Soils recovered from disaster debris

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ABSTRACT

Utilization of the soils recovered from the disaster debris is one of the geoenvironmental challenges related to the 2011 East Japan earthquake and tsunami. The disaster debris contained significant amount of soil fractions and these soils are expected to be separated from the disaster debris and utilized in re-construction works in the areas affected by the disaster. In this paper, generation and treatment of disaster debris are briefly summarized. Mechanical properties of recovered soil were discussed from the viewpoint of composition, compaction, and compressibility in order to utilize it in geotechnical applications. A lower amount of admixed combustible matter can lead a higher quality of recovered soils as a geo-material. Difficulty of characterizing the recovered soil and feasible strategies for utilization are also briefly discussed based on the experimental results.

Keywords: disaster waste treatment, strategic utilization, compressibility, compaction, composition

1. INTRODUCTION

The earthquake of magnitude 9.0 and subsequent tsunami affected coastal areas in eastern Japan on March 11, 2011. This earthquake and subsequent tsunami caused several serious geoenvironmental issues mainly in the coastal area in the eastern Japan (Inui et al. 2012). These geoenvironmental issues may include; 1) generation of disaster debris and tsunami deposits, 2) salt damage on agricultural lands, 3) land subsidence, and 4) subsurface contamination with nuclides caused by the Fukushima Daiichi nuclear disaster.

Treatment of the disaster debris in the affected areas was conducted and completed in most sites by the end of March 2014. Since the disaster debris and tsunami deposits included a significant amount of soil fractions, proper treatment to recover these soils and utilization of such recovered soils in geotechnical applications in re-construction works have strongly been encouraged.

The Japanese Ministry of Environment (MOE) is currently preparing a particular principle that enables proper disaster waste treatment in forthcoming huge disasters such as Nankai Trough earthquake and Tokyo Inland earthquake. According to an estimation in an interim report of “Grand Design for Countermeasures to Disaster Debris in Disasters” released by MOE in March 2014, the amount of disaster debris in Nankai Trough earthquake may reach to total 322 million tons that corresponds approximately 11 times of that in the East Japan earthquake and tsunami, and 27 million tons of soil including tsunami deposits will be generated (MOE 2014a). For treatment of such considerable amount of disaster debris, careful simulation of disaster damage, plans of proper waste treatment system, and initial response for smooth treatment have to be preliminarily considered. Even in such catastrophes, utilization of soil fractions after proper treatment is required by the above-mentioned grand design of MOE. This paper discusses strategic utilization of recovered soils through overview of disaster waste treatment in this earthquake and several laboratory tests in anticipation of forthcoming huge disasters.

2 GENERATION AND TREATMENT OF DISASTER DEBRIS

Generation and treatment of a huge amount of disaster debris are the first experience in human history. Immediately after the earthquake and subsequent tsunami in 2011, the Japanese government estimated
that approximately 20 million tons of disaster debris and 10 million tons of tsunami deposit had been generated through this disaster mostly in Iwate, Miyagi, and Fukushima Prefectures. Tsunami deposits are mainly soil transported by the tsunami and, similarly to other disaster debris, also require proper treatment. It was geographically and economically unrealistic to construct new landfill facilities with sufficient capacities to accept these wastes, since their amounts are several times larger than the annual generation of municipal solid waste in each local municipality. For example, disaster debris generation in Iwate prefecture corresponded to 12-year municipal solid waste (MSW) generation in the whole prefecture and, in a more extreme case, in Rikuzentakata city, Iwate prefecture, it corresponded to 280-year local MSW generation. Utilization and minimization of these disaster debris were, therefore, required. The national government decided that proper treatment and utilization of debris and tsunami deposits should be completed by 2014 March (MOE 2011a, 2011b). A significant fraction of these wastes corresponds to tsunami deposit soils. Fig. 1 shows the fractions of generated waste materials in Iwate and Miyagi prefectures (MOE 2014b). Although combustible and incombustible mixtures must be disposed as waste, organic fractions, such as tsunami deposit, concrete, and asphalt, consisted approximately 65% of disaster waste.

A common system of disaster waste treatment can be illustrated in Fig. 2, while the detailed processes of treatment vary by municipality. First, the debris was removed from the affected areas and transported to primary storage sites. Only rough separation, such as separation using operation vehicles and manual separation, was conducted at the primary storage sites. Then, an advanced treatment was conducted at the secondary storage and treatment sites, which were set 1 or 2 sites per one municipality (approximately 30 sites in Miyagi and Iwate prefectures). The system of advanced treatment varies from sites to sites, depending on given conditions of disaster debris to be treated (generated amount of disaster debris, primary separation and storage, type of original soil, etc.), site environments (area limitation, air pollution risks, the number of primary storage sites, etc.), and local resources (waste incinerators, cement plants, etc.). Accordingly, properties of recovered soils obtained through these advanced treatments would be also variable. In order to accelerate the utilization of recovered soil, the Japanese Ministry of Land, Infrastructure, Transports and Tourism (MLIT) established two technical guidelines to construct (1) parks and green spaces as a redundancy zone against tsunamis in which embankments be constructed using disaster wastes and (2) fill embankments at the areas where ground subsidence occurred significantly due to the earthquake (MLIT 2011a, 2011b).

Fig. 1. Composition of disaster waste in each prefecture (data from MOE3)).

Fig. 2. Basic flow of disaster waste treatment (Katsumi et al. 2014).

3 PROPERTIES OF RECOVERED SOIL

3.1 Composition of recovered soil

Eight different recovered soil and residue after treatment, which is soil-like fine fractions after the advanced treatment, were collected at actual treatment sites in Iwate prefecture in September 2012. Fig. 3 illustrates compositions of recovered soils of raw conditions, of re-sieved by 9.5-mm screen, and of re-sieved by 4.75-mm screen. In this graph, “recovered soils” indicate the soils after rough treatment, while “residues” or “residue after treatment” indicate the soil-like fine fractions after advanced treatment. Since the disaster debris was crushed into smaller fractions by the advanced treatment, residue after advanced treatment basically included wood fractions more than recovered soil. All recovered soils and residues were generated after sieved by a 20 mm opening screen except Noda town of 15 mm. Compositions of recovered soils are similar to each other, while those of residues vary by sites. Any recovered soil consists of 80 to 90% soils as a sum of soil fractions both larger and smaller than 2 mm. For example, residues from Yamada town consisted of low fractions of combustible and incombustible matters larger than 2 mm, which may indicate that concise separation can be achieved by the system installed in this town.

The combustible matter content, which may affect material properties as soil, decreased with smaller...
maximum diameter regardless of types and areas of generated material; that is to say, quality of the recovered soil can become increasingly similar to the real soil by re-sieving with smaller screens from the viewpoint of their composition.

### 3.2 Compaction characteristics

Proctor test was conducted on actual recovered soils and residues of raw condition, under 9.5 mm, and under 4.75 mm, respectively, to evaluated compaction characteristics as shown in Fig. 4. Any recovered soils can be expected to be compacted well because the compaction curves of recovered soils are located relatively higher than those of residues after advanced treatment, and have a clear peak due to fewer combustible matters such as wood.

By re-sieving with smaller mesh, compaction characteristics of residues can be improved. For example, the maximum dry density of residue collected from Otsuchi town was improved from approximately 0.75 g/cm³ to 1.00 g/cm³ by re-sieve with 4.75-mm mesh. The compaction characteristics of any recovered soils were almost equal with or without re-sieving because improvement effect was relatively small due to a limited amount of coarse wood chips in original material.

### 3.3 Effect of wood content and wood size

Fig. 5 illustrates unconfined compression strength versus ignition loss at 330°C ($IL_{330}$) after the experiment. As detailed later, since organic matters as well as crystalline water and adsorbed water in soil can be volatilized at 750±50°C, materials were heated at 330°C to evaluate combustible matter content in this study. Simulated recovered soil used in this series of test was prepared by mixing commercial granite soil and wood chips separated from actual recovered soil collected from Iwate prefecture in order to control an amount of wood content of the mixture from 0% to 15.0% in dry mass basis. The simulated recovered soils were prepared with two different wood sizes; one is the mixture with wood chips smaller than 2 mm, and
another is that with wood chips smaller than 4.75 mm. As indicated in this figure, higher $IL_{330}$, i.e. wood content, led smaller unconfined compression strength regardless of wood size, while actual recovered soil at Yamada and residue at Otsuchi represented rather high strength probably because of cementation by calcium carbonate generated by seawater inundation. From the viewpoint of wood size, simulated recovered soil containing smaller wood chips represented higher strength because soil particles can contact and interlock each other.

Compression index increased with increasing $IL_{330}$ as shown in Fig. 6 due to softness of wood fractions. Also, effect of water immersion during consolidation steps was evaluated for all compositions. By comparing with or without water immersion, specimens with water immersion represented compression indexes higher than those without water immersion because wood fractions became more pliant by absorbing water inside.

Table 1. Various ignition losses (Endo et al. 2014).

| Area         | Method and target                                                                 | Target          |
|--------------|-----------------------------------------------------------------------------------|-----------------|
| Geotechnics  | Ignition at 750±50°C for 1 hour                                                     | Volatile substances in soil such as organic matter, crystalline water, and bound water, can be measured. |
| Cement industry | Ignition at 975±25°C (700±25°C for portland cement)                | Impurity content can be measured. Clinker, dehydration by hydration, etc. affects the value with up to 4.78%. |
| Waste treatment | Ignition at 600±25°C for 3 hours                                                | Residue after incineration can be measured. Japanese standard for landfilng is 15% of this value. |
| Industrial wastewater | Ignition at 600±25°C for 30 minutes                                                | Inorganic matter content in industrial wastewater can be measured. |

5 UTILIZATION STRATEGY FOR FORTHCOMING DISASTERS

In this paper, mechanical properties of recovered soils were discussed based on the experimental results from the viewpoint of effect of re-sieving, wood content, and wood size. Since the combustible matter content can be reduced by re-sieving with a smaller size of screen, the recovered soil can be utilized in various applications by re-sieving into a proper maximum diameter.

The Japanese Geotechnical Society established Technical Committee on Recovered Geo-Materials in 2013 with the supports from National Institute for Environmental Studies and Mud Recycling Association, and released “Guideline for Utilization of
Geo-Materials Recovered from Disaster Debris” to tie different institutions and sections to promote the effective use of soils, either recovered, excavated, or new as shown in Fig. 7. In this guideline, three important concepts are presented; (1) construction of resilient infrastructures, (2) promotion of utilization of the recovered geo-materials, and (3) optimization of combined projects, but not single projects, in the area. For strategic utilization, necessary volume and quality of geo-material in each application should be figured out as quickly as possible after disasters in terms of material balance.

Fig. 7. Concept of integrated management of the soils for the disaster recovery (JGS 2014).

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