Evaluation and Usage of the Soil Generated from Disaster Waste - Case History of Great East Japan Disaster

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ABSTRACT: Soils including disaster waste and tsunami deposition soils were generated in large quantities from the Great East Japan Earthquake Disaster in 2011. Organic matters, such as wood waste, are contained in these soils in large quantities, and in order to use as an engineered fill material for suitable purpose at suitable place, it is necessary to evaluate the soil mechanical properties. It is reported how the waste was treated and how much and what kind of soils were generated from the disaster. Soil specimen was prepared through the same separation treatment as that conducting at the actual waste treatment site. Using the specimen with different wood waste percentage, the availability of soils as a construction material was studied.

1 INTRODUCTION

The 2011 off the Pacific Coast of Tohoku earthquake resulted in the huge disaster waste and tsunami deposition soils. Total amount of the waste in the most affected three prefectures (Iwate, Miyagi and Fukushima) is about 28 million tons. The processing work in Iwate and Miyagi prefectures have already been finished by end of March 2014. However, in the Fukushima prefecture, the work has not been finished yet, because of the waste being contaminated with nuclear substances. Fig.1 shows a map of the north part of mainland Japan and the location of debris processing site in Ishinomaki City. Ishinomakifaces the Pacific Ocean and was one of the most severely affected areas. It is located about 400km North of Tokyo and about 50km from Sendai-City, the capital city of Miyagi prefecture.

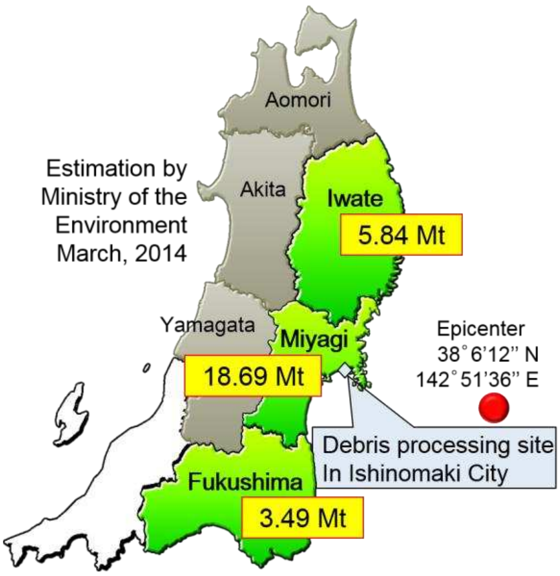

Fig.1 Amount of disaster waste generated including tsunami deposition soils and the location of debris processing site in Ishinomakicity, which is the largest treatment site in affected area.

During the processing work, huge amount of soils such as soils included in waste and tsunami deposition soilsare generated. Because these soilsare being considered to be usedas an earth fill material for embankmentsand residential land, a foundation ground of seashore disaster-prevention forests, a quality control method is needed, and the engineering properties of the soils containing large quantities of organic matter, such as wood waste should be evaluated.

We studied the physical and engineering properties of actual soils generated by the disaster and clarify the relationship between the strength property and the degree of compaction, and to examine the points for quality control when using the generated soils as construction materials.

2 SAMPLE SOILS AND PREPARATION

2.1 *Sampling site and original soil specimen*

In this research, soil sampled from the disaster waste treatment stockyard in Ishinomaki, hereafter referred to as "original soil", were used (refer to Fig.2). Operation flow A-line and the sampling position of the original soil are shown in Fig.2.The original soil are crushed and sorted which have passed through a 30mm sieve under dry condition in the first separation process. As shown in the photograph, the original soil include many wooden tips. Its ignition loss obtained from a standardlaboratory test was about 13 %.

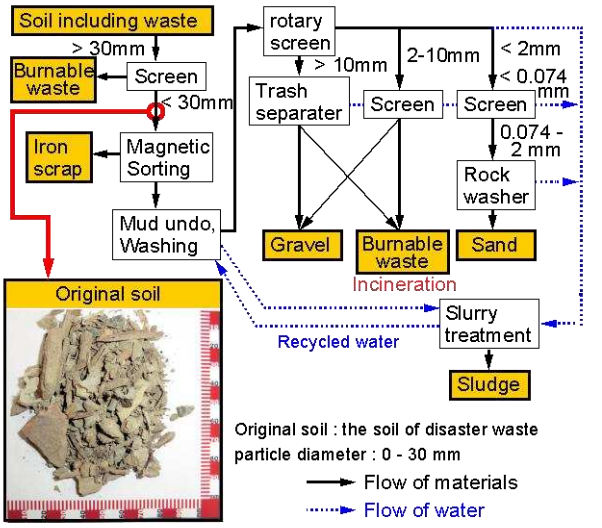

Fig.2 Waste separation flow A-line (under dry condition) and the original soil.

2.2 *Preparation of the other specimens*

Since the original soilincluded significant organic matter and other waste, two more separation steps in the sieving processes were added as shown in Fig.3.As a result, the other two soil specimens were obtained. One is referred to as the "5mm sieve soil", which passed through a vibrating-screen sorterwith punched holes of 5mm diameter. The other is the "3mm sieve soil", which passed through a special sieve (a wind power sorter) with punched holes of 3mm diameter. The ratios of inorganic substances to organic matter in the original soil and their grain sizes are listed in Table 1.

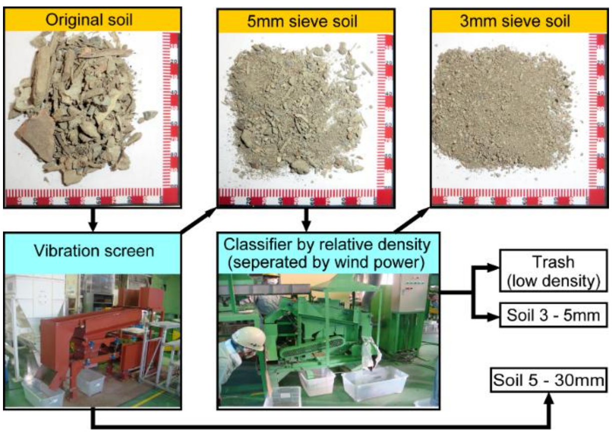

Fig. 3 Creation method of the 5mm and 3mmsieve soil.

Table 1Quantity of organic and inorganic matter contained in the original soil and rate of grain size

Inorganic matter			Organic matter (Ignition loss , 650℃)		
86.9%			13.1%		
5- 30mm	**3- 5mm**	**0- 3mm**	**5- 30mm**	**3- 5mm**	**0- 3mm**
69.6%	2.0%	15.3%	10.4%	1.2%	1.5%

As control specimens, a tsunami deposition soil named "Watari sand", which was deposited near the seashore ofWatari-town, and "washed sand" (refer to Fig.4), which was the tsunami deposition soils carried into the Ishinomakiarea disaster waste treatment stock yard, washed withfresh water and then passed through a 2mm sieve.

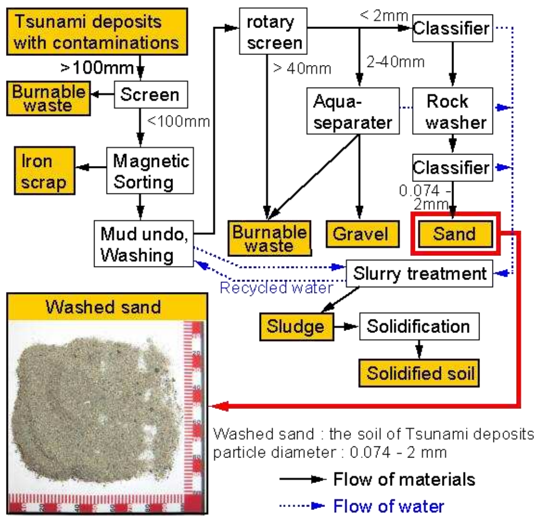

Fig.4 Extraction of the "washed sand" in a separation flow B-line(under wet condition)

3 TEST RESULTS AND DISCUSSION

3.1 *Grain size distributions*

The particle size distribution of each sample is shown in Fig. 5. The original soil containapproximately 60% of the particles of diameter of 5mm or more. Although this value is different from the values in Table 1, the value in Table 1 is a mass ratio of the soilsseparatedwith the sorting machine, and since the soil passes through the sieve sorter in about 5 to 10 seconds, the mass ratio is smaller than that passes through the ordinary sieve.

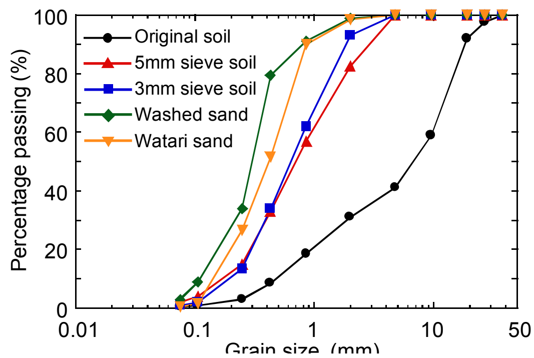

Fig. 5 Grain size distribution curves of each sample

Although the difference between the 5mm and 3 mm sieve soil is not so clear on the grain size distribution curves, photograph in Fig.3shows an actual sample withalarge piece of woodremoved from the 3 mm sieve soil. The reason why small difference in the grain size distribution curve is that the density of pieces of wooden waste is lower than that of soil grains, so the mass percentage does not reflect the volume of the removed piece of wooden waste.

3.2 *Physical properties of the specimens*

The physical properties as determined by the tests are shown in Table 2.

1) Density of soil particles
The density of the soil grains of the original soils was 2.601g/cm^3. Despite the largeconspicuous piece of wood, the density did not decrease noticeably. On the other hand, the densitiesof the 5mm and 3mm sieve soilwere 2.527g/cm^{3}and 2.534g/cm^3, respectively.

2) Ignition loss
The decrease in the mass ratiosin the ignition loss test (650℃) were from 7.42% for washed sand to13.37% for the 5mm sieve soil. Since the ignition loss of 3mm sieve soil is smaller than those of the original soil and 5mm sieve soil, the special sieve sorterused when creating the 3mm sieve soil sample was effective for the removal of organic matter such as wooden waste.

3) Liquid limits of soils including waste
The liquid limits of the samples of the original soil, and the 5mm and 3mm sieve soil were all approximately 30%, and there was no large difference arising from the separating operation. When liquid and plastic limit tests are performed, the fraction passing 0.425mm was used.

4) Compaction test (maximum dry density and optimum moisture content)
When the maximum particle diameter of the original soil was 30mm, the compaction test used a15cm diameter mold and the B-a method (a 2.5-kg rammer, three layers of 55 blows timescompaction, dry technique non-duplication method). When the maximum particle diameter was below 19mm, the samples were examined us-

Table 2 Physical and engineering properties of sample soils obtained from JGS standard.

Item			Unit	Original soil		5mm sieve soil	3mm sieve soil	Washed sand	Watari sand
Soil classification			(-)	Very Sandy Gravel		Gravelly Sand	Slightly GS	Sand	Sand
Soil particle density			(g/cm^3)	2.601		2.527	2.534	2.696	2.596
Ignition loss			(%)	13.11		13.37	8.90	7.42	-
Liquid limit			(%)	33.7		31.7	32.0	NP	NP
Maximum dry density by compression test			(g/cm^3)	1.46		1.47	1.56	1.59	1.67
Optimum moisture content			(%)	23		24	21	17	15
Permeability	Maximum		(m/s)	9.7×10^{-8}	3.9×10^{-5}	2.0×10^{-8}	1.2×10^{-7}	-	-
	Minimum		(m/s)	8.4×10^{-8}	2.9×10^{-5}	1.5×10^{-8}	8.0×10^{-8}	-	-
	Dry density		(g/cm^3)	1.449	1.397	1.470	1.479	-	-
	Water Content		(%)	24.2	16.7	23.6	19.7	-	-
Triaxial compression test *	c'		(kPa)	50		50	40	-	-
	φ'		(degree)	43～51		32.8	38.2	-	-
Consolidation test	Yield stress	$Pc_{,dry}$	(kPa)	28		165	135	140	190
		$Pc_{,wet}$	(kPa)	62		140	150	280	260
	Compression index	$Cc_{,dry}$	(-)	0.280		0.415	0.445	0.935	0.445
		$Cc_{,wet}$	(-)	0.360		0.365	0.360	0.122	0.400

Each result of triaxial compression test is the value at the condition of maximum dry density. , - : no measurement

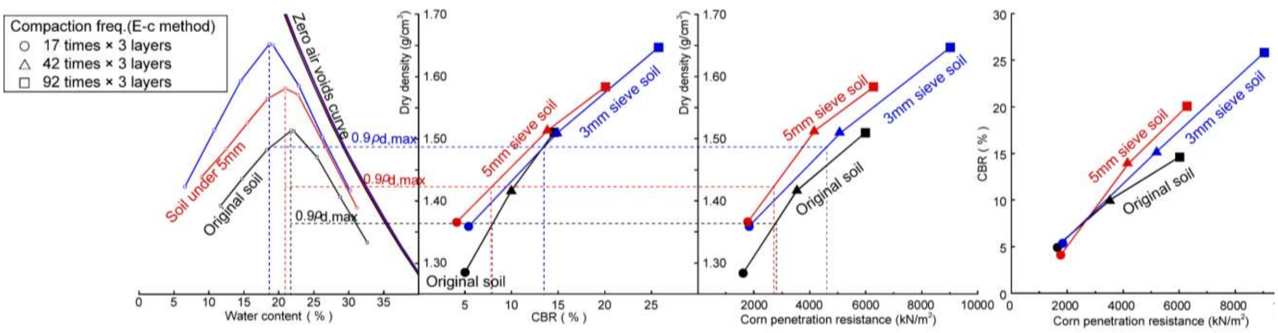

Fig. 6 Tests results of CBR test and cone penetration test, and its relation to compaction property.

ing a10cm diameter mouldand the A-a method (a 2.5-kg rammer, three layers of 25 blows times compaction, dry technique non-duplication method). The maximum dry density and the value of the optimal moisture contents are shown in Table 2.For all the soils, the compaction characteristic was shown to improve with separating operation as shown in Fig.6. A large variation was noted in the original soil in dry density by compaction because of the large pieces of wood or rubble in the soils. The washed sand appears to be ordinary sand which is easy to treat, but compaction was shown to be difficult.

5) Permeability coefficient

The permeability coefficients of the original soil, and the 5mm and 3mmsieve soil were all in the order of 10^{-6}cm/s when fully well compaction state at the optimum moisture content. However, in the case of the original soil, when the dry density becomes 1.397g/cm^{3}from 1.449g/cm^3, the coefficient of permeability increases rapidly to the order of 10^{-3}cm/s from the order of 10^{-6}cm/s. This point should be paid attention to.

6) Triaxial compression test

CU bar triaxial monotonic compression tests were conducted using reconstituted specimen sizes 10 cm in diameter and 20 cm in height for the original soil, and 5 cm in diameter and 10 cm in height for the 5mm and 3mm sieve soil samples. The test specimens were created so that all of the samples might serve as the maximum dry density of compaction. Since the samples contained gravel, φ' of the original soil increased from 43 to 51 degree. The wide range of values of φ' can be attributed to the nonhomogeneous content of soils. The value for the 5mm and 3mm sieve soil were 32.8 and 38.2 degrees, respectively.

7) Consolidation properties

A newly created test container 10 cm in diameter and 8 cm in height was used. The tests were performed until 157kPa, which corresponds to an overburden height of about 10m.In order to observe the difference of the compressibility between the dry and wet condition, firstly the test under the dry condition was conducted with the loading and unloading process. Then, the rebound behavior was observed during the saturation (water absorption) process under the low compression stress condition. Finally, a re-compression test under the wet condition was conducted. The compaction yield stress ($pc_{,\,dry}$) of the dry sample, the compaction yield stress ($pc_{,\,wet}$) of the saturated sample, the compression index ($Cc_{,\,dry}$) of the dry sample, and the compression index ($Cc_{,\,wet}$) of the wet sample are shown in Table 2. In the event that stress is concentrated locally on a large pieces of wood waste contained in the original soil, the soil skeleton is considered deformable even at a small effective consolidation stress. On the other hand, in the case of the 5mm and 3mm sieve soil, the ($pc,\,_{dry}$) and ($pc,\,_{wet}$) values range from 135 to 165kPa, which is larger than that of the original soil.

8) CBR test and cone penetration test

The specimens with the optimum moisture content were compacted in three equal layers, each layer receiving the same number of blows with a 4.5kg rammer, and the CBR value was calculated after submersion for four days using the 15 cm diameter mold.The relationship between the compaction curves, the CBR values and the cone index is shown in Fig.6. The CBR values at the maximum dry density of the original soil, and the 5mm and 3mm sieve soil were 14.6, 20.1 and 25.8%, respectively. The results show that the increase in the CBR value to the increase in dry density was small in the original soil. This indicates that the bearing capacity does not increase easily in the original soil.Regardless of the sample, when the degree of compaction is maintained at 90%, it has been shown possible to secure a CBR value of 5% or more (which makes it possible to use the material as housing development fill) and a cone index of 400kN/m^2 or more (which makes it possible to use the material in a railroad bed).

4 CONCLUSIONS AND REMARKS

As a whole, when the mechanical properties of sample soils and the time and effort of sieving (the separating operation) are taken into consideration, it is thought that the 5mm sieve soil is the most efficient. By reducing the amount of wooden waste in the original soil, the compaction yield stress increases sharply, and providing thefill thickness is about 10 m, large subsidence will not arise. Provided that suitable handling processing is performed to ensure that the soils meet the demand quality required to be used as construction earth material.

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