Recycling Excavated Soil to Back-Filling Material with Liquefied Stabilized Soil Method

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Abstract
Some attempt on recycling excavated soil at site was conducted in order to reduce total amount of soil carrying out of a site. It becomes more and more difficult to find reclamation sites for excavated soil to dump around large cities, typically Tokyo and Osaka in Japan. This trend is due mainly on shortage in reclamation sites around large cities and increase in excavated soil around there.
Under such a circumstance, the ministry of construction in Japan has set a campaign, called Recycle Plan 21 Century, in 1995 and promotes R & D on new recycling technologies in order to utilize more amounts of construction wastes. This paper relates to this campaign and copes with recycling excavated soil.

The developed recycling technique, called “Liquefied Stabilized Soil” is a method that excavated soil is thoroughly mixed with muddy water (or water) and cementing material and then placed in space where back filling is necessary at site. The method is simple to apply at site except a mixing design specification and a mixing machine. Excavated soil may be any kinds, including cohesive soil with high water contents that has conventionally been considered unsuitable for earth works. Thus, it is thought acceptable widely over construction sites and promotive on recycling.

On the one hand, the method is possible to simplify construction sequence; one of examples is that LSS flows like concrete mortal and its placing requires no compaction effort. On the other hand, the soil after hardening shows good outcomes; at the level of strength where hand shovel excavation is available, the soil is substantially little in shrinkage, permeability, and corrosion under ground water level.

This paper presents a recent application example of this method; a large amount of excavated soil is recycled at site where excavation is done. The application is oriented to reduce soil to be carried out of the site. The paper also presents a proportional mixing design of LSS and its producing system with outcome of quality control tests.

Keywords
Recycling Excavated Soil, Clay with High Water Contents, Liquefied Stabilized Soil, Back-Filling, Narrow Space, No Compaction
1 Introduction

Some recycling technique for excavated soil to be a back fill material has been developed, namely ‘Liquefied Stabilized Soil Method”. The method consists of simple stabilizing processes except a mixing specification. It deals with any kinds of soils, including a cohesive soil with high water contents that has conventionally been considered unsuitable for earth works. Thus, the method is thought acceptable widely over construction sites and promotive on recycling.

A common recycling procedure is that excavated soil is carried to a remote plant for stabilizing and carried back to a site for back filling. When an amount of handling soil is large, thousands of trucks necessarily transport them. Thus, a plant at a construction site is preferable from environmental and economical points of view. The paper presents a case history of this site plant application with introduction of Liquefied Stabilized Soil Method.

2 Excavated soil

In 1997, excavated soils resulted in 44 million cubic meters in Japan. This amount is 18% increase from 1992. Except soil with high water contents, excavated soil is basically re-useable without any stabilizing process for an embankment fill material and/or a back filling material. Yet, in past only 15% of them are re-used at construction site while 85% is simply dumped at inland and/or offshore reclamation sites.

On the other hand, construction sites prefer purchasing new sand as a filling material. In 1997, sands used at construction sites are 20.6 millions cubic meters. Among them, a new sand is 68%, a recycled sand 29%, a stabilized soil 3%; these values were 64%, 34%, and 2% in 1992 respectively.

It would be concluded from these data that recycling is slowly progressing but a large amount of reusable excavated soil is still dumped at reclamation sites while a large amount of a new sand is excavated from a natural ground.

3 Liquefied stabilized soil

Liquefied Stabilized Soil (hereinafter called “LSS”), a new soil stabilization technique is made by mixing soils as principal materials with muddy water (or water) and cement. LSS flows like concrete before hardening. It yields the necessary strength according to proportion of the mixture. It requires no compaction at the time of use and little volumetric shrinkage after hardening. Therefore, it is expected that this stabilized soil is highly applicable for back filling and filling at construction sites where compaction is difficult (Picture 1).
By adjusting the content of the principal materials, muddy water and a cementing material, it is possible to set the condition of LSS where wanted filling characteristics can be obtained. The filling characteristics are expressed in parameters such as strength, flow value, density, and bleeding ratio. They are decided according to the purpose of the site and produced through a proper mixing proportion after a certain combination of soil tests. The strength of LSS is set at the level fitted for the purpose ranging from the strength of such degree so as to permit hand excavation to the strength equal to the lean mixture concrete.

The fluidity is evaluated by flow value; the spread diameter of LSS originally set in and released vertically from a cylinder measuring 8 cm high and 8 cm in diameter (Picture 2). By changing mix proportion, it is possible to yield the required flow value. The flow value changes along with density and time passage. It is known that a low value of 11 cm is the limit to pump LSS out and 14 to 25 cm is a good range. The density is related to all parameters and usually set at 1.4 or higher. The bleeding ratio is restricted to within 1% in most cases or 0.5% in the case of strictly limited volumetric change like when filling a cavity.

Beside from above expertise, past series of experiments show that hardened LSS in ground revealed following characters.
1) easy to re-excavate
2) little shrinkage in the ground
3) little corrosion by the running water in the ground
4) almost in-permeable
5) liquefaction free in earthquake
6) no pH rise around the ground
7) slurry waste also useful

4 Application example

General condition
In the center of Tokyo, two buildings adjacent each other were constructed sequentially. First building was chosen for this application and was 19 stories building with 4 basements; its total floor area 112,700 square meters, height 90 meters, and ground area 7,500 square meters.
A depth of excavation was 33.5 meters at the deepest and an amount of excavated soil was nearly 261,000 cubic meters. Back filling between a retaining wall and basement structures, typically 4 meters wide, was initially planed by placing sand with compaction. Its space is about 36,000 cubic meters (Picture 3). A retaining wall was made by a Soil Mixing Wall Method and bottom grounds were improved by deep soil stabilization before excavation so that excavated space was isolated from underground water.

LSS method became attractive comparing to back filling sand and compaction by following reasons.

1) An amount of excavated soil is massive and recycling is preferred.
2) A back filling period overlaps with an above structure work which prefers no men working below.
3) There are narrow spaces where back filling with sand and compaction is barely possible.
4) Excavated soil is a kind of clay with high water contents.

**Application of LSS**

It is common that LSS plant is set remote from a construction site. Its procedure is that first excavated soil is carried to the remote plant, secondly it is processed to LSS, and LSS sends back to a site for back filling. This system is available in adjusting time lag of excavation and back filling and/or supplying LSS to any sits when it is necessary.

However, the system needs transportation carrying soils out and bringing LSS back, resulting not ignoring amount of cost.

This application uses a site plant experimentally. Since two buildings are constructed in some time differences, it is thought possible that excavated soil at one building is used for the other. For this application, a movable mixing plant was developed to reduce a plant area (Picture 4 and Figure 1). This plant is moved out of site easily when no needs. In addition, construction sequence is carefully re-scheduled so that amount of soil to excavate and LSS to back fill is balancing.

**Soil Property and Mix Proportion**

Excavated soil is mainly Kanto-Loam whose characteristics are seen in Table 1. Since silt and clay proportion is 66%, bleeding can be controlled within 1% without any treatment. However, it is difficult to make dense LSS with this material alone.
Main properties wanted for LSS are strength and bleeding ratio. Table 2 shows target properties of LSS for this application.

Unconfined strengths were set at the level equal to that of surrounding grounds. At that levels hand excavation is still available and substructure was sustained firmly by lateral earth pressure. However, target strengths were modified somewhat higher by two considerations. A Soil Mixing Wall exhibits stiff behavior and soil between the wall and substructure is preferred similar to that of the wall. A target density is slightly lower than 1.4 and higher strength can be secure in durability.

A bleeding ratio is less than 1% and expected no segregation with water and no substantial shrinkage in the ground.

A density prefers being high because of durability. To do so is to reduce a void in LSS; concretely lowering water contents. On the other hand, it becomes difficult to flow when water contents becomes low; placing prefers a high flow value. At a flow value of 300 mm, LSS flows by less than 1% gradient. In this proportion, a designed flow value is set low for gaining more density.

Table 3 is a designed mix proportion for the target properties. Since an original soil is rather uniform, one proportion is adopted.

**Table 1** Excavated Soil Characteristics

<table>
<thead>
<tr>
<th>Soil</th>
<th>Gravel</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Water Contents</th>
<th>Unit Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kant0 Loam</td>
<td>11.7%</td>
<td>22.2%</td>
<td>24.0%</td>
<td>42.1%</td>
<td>80.0%</td>
<td>1.42 (t/m³)</td>
</tr>
</tbody>
</table>

**Table 2** Target Properties for LSS

<table>
<thead>
<tr>
<th>Location</th>
<th>Initial UCS (kgf/cm²)</th>
<th>Final UCS (kgf/cm²)</th>
<th>Bleeding Ratio (%)</th>
<th>F. Value (mm)</th>
<th>LSS Unit Weight (t/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above GL – 10 m</td>
<td>2.00</td>
<td>10.2</td>
<td>Less 1%</td>
<td>Over 160 mm</td>
<td>1.387</td>
</tr>
<tr>
<td>Below GL -10 m</td>
<td>3.75</td>
<td>10.2</td>
<td>Less 1%</td>
<td>Over 160 mm</td>
<td>1.387</td>
</tr>
<tr>
<td>Concave Space of Substructure</td>
<td>10.2</td>
<td>10.2</td>
<td>Less 1%</td>
<td>Over 160 mm</td>
<td>1.387</td>
</tr>
</tbody>
</table>

Note: UCS at 28 days and 1 kgf/cm² = 100 kN/m²

**Table 3** Mixing Proportion

<table>
<thead>
<tr>
<th>Excavated Soil</th>
<th>Water</th>
<th>Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>664 kg</td>
<td>505 kg</td>
<td>218</td>
</tr>
</tbody>
</table>

Cement is for 1.25 time of target strength

**LSS work at site**

Figure 2 shows a system flow at this site. Excavated soil is moved to the plant in a site. Sequentially, it is mixed with water by a bucket rotary mixer. Density of slurry is monitored every minute so that it meets with the mix design. A movable plant draws in necessary amounts of slurry and cementing agent by a vacuum and a measure. After cementing agents are uniformly mixed among slurry, LSS has been made and sent to a
storage in which an agitator runs preventing segregation. Finally, LSS goes to where back filling is necessary by a squeeze pump.

Pumping does placement of LSS. Pipes for placement are set when no structural works are active. They are easy to carry and joint together. Length of piles is long, say 250 meters at longest, their setting is arranged in a way that their length is shorter and bends are less. Picture 5 shows LSS placing. A previously set pipe discharges LSS where back filling is necessary. Note there is few men in back filling operation.

This placement of LSS consists of three phases. The first phase is for back filling until one third of total depth from the bottom. Around the top, there are stress units of anchors and lateral bracing. A total length around the substructure is about 350 meters. A pipe is extended to the far end from the plant site and discharges LSS.

During this far end placement, water, if any remained at the bottom, is pushed by LSS toward the location of the plant and drained. After LSS accumulates near the bracing, the pipe is located where LSS piles up low, typically 15 meter away for the previous discharge point. A placement continues till a surface of LSS coming equal to the other. When placed LSS gets hardened at the surface, stress units and lateral bracing are taken apart without scaffolding works. The second and third phases go up to next stress units of anchor and lateral bracing level with same procedure of the first phase. When LSS comes to near ground, its surface is covered by excavated soil. Figure 3 shows results of placement in a day. A total amount of placed LSS became 36,000 cubic meters.

Quality test
Quality control tests are conducted before and after hardening of LSS. The former is for confirming if LSS is adequately produced according to the mix proportion while the latter is for assuring...
quality of placed LSS. The former type of a quality control test is done every batch in terms of slurry density, LSS density, flow value and the latter type is two sampling a day in terms of bleeding ratio and unconfined strength. Test results are shown in Figure 4 to 6. Produced LSS are fallen over acceptable ranges of the target values and there are no defect products. The figures also indicate no significant deviation in distribution.

A newly developed recycling technique is applied for a soil with high water contents at the construction site. This application indicates following expertise;

1) Excavated soil with high water contents is easily reused at a site and considered as useful resources.
2) A small plant space is capable of producing a large amount of LSS, in this case 300 cubic meters a day at maximum.
3) Quality of LSS is steady if excavated soil is uniform; this implies a site plant is preferable to a remote plant, which collects any kinds of soils.
4) Placing LSS with pumping reduces labor resources significantly.
5) LSS little segregates into water if bleeding ratio less than 1%.

Acknowledgement
The Liquefied Stabilized Soil Method was developed by the collaboration study with Public Work Research Institute, Ministry of Construction and Japan Association of Representative General Contractors during 1992 to 1997. This case history was conducted after this research. During that time, many research engineers contributed significant efforts. Here at the end, authors give special thanks to those related the development, especially, Dr. Miki, H and Mori, N at the Public Work Research Institute.

References
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