Material Characteristics and Leaching Behaviour of Recycled Bassanaite as Soil improvement Effects from Waste Plaster Boards

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ABSTRACT

Plaster boards are interior materials for buildings primarily comprising of plaster shaped into a board and then coated on both sides with paper. They are widely used for the walls and ceilings of buildings. Furthermore, they are also widely used as building foundation materials; consequently, the amount of waste plaster boards being discharged from construction sites is increasing every year because either new buildings are built or old buildings are dismantled. The total annual amount of waste plaster boards discarded in 2013 is expected to be about 2 million tonnes. For this reason, the development of recycling and reusing technologies for waste plaster boards discarded from construction sites is an urgent issue. This paper reports on the results of research conducted for the development of soil improvement materials using recycled bassanite.

Keywords: recycled bassanite, soil improvement, waste plaster board, unconfined compression strength, leaching behaviour

1 INTRODUCTION

It is considered that in the future, the cost of processing waste gypsum boards will increase greatly due to the shift from stable disposal facilities to managed-type disposal facilities, and the quantity of building waste associated with renewal of housing and social capital stock. Therefore, the development of recycling and reuse technologies for waste gypsum boards from building sites is an urgent task. Kamei and the author have investigated the use of regenerated bassanite obtained by calcining gypsum separated from waste plasterboard as a geotechnical material (Sato et al. 2009, Kamei et al. 2009). The results indicated that there is an improvement effect soon after mixing into comparatively high-water-content soil materials. In this paper, we report on the results of Ministry of the Environment Notification JLT No. 46 tests, which were carried out to investigate the leaching characteristics of soil improved by recycled bassanite. Unconfined compression tests were carried out to investigate the material improvement effect of mixing recycled bassanite as a hardener into some kinds of soil generated from construction site.

2 RECYCLED BASSANITE

There are three methods used to calcinate recycled bassanites: the direct calcinating method, the indirect calcinating method and the IH calcinating method. Currently, the indirect and IH calcinating methods are primarily used. Incidentally, two types of recycled bassanites were used for this research: recycled bassanite calcinated by the indirect calcinating method (hereinafter referred to as 'Recycled bassanite A') and recycled bassanite calcinated by the IH calcinating method (hereinafter referred to as 'Recycled bassanite B'). Symbols indicated in the legend are "P_A" for Recycled bassanite A, "P_B" for Recycled bassanite B and "C" for the blast furnace slag cement type B.

3 CHARACTERISTICS OF SOIL IMPROVEMENT MATERIALS

3.1 Soil samples used in the experiment

Decomposed granite soil (DS) collected in Fukuoka City and dewatering cake (DC), which is generated in the process of washing and reusing soil resulting from construction work, were used. The grain size accumulation curve is shown in Figure 1, whereas the physical characteristic values of the soil samples are shown in Table 1. The dewatering cake has a high percentage of fine-grain content and contains considerable organic matter. In contrast, the decomposed granite soil has a broad range of grain sizes and a soil sample with a good size distribution

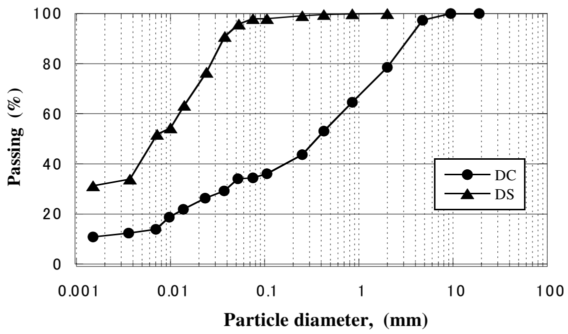


Figure 1 Grain size distribution curve

Table1 Physical properties of soil

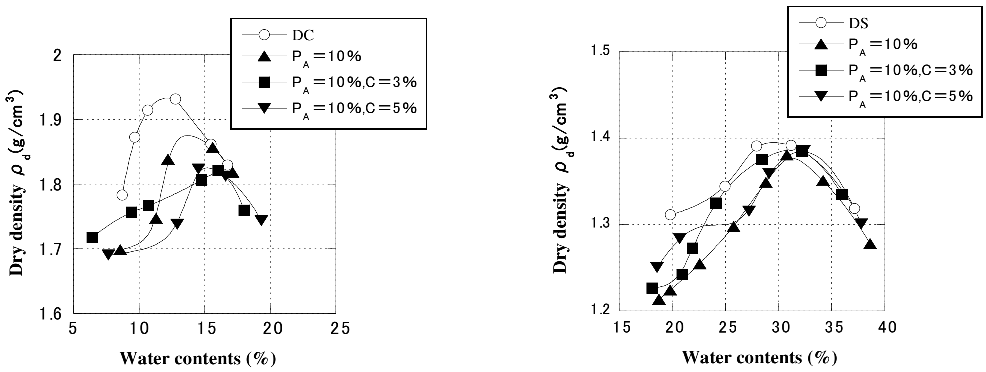
	DC	DS
ρ_s (g/cm^3)	2.64	2.62
Initial water contents (%)	3.0	15.0
F_c (%)	34.4	100.0
I_p	-	21.0
Ig-loss (%)	3.7	18.4

3.2 Strength characteristics of improved materials

The composition conditions are described in Table 2. Blast furnace cement type B was used as a supplementary hardening material for investigation 1. An unconfined compression test was performed to understand the strength and deformation characteristics of the compacted soil material. First, a compaction test (A-a method) was performed on the respective mixed materials for obtaining the maximum dry density and optimum water content (Figure 2). The test specimen used for the unconfined compression test was prepared with the optimum water content; from the results of the compaction test, the compaction density was determined as D (ρ_d/ρ_{dmax}) = 95% and was created by filling a mold with a diameter (ϕ) = 5 cm and a height (h) = 10 cm, with stamping in five layers. It was then cured at a constant temperature (room temperature, 20 $\pm$ 2°C) over prescribed periods (0, 7, 28 and 56 days).

Table 2 Mixing condition

Soil	Recyeled Bassanite		S.H.M	
Varieties	Varieties	Mixing ratio (%)	Varieties	Mixing ratio (%)
DC DS	P_A P_B	10, 15	Cement	0, 3, 5



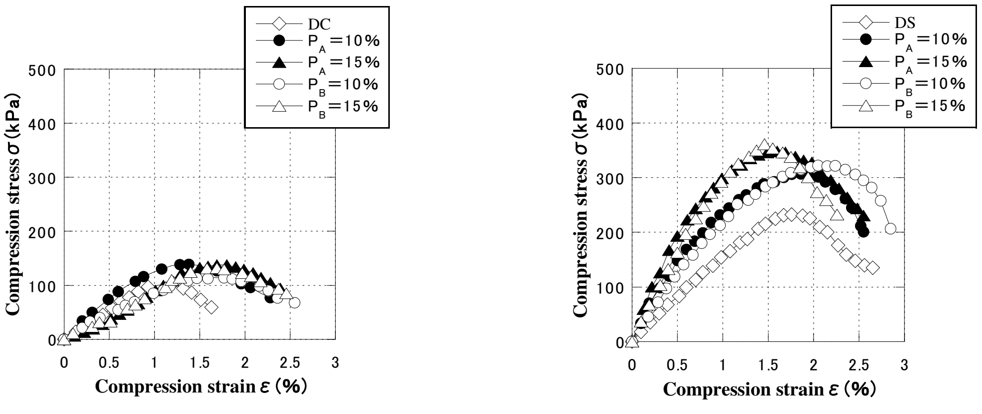
(a) DC **(b) DS**

Figure 2 Compaction carve (P_A=10%, C= 3, 5 %)

3.3 Results of unconfined compression test

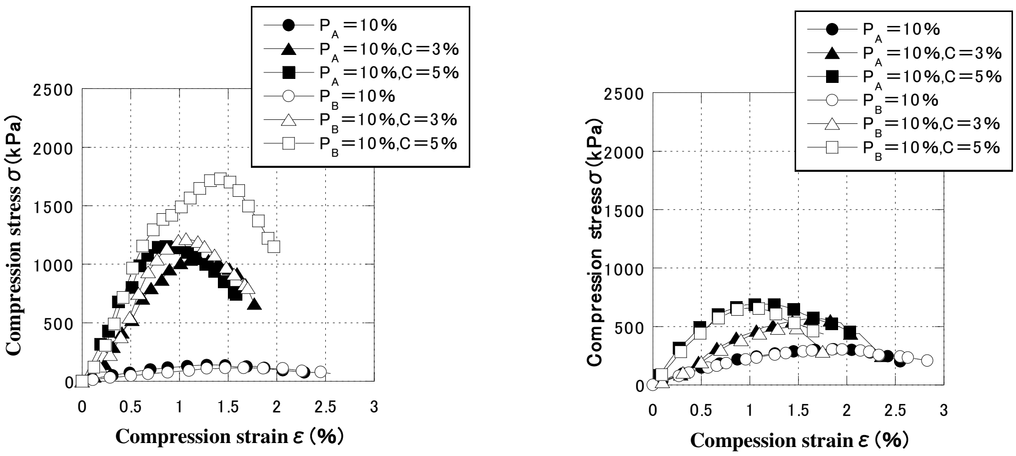
The stress–strain curve of the material after seven days of curing and with only recycled bassanite added is shown in Figure 3. As seen from the results, the shear strength improved with each soil material owing to the addition of recycled bassanite.

An increase in the initial stiffness of the materials was also verified. It is apparent from these results, however, that this improvement material is unable to provide a significant increase in the strength of materials. The results of the unconfined compression test on the test specimen on mixing more supplementary hardening material (S.H.M.: blast furnace slag cement type B) to recycled bassanite is shown in Figure 4. The results reveal that there is a prospect for increasing the strength of the material by mixing the supplementary hardening material. This tendency is more significant with an increase in the strength of the decomposed granite soil. However, speculation regarding the dewatering cake (DC) is that the organic matter in the soil is inhibiting the strength manifesting effects.



(a) DC **(b) DS**

Figure 3 Unconfined compression tests (t_c = 7, $P_{A,B}$ =10,15%)

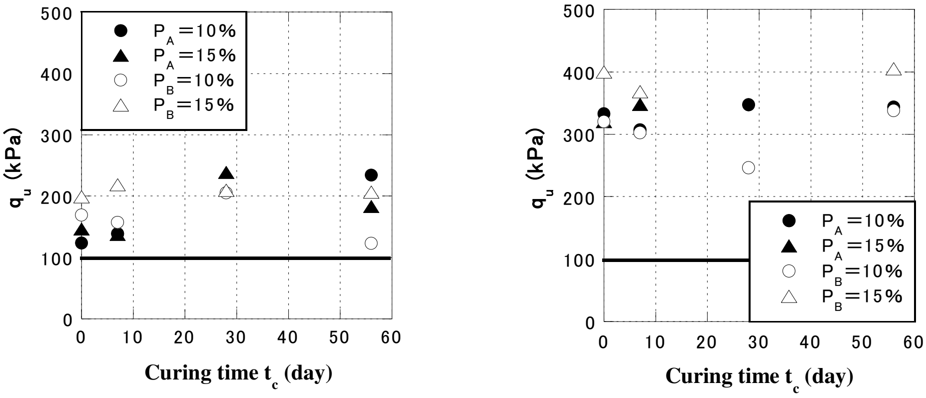


(a) DC **(b) DS**

Figure 4 Unconfined compression tests (t_c = 7, $P_{A,B}$=10%+C=3, 5%)

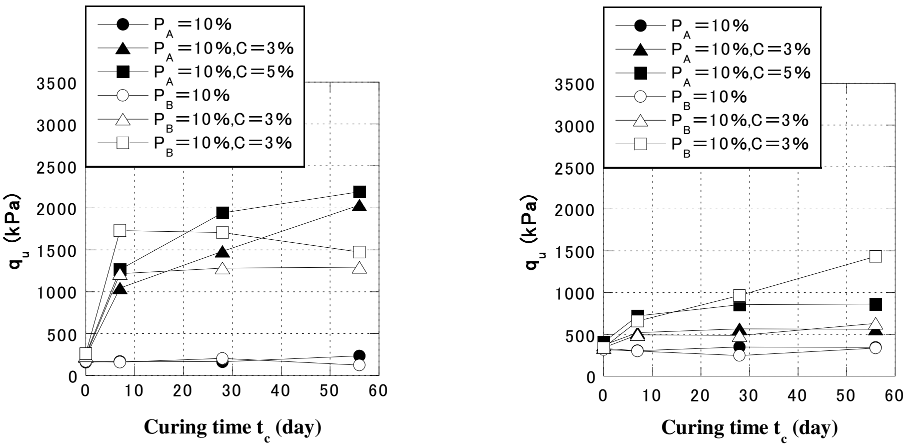
3.4 Relationship between the number of curing days and unconfined compression strength

The relationship between the number of curing days and the unconfined compression strength of the material to which only recycled bassanite was added is shown in Figure 5. The black line in these charts represents the target strength (q_u = 100 kPa) of ordinary banking materials. The results indicate that regardless of the soil material, an almost constant value is obtained for an unconfined compression strength with respect to an increased number of curing days, thereby satisfying the target strength of ordinary banking materials. In this manner, an increase in the strength of soil materials can be expected immediately after adding recycled bassanite, regardless of the type of soil material involved. In other words, by using recycled bassanite, the trafficability is improved at the construction site at an early stage and it is the improvement material that shortens construction periods. The relationship between the number of curing days and the unconfined compression test for materials with the added supplementary hardening material is shown in Figure 6. The effects of the supplementary hardening material are indicated by the trend of increasing unconfined compression strength after seven days (t_c=7) of curing, after which the increase becomes more gradual with the passing of curing days. A significant increase in strength occurs with the decomposed granite soil with the passing of curing days. The increase in strength of the dewatering cake was not as significant as with that of the decomposed granite soil. As mentioned earlier, this is believed to be caused by the organic matter in the soil of the dewatering cake.



(a) DC (b) DS

Figure 5 Effect of bassanites types and volumes on unconfined compression strength



(a) DC (b) DS

Figure 6 Effect of cement content on unconfined compression strength

4 INVESTIGATION OF ENVIRONMENTAL SAFETY FOR MATERIAL WITH RECYCLED BASSANITE MIXTURE

4.1 Test sample used in the experiment

In this section, six types of soil materials, which are anticipated in parts of Kyushu, were used:1) decomposed granite soil (DS), 2) dewatering cake (DC) and 3) Shirasu soil (SS), 4) Hakata clay (HC), 5) Kuroboku soil (KS) and 6) weathered rock soil (WS). Recycled bassanite A (P_A), Recycled bassanite B (P_B) and the blast furnace type slag cement B(C) was also used.

Table 3 Physical properties of soil

	DS	DC	SS	HC	KS	WS
ρ_s(g/cm^3)	2.64	2.62	2.42	2.76	2.39	2.72
Initial water contents (%)	3.0	15.0	12.0	83.3	22.0	4.5
F_c(%)	34.4	100.0	43.0	90.0	79.9	72.2
I_p	-	21.0	-	41.6	-	38.5
Ig-loss(%)	3.7	18.4	5.6	43.0	23.7	10.9

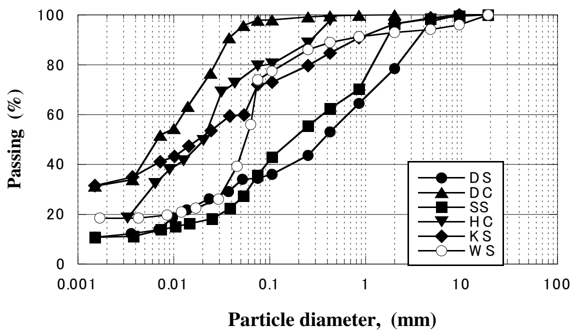


Figure 7 Grain size distribution curve

Table 4 Mixing condition

Soil	Recyeled Bassanite		Optimum water contents (%)
	Varieties	Mixing ratio (%)	
DS	P_A	10	143
DC		15	
SS		20	
HC	P_B	10	116
KS		15	
WS		20	

Physical properties are shown in Table 3, whereas the grain size accumulation curve is shown in Figure 7. The dewatering cake(DC), Hakata clay(HC), Kuroboku soil(KS) and weathered rock soil(WS) have a 70% fine-grain content. This is a particularly high percentage and these materials contain considerable organic matter. In contrast, the decomposed granite soil (DS) and Shirasu soil(SS) have a broad range of grain sizes and these soil samples have a good size distribution.

4.2 Impact of soil material on fluorine elution characteristics

The composition conditions are described in Table 4. The rate of plaster addition refers to the weight ratio (%) of soil material in dry condition, while the water carrying capacity refers to the optimum amount of water required for the solidification of plaster, as stipulated by JIS R 9112. It is thus the weight ratio (%) with respect to plaster. The test sample preparation method involved mixing and agitating the soil material, plaster and water in a mixer for one minute, then placing them in a bag with a zipper, which was then left in a room with a constant temperature (room temperature, 20 ± 2°C) over prescribed periods (0, 7, 28 and 56 days) for curing. After curing, a fluorine (F^-) measurement was taken with ion chromatography, according to the test method described by Notification No. 46 of the Environment Agency.
The relationship between the plaster additive rate after curing for one day and the fluorine elution amount is shown in Figure 8. The figure reveals that the amount of fluorine elution increases with an increase in the plaster additive rate. This is considered to be caused by the fact that from the start, the plaster displayed fluorine elution five to six times the soil environmental standard value, as shown in the results of the elution test for the test sample in Table 5.

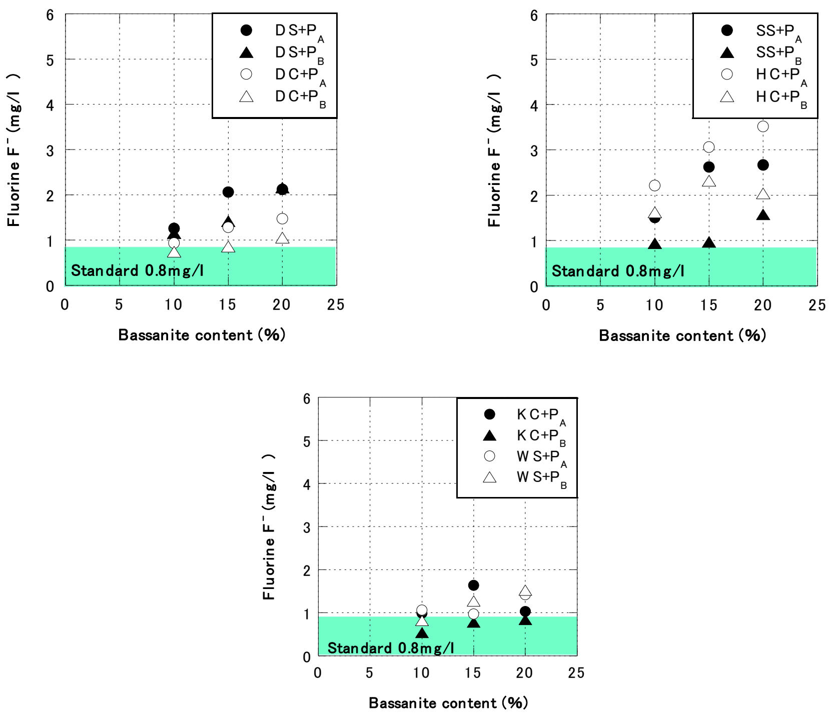


Figure 8 Effect of surplus soil type on fluorine solubility from leaching

Table 5 Leaching test results

Soil	pH	F (mg/l)
DC	6.81	N.D
DS	8.57	0.54
SS	4.03	N.D
HC	7.71	1.23
KC	6.00	0.56
WS	5.03	N.D
P_A	6.97	4.84
P_B	7.46	5.94
Standard	-	0.80

4.3 Fluorine elution characteristics of solidified sample

The test sample was the same test sample used for an unconfined compression test from which an Fluorine (F^-) measurement was taken with ion chromatography, according to the test method described by Notification No. 46 of the Environment Agency, after completing the air curing in a room with a constant temperature (room temperature, 20 ± 2°C) for 28 days. Furthermore, the test was performed only for the dewatering cake.

The results of the elution test for $P_{A,B}$= 15% conducted after 28 days of curing are shown in Table 6. The table reveals that addition of a supplementary hardening material (blast furnace slag cement type B) decreased the amount of fluorine elution. This is considered to be caused by the trapping of cement hydrated minerals by heavy metal ions inside crystals. It was therefore indicated that fluorine elution can be inhibited by adding a supplementary hardening material.

Table 6 Elution test results

<table>
<tr><th rowspan="2">Soil</th><th colspan="2">Recyeled Bassanite</th><th>Cement</th><th colspan="2">JLT46</th></tr>
<tr><th>Varieties</th><th>Mixing ratio (%)</th><th>Mixing ratio (%)</th><th>pH</th><th>F (mg/l)</th></tr>
<tr><td rowspan="6">DC</td><td rowspan="3">P_A</td><td rowspan="6">15</td><td>0</td><td>8.65</td><td>1.235</td></tr>
<tr><td>3</td><td>11.11</td><td>1.040</td></tr>
<tr><td>5</td><td>11.35</td><td>N.D</td></tr>
<tr><td rowspan="3">P_B</td><td>0</td><td>7.85</td><td>0.722</td></tr>
<tr><td>3</td><td>11.20</td><td>0.640</td></tr>
<tr><td>5</td><td>11.45</td><td>0.216</td></tr>
</table>

5 CONCLUSION

The following conclusions were obtained as a result of the experiments.

1. It is possible to increase the strength of the mixture material by mixing the soil material with recycled bassanite and compacting it. This improvement effect, furthermore, is exhibited immediately after the materials are mixed. It was also revealed that this does not change by curing.
2. It was revealed that the increased strength of mixture material can be expected by adding a supplementary hardening material(S.H.M.: blast furnace slag cement type B). Further, it was revealed that the necessary amount of strength can be set at the time it is put to effective use.
3. Fluorine elution characteristics vary depending on the soil material and a high degree of correlation between the percentage of fine-grain content and fluorine absorption rate.
4. Fluorine elution can be inhibited by adding a supplementary hardening material.

6 REFERENCES

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