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# DEVELOPMENT THE SOIL IMPROVED ABOUT LIQUEFACTION COUNTERMEASURE USING SLAG AND MUD

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***Abstract*—My research has focused on the construction waste sludge that we do not reuse. We aim to develop improved soil that does not cause the liquefaction by mixing the construction waste sludge and slag. The results of the research, construction waste sludge 20% slag 80% modified soil was found to be a specimen with a tenacious resistance to liquefaction when compared with 100% slag specimen. *(Abstract)***

***Keywords*—construction waste sludge, liquefaction, conbination rate, modifiled soil *(key words)***

## I. Introduction

Sand has been used as backfill material in the water pipe way buried in the ground in Japan because the easiness of the construction. However, when a disastrous earthquake like Eastern Japan Great Earthquake happens in recent years, liquefaction occurred to sand-rich foundation. For example, the underground manhole rise to surface in Figures 1, land subsidence in a backfill part also happened and big steps was formed on the road by liquefaction phenomenon, that leads to a road traffic obstacle. A liquefaction phenomenon like this has a great influence on traffic infrastructure and life environment. Therefore it is very important problem to create backfill material which has effectiveness of liquefaction countermeasure to prevent damage by a liquefaction phenomenon. Meanwhile, in the narrow land, Japan, the reuse of construction generated soil which is discharged at construction site is the important issue. Among the construction generated soil, sediment of large grain size, such as gravel or sand , has the effective using methods which have been established. However, small particle size soil, such as the clay, the usage has not been established because it is soft since it contains a lot of fine particles. Currently, the method of using the small particle size soil has been demanded in the society, in my research, it is an object to develop an improved soil which is effective in the liquefaction measures by mixing the clay with sand for using for the pipe backfill material. In this study, we were also paying attention to the effective utilization of waste soil, instead of the using the natural sand, we conducted our experiments by using the slag as the soil of large particle size (sand-like waste casting sand) and the dried construction waste sludge as the soil of small particle size.

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## II. Experimental content and method

### A. *Preparation of Samples*

The basic physical properties of the slag and construction waste sludge used in this study are summarized in Table 1. The ignition loss is represented percentage of the decrease mass of the oven-dried soil. The value of the ignition loss is equal to the organic matter content of the soil. In addition, it is shown the respective grain size characteristics in Figures 2 and 3. The particle size of the slag is all-sand fraction (75 μm ~ 2 mm) and the particle size of the construction waste sludge is

Figure 1 Manhole protruding by liquefaction

Table 1 Basic physical properties of the samples

| | Soil particle density (g/cm$^3$) | Loss on ignition (%) |
|---|---|---|
| Slag | 2.703 | 5.9 |
| Construction waste sludge | 2.697 | 11.3 |

composed by 50.6% sand, 42.1% silt (5 μm ~ 75 μm) and 7.3% clay fraction (5 μm or less) .

## B. *The Proctor compaction test*

In order to investigate the influence of construction waste sludge compounding ratio on the compaction characteristics of samples of slag and construction waste sludge, it was conducted to proctor compaction test in accordance with JIS A 1210. JIS is Japanese Industrial Standard. The construction waste sludge compounding rate of samples with respect to the mass is set to 0%, 10%, 15%, 20%, 25% and 30%. The maximum dry density and the optimum water content ratio was detected from the six each of compaction curve. Proctor compaction test has adopted a B method in the JIS A 1210. In Method B, was placed a sample soil in mold(inner diameter 15cm, volume 2209cm$^3$), and performed compaction by rammer, it is allowed to repeatedly fall freely from the prescribed height. The weight of the rammer is 2.5 kg, drop height is 30 cm, the number of tamped layer is three, and the number of falling of rammer is 55 times.

## C. *The CBR test*

To determine the strength characteristics at maximum dry density of the six types of mixed samples, the CBR(California Bearing Ratio) test was conducted, in accordance with JIS A 1211. The loading apparatus using the test is shown in Figure 4. Piston penetrating speed to the specimen is 1 mm / min, and the relationship between the surcharge load and penetration amount was determined. From the relation curve of surcharge load and penetration amount, the surcharge load was detected at the case of a penetration amount of 2.5 mm or penetration amount of 5.0 mm, and the CBR (%) was evaluated from the following equation (1).

$$\text{CBR} = (\text{load} / \text{standard load}) \times 100 \qquad (1)$$

Here, the standard load is the value that is determined from the relationship between the load and a predetermined penetration amount when crusher-run stone compacted to which was of the reference material using in the lower roadbed and basic material of the road. Standard load is 13.4 kN at the penetration amount of 2.5mm, is 19.9 kN at the penetration amount of 5.0 mm. CBR value was represented CBR2.5 in penetration amount of 2.5 mm. But, CBR test is performs again if CBR2.5 ≦ CBR5.0. If the test result because the same result again, the CBR value is the CBR5.0.

## D. *Vibration experiment of ground model*

The compounding ratio of construction waste sludge with the high maximum dry density and the high CBR value was detected from the result of proctor compaction test and the CBR test. The vibration experiments was conducted to the ground model which was made by using the sample mixed slag and the construction waste sludge mixed sample with the

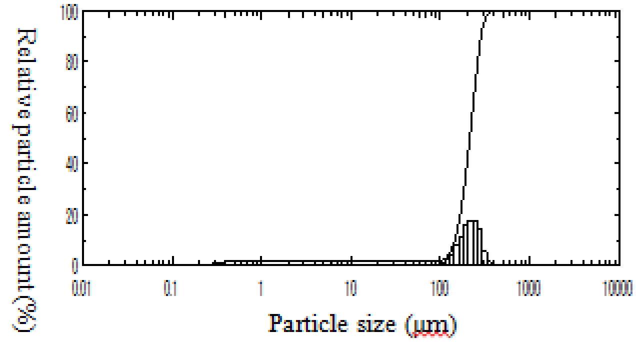


Figure 2 Particle size distribution of slag

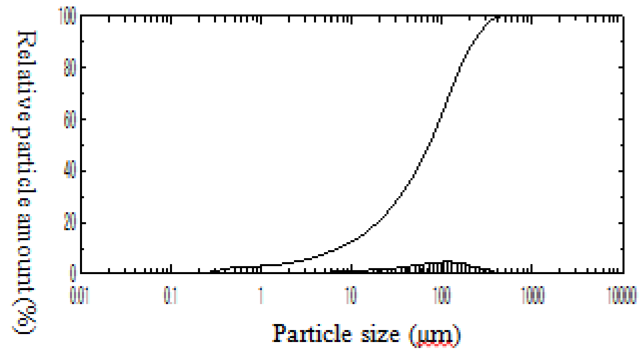


Figure 3 Particle size distribution of construction waste sludge

Figure 4 Penetration device used in CBR test

compounding ratio. An acceleration sensor was set at vibration table, as shown in Figure 5, and the pore water pressure gauge was set at the bottom of acrylic container (length 27 cm, horizontal 42 cm, height 29 cm), as shown in Figure 6. The preparation of ground mode is as follows: first, the mixed sample was set up to 7.5 cm height in acrylic container, secondly, it was compacted by mounting stress of about 5 kPa for 1 minute, thirdly, the mixed sample was added up to height 15 cm in acrylic container and similarly it was compacted by mounting stress of about 5 kPa for 1 minute. Finally, the ground model of 15cm soil layer was made, the saturation condition of the model was controlled by flowing water from the top of the soil container to achieve the saturated state. The saturated ground model was placed on the vibration table and start vibrating under the condition that the upper mounting stress 1 kPa was applied. Gradually increasing the acceleration at every minute from the vibration started and while the value of pore water pressure gauge buried in the ground model was recorded. The experiment was ended when the liquefaction on the ground model has been judged visually.

# III. Experimental results and discussion

## A. *Compaction characteristics*

It was shown the results of the compaction tests in Figure 7. It shows the compaction curve of construction waste sludge which the compounding rate is 0%, 10%, 15%, 20%, 25% and 30%. The samples mixing construction waste sludge has larger maximum dry density than the sample not mixing construction waste sludge. In particular, the samples of construction waste sludge compounding ratio at 10% and 20% showed a significantly high maximum dry density. The construction waste sludge sample of compounding rate at 25% and 30% was reduced the maximum dry density from other samples. The maximum dry density of sample of construction waste sludge compounding rate at 10%, 15% and 20% equal to or higher than the dry density of slag only sample in the water content ratio except for optimum moisture content.

## B. *Strength characteristic*

Figure 8 shows the curve of the relationship between load and penetration amount obtained from the CBR penetration test. As shown in Figure 8, the sample of compounding rate at 20% construction waste sludge showed a significantly higher strength than the other samples. Samples of high compounding rate more than 20% indicated low strength, because the clay content increases relatively. Similarly, in the case of slag only sample, the sand fraction is relatively increased, the sample because loose and the strength becomes weak. The samples of construction waste sludge compounding rate 10% and 20% is improved particle size distributed because sand and clay component are mixed together. It is considered that the strength is larger than slag only sample. The sample shows high CBR values against slag only sample were the sample compounding rate of 10% and 20% of construction waste sludge. The strength of the sample of the construction waste sludge mixing ratio of 15% is lowered. This phenomenon is considered to be due to how mixed the sample. The inference of construction waste sludge compounding rate on the CBR value was organized in Table 2. About the slag mixing samples used in this study, in terms of strength, it can be satisfy the material provisions of the subgrade lower part of the general road in japan, if 20% construction waste sludge was added to slag.

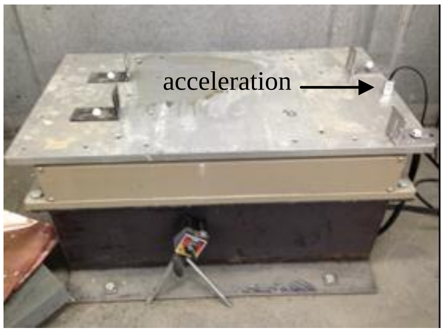


Figure 5 Shaking table used in vibration test


Figure 6 Acrylic soil tank

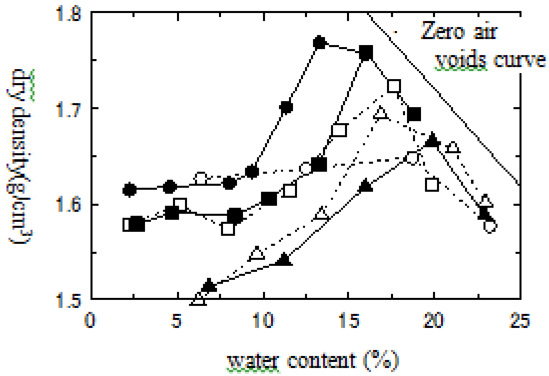


Figure 7 Influence of construction generated sludge compounding rate on the compaction curve

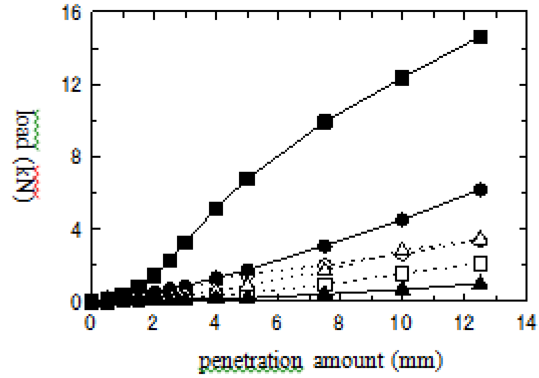


Figure 8 Influence of construction generated sludge compounding rate on the relationship between the load and the Penetration amount

## *C.* *Liquefaction characteristics*

From the results of the CBR test and the compaction test, the compounding condition that the sample of compounding rate 20% of construction waste sludge is the most strongest condition. Therefore, the vibration experiments of ground models made with the condition and slag only models was prepared. The profile obtained from the acceleration sensor and the pore water pressure gauge are shown in Figure 9 and 10. It should be noted, excess pore water pressure(dashed line) in the figures represent the pore water pressure value when the theoretical effective stress becomes zero, and the value of the pore water pressure gauge indicate a standard that liquefaction occurs when the pore water pressure excess this value. In the case of the sample of compounding rate at 0% construction waste sludge, when acceleration was increased every 60 seconds, the soil in tank begins to loose gradually at 960 seconds (about 6.3 $m/s^2$), and the soil in tank was visually confirmed fully liquefaction at 1020 seconds (about 7 $m/s^2$). From the profile of the acceleration and the pore water pressure are shown in figure 9, the following were revealed. The pore water pressure also gradually increases as the increasing of acceleration, and then, the pore water pressure increase rapidly at 960 seconds when liquefaction begin to occur. At this time, the begin of liquefaction because the pore water pressure exceeds the pore water pressure value when the pore water pressure value when the theoretical effective stress becomes zero. This is consistent with liquefaction timing that can be visually confirmed. In the case of the sample of

Table 2 CBR value in the compounding sample of slag and construction generated sludge (%)

| Construction generated sludge mixing ratio | 0% | 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|---|
| Water content (%) | 17.6 | 14.0 | 17.4 | 16.2 | 17.5 | 19.6 |
| Dry density ($g/cm^3$) | 1.65 | 1.74 | 1.72 | 1.76 | 1.70 | 1.67 |
| $CBR_{2.5}$(%) | 4.7 | 5.1 | 1.4 | 17.0 | 2.7 | 0.7 |
| $CBR_{5.0}$(%) | 7.4 | 8.8 | 2.4 | 34.0 | 4.3 | 0.96 |

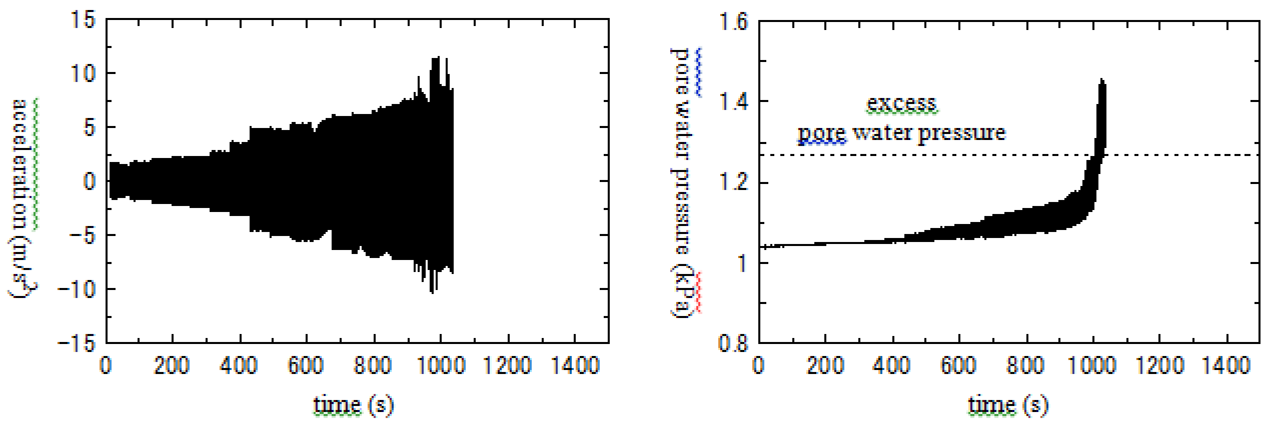


Figure 9 The pore water pressure in the soil tank bottom and acceleration of the vibration table, with the ground of slag only.

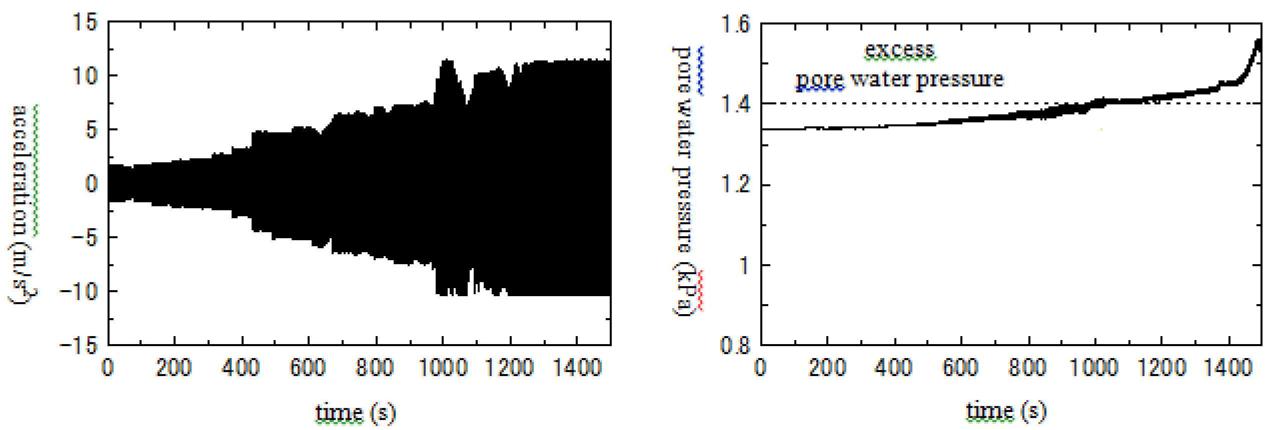


Figure 10 The pore water pressure in the soil tank bottom and acceleration of the vibration table, with the sample of compounding rate at 20% construction waste sludge

compounding rate 20% of construction waste sludge, the soil is becomes loose at 1080 seconds (about 7.7m/s$^2$) but the state of the soil unchanged until 1380 seconds(about 11 m/s$^2$), and liquefaction began beyond at 1380 seconds. The soil's completely liquefaction occurred at 1500 seconds. Although, from to figure 10, it were revealed that the pore water pressure exceeded the pore water pressure value when the pore water pressure value when the theoretical effective stress becomes zero, but it can be visually confirmed that the liquefaction in the soil tank occurred. From the above, it was found that the sample of compounding rate 20% of construction waste sludge the specimen with tenacious resistance against become liquefaction in comparison the sample of compounding rate 0% of construction waste sludge.

From the results of vibration experiments and the calculated the pore water pressure value when the theoretical effective stress becomes zero, the ground model compounding rate at 20% construction waste sludge has more resistance strength against liquefaction due to vibration than the ground model compounding rate at 0% construction waste sludge. In addition, the ground model compounding rate at 0% construction waste sludge, liquefaction has occurred instantly and completely after the ground models become loose. But in the case of the ground model compounding rate at 20% construction waste sludge, time lag until complete liquefaction was observed.

## IV. In conclusion

・By adding construction waste sludge to slag, the preparation of samples with excellent strength against liquefaction was investigated. From the proctor compaction test and CBR test, with samples at construction waste sludge mixing ratio of six levels changed from 0-30%. We can get to the CBR5.0 = 34% when the sample of compounding rate 20% of construction waste sludge was compacted at the optimum water content ratio. This is highest strength in our experiments.

・To the beyond the pore water pressure value of when the effective stress on the theory becomes zero up to the liquefaction was observed for some time lag. From this, It was found that the sample of compounding rate 20% of construction waste sludge.

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Figure 1) The Asahi Shimbun Company.

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