Study on subjects and applicability for mud improvement due to mixing with paper sludge ash

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ABSTRACT

Paper sludge (PS) ash is cinder that is generated when paper sludge (waste of paper manufacturing) is incinerated. We have previously studied application of PS ash in the construction field (improvement of excavated mud etc.) and found that PS Ash had high swelling ability and can be used for environmental clarification of mud. We developed a new soil improvement method and design. However, in late years it comes to be recognized that the improving effect becomes bigger than early stage having curing function and the coverage of PS Ash product spreads out because the property of PS ash changes and some product is manufactured using different PS ash by different processing. In this paper, I examine the improvement function of the present PS ash materials and report the applicability of new PS ash improvement.

Keywords: cone penetration test, industrial wastes, paper sludge ash, soil improvement

1 BACKGROUND AND PURPOSE

Background of this study is on the promotion of zero emissions across the different industrial fields including environmental issues as shown in Fig.1.

Main characteristics of improving material products based on high physical water absorbing performance were that improvement finished immediately without curing time and pH of improved soil returned to a neutral level just after improving but the instantaneous improving by only absorbing without curing effect has the disadvantage that it is necessary to use more mixing weight than chemical improvement for high water content mud. In order to improve these weak points taking advantage of drying in a few days for a poor mixing, a short-term curing improvement was proposed. But in late years it comes to be recognized that the improving effect becomes bigger than early stage having curing function and the coverage of PS Ash product spreads out because the property of PS ash changes and some product is manufactured using different PS ash by different processing. Therefore, investigating the improvement function of the present PS ash materials and report the value-added application for new fields.

2 EVALUATION OF THE WATER ABSORPTION PERFORMANCE

In order to establish a rational mixing design for instantaneous water absorption performance without curing period, the results of the formulation studies were performed on 188 kinds of mud samples taken from the various fields was organized in Fig.2.

Fig. 1. Background of this study.

The surplus water of mud is assumed to moisture above the liquid limit w_L and organized the relationship between surplus water ($w-w_L$) and additive ratio η to gain design strength ($q_c = 200\text{KN} / \text{m}^2$) so that additive ratio η is given by estimation equation (1)

$$\eta = a \{ (w-w_L) + 37.8 \log IP - 33.5 \} \quad (1)$$

The additive ratio η is Mm / Ms and each parameter is defined as follows. (Mm: additional weight of the improvement material Ms: mud dry weight).

In equation (1), I_p is plasticity index. Table 1 shows the component composition and the physico-chemical characteristics of the A type product at the time of a start. About instant improving performance of PS ash materials by absorbing function, please refer literature 1)-2) because it describes in detail.

Fig. 2. Relationship between η and $w-w_L$.

Table 1. Physico-chemical characteristics of the A type (at the time of a start) product.

Chemical ingredient	Ingredient content(%) A Type (At the time of a start)	Product	A Type (At the time of start)
Al_2O_3	22.6	Particle density(g/cm ³)	2.4
SiO_2	33.8	pH	under 10
CaO	18.1	Bulk density(g/cm ³)	0.67
MgO	5.2	Absorbing ratio w_{ab} (%)	105
Fe_2O_3	1.8		

3 IMPROVING PERFORMANCE

The results comparing the present PS ash improvement material with cement-based solidifying material on improving effect under same 1-week curing condition is shown in Fig.3. This results indicated that the present PS ash improvement material had the improving effect including curing more than the same level with cement-based material.

3.1 Material characteristics

The component composition and the physico-chemical characteristics of the current A type and B type product that was used in this test are shown in Table 2. Initial Ca content is very low in the present circumstance, it can be seen that the Ca component has become bigger.

Fig. 3. Improving effect of present PS ash material.

Table 2. Physico-chemical characteristics of product.

Chemical ingredient	Ingredient content(%) A Type (At Present)	Ingredient content(%) B Type (At Present)	Product	A Type (At Present)	B Type (At Present)
Al_2O_3	15~35	16~20	Particle density(g/cm ³)	2.55	2.77
SiO_2	15~35	23~37	pH	under 12	under 11
CaO	30~60	35~40	Bulk density(g/cm ³)	0.67	0.67
			Absorbing ratio w_{ab} (%)	100	150

3.2 Test method

For the evaluation of the improving effect of mud, cone index test of compacted soil was performed (JIS A 1228). As mud sample in this study, Fujimori clay of the criteria that is used for the quality control of PS ash improvement material (Table 3) and the sample generated in the field site sample (drilling mud, deposited sludge, dam sediment) are used.

3.3 Test result

Fig. 4 shows the results of curing effect of PS ash improvement material for high water content mud. In this experiment Curing period is provided for one week, but it's clear most of curing effect is achieved within 4 days and it's possible to reduce the mixing weight to about 50%. Figure. 5 shows the difference of absorbing performance between 2kinds of products (type A, type B). Especially type B at present continue absorbing for 2days and eventually the water absorbing ratio (w_{ab}) has become 1.5 times.

Table 3. Physical characteristics of Fujimori clay.

Name	Fujimori clay
Particle density(g/cm ³)	2.671
w(%)	72
wL(%)	58
wP(%)	24
Ip	34

Fig. 4. Curing effect of PS ash improvement.

Fig. 5. Absorbing characteristics of PS ash materials.

Though the absorbing performance of type A doesn't change in spite of big changes in the Ca component, in the absorbing characteristic of type B the quite difference appears despite a little change of component configuration. Fig .6 shows the difference between the curing conditions (air-dry curing and sealed curing). It was clear that type A and type B had same curing effect in spite of different absorbing performance. As the curing effect exists under sealed condition, it was to organize the relationship curing days and required mixing weight ratio S_d / S_0 in Fig .7 (S_d : required mixing weight in d days curing, S_0 : required mixing weight without curing). Until curing 4 days, S_d / S_0 is reduced proportionately, the half of the curing effect can be caused not due to drying.

Fig. 6. Comparison of curing condition.

Fig. 7. Rate of curing effect.

4 ENVIRONMENTAL INFLUENCE

The main characteristics of PS ash improvement materials were that improved soil was in the Neutral area and not to give the harmful impact to neighboring environment.

But in this paper, I investigated pH properties, a deodorant function and the insolubilization function of the harmful things to be related to pH of the material as

the pH level of present materials becomes higher with the increase of the improving effect.

4.1 Time-dependent change of pH

The result of time-dependent change of pH for six kinds of mud specimen is shown in Figure.8. It was confirmed that all improved soils almost returned to a neutral level in 1-2 weeks.

Fig. 7. Comparison of curing condition.

4.2 Deodorizing function

Deodorization can be seriously cited as an environmental problem in mud improving. Especially mud hydrogen sulfide odor and ammonia odor improving the mud by cement lime-based solidifying material becomes a problem. Table 4 shows the test results performed by triangle odor bag method for odor sensory measurement for bottom mud of fishing port. It was clear that the deodorizing effect of PS ash material was shown for all samples. In the B fishing port bottom mud having a particularly strong putrid odor, odor concentration was reduced to less than 1/1000. The result to organize ammonia and hydrogen sulfide concentration and pH for the parameters for many of the odor test results was carried out at the fishing port bottom mud was shown in Fig.8. A strong correlation has been confirmed to the pH and odor concentration. Optimum pH is in the 8.5-9.5 and it was clear that present PS ash material in the tendency to alkali has deodorizing function.

Table 4. Odor test by triangle odor bag method for odor sensory measurement.

Fishery Harbor A Bottom Mud	Quality of Odor	Sewage Smell	No Smell
	Odor Concentration	98	12
Fishery Harbor B Bottom Mud	Quality of Odor	Putrid Odor	Amine-like Odor
	Odor Concentration	55000	41
Fishery Harbor C Bottom Mud	Quality of Odor	Amine-like Odor	No Smell
	Odor Concentration	17	<15
	Odor Index	12	<12

Fig. 8. Relationship between pH and odor.

4.3 Insolubilization effect for harmful component

PS ash to develop the insolubilizing technology in processing PS ash, currently, are aimed insolubilizing technology deployment. The result of dissolution test (Environmental Notification No.46) for soil samples that artificially contaminated hexavalent chromium, arsenic, fluorine, boron, lead and cadmium and contaminated natural harmful component was shown in Table 6. In this result, Insolubilization effect on all heavy metals was confirmed.

Table 6. Insolubilization of the heavy metal by the PS ash improving material.

		Sexivalent chrome			arsenic	fluorine		boron	lead	Cadmium
	Initial Density	1.35	0.42	0.095	0.044	5.4	1.10	5.1	0.437	0.237
Marine Waste	50kg/m ³	0.203	0.11		0.020	4.8		1.0	<0.001	<0.001
	75kg/m ³			<0.05			0.66			
	100kg/m ³	0.088	0.015		0.010	4.5	0.72	0.95	<0.001	<0.001
	150kg/m ³	0.057			0.006	2.9	0.60	0.73	0.001	<0.001
	200kg/m ³		<0.005				0.47			
	Environmental Standard Value	≤0.05			≤0.01	≤0.8		≤1.0	≤0.01	≤0.01
Remarks	Polluted in Lab for Experiment	Contaminated Soil	Contaminated Soil	Polluted in Lab for Experiment	Polluted in Lab for Experiment	Marine Dredging Soil	Polluted in Lab for Experiment	Polluted in Lab for Experiment	Polluted in Lab for Experiment	Polluted in Lab for Experiment

5 APPLICATION EXAMPLE FOR THE NEW FIELD

Some of new application examples using the value-added materials for the different fields are shown as following. Fig. 9 is deodorization at fishing Port. Fig. 10 is classification of the tsunami sediment.

Fig. 9. Deodorization at fishing Port.

Fig. 10. Classification of the tsunami sediment as disaster recovery.

Fig. 11. Turbidity prevention of the marine landfill mud.

Fig. 12. Application for producing granulated soil.

Fig. 11 is the turbidity prevention method of the marine landfill mud. Fig. 12 shows the granulated soil produced by PS ash material.

6 CONCLUSIONS

- 1) The manufacture processing method of PS ash improvement materials changes depending on a property of the PS ash.
- 2) The preset PS ash improvement materials (A type and B type) have not only improving ability by instant absorbing but also curing improvement at the same level.
- 3) The curing effect is almost achieved in four days.
- 4) The improving performance of current PS ash improvement materials became more than double at the time of start.
- 5) The improving effects of the PS ash improvement materials of A type and B type are same but each absorbing function seems to be different.
- 6) The water absorbing performance of PS ash improvement material of the B type needs 2days not instantly to show the 100%absorptivity.
- 7) The absorbing ability of present B type product is 1.5 times of one of A type at the time of start
- 8) Application technologies to spread except improvement of mud are as follows.

- Deodorization
- Countermeasures for earthquake and disaster recovery (classification of waste and wood mixture soil)
- Handling of the polluted soil
- Insolubilization of the naturally polluted soil by the PS ash improving material
- Application for producing granulated soil
- Turbidity prevention of the marine landfill mud
- Acceleration of Consolidation

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