Liquefaction characteristic of alluvial soil distributed at Sawara dry riverbed in Chiba prefecture

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ABSTRACT

Large-scale sand boiling has occurred at Sawara dry riverbed in Chiba prefecture by Tohoku Region Pacific Coast Earthquake. Alluvial clay and sand layer, which is considered natural soil, are distributed at this site. In this study, the liquefaction characteristic of alluvial natural soil has been examined. The alluvial soft clay layer is distributed from earth surface to 3m in depth. The alluvial sand layer distributed below the soft clay is in loose condition. The grain size distribution curbs of sand layers are very steep and are not vary, the sand layers are almost uniformity. The content of fine-grained fraction is 20% from 5%, and water content is 40% from 30%. In addition, \( N \) value is 25 from 5. The cyclic triaxial test has been carried out using the samples obtained by GS sampler. The liquefaction resistance ratio, \( R_{L20} \), is in the range of 0.15 to 0.26, which is small value. The initial shear modulus, \( G_0 \), obtained by cyclic triaxial test and the one calculated by the result of PS logging are almost same. The sample quality obtained by GS sampler can be estimated good condition because \( G_0 \) calculated by PS logging is regarded the original in-situ initial shear modulus. It is considered that the thickness of non-liquefaction layer near surface ground is related whether the sand boiling will occur or not. According to ‘Guidance of the Countermeasure for Liquefaction in City Area provided by Ministry of Land, Infrastructure, Transport and Tourism, as the thickness of non-liquefaction layer becomes thinner, the sand boiling is easily to occur. In this guideline, if the clay layer is very soft, whose \( N \) value is less than 2, and artificial soil, it is not able to count to the thickness of non-liquefaction layer. But, it is not commented that when the soft clay layer is natural soil, it is able to count to the thickness of non-liquefaction layer or not. It is very important issue to estimate the sand boiling phenomena of natural soil.

1 INTRODUCTION

Extensive damage of houses by liquefaction has occurred along the Tokyo Bay coastal area and Tone river by Tohoku Region Pacific Coast Earthquake (The Japanese Geotechnical Society, 2011). The liquefaction damage has intensified at artificial ground which located seaside area, trace of a river channel and lake. Furthermore, the liquefaction at natural ground of alluvial plain has occurred along Tone river (Wakamatsu and sakina, 2013).

The study of the relationship between liquefaction damage and aging effect of the ground has been conducted (Taguchi et al., 2012). In this paper, it has been showed that the alluvial soil which has been formed older than the artificial dredged soil has the bigger strength for liquefaction. A field experiment has been conducted at Sawara dry riverbed of Tone river in order to confirm the strength of the natural alluvial soil. Sawara dry riverbed consists of dredged land area of Tone river and natural ground area of alluvial plain.

Keywords: Characteristic of Liquefaction, Alluvial Sand, GS Sampling and Characteristic of Dynamic Deformation

Photo 1. Scope of Sawara dry riverbed

\begin{quote}
Note)Trace of sand boiling has been seen entire riverbed surface
\end{quote}

Sand boiling by liquefaction has been occurred over the entire surface of this site as shown in Photo 1. This paper presents the liquefaction characteristic of natural ground area of alluvial plain.

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2 SITE OF FIELD EXPERIMENT (SAWARA DRY RIVERBED)

A field experiment for examining liquefaction phenomena has been conducted at Sawara dry riverbed of Tone river. As I mentioned before, the terrain of this site can divide into two areas, one is dredged land area and the other is natural ground area. The northwest side of this area was sandbank in stream previously as shown in Fig.1. The southeast side which was flow path of Tone river in Meiji era has been landfilled in Showa era. The field experiment has been carried out at the northwest side which natural alluvial soil is distributed.

Fig. 1. Map of experimental site (Topographic map of the Meiji Era)

3 RESULTS OF BORING AND TEST FOR PHYSICAL PROPERTIES

Boring survey has carried out in two stages. At first stage, standard penetration test for each 0.5m interval in depth and seismic velocity logging for each 1m interval has been conducted. At next stage, undisturbed samples for soil test have been recovered. The results of standard penetration test and seismic velocity logging are shown in Fig.2.

It has been found that an alluvial clay layer, Ac, and sand layers, As1, As2 and As3, are distributed at this area. Ac layer is distributed from the earth surface to 3m in depth. Ac layer is very soft because N value is 1 from 0 and seismic velocity, Vs, is 60m/s. Ac layer and the sand layers are distributed to 20m in depth. The alternation of strata, Asc, is sandwiched in sand layers.

Test for physical properties and unconfined compression test have been carried out for Ac layer using undisturbed samples obtained by thin-walled tube sampler with fixed piston. Ac layer is mainly composed of fine-grained fraction. The clay fraction is 39% from 31%, the silt fraction is 62% from 54% and the sand fraction is 14% from 7%. In addition, the liquid limit, wL, is 72% from 64%, the plastic limit, wP, is 37% from 29% and the natural water content, wN, is 73% from 55%. Ac layer is very soft soil since the natural water content is close to the liquid limit and the unconfined strength, qu, is 53kN/m² from 40kN/m².

Fig. 2. Result of boring and PS logging

The grain size distribution curbs of sand layers, As1, As2 and As3, are shown in Fig.3. Since these curves are very steep and are not vary, the sand layers are almost uniformity. The content of fine-grained fraction is 20% from 5%, and water content is 40% from 30%. In addition, N value is 25 from 5 and seismic velocity is 230m/s from 120m/s. These values have a tendency to increase gradually to the depth.

Groundwater level has been confirmed to a depth of 1.5m.

Fig. 3 Result of grain size analysis (Alluvial sand As1-As3)

4 UNDISTURBED SAMPLING FOR ALLUVIAL SAND (GS SAMPLING)

The new type soil sampler called GS sampler shown in Fig.4 has been used for collecting undisturbed alluvial sand samples (Atec Yoshimura Co., LTD, 2014). GS sampler is high-quality sampler for collecting loose sandy soil, gravel, fractured zone and waste matter which have been very difficult to obtain good samples with undisturbed condition. GS sampler has some structural features. Firstly, drilling fluid such as muddy water, bubble and air are used for protecting
borehole wall at the time of sampling. The drilling fluid is circulated just above the sampler tip and not touched directly the tip. As a consequence, the samples can be collected without outflow. Secondary, The fixed piston is set into the sampler in order to prevent the co-rotation and falling of the samples. Finally, the samples are stored in acrylic transparent tube in order to see the sample condition in the field.

In this experiment, 9 undisturbed samples have been collected from As1, As2, As3 and Asc layer by GS sampler. The collecting rate of samples is almost 100%. The typical photo of appearance and X-ray photograph are shown in Photo2. There are no cracks and disturbance of the samples. Thus, the sample quality obtained by GS sampler is considered in good condition.

![Photo of recovered sample (Depth 9.0m from 9.9m)](image)

Photo 2. Typical photo of appearance and X-ray photograph

5 DYNAMIC CHARACTERISTIC OF ALLUVIAL SAND

Cyclic triaxial test has been carried out for alluvial sand, As1, As2 and Asc layer, using the samples obtained by GS sampler. The liquefaction resistance ratio, $R_{L20}$, obtained by cyclic triaxial test, $N$ value and fine-grained fraction, $F_c$, are shown in Fig.5. $R_{L20}$ of sand layers is in the range of 0.15 to 0.26, which is small value. The average of $R_{L20}$ of As2 and Asc layer is bigger than $R_{L20}$ of As1 layer.

The liquefaction resistance ratio, $R_{L20}$, obtained by cyclic triaxial test and the liquefaction resistance ratio, $R_L$, calculated using $N$ value and $F_c$ based on ‘Specification for Highway bridges (May, 2012)’ are shown in Fig.6. In As1 layer, $R_{L20}$ is a little smaller than $R_L$. However, the both results, $R_{L20}$ and $R_L$, are approximately equal in Asc and As2 layer. While $R_L$ of As1 layer is approximately equal to $R_L$ of As2 layer, $R_{L20}$ of As2 is bigger than $R_{L20}$ of As1. $N$ value of As1 and As2 layer showed in Fig.2 are almost same. In contrast, $V_y$ obtained by PS logging of As2, $V_y=150m/s$, is greater the one of As1, $V_y=120m/s$. The trend of $V_y$ is the same as the trend of $R_{L20}$. Therefore, it is possible to point out that $R_L$ calculated using $N$ value and $F_c$ of As1 may underestimate than the actual value.

The result of cyclic triaxial test to determine deformation properties of geomaterials using the samples corrected by GS sampler is shown in Table 1. The relationship between the initial shear modulus, $G_0$, obtained by cyclic triaxial test and the one calculated by the result of PS logging is shown in Fig.7. While there are only three data, both values are almost same. The sample quality obtained by GS sampler can be estimated good condition because $G_0$ calculated by PS logging is regarded the original in-situ initial shear modulus.
6 DISCUSSIONS

The resistivity against liquefaction, $F_L$, of alluvial sand in this site is calculated from 0.8 from 0.6 as is shown in Fig.8. This calculation is based on ‘Specification for Highway bridges’ at the level 1 ground motion. The result shows that the alluvial sand layer is easily to liquefy. The alluvial clay distributed above alluvial sand is considered very soft soil because its unconfined compressive strength is 53kN/m² from 40kN/m². Therefore, this layer is considered non liquefaction layer because of containing rich fine fraction.

The phenomenon of liquefaction at Sawara dry riverbed is considered that the liquefied alluvial sand was boiling up to the earth surface through the cracks in the soft clay made by earthquake motion. It is considered that the thickness of non-liquefaction layer near surface ground is related whether the sand boiling will occur or not. According to ‘Guidance of the Countermeasure for Liquefaction in City Area’ provided by Ministry of Land, Infrastructure, Transport and Tourism, as the thickness of non-liquefaction layer becomes thinner, the sand boiling is easily to occur. In this guideline, if the clay layer is very soft, whose N value is less than 2, and artificial soil, it is not able to count to the thickness of non-liquefaction layer. But, it is not commented that when the soft clay layer is natural soil, it is able to count to the thickness of non-liquefaction layer or not. It is very important issue to estimate the sand boiling phenomena of natural soil.

7 CONCLUSIONS

Large scale sand boiling has occurred at Sawara dry riverbed by Tohoku Region Pacific Coast Earthquake. The liquefaction characteristic of alluvial natural soil distributed at this site has been examined. As a consequent, it has been confirmed that the alluvial sand layer tend to become liquefaction condition easily because this layer consists of uniform sand and liquefaction resistance ratio, $R_{L20}$, is small value, which is 0.26 from 0.15.

Extensive damages of houses has occurred not only dredging ground but also alluvial natural ground along Tone river. The same investigation like this paper has been carried out at Inashiki city and Katori city in Ibaragi prefecture. We are going to promote the research for clarifying the liquefaction characteristic of natural alluvial soil using these date.

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