UTILIZATION OF WASTE SLURRY FROM CONSTRUCTION WORKS

UTILISATION DE LA BOUE RESIDUAIRE PRODUITE PAR LES OEUVRES CONSTRUCTRICES

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SYNOPSIS : A number of waste slurry or sludge with high water content are produced in large scale construction works, especially in foundation works, and then a proper treatment method of these wastes must be established based on a viewpoint of environmental geotechnology. In this paper, we propose an utilization system of waste slurry, which consists of two treatment methods for dehydration and solidification. The selection of the treatment methods should be done based on the density and the viscosity of the waste slurry. Through experimental studies it is clarified that Carbonated-Aluminate Salts and coal fly-ash are used effectively for flocculant and stabilizer in this system, and this system results in efficient treatment, decrease in volume, stabilization, and recycling as resources.

INTRODUCTION

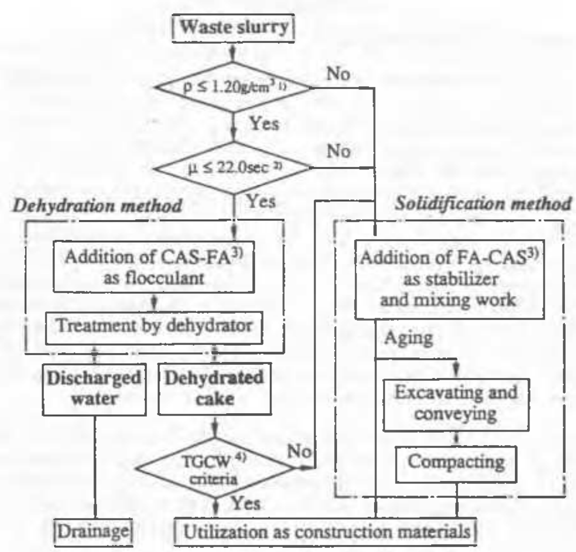
The importance of environmental geotechnology within the discipline of geotechnical engineering focuses on (1) the creation of better environment, (2) prevention of environmental risks due to human activities, and (3) the prevention of danger to human life caused by natural hazards, as suggested by Kamon (1989). Kamon et al. (1991) proposed NICE criteria, which stands for Nonhazardous, Improvable, Compatible, and Economical treatment, to utilize the wastes as the construction materials, which falls into the second category. Utilization of wastes from various industries, e.g., electric power generation companies etc. has been well documented. However, there is a need to utilize the wastes that have been generated from various construction sites. The generation of waste slurry or sludge, discharged from slurry excavation methods such as cast-in-place concrete piles, continuous diapham walls, shield tunnel, and so on, has reached the level of 14 million tons per year in Japan. More than 80% of the produce is still disposed of without any proper treatment. These discharged slurries with high water content can be treated by dehydration method, such as Filter-press method, Roller-press method, and so on (Kita et al. 1981). The application of the dehydration method, however, is not universal because many kinds of waste slurries have protective colloids which are difficult to separate into water and solid. Moreover, most of the dehydrated cakes have lower strength than the criteria ($q_c = 2$ kgf/cm^2 (= 196 kPa) or $q_u = 0.5$ kgf/cm^2 (= 49 kPa)) set for Treatment Guideline of Construction Wastes (TGCW) established by the Ministry of Health and Welfare of Japan in 1990. Therefore, they are considered as waste and should be disposed of.

The object of this study is to propose a new utilization system of waste slurry which consists of two treatment methods: (1) dehydration method; and (2) solidification method, and also to clarify the effectiveness of this system.

NEW UTILIZATION SYSTEM OF WASTE SLURRY

The waste slurry is the mixture of excavated soil and water discharged from many kinds of excavation works. Generally, it contains many fine particles and is difficult to dehydrate rapidly. In the case of slurry excavation methods in which bentonite or polymer such as Carboxy-methyl cellulose (CMC) are often used for regulating viscosity, these dispersants remain in the waste slurry. Therefore, it is very difficult to dehydrate the waste slurry. In the case of disposal of these slurries, a large amount of stabilizer (e.g., cement) is needed to solidify the waste slurry up to a proper strength.

In order to solve these problems we propose a new utilization system of waste slurry. The conceptual outline of the system is shown in Fig. 1. It consists of dehydration and solidification methods and results in efficient treatment, decrease in volume, stabilization, and recycling as resources.



Note
1) ρ; density of waste slurry.
2) μ; funnel viscosity with 500cc-funnel of waste slurry.
3) CAS; Carbonated-Aluminate Salts.
FA; Fluidized Bed Combustion Coal Ash.
4) TGCW criteria; $q_c \geq 2.0$ kgf/cm^2 (= 196 kPa) or $q_u \geq 0.5$ kgf/cm^2 (= 49 kPa) .

Fig. 1. Outline for utilization system of waste slurry.

The selection of the treatment method is based on the character of the waste slurry. Based on the experience gained from many dehydration experiments and various kinds of dehydration properties of waste slurries, it has been proposed that the density (ρ) and funnel-viscosity (μ) with 500cc-funnel can be used as the criteria of selection for treatment. These parameters are universally measured to control the character of slurry at the excavation sites. The solid content which is indicated by the density of slurry, and the funnel-viscosity which is increased by the remain of bentonite and CMC, show the possibility or the effectiveness of dehydration treatment. The attempt on volume reduction by dehydrating a high solid content slurry is not always the best strategy from technical and economical aspects. The slurry with low density can be dehydrated easily, but the slurry which has high viscosity because of the remains of dispersants is difficult to dehydrate though these slurries have low density. So the waste slurry which has higher ρ-value than 1.2 g/cm^3 or higher μ-value than 22 sec can be treated effectively in solidification method.

In dehydration method, it is proposed that the waste slurry with Carbonated-Aluminate Salts (CAS) and Fluidized Bed Combustion Coal Ash (FA) as flocculant should be dehydrated with the object of volume reduction. Especially by using high pressure dehydrator, the strength of dehydrated cakes can reach easily the criteria set by TGCW, therefore, they can be directly utilized as embankment and subgrade material. Also the discharged water satisfies the environmental standards in potential of hydrogen (pH) and suspended solids (SS). In solidification method, it is suggested that the slurry is stabilized by CAS and FA to increase the strength for embankment or subgrade purposes. The use of FA can be very effective from both technical and economical point of view.

CAS used as flocculant and stabilizer are differential mixtures of cement, $Al_2(SO_4)_3$, Na_2CO_3, $CaSO_4$, and so on. FA used in this study is derived from fluidized bed combustion system, which has gypsum and lime because of the use of desulphurizer and incomplete oxidation reaction due to the incineration method.

DEHYDRATION METHOD BY A NEW FLOCCULANT

The flocculant used in the dehydration method is required to have the following characters; (1) rapid flocculation, (2) large diameter and high durability of flocs, (3) clean discharged water, (4) high strength and durability of dehydrated cake, and (5) economy.

Flocculation Characteristics

Flocculation and sedimentation tests are carried out on CAS, CAS-FA (the mixture of CAS and FA in the ratio of 5:2), and PAC (Polyaluminium chloride, ordinarily used), using slurry discharged from a shield tunnel work. When using PAC, 10cc of anionic polymer is always added for 1000cc of slurry. While the slurry with PAC has too small floc to observe the separation of water phase from the slurry, the addition of CAS and CAS-FA causes the immediate formation of 0.5-1.0mm diameter flocs and the boundary between solid (flocs) and water is distinct. As shown in Fig. 2, though the tendency of sludge sedimentation is changeless in spite of the variation in the additive content of PAC, the increase of CAS and CAS-FA causes the formation of larger flocs and the consequent efficient sedimentation. Therefore, CAS and CAS-FA not only have better sedimentation characteristics but are more practical to be used in dehydration plant than PAC because of the close relation between additive content and flocculation.

Though the flocs formed by CAS are completely destroyed by 5 minutes churning by an agitator, flocs are reformed by releasing the slurry from churning. A little decrease of sedimentation velocity are caused by churning as shown in Fig. 2, but it is considered that the flocs by CAS and CAS-FA are durable enough to be used in dehydration plant.

Dehydration Characteristics

The consolidation tests are carried out on the sludge sedimented for 30 minutes. In the case of using PAC, much of suspended solids are intermixed with discharged water not being separated well. CAS and CAS-FA can realize the compressive dehydration because of the large and strong flocs. According to examples of compression curves shown in Fig. 3, it takes 5-10 minutes for the slurry with CAS to reach the final volume by compression, which is applicable to the practical dehydrator.

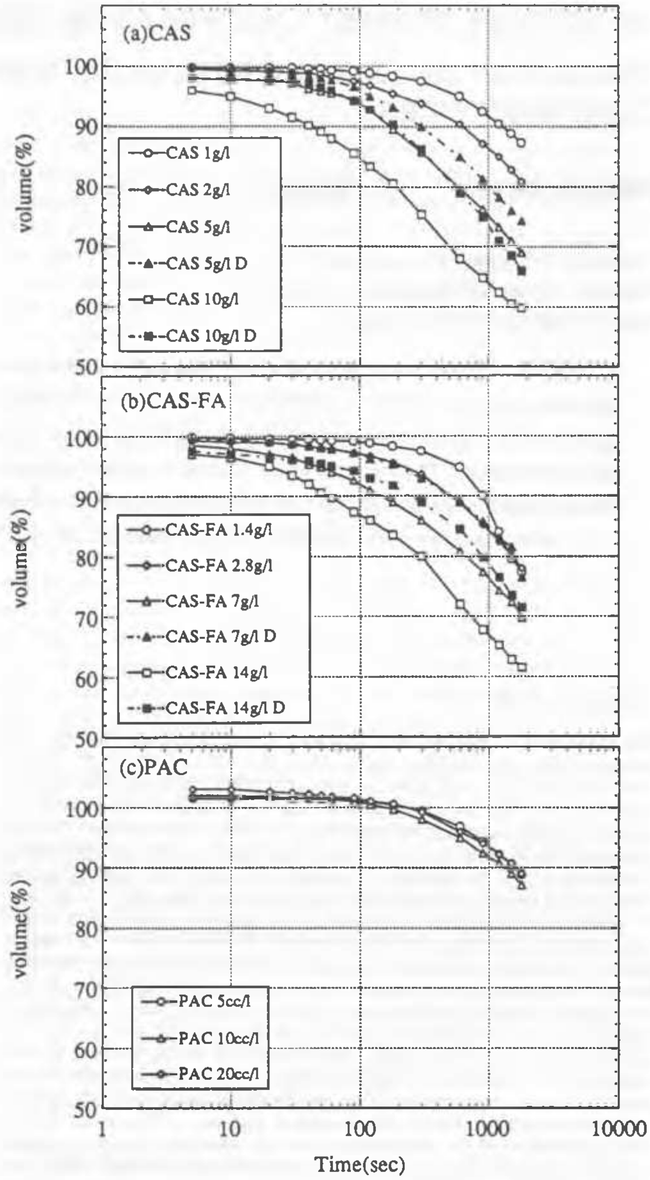


Fig. 2. Sedimentation characteristics of waste slurry with flocculants. (Waste slurry ; ρ = 1.06 g/cm^3, μ = 19.2 sec 'D' indicates the slurries obtained through churning test.)

Dehydrated Cake

The dehydrated cakes treated by CAS-FA have higher q_c-value and higher density than the cakes by CAS only, as shown in Fig. 3 and Fig. 4, and q_c of the cakes with CAS-FA consolidated by high pressure (2.51 MPa) reaches the criteria set by TGCW. Though the dehydration pressures in general dehydrator plants are equivalent to 0.5-1 MPa, the new Filter-press plant which realizes the dehydration by high pressure of 4 MPa has been developed. So, the combination of CAS-FA with the high pressure Filter-press plant can produce the dehydrated cake which is directly utilized as embankment and subgrade material.

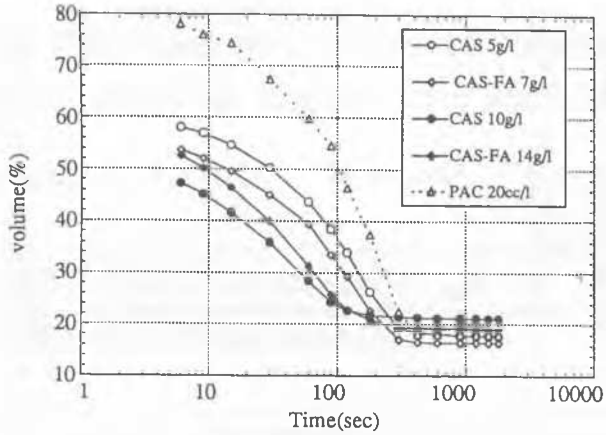


Fig. 3. Consolidation curves of waste slurry with flocculants. (Waste slurry ; $\rho = 1.06\ g/cm^3$, $\mu = 19.2$ sec consolidation pressure ; 9.8 kPa)

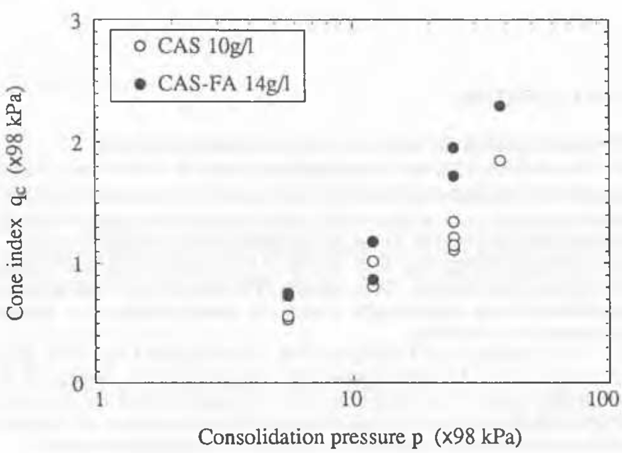


Fig. 4. Strength characteristics of dehydrated cakes. (Waste slurry ; $\rho = 1.06\ g/cm^3$, $\mu = 19.2$ sec)

Discharged Water

Using PAC, the supernatant water has more SS than 100mg/l and reaches pH 4 and the discharged water indicates so much of SS. It is suggested that in using PAC in Filter-press plant the excessive compression can result into unclearness of discharged water. In the case of using CAS and CAS-FA, the quantity of SS is less than 10mg/l in the discharged waters obtained by both the sedimentation and the consolidation, and the pH varies between 7-8, therefore satisfying environmental standards.

CAS as flocculant has been used in some construction sites on experimental basis, and following advantages have been observed: simple execution management, peel-off characteristics of dehydrated cake from filter cloth, and dehydration characteristics because of the low viscosity of the slurry with CAS.

Table 1. Quality of discharged water.

Type of flocculant	Additive content	SS (mg/l) Water(S)	SS (mg/l) Water(C)	pH Water(C)
CAS	1.0(g/l)	2.6		
	2.0(g/l)	1.8		
	10.0(g/l)	3.5	2.1	7.5
CAS-FA	1.4(g/l)	1.4		
	2.8(g/l)	1.4		
	14.0(g/l)	3.0	4.0	7.8
PAC	20.0(cc/l)	428.4	5644.3	4.4

Waste slurry; ρ=1.06 g/cm³, μ=19.2sec

Note 1) 'Water(S)' and 'Water(C)' indicate water discharged by sedimentation and consolidation.

Note 2) Environmental standards of discharged water; SS < 300mg/l, 5.0 < pH < 9.0

SOLIDIFICATION METHOD BY COAL ASH UTILIZATION

Strength Characteristics

Table 2 illustrates the change in strength of waste slurry discharged from a cast-in-place concrete pile work, mixed with FA and CAS. When using CAS only, the strength required by TGCW can not be achieved at 7 days curing even if the CAS content raised as high as 25%. The strength of the waste slurry reaches 49 kPa when using 70% FA - 13% CAS mixture cured for only 3 days, a criteria set by TGCW. For embankment or subgrade purposes, it is suggested that the strength after 7 days curing should be able to sustain a 100-200 kPa stress, and the required strength can be achieved when the FA content and the CAS content are more than 40% and 10% respectively. The decrease in the FA content and the increase in the CAS content result in the larger growth in strength versus aging period, so it is possible to attain both early and later strength by adjusting the contents of FA and CAS.

In this treatment method, the addition of FA and CAS results in the volume increase of 20-40%, as shown in Table 2. This volume increase is relatively small comparing with the additional amount of FA, and this method has the great efficiency from the viewpoint of coal ash utilization.

Table 2. Strengths of the slurry-FA-CAS mixtures.

Additive content(%) FA	CAS	Compressive strength q_u (kPa) 3 days	7 days	14 days	28 days	Volume Change
40	7	-	65	199	228	1.20
	10	-	101	356	435	1.22
	13	19	142	629	761	1.24
50	4	-	73	172	219	1.26
	7	-	112	348	314	1.27
	10	15	175	534	665	1.28
	13	29	213	931	855	1.31
60	4	-	123	253	419	1.31
	7	-	194	411	637	1.32
	10	27	282	670	978	1.33
	13	40	396	1145	1381	1.34
70	4	15	215	493	467	1.36
	7	17	319	720	891	1.37
	10	38	435	980	1178	1.38
	13	61	579	1260	1711	1.39
0	10	-	13	15	30	1.02
	20	-	26	40	74	1.09
	25	-	40	67	98	1.10
	30	-	133	183	305	1.17

Waste slurry; ρ=1.04 g/cm³, μ=51.7sec

Note 1) 'Volume change' indicates the volume of slurry-FA-CAS mixture after mixing versus the one of waste slurry only.

Durability

Fig. 5 shows the strengths of samples remolded after 3 or 7 days curing in comparison with undisturbed samples. Because of the increase of density by remolding and the incomplete hardening reaction, the mixtures remolded for 3 days have higher strength in early stage than the samples cured normally, and have 100-200 kPa strength at 3 days curing after remolding to be considered of utilization as embankment or subgrade materials. Through the soaking test on the samples cured normally for 7 days, the collapse or the softening of the mixtures can not be indicated. So the slurry-FA-CAS mixture can be used very effectively as ground materials through the process of mixing, hardening, excavating, conveying, and compacting, taking the durability into consideration.

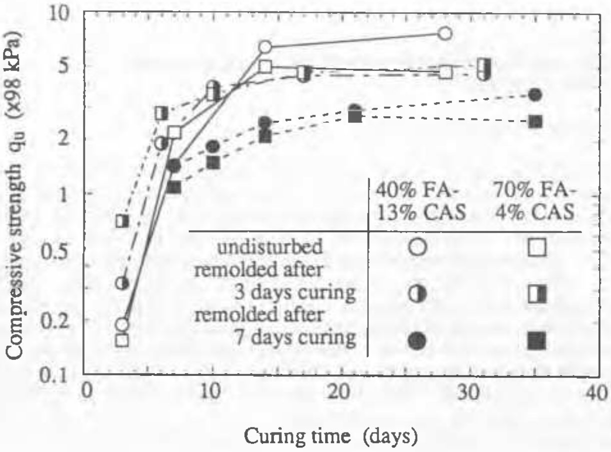


Fig. 5. Strength characteristics of remolded slurry-FA-CAS-mixtures. (Waste slurry ; $\rho = 1.04$ g/cm^3, $\mu = 51.7$ sec)

Mixing Workability

In using CAS only, it is difficult to mix up the mixtures for the high viscosity of slurry, and the obtained mixtures are not homogeneous. The slurry-FA-CA mixture is uniform because of the material congeniality between slurry and FA in mixing.

The full scale tank test was carried out to investigate the application of this solidification method to practice. Two tanks which have 2.3m x 8.0m width and 1.6m depth were used, and a back hoe with an exclusive dipper (0.7m^3 volume) adjacent to the tank conducted mixing work. As the total volume of waste slurry discharged from a cast-in-place concrete pile work was 12m^3, based on our previous experimental experience, it was decided that the additive contents in the tanks were to be 70% (8400kg) FA and 7% (840kg) CAS, and 77% (9200kg) FA and 7.7% (920kg) CAS for each tank. After mixing for 40 minutes, the mixtures were kept undisturbed for 24 hours, 3 days, and 7 days. The strength gained by the mixture left for 24 hours was strong enough to enable a walk safely on it. Fig. 6 shows the strengths of specimens sampled at various points in the tanks. The strength dispersion of samples is very small in consideration of the expected roughness of mixing work because of the size of the dipper versus the tank. The ratio of the strengths sampled in the tanks versus the ones of the laboratory specimens is very high compared with the ones in the case of the traditional soil stabilization. The strengths at 3 and 7 days curing are more than 100 kPa and 500 kPa respectively . The mixture has a potential to be utilized as embankment and subgrade material.

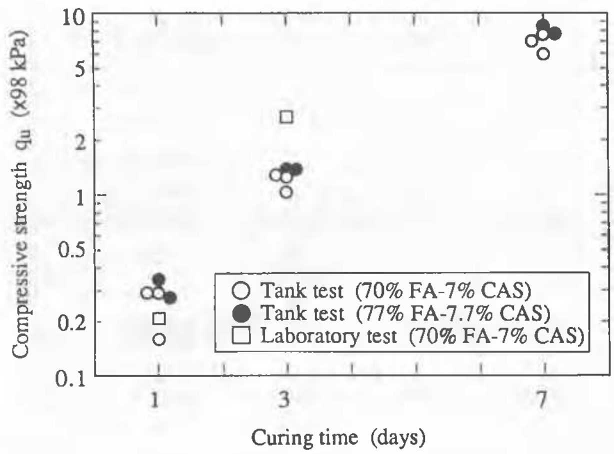


Fig. 6. Strengths of specimens sampled through the tank tests. (Waste slurry ; $\rho = 1.05$ g/cm^3, $\mu = 22.7$ sec)

CONCLUSIONS

The main results of this study can be summarized as follows:
(1) The authors propose the utilization system of waste slurry which consists of dehydration and solidification, and find that density (ρ) and funnel-viscosity (μ) of the waste slurry can be the criteria to judge whether the slurry should be treated by dehydration or solidification.
(2) Cabonated-Aluminate Salts (CAS) as flocculant in this system leads to form large and durable flocs rapidly. The formed flocs can be easily dehydrated and discharged water is clear enough to satisfy environmental standards.
(3) The addition of Fluidized Bed Combustion Coal Ash (FA) combined with CAS can improve the strength and the density of the dehydrated cake. The combination of CAS and FA with the operation of the high pressure dehydrator must bring the produce of the cake, which can be directly utilized as embankment or subgrade materials.
(4) Solidification method mixed with FA and CAS is very effective in treating the high density waste slurry. The well mixed waste slurry with stabilizers is highly homogeneous and strong enough. It also has high durability under the soaked or remolded conditions, so it can be used effectively as embankment or subgrade materials.

The utilization system can be applicable from the viewpoint of complete utilization of waste slurry as construction materials.

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REFERENCE

Kamon, M. (1992). Definition of Environmental Geotechnology, Environmental Control and Waste Disposal, *Proc. of 12th ICSMFE*, Reo de janeiro, Vol.5, pp.3126-3130.

Kamon, M., Tomohisa, S., and Nontananandh, S. (1991). Environmental Geotechnology for Potential Waste Utilization, *Proc. of 9th ARC*, Bangkok, pp.397-400

Kita, D. and Tsuji, H. (1981). Treatment and Utilization of Discharged Slurry from Slurry Excavation Methods, *Tsuchi-to-Kiso, JSSMFE*, Vol.29, No.11, pp.57-64 (in Japanese).