinohe area the local geotechnical information data base was constructed. In Hachinohe area because there was liquefaction damage in the past, we think that estimation liquefaction risk make a remarkable contribution to prevent liquefaction.

[1)] Post-Doctoral Fellow
[2)] Graduate Student
[3)] Professor

In this study, we estimate liquefaction risk using 2507 measurement sites of boring log from Hachinohe area geotechnical information data base. Then enter the those point on Hachinohe local area map, which shows distribution of liquefaction risk. And we make some comparative calculation which are adopted different seismic intensity.

2. THE RAPID INDENTIFICATION METHOD OF LIQUEFACTION ACCORDING TO SPECIFICATIONS FOR HIGHWAY BRIDGES

Liquefaction index P_L was calculated according to specifications for highway bridges part V seismic designs as shown in Eq. (1)

$$P_L = \int_0^{20} (1 - F_L) \times W_Z \, dz \tag{1}$$

indicates a safety factor of each soil layer. So It is calculated by the earthquake shear stress ratio L and dynamic shear strength ratio R.

$$F_L = R / L \tag{2}$$

In the case of the F_L value is greater than or equal to 1.0, the F value will be defined 1.0. W_z is the weight coefficient by each layer's depth and calculated in Eq. (3)

$$W(z) = 10 - 0.5z \tag{3}$$

2.1 Calculation of the Dynamic shear strength ratio R

The dynamic sheer strength ratio R is calculated in Eq. (4)

$$R = C_w \times R_L \tag{4}$$

where C_w=modification coefficient reflecting characteristics of earthquake motion; R_L=undrained cyclic shear resistance. Normally R_L is determined by the experimental values, in this study R_L is calculated by N-value from geotechnical information database. As shown by Eq. (5)

$$R_L = \begin{cases} 0.0882\sqrt{N_a/1.7} & N_a < 14 \\ 0.0882\sqrt{N_a/1.7} + 1.6 \times 10^{-6}\left(N_a - 14^{4.5}\right) & N_a \geqq 14 \end{cases} \tag{5}$$

In case of sandy soil, N_a is calculated as Eq. (6) ~Eq. (9) and in case of gravelly soil, N_a is calculated as Eq. (10)

$$N_a = C_1 \times N_1 + C_2 \tag{6}$$

$$N_1 = 1.7N/(\sigma'_v + 0.7) \tag{7}$$

$$C_1 = \begin{cases} 1 & (0\% \leqq F_C < 10\%) \\ (Fc + 40)/50 & (10\% \leqq F_C < 60\%) \\ F_C/20 - 1 & (F_C \leqq 60\%) \end{cases} \tag{8}$$

$$C_2 = \begin{cases} 0 & (0\% \leqq F_C < 10\%) \\ (F_C - 10)/18 & (10\% \leqq F_C) \end{cases} \tag{9}$$

$$N_a = \{1 - 0.36 \times \log_{10}(D_{50}/2)\} N_1 \tag{10}$$

where N=N-value from standard penetration test; N_1=converted N-value to effective overburden pressure equal 1.0kgf/cm^2; N_a =corrected N-value by considering the effect of soils particle size; C_1 and C_2= correction factor of N-value which were considering to fine fraction content ratio; F_C= fine fraction content ratio; D_{50}=average grain size.

2.2 Calculation of the earthquake shear stress ratio L

The earthquake shear stress ratio L is calculated in Eq. (11)

$$L = d \times k_{hc} \times \sigma_v / \sigma'_v \quad (11)$$

where k_{hc} is the design horizontal seismic coefficient and defined as Eq. (12)

$$k_{hc} = C_z \times k_{hc0} \quad (12)$$

$$d = 1.0 - 0.015z \quad (13)$$

where k_{hc0} is the standard design seismic coefficient and selected from table 1; d= the Reduction coefficient of the Dynamic shear strength ratio by each layer's depth.

Table 1. Standard design seismic coefficient k_{hc0}

		Seismic ground motion type	
		Type I	Type II
Ground soil type	Type I	0.30	0.80
	Type II	0.35	0.70
	Type III	0.40	0.60

Seismic ground motion type I means the infrequent large scale ground motions in plate boundary. Type II means the inland near-field earthquake ground motions. and also we Classified the ground into 3 types according to specifications for highway bridges part V seismic designs. Ground type I means good condition diluvial ground and bedrock. Type III means Soft ground in the alluvial ground. And type II means the ground it is not either type I and type II. Where σ_v = the overburden pressure; σ'_v = the effective overburden pressure; there are follow as Eq. (14) and Eq. (15)

$$\sigma_v = \{\gamma_{t1} \times h_w + \gamma_{t2}(z - h_w)\}/10 \quad (14)$$

$$\sigma'_v = \{\gamma_{t1} \times h_w + \gamma'_{t2}(z - h_w)\}/10 \quad (15)$$

Where γ_{t1}=the unit weight of soil above the groundwater level; γ_{t2}=The unit weight of the soil deeper than groundwater level; γ'_{t2} =The effective unit weight of the soil deeper than groundwater level; h_w=the depth of groundwater level.

2.3 Parameters

Usually such data has been recorded on the ground information database contains the N value, However many those data dose not contains the unit weight of soil. Therefore in this section, how to determine the answer is shown.

If the soil unit weight is not included the information database, we Create some approximate curve of relationship between N value and unit weight in each soil by using geotechnical information database's data in the neighborhood.

And using those approximate curves, we estimated the unit weight from N value. In addition, groundwater level is also a major effect on the liquefaction index. Some data that does not contain the groundwater level Ware determined by reference to the data

of neighborhood. And Sometimes, Soil classification indicated on the bowling log has a different notation by difference of investigator. That also determined by reference to the data of neighborhood.
Some layers which dose clearly not liquefaction like a clay soil layer sets to non-liquefaction layers. But the layer which is difficult to determine of liquefaction like a sandy loam and sand mixed volcanic ash, sets to liquefaction layers. In this study, soil layer which is classified into liquefaction layer are Cohesive soil, loam, volcanic ash, organic soil, and Humus soil.

Earthquake expected the greatest damage in Hachinohe is a subduction-zone earthquake which seismic center is north part off the coast of Sanriku. Therefore we have determined that ground motion is type I. And because of the most of Hachinohe area is a alluvial plain which is soft ground of low N value, we have determined that ground soil type is type III.

For these reasons, we determined that the standard design seismic coefficient k_{hc0} is 0.4. Regional correction factor C_z is 1.0. Modification coefficient reflecting characteristics of earthquake motion C_w is 1.0

3. DISTRIBUTION OF LIQUEFACTION RISK

By the method described above, we calculated the liquefaction index PL of each point using each boring data. Table 2 shows the criteria of liquefaction potential. Also Fig. 5 shows the spatial distribution of the PL value calculated.

Table 2. Determination of liquefaction potential

$15 < P_L$	extremely high
$5 < P_L =< 15$	high
$P_L =< 5$	infrequently

From the Fig. 1, it can be seen that the value of liquefaction index P_L is high around the city center, where a high liquefaction potential is often about Hachinohe area. In particular, Large value of PL value of 40 or more are distributed along the riverbed of two rivers (riv. Mabechigawa, riv. Niidagawa) flowing down the city. Consider to the ground situation of these points, With the exception of the embankment portion that is artificially constructed, it can be clearly understood that the ground of those point is a floodplain formed by river sediment. In addition it can be understood that factors such as the height of the groundwater level and looseness of the soil has led to such a result. In other area, Kawaragi, Numadate and Sirosita area have a many point of P_L value of 40 or more, ground of those area are also alluvial lowland formed by floodplain.

Fig. 2 shows a simplified boring log typical of each area. In areas like a Kawaragi, Sirosita and Niida area where have high liquefaction risk, loose sandy soil are deposited in a place close to the surface and underground water level depth is also close to the ground surface (about 1m) , therefore Liquefaction risk is increased. In areas like a Sinminato, Shirogane and Choja area where have low liquefaction risk, there is a tendency to deposited fine-grained soil region-specific soil of Hachinohe area like a Hachinohe loam on the portion close to the surface. And also it is understood that

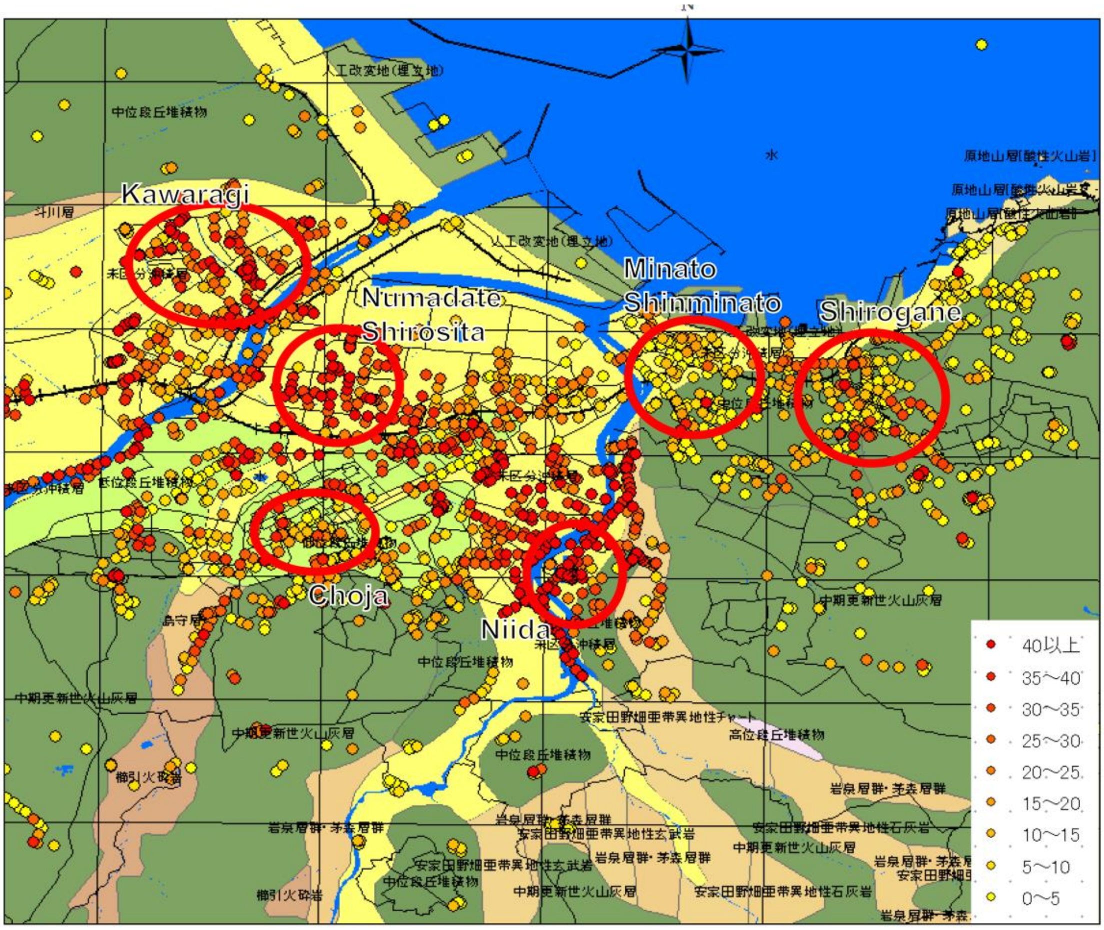

Fig.1 Liquefaction risk map

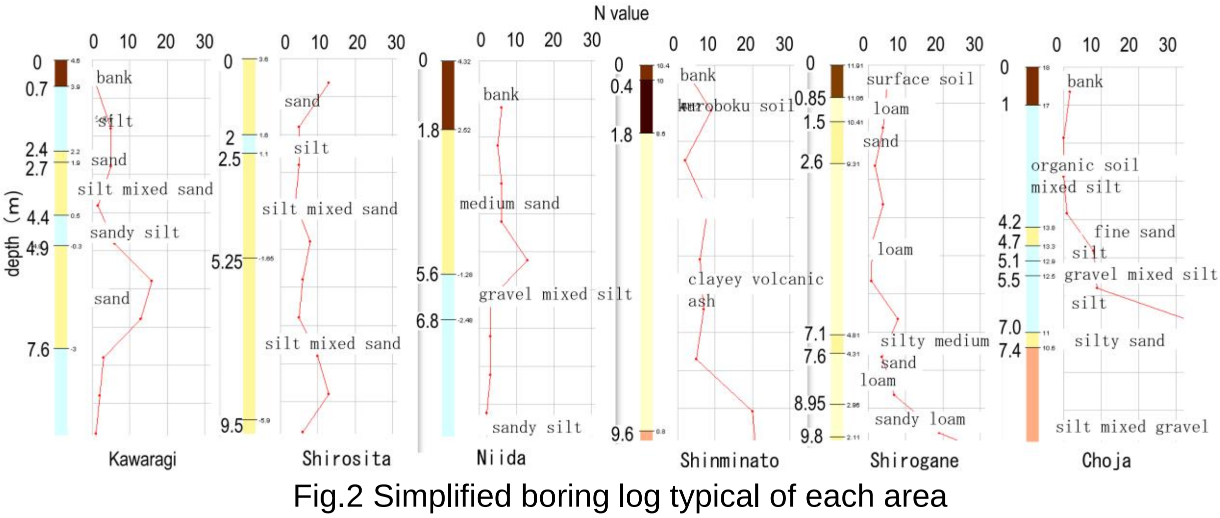

Fig.2 Simplified boring log typical of each area

some area as including Shinminato of the portion near the coastline is not necessarily P_L value is high.

From those reasons, the distribution of liquefaction risk in Hachinohe area is roughly appropriate.

4. RENEWED GEO-TECHNICAL INFORMATION DATA BASE SYSTEM

The number of the collecting data of the database exceeded 3000 points by last year. Therefore we renewed the geotechnical information data base. That new system can calculate PL-Value automatically, when the new geotechnical information data is uploaded. And we opened that result as a Liquefaction risk distribution map to the public. which showed in Fig.3

Table.3 Fundamental soil properties

Soil classification	Under ground water level on the unit volume γ_{t2} (kN/m^3)	Under ground water level below the unit volume γ_{t1} (kN/m^3)	D_{50} (mm)	Fine fraction content *FC* (%)
Surface soil	17.0	15.0	0.02	80
Silt	17.5	15.5	0.025	75
Sandy silt	18.0	16.0	0.04	65
Sandy faine sand	18.0	16.0	0.07	50
Very fine sand	18.5	16.5	0.1	40
Fine sand	19.5	17.5	0.15	30
Medium sand	20.0	18.0	0.35	10
Coarse sand	20.0	18.0	0.6	0
Fine gravel	21.0	19.0	2.0	0

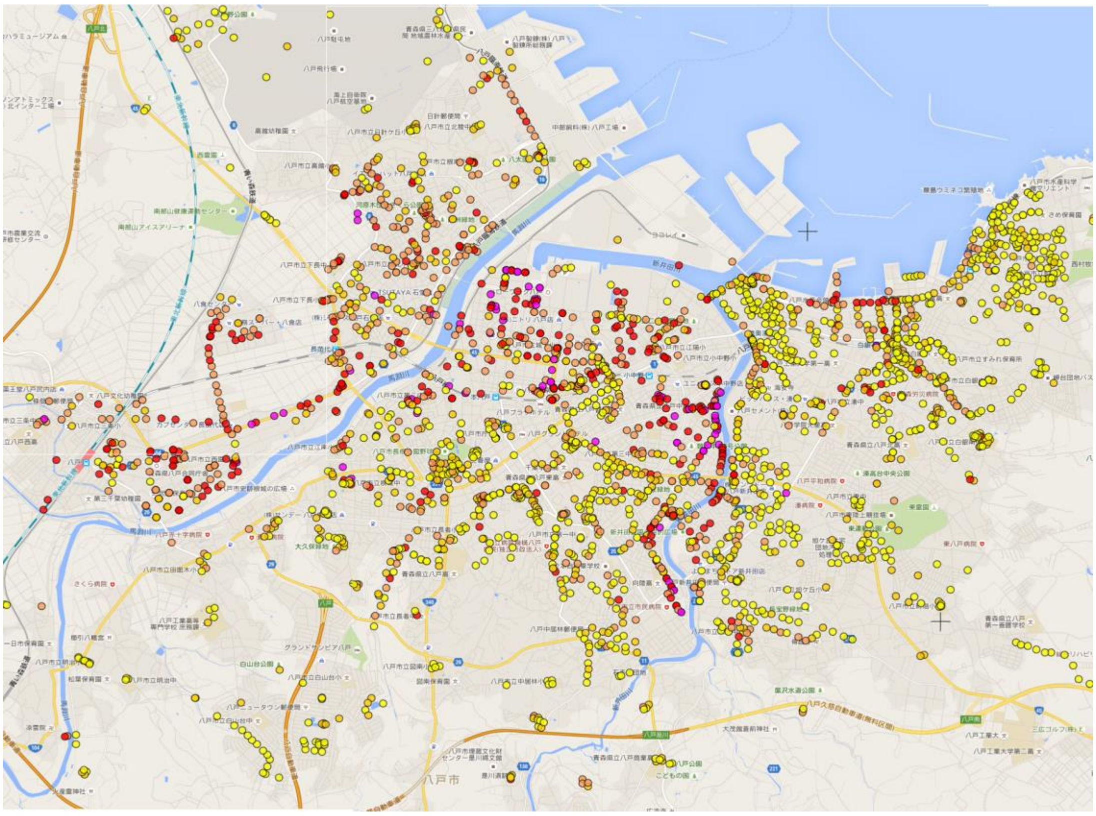

Fig.3 Liquefaction risk map from automatic calculation

Because that data must be calculated automatically, some of calculation parameters such as the unit volume weight simplify calculation work using properties of physical properties showing in specifications for highway bridges Japan. Therefore, the calculation method is not region-specific, it is everywhere adaptable system. Compared to Figure 2 which is calculated by considering the above-mentioned Hachinohe regional specific soil properties, although there are some differences, it is possible to say that it is not intended accuracy a bad result in it was similar. Table 3 shows the Japanese soil physical properties of a road bridge specifications used for the calculation.

5. CONCLUSION

In this study, we create a liquefaction risk map of Hachinohe area by using the Hachinohe local geotechnical information database, and we was understanding of spatial distribution. And The last year, The geotechnical information data base system was renewed like that the PL-Value will be calculated automatically, when the boring-log data will be registered. And the system is changed that anyone can check as a distribution map which was classified by color.

It was understood that In areas where high liquefaction risk is distributed many, loose sandy soil are deposited in a place close to the surface, and that underground water level is located on shallow underground and about 1m depth. In areas with low liquefaction risk, it tend to fine-grained soil like Hachinohe loam and Takadate loam of the Hachinohe region-specific is deposited to the portion close to the surface contrast. Further, it was understood that PL value in the portion close to the coastline is not large. Looking at the Hachinohe region as a whole, especially In areas where are sandwiched Niidagawa river and Mabechigawa river and are their riverside, Where has many point of high groundwater level and is deposited loose sandy soil in close to the surface layer, high liquefaction risk Area is widely distributed.

By renewed database, data will be added accumulated continuously in the future, PL value of that point will be added automatically calculated. By that, it becomes possible to a more dense and globally judgment of liquefaction risk.

And it will be Browsed the new information that has been updated to the citizens, and get to enhance the disaster prevention awareness. And also, we think that get to play a part of the commitment to individual disaster prevention.

Future, We will conducted comparative study of each disaster of the past and the risk map and will conducted a detailed examination of soil classification of borling data, and are aim to improve the accuracy. In addition, It is also possible to understand by experiment liquefaction strength characteristics of the soil of volcanic origin region-specific is required.

REFERENCES

A, Hasegawa. & K, suzuki. & K, Kaneko. & K, Kumagai. “Construction and Continuity of the Geotechnical Information Database of the Area.”, The Japanese geotechnical symposium, 189-192, 2009.

Government of Hachinohe city. “A record of Far off Sanriku earthquake(1994).”, 1997.

Ministry of Land, Infrastructure, Transport and Tourism. “The geotechnical information search site ”Kunijiban”” <http://www.kunijiban.pwri.go.jp/> (Jan. 13, 2011)

N, Moroto. & A, Hasegawa. “Development and Example for use of a Geotechnical Information System.” , Soil and foundations, 37-1(372), 41-46, 1989.

Tong Huanan. & F, Yamazaki. “Relationship between Ground Motion Indices and New JMA Seismic Intensity.” , University of Tokyo Production Research, 48-11, 33-34, 1996.

S, Yasuda. et al. “A Prediction Method for Liquefaction Using Spectral Intensity.” ,28th Japan national conference on geotechnical engineering, 1325-1328, 1993.

Y, Sato. & D, Tachibana. & K, Suzuki. & H, Matsumura. & K, Kaneko. & A, Hasegawa. & K, Kumagai. “The Making of a Geotechnical Information Database for Geotechnical Investigation Data in the Hachinohe Area.” , The Japan society of civil engineers tohoku local presentation meeting, Mar. 19, 2010.

Y, Hashizume. (2001). “The Seismic Response and Vibration Characteristics of Ground.” a dissertation, Graduate School of Hachinohe Institute of Technology, Hachinohe city, Aomori, JAPAN.