Journal of Engineering and Applied Sciences 12 (24): 7435-7440, 2017
ISSN: 1816-949X

Development of an Eco-Friendly Inorganic Consolated Soil

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Abstract: In Japan, environmental problems have been a big social issue such as ground contamination due to heavy metal and water pollution due to hexavalent chromium. This study is related to a soil solidifying agent of soft ground to be made by mixing and homogenizing 800~1000°C furnace at a paper mill sludge material 40~60 wt.% calcined at slag fine powder, 20 wt.%, mixed homogenized quicklime 10~32 wt.%, anhydrite 3~10 wt.% as a raw material. There is a big advantage in the most used raw material waste as an environmental dimensions or production stage mask. Also, recording of the plant is available because there are no substances causing pollution in the modified soil functions and soil is close to neutral and a solidification time is faster and improved processing can be easily and widely applicable to shorten the air on a large scale without limitation to the type of soil.

Key words: Soil, sewage, consolidation, recycling, sludge, arge

INTRODUCTION

Organic waste treatment of rotten fish was suggested by using heat energy recycling (Han, 2017). In inorganic waste case, red soil and paper waste can be manufactured to mud blocks by mixing with cement (Han, 2015). There are many solidifying agents and hardening agents used for stabilizing reinforcement of soft soil and the soil and poor soil modification or settable material such as the water glass type of solidifying agent cured of sodium silicate as curing agents such as calcium chloride, aluminate shed, acetic acid and dichromic acid soda and regulations fluoride soda change silicate gel type solidifying agent, lignin and dichromate curing initiator such as soda, chrome lignin-based soil that is configured with water, a solidifying agent, acrylamide-based solidifying agent for polymerization by adding an initiator and promotes material, etc., to an aqueous solution of monomer and crosslinking agent, urea resin initial condensate and injecting a small number of curing agent and an aqueous solution of acrylic acid calcium boundary. There are polyurethane-based solidifying agents with a hydrophilic polyurethane. Also, in the function of the solidifying and solidified by the curing, there are differences such as solidified by hardening and the solidifying insoluble by polymerization. Solidifying agent is difficult to use in large soil solidification regardless of the performance because the solidifying agent is expensive. Especially, when solidifying dredging soil from ponds, rivers, lakes or swamps or a large scale of soil with silty clay from construction site, the cement (PO Haute Sealant cement) solidifying agents, lime-based, plaster-based agent and the solidifying agent composed of more than one have been used widely. However, these solidifying agents need heavy oil as a fuel because the sewage sludge ash and waste incineration ash used as raw materials were heated with high temperatures, so, they further increased manufacturing costs due to heating work again. Also, ashes have been used as a soil conditioner for a long time as an effective material by incineration of paper sludge but rising production costs cannot be avoided due to the step of firing again. In addition, Chromium in the ash is changed to hexavalent Chromium because waste or sewage sludge incineration ash waste paper are burnt at a high temperature of 1400~1500°C. If a soil solidifying agent is used in such a high temperature, the pollution is unavoidable due to hexavalent chromium in the environment. In case of using ash in the step of re-heating, being cement is inevitable since gypsum or other components such as $C_{11}A_7CaC_{l2}$ and $C_{11}A_7CaF$ are added to cement. In case ash is used as a solidifying agent, pH is higher to pH 10.5~13 and that results in even adversely affecting the ecosystem in the environment. Moreover, there are shortcomings in the cement solidifying agent that cannot be transported and mixed with mud because the time required to screen unworthy 5-7 days long. This study is on a development of the solidifying agent and suggests conventional soil to solve the problems of the solidifying agent by incinerating the paper sludge at a comparatively low temperature of 800~1000°C. That can reduce the fuel cost and suppress generating hexavalent chromium and does not rise up environmental problems and reduce the problems of the prolonged time of the curing of the cementitious drawbacks and odors. The main ingredient is obtained by adding paper sludge ash, quicklime, anhydrite and fry ash added with small amounts of polymer flocculant to incineration furnace slag. It is suitable for large-scale construction to improve soil solidifying agent of the massive demand.

Table 1: Componebts of raw materials

Raw material/ Components	CaO	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	ZnO	P_2O_5	SO_3	MgO
Paper ash	27.50	25.30	22.10	12.20	4.37	1.85	1.58	1.23	1.14
Slag of a blast furnace	42.60	33.70	0.60	14.60	-	-	-	2.00	6.10
Slaked lime	70.10	0.60	0.10	0.40	-	-	-	0.40	0.10
Fly ash	0.51	46.92	7.40	44.45	-	-	-	0.98	1.81

MATERIALS AND METHODS

The configuration and operation of the solidifying agent: Developed solidifying agent which supplements the problem of function and cost of manufacturing ensures excellent functionality as well as adding high-value by recycling nearly all of the materials of the solidifying agent. Thus, it is suitable for large-scale soil improved construction that requires a lot of amount of solidifying agent.

Main material is a paper sludge material 40~60, 20 wt.% in blast furnace slag fine powder calcined at 800~1000°C, calcium oxide 10~32 wt.% and Anhydrite 3~10 wt%. Here, depending on physical propertiesand the type of soil, a fry ash 5~20 wt.% containing an organic polymer flocculating agent 0.1~1.0 wt.% is added to the basic mixture 80~95 wt.%. The main ingredient of paper sludge incineration ash, blast furnace slag fine powder, calcium oxide, the components of the anhydrite and fry ash are shown in Table 1 (Mahendran and Vignesh, 2016).

RESULTS AND DISCUSSION

Main contents: A soil is complicated substances. So, chemical and mineralogenic properties should be checked and physical substitutional action should be also considered to determine the distribution of ingredients. The property change should be considered when clay mineral with electric neutrality makes is omorphous exchange. Action of clay mineral which changed to minus electric charge should be considered. If, we consider what parent rock of clay mineral is consider expansion and hydration ability and consider the chhange of pH then, we see through condensation, expansion and swelling action of soil. The ettringite reaction would be generated to prevent exudation of heavy metal and circular crystal would be generated through above reaction to bind particles of soil. In case of heavy metal contamination, consolidation technology would be applied not to generate exudation by ingredient of heavy metal. There are several kinds of consolidation principle, hydration reaction by lime, pozzolanic reaction, ettrngite and soil granulation. Figure 1 shows the consolidation reaction structure map. Carbonation by remaining lime powder reacts to carbon dioxide in soil. Also, as this reaction repeats, long age strength constantly increases reaction of re-carbonation. In initial stage of reaction, we used supplemental agent such as alum which includes high activity alumina. Figure 2 shows the principle of consolidation reaction.

Application example: As a paper sludge ash, other mineral powders including fillers, calcium carbonate when sizing, talc powder and clay during the process of grassland Sinai sizing are often used while being discarded propelled waste fluid contain many inorganic component with the pulp. When incinerated or fired in any case using the pulp or paper sizing agent, the organic material is burned away, leaving only the inorganic ingredients as shown in Table 1. The remnants are useful.

In addition, the furnace slag is a material pulverized as the iron melt solidified non-mineral contained in the ore upon melting of iron ore in steel mills and fry ash which is a byproduct when burning coal in thermal power plants is a porous, light, absorptive and strong gas adsorption material. Gypsum also has two kinds of types such as a natural gypsum and chemical gypsum. The chemical gypsum are mud-plaster (CaS_4O and $2H_2O$), half of gypsum ($CaSO_4$ and $½H_2O$) and anhydrite ($CaSO_4$). In this study, the chemical gypsum with easy composition and the anhydrite which has small impurities are used.

They are homogenized to a fine powder <200 mesh in order to increase the specific surface area. Basic agents are widely applied to soil which has relatively less water but solidifying agent for cultivating soil added with a small amount of organic flocculants and fry ash is effective in solidifying remaining soil after condensing and sinking a lot of soil with large amounts of moisture dispersed in wetlands and tidal zone, removing moisture.

Looking at the action and functionality of the raw materials used in the solidifying agent, the calcination of the paper ash (residue) hardly occur due to the incineration temperature at the 800~1000°C. Instead, a partial portion calcination takes place and a part of the carbon (material) remains because organic sizing agent including pulp is burned but he chromium oxide component has not changed yet as hexavalent

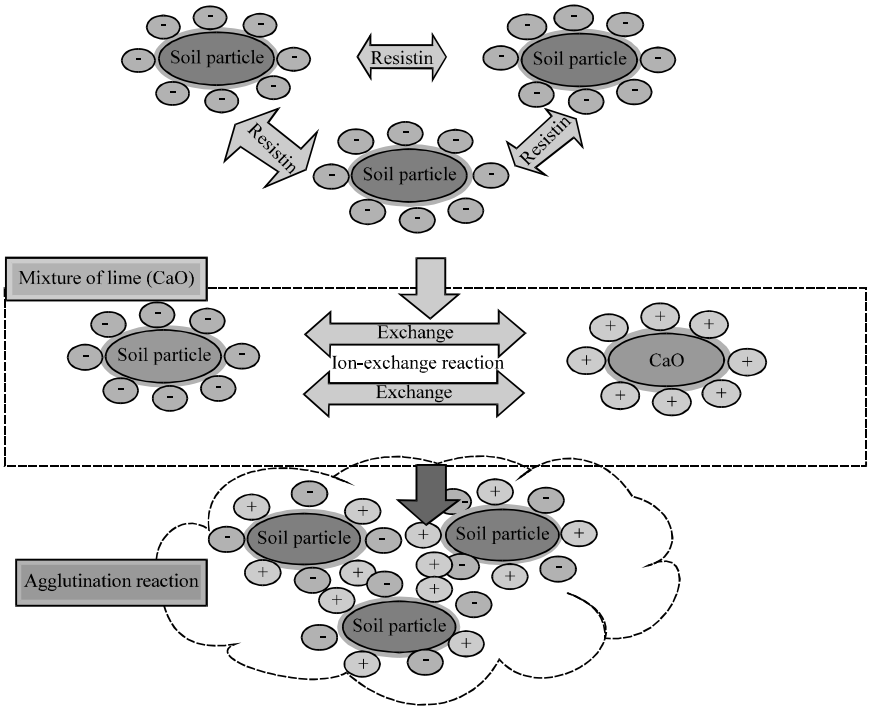

Fig. 1: Consolidation reaction structure map

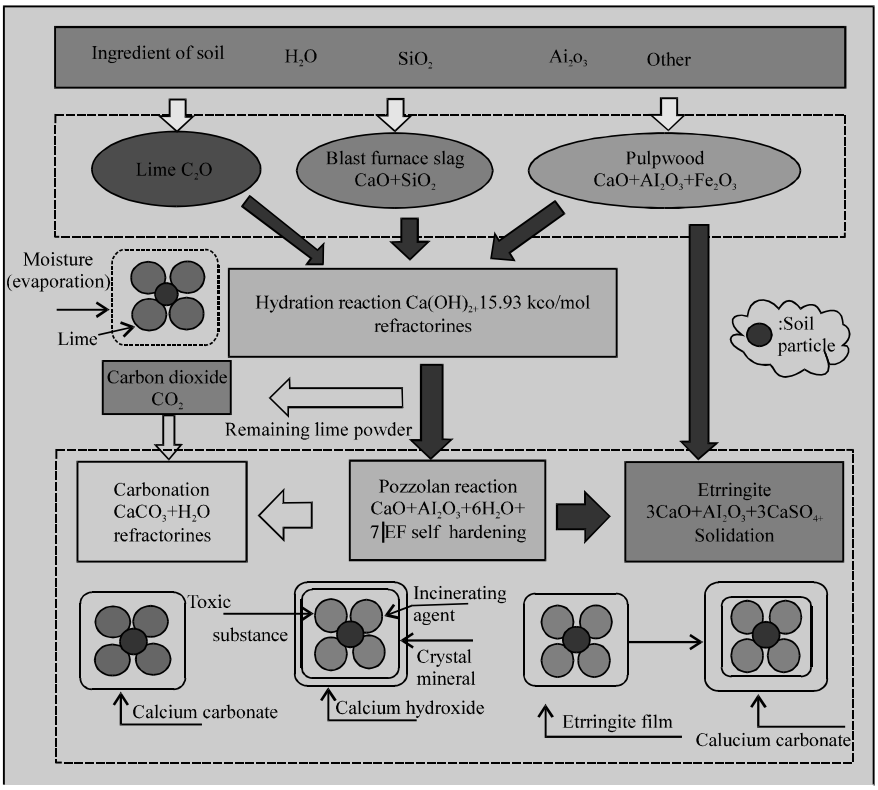

Fig. 2: Principle of consolidation reaction

chromium. When water was added to the soil as component, ratio is greater in the ingredient list in Table 1 including lime, silica, alumina, iron oxide, etc. and C_3S, C_2S, C_3A and C_4AF among these ingredients are the solubility anhydride which has very good reactivity to water and makes hydrate with low solubility.

When reacted with water, C_3S is disconnected to Ca-O bond. And when Ca^{2+} is melt in an aqueous solution reaches super saturation, the crystals of calcium hydroxide are precipitated and the rest of $[SiO_4]$ will react with water $[Si(OH)_6]$ such as 2-soluble silicate in the form of hydrogen ions and polymerization to make the hydrated silica gel around C_3S grains. The gel is precipitated in combination with Ca^{2+} a crystal of Calcium Silicate Hydrate (C-S-H) is generated.

Also, C_3A (3CaO and A_2O_3) is reacted with the water very rapidly and generates heat. The produced hydrate is a mixture of C_4AH_{10} and C_2AH_8 to the calcium aluminate hydrates of the hexagonal tubular which is safe to the aluminate hydrate of cubic system in accordance with a sense of time.

The gypsum should inhibit the reaction of the C_3A. This is because the double salt of calcium interfere aluminate (Calcium-aluminate) hydrate made on the surface of the reaction of water with C_3A C_3A. The hydrate is stable in basic and has two kinds of high sulphate in the form of insoluble compounds in water-type and that has the low sulfate.

When C_3A, plaster and water react together, high sulphate with the big surface area is made. And when gypsum is consumed, high sulphate reacts with C_3A and becomes low sulphate. It can also improve the workability by delaying the hardening time due to poor workability if the large modified soil is rapidly solidified in the process and is used to improve the long-term strength.

And the blast furnace slag does not have the characteristic of solidity due to reacting with water directly, but particularly paper sludge ash may exhibit the hydraulic potential. On other hand, blast furnace cement has low hydration heat and the high chemical resistance. The state in the blast furnace slag is the main compound of the solid solution β-C_2S-Ca_2Mg Si_2O_7-CaAl ($SiAlO_7$).

Other fly ash is mainly composed of silica and substance with much the content of aluminum oxide glassy state and improves the workability due to giving initial strength in the soil improved construction. In spite of poor initial strength and delayed curing, latter-strength is good. The reason why latter-strength is favorable is pozzolanic reaction of the primary ash. The effects of developed soil by adding pozzolanic are improvement of the workability and stability and the increasement of compressive strength, tensile strength and the waterproofing. Also, the strength is increased by the reduction of bleeding.

Table 2: The result table of measuring left soil according to burying work of the sewage pipe

Mixing ratio (wt.%)	Moisture content (%)	Wet density (%)	Dry density (g/m^2)	CBR (%)
0.00	42.1	-	-	1.1
8.00	26.2	1.917	1.519	15.6
10.0	25.2	1.927	1.541	20.3
12.0	21.3	1.934	1.591	24.2
14.0	20.8	1.942	1.604	26.1

In addition, the fly ash has a small percentage and pretty good adsorption of gases such as greater absorbency. These enable the function a ratio of the soil. But in extremely high or severe suspension water, the solidifying agent for cultivating soil added with fly ash is used.

After removing as much as water in a state with a small amount of aggregation sedimentation of suspended material with the addition of organic polymer materials. Besides, adding creation serves to make up for the deficiency of calcium oxide.

As a result, the characteristics of the solidifying agent: can safely use harmless materials in construction and environmentally, a greater dimension in recycling because it uses industrial waste as a raw material of social and economic synergies. Cheap, the raw material costs enormously compared to conventional chemical coagulants can be used in large-scale soil construction soil without special mixing equipment needed during construction when work is available and pH value neutral and mixed with the topic destination Saturday as a universal medium term of Forklifts, etc., pH at an early stage when it is close to neutral. Since, different functions of the soil can be solidified after by vegetation can be recorded and such a fast time to solidify the initial act effectively as an improvement (Anonymous, 2007, 2013).

Example on burying work of sewage pipes: The solidifying agent for cultivating soil was made by mixing and homogenizing a 55 wt.% paper sludge produced at 800~1000°C, 20 wt.% slag fine powder, 15 wt.% calcium oxide and 10 wt.% anhydrous gypsum as a raw material. The results of measuring construction waste soil using the solidifying agent for cultivating soil caused by disposal sewage pipes buried are shown in the field Table 2.

The soil has been improved to 24.1% in the result of the CBR value 12 wt.% formulation and the muding

Table 3: The analysis result list of modified soil hazardous substances

The object of the metric	The result of the metric	The method of the metric
Cd	ND	JIS K0102
Total cyanogen	ND	JIS K0102
Pb	ND	JIS K0102
Cr(VI)	ND	JIS K0102
Arsenic	ND	JIS K0102
Total Hg	ND	S46 protection agency bulletin the 59 call drifting buoy 3
Alkil Hg	ND	With the S46 protection agency bullet in the 59 call the S49 protection agency bullet in the 64 call drifting buoy 4 and drifting buoy 4
PCB	ND	S46 protection agency bulletin the 59 call drifting buoy 5
Dichloromethane	ND	JIS K0125
Carbon tetrachloride	ND	JIS K0125
1, 2-dichloroethane	ND	JIS K0125
1, 1-dichloroethane	ND	JIS K0125
1, 1,1-tricholoro ethane	ND	JIS K0125
1, 1, 2-tricholoro ethane	ND	JIS K0125
Tricholoro ethylene	ND	JIS K0125
Tetrachloroethylene	ND	JIS K0125

did not happen again. Even in absorption due to immersion test, expansion ratio from 8.0~14.0% was zero. The test method was carried out by (JIS A1211). Soil is clayey soil consisting of silt and clay from. The soil before improved was a neutral pH 6.8, 42% moisture content, specific gravity 1.79. The soil after improved, greenish gray clay was improved after 48 h and there is pH 8. 4. Three weeks later, it was changed to pH 7.0. Also, even when mixing a solidifying agent, the odor was not generated. Further, embodiments (1), the hexavalent chromium was not detected in the other hazardous substances such as the solidification processing result (Table 3) and the construction waste was not generated.

The example of using mud on the renovation work of agricultural development: As test results in condition of the weight of the mud at adding 12%, the mud quality improved as much as digger with 0.6 m^2 capacity can do operation on the soil covered with the steel plate after 2 h. This is due to the effect of absorption and paper sludge ash and anhydrite (Table 4).

Also thereafter, the construction site for soil improvement was observed continuously. The water level of the dam was also raised by the rains and large amounts of water penetrated improved mud but returning the to soil did not happen. It is judged that the blast furnace slag component of the reaction slowly enough to prevent the

Table 4: The result list of mud improvement of agricultural development

Inspection item/ combination ratio ---------- Testing method	Compression resolution (%)	Compression resolution (%)	Compression resolution (%)
Combination ratio (%)	10.000	12.000	0.150
Natural moisture cantent (%)	46.100	40.600	42.600
Wet density (g/cm^2)	1.659	1.712	1.687
Dry density (g/cm^2)	1.132	1.217	1.183
Blow ratio	0.250	0.400	0.420
Penetration test aftermoisture content (%)	47.700	42.200	44.500
Average CBR (%)	17.300	26.100	41.300

Fig. 3:Construction of road with consolation soil

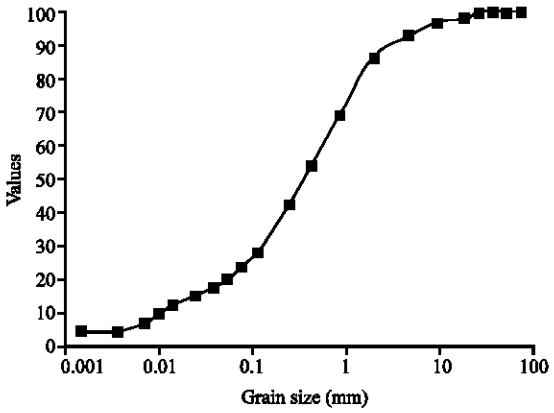

Fig. 4: Grain size accumulation curve

re-solidified mud by the anger generated by hydraulic provisional. Also, the reuse of construction and mineral mud is quite possible that if CBR value is more than 20%.

The example of golf course construction: The developed consolidation soil was applied to construct the road in golf course. Figure 3 shows the construction of road with consolation soil. Figure 4 shows the grain sizes and Fig. 5 shows the dry density and CBR curve.

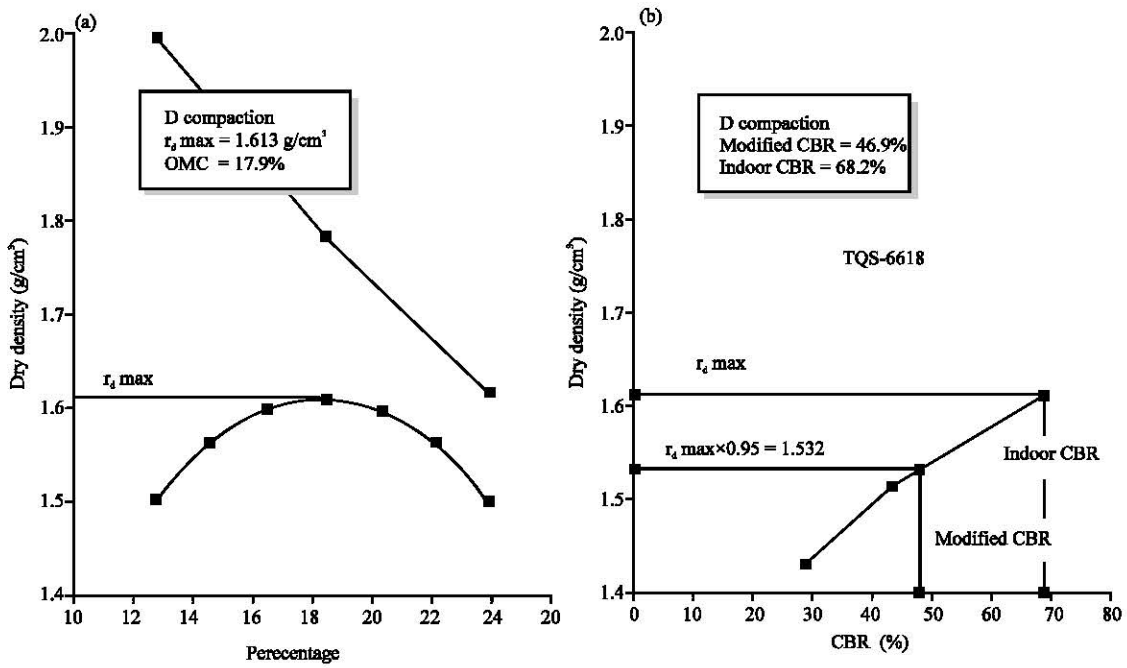

Fig. 5: Dry density and CBR curve

CONCLUSION

The solidifying agent for cultivating soil in this study has a big advantage in most environmental dimension due to waste material In addition, there are no substances causing pollution in the modified soil functions and soil is close to neutral and a solidification time is faster and improved processing can be easily and widely applicable to shorten the air on a large scale without limitation to the type of soil.

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