

Effect of Chemical Admixture on Property of Fresh Mortar Using Sludge Water

Takashi FUJII^{1*}, Tadashi SAITO² and Toshiki AYANO¹

¹Okayama University, Japan

²Nagao & Co., Ltd., Japan

*3-1-1 Tsushima-naka, Kita-ku, Okayama 700-8530 Japan,
t-fujii@okayama-u.ac.jp, saitoh@nagaosh.co.jp, toshiki@okayama-u.ac.jp

ABSTRACT

Addition of sludge water as a part of mixing water had little influence on strength and durability of hardened concrete, but caused a slump decrease of fresh concrete. The decrease of slump was improved by addition of a certain set retarder such as gluconate into sludge water due to control of cement hydration. Some of polymers were also effective in improvement of slump. However hydration of cement was observed in those cases of polymers. Therefore it is presumed such the polymers improve slump not by hydration control effect but by another one.

Keywords. Sludge water, Mortarflow, Organic compound, Polymer, Sludge sedimentation

INTRODUCTION

It is said that returned fresh concrete is up to 1.6% of ready-mixed concrete production (Policy Bureau, Ministry of Land, Infrastructure, Transport and Tourism, 2006). The amount of returned fresh concrete is 1,380,000m³ in Japan in 2009. The waste concrete and mixer wash water cause a huge amount of sludge water. Then utilizing of the sludge water is needed. Using sludge water as a part of mixing water is permitted as long as solid content of sludge water is kept at 3% of unit cement or less according to JIS A 5308: 2009 Appendix C. But utilization of sludge water does not prevail actually because of anxiety about quality of concrete and slump loss. As a solution of slump loss, addition of set retarder to sludge water has been researched (Kenichi AIZAWA, 1996) (Naoshi OZAWA, 1997) (Young-jin SONG, 2007). Above all, hydroxycarbonic acids have been much studied. In this study, we compared the effect of several organic compounds including gluconates and little studied compounds on mortarflow as an admixture into sludge water. As a result, those compounds including polymers such as an polyacrylate proved to be effective in keeping flowability.

OUTLINE OF EXPERIMENT

Characteristics of concrete with sludge water. Ordinary Portland cement and ground water (C/W=20/80) were mixed for 3 days assuming that sludge water would be used even after weekend. Then a certain admixture including hydroxycarbonate was added to the sludge water. The sludge water was used as a part of mixing water to make fresh concrete

Table 1. Mixture proportion of concrete

Type	G _{max} (mm)	W/C (%)	Slump (cm)	Air (%)	s/a (%)	Unit content (kg/m ³)				Ad.(kg/m ³)	
						W	C	S	G	Ad.*	AE
21-8-20BB	20	60.0	8.0	4.5	48.5	168	280	873	928	3.36	4.20
30-18-20N	20	49.0	18.0	4.5	49.3	175	357	852	878	3.21	9.64

*Air Entraining and High-Range Water Reducing Agent

Table 2. Hydroxycarbonates used in this study

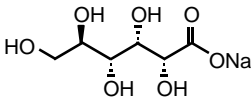
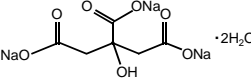
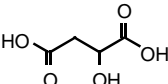
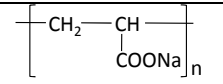
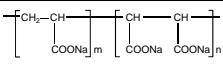
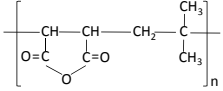
Name	Structural formula	Molecular mass
Sodium gluconate		218
Trisodium citrate dihydrate		258
DL-Malic acid		134

Table 3. Polymers used in this study

Name	Structural formula	Molecular mass
Sodium polyacrylate (PAA-3,500)		About 3,500
Sodium maleate acrylate copolymer (PAM-5,000)		About 5,000
Isobutylene/ maleic anhydride copolymer (IMA-6,000)		About 6,000

with mixture proportions of 30-18-20N and 21-8-20BB which are available in Japan. Table 1 shows the mixture proportion of the concrete. The ratio of solid content of sludge water to cement was 3% or 7%. Ordinary Portland cement (OPC) or Portland blast-furnace slag cement Type B (BB) as a binder, andesite crushed stone and granite sand as aggregate, and ground water as mixing water were used. Slump of fresh concrete and compressive strength of hardened concrete were measured. Carbonation tests using 28 days-cured specimens were done at 30 ± 1 °C, $60 \pm 5\%$ RH and $5.0 \pm 0.2\%$ of CO₂ concentration. Drying shrinkage tests using cylindrical specimens (50 by 100 mm) cored from 7 days-cured cylindrical concrete (100 by 200 mm) were done at 20 ± 1 °C, $60 \pm 5\%$ RH.

Property of Fresh mortar with sludge water which added various chemical admixture. Name, structure and molecular mass of the hydroxycarbonates and the polymers used in the study of mortar flowability are shown in Table 2 and Table 3 respectively. Three kinds of organic compounds including sodium gluconate known as a set

retarder were used. Each of them has a hydroxyl group and one carboxyl group or more. The three kinds of polymers shown in Table 3 have also one carboxyl group or more in their monomer unit. In general, sodium polyacrylate and sodium maleate acrylate copolymer are used as a dispersant of pigment or cement and a sequestering agent. Isobutylene maleic anhydride copolymer is used as a dispersant and a binder. Polyacrylate and polymaleate derivatives grafted with polyethylene oxide long chain are known as a superplasticizer because of their steric hindrance. However isobutylene maleic anhydride copolymer does not have such a long chain graft. It has been little studied as a cement dispersant. Dosage of the chemical admixtures were 0.1% to 1.2%.

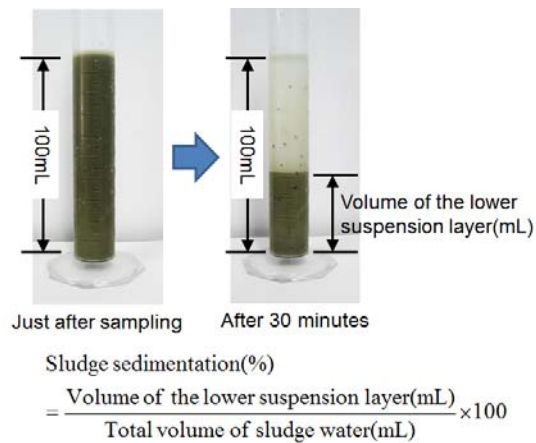


Photo 1. Test method of sludge sedimentation

Ordinary Portland Cement (3.15g/cm^3 , $3,350\text{cm}^2/\text{g}$) and tap water was used as sludge water in this experiment. Cement and water ($C/W=20/80$) were stirred in a plastic cylinder (2L) for 3 hours. After addition of a chemical admixture, the sludge water was kept stirring for a given time.

Mortar was made with above-mentioned OPC, crushed sandstone and tap water with W/C of 50% and s/c of 2.25 using a Hobart mixer according to JIS A 1146. A part of tap water was replaced with the sludge water so that the ratio of solid content of sludge water to cement is 3%. An amount of sand equal to the sludge solid content was decreased. Mortarflow test was done according to JIS R 5201. Percent flow of mortar with sludge water to mortar without it was estimated. Cylindrical specimens (50 by 100 mm) were used for compressive strength test.

Sludge water (100ml) at a given time was poured into a transparent plastic cylinder (100mL) and left for 30 min to separate into two layers shown in Photo 1. A volume of the lower suspension layer was measured as sludge sedimentation.

Sludge water was filtered with a 5-B filter and about 15mg of mixture from the residue on the filter was used as a ignition loss sample. A sample was heated at 105°C for 2 minutes and up to $1,100^\circ\text{C}$ at a elevation rate of $50^\circ\text{C}/\text{min}$ using TG-DTA equipment. In this paper, a value of difference between mass at 105°C and that at $1,100^\circ\text{C}$ by that at 105°C was defined as an ignition loss.

EXPERIMENTAL RESULT AND DISCUSSION

Characteristics of concrete with sludge water. Slump test results of concrete using sludge water are shown in Figure 1. A marker of ● and that of ■ shows slump of concrete using sludge water without admixture of 30-18-20N and 21-8-20BB respectively. As a ratio of solid in sludge water to cement increased, slump decreased. A marker of ○ and that of □ shows slump of concrete using sludge water with a set retarder of hydroxycarbonate of 30-

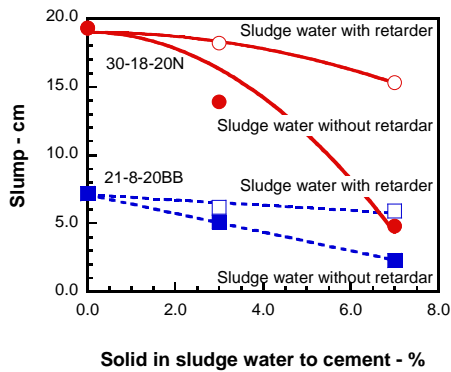


Figure 1. Slump of concrete using sludge water

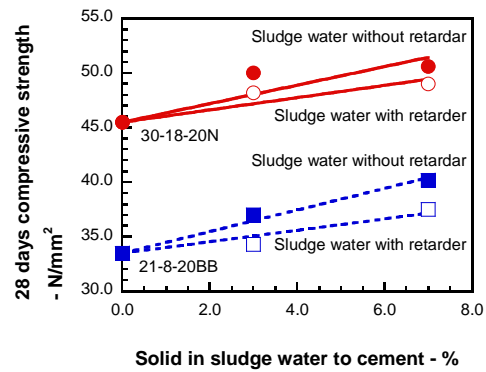


Figure 2. Compressive strength of concrete using sludge water

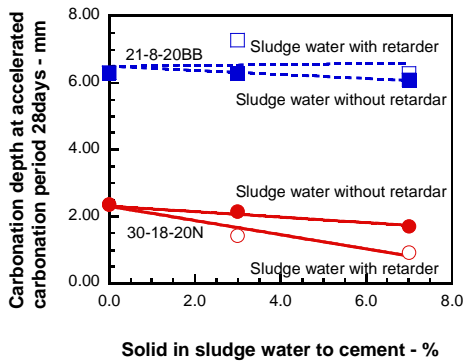


Figure 3. Carbonation of concrete using sludge water

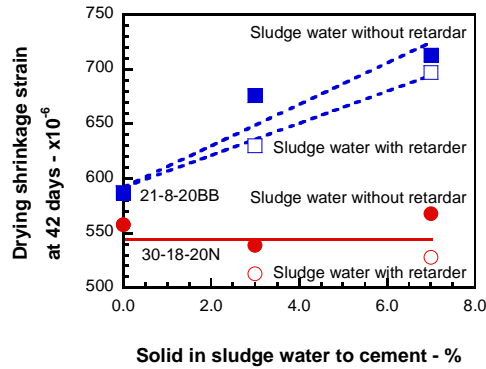


Figure 4. Drying shrinkage strain of concrete using sludge water

18-20N and 21-8-20BB respectively. Addition of a set retarder reduced the decrease of slump.

Compressive strength test results of concrete using sludge water are shown in Figure 2. As a ratio of solid in sludge water to cement increased, compressive strength increased.

Accelerated carbonation test results are shown in Figure 3. Carbonated thickness of concrete using sludge water at 28th day is comparable to or less than that of concrete using only ground water.

Drying shrinkage strain at 42nd day in drying shrinkage test are shown in Figure 4. Drying shrinkage strain of cylindrical specimen (50 by 100 mm) at 42nd day is said to be equivalent to that of prismatic specimen (100 by 100 by 400 mm) at 6 months (Takashi TANIGUCHI, 2010). As a ratio of solid in sludge water to cement increased, drying shrinkage strain increased a little. However, the increase of strain was only about 100×10^{-6} even when a ratio of solid in sludge water to cement was up to 7%.

Consequently, using sludge water as mixing water to a certain extent has only a little effect on strength and durability of concrete. But it causes a decrease of slump. Therefore if flowability is improved by addition of a set retarder, sludge water will be used widely.

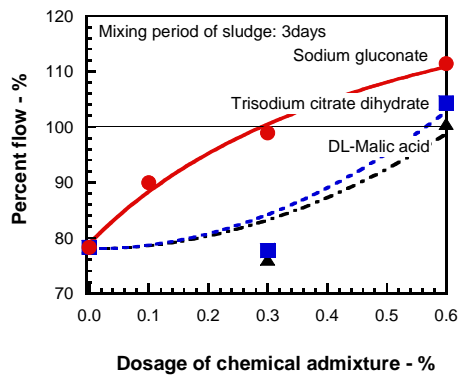


Figure 5. Flow ratio of mortar using sludge water with an organic compound

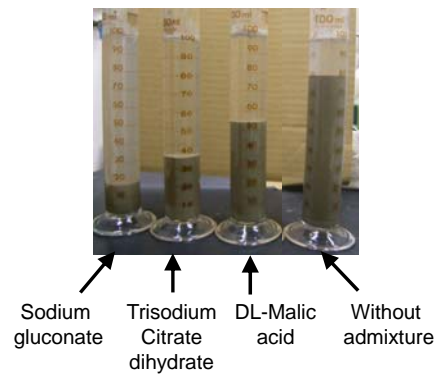


Photo 2. Sludge sedimentation

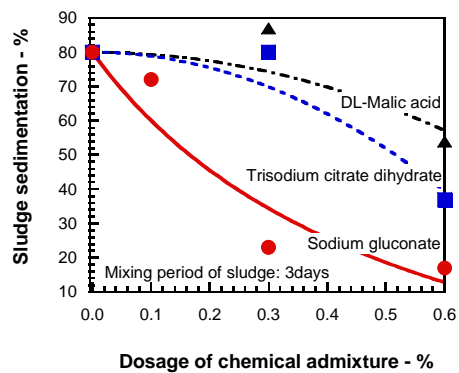


Figure 6. Sludge sedimentation of sludge water with an organic compound

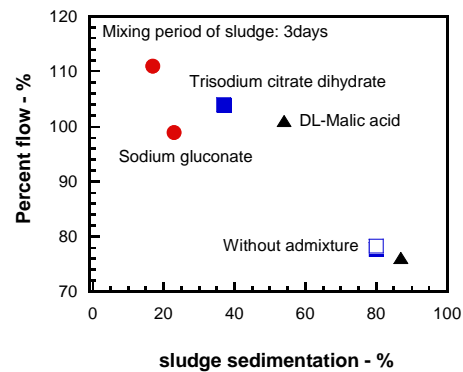


Figure 7. Relationship between sludge sedimentation of sludge water and flow ratio of mortar with an organic compound

Property of Fresh mortar with sludge water which added various organic compounds. Figure 5 shows percent flow of mortar using sludge water adding an organic compound as a chemical admixture shown in Table 2 to that of mortar without them. A marker of ●, ■ and ▲ shows percent flow of mortar using sludge water with gluconic acid, citric acid and malic acid respectively. The ratio of solid content of mortar to cement is 7%. Mortar flow increased by addition of each organic compound. Photo 2 shows sedimentations of sludge water with gluconate, citrate, malic acid and none at the dosage of 6% of cement. Order of the volume of the lower layer is gluconate, citrate, malic acid and none from the smallest. The smaller volume of the lower layer is, the larger mortar flow of the mortar using the sludge water is.

Figure 6 shows the sedimentation test results of the sludge water used in the mortar shown in Figure 5. The larger percent flow of mortar is, the smaller sludge sedimentation is.

Figure 7 shows a relationship between percent flow of mortar and sludge sedimentation. The smaller sedimentation is, the larger percent flow of mortar with the sludge water is.

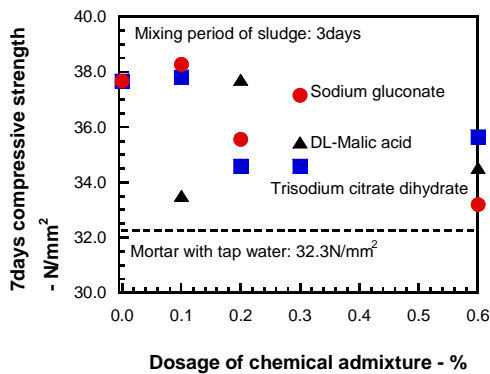


Figure 8. Compressive strength of mortar using sludge water with an organic compound

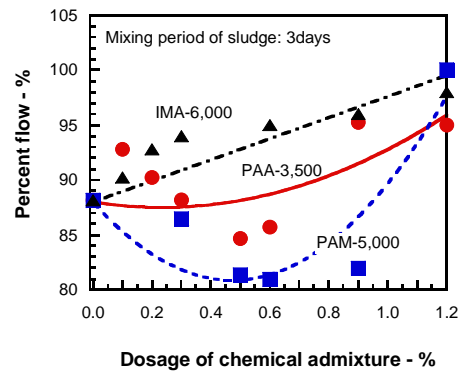


Figure 9. Flow ratio of mortar using sludge water with a polymer

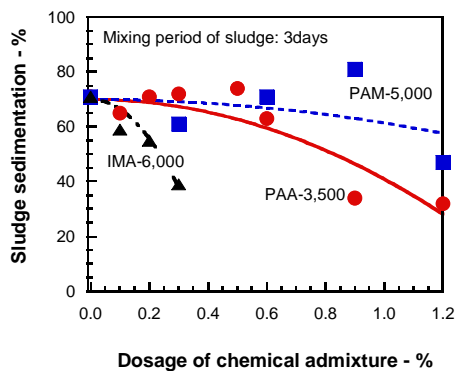


Figure 10. Sludge sedimentation of sludge water with a polymer

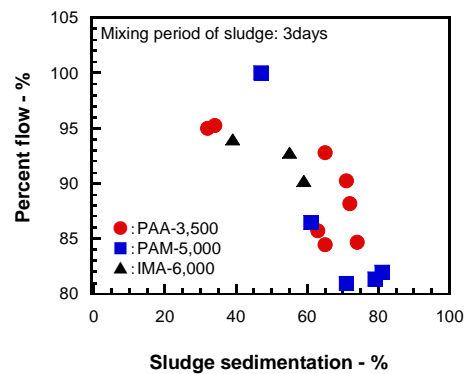


Figure 11. Relationship between sludge sedimentation of sludge water and flow ratio of mortar with a polymer

Figure 8 shows compressive strength of 7days-cured mortar using sludge water with an organic compound above. The compressive strength of mortar without sludge water was 32.3N/mm². Compressive strength with each sludge water is larger than that without sludge water. It means addition of the above organic compound do not cause a negative influence on concrete strength.

Property of Fresh mortar with sludge water which added various polymers.

Figure 9 shows percent flow of mortar using sludge water adding a polymer shown in Table 3 to that of mortar without them. A marker of ●, ■ and ▲ shows percent flow of mortar using sludge water with sodium polyacrylate, sodium maleate acrylate copolymer and isobutylene/maleic anhydride copolymer respectively. Mortarflow increased by addition of each a polymer at a sufficient dosage, too. Figure 10 shows the sedimentation test results of the sludge water used in the mortar shown in Figure 9. Sludge sedimentation decreased by addition of the polymers. Figure 11 shows a correlation of percent flow of mortar and sludge sedimentation. The smaller sedimentation is, the larger percent flow of mortar with the sludge water in the cases of polymers similar to the above organic compounds.

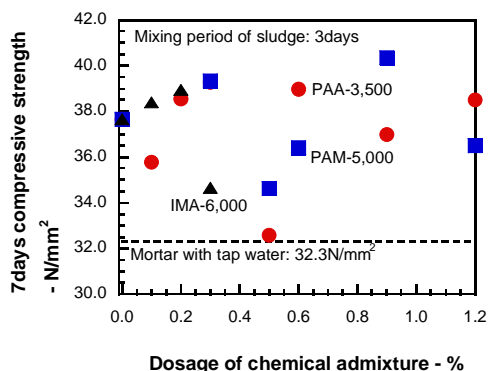


Figure 12. Compressive strength of mortar using sludge water with polymer

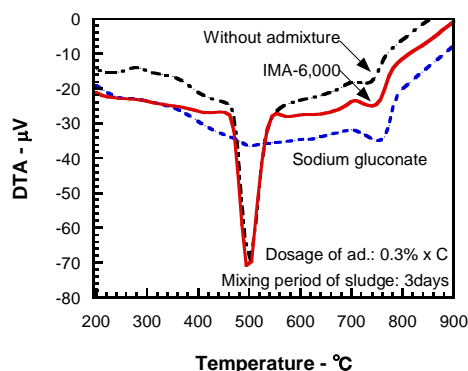


Figure 13. Result of DTA of sludge water

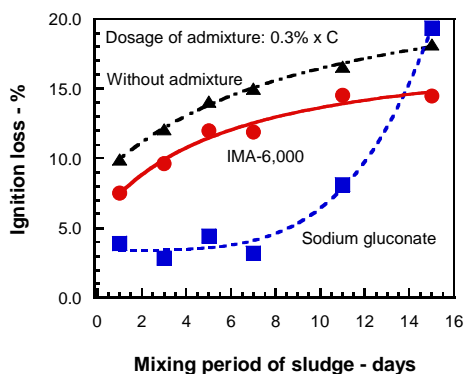


Figure 14. Ignition loss of sludge water

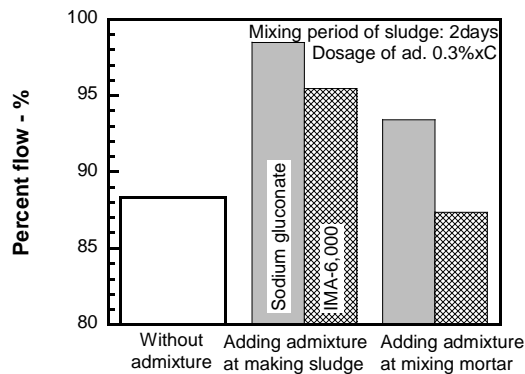


Figure 15. Effect of addition method of the admixture on mortar flow

Figure 12 shows compressive strength of 7days-cured mortar using sludge water with a organic compound above. The compressive strength of mortar without sludge water was 32.3N/mm². Compressive strength with each sludge water is larger than that without sludge water. It means addition of the above polymers do not cause a negative influence on concrete strength.

Figure 13 shows differential thermal analysis (DTA) results of sludge sampled after 3days from addition of the admixtures. We can find endothermic reaction of sludge without any admixture at 400-500°C, which is presumed to be a dehydration of calcium hydroxide produced from hydration of cement. Such a dehydration of calcium hydroxide was not found in a case of sludge with a gluconate. It means the gluconate probably controlled the hydration of cement. On the other hand, we can find endothermic reaction of sludge with an isobutylene/maleic anhydride copolymer at 400-500°C similar to that without any admixture.

Figure 14 shows change of ignition loss with time. Ignition loss increased with progress of hydration of cement. The ignition loss of the sludge with a gluconate keep lower value till about 7th day, then increased, which means hydration was controlled till about 7th day. Ignition loss of sludge with the above polymer increased with time like that without any

admixture, which means hydration proceeded. It is presumed such a polymer improved slumpflow not by hydration control effect but by another effect such as dispersion.

Figure 15 shows an influence of an addition method of admixture on mortarflow. Percent flow of mortar with sludge water added an admixture 2days before mortar mixing are larger than those added an admixture on mortar mixing.

CONCLUSIONS

Addition of sludge water as a part of mixing water have only a little influence on strength and durability, but cause a decrease of slump. The decrease of slump can be improved by addition of a set retarder such as gluconate into sludge water due to control of cement hydration. Some of polymers also have an effect on slump improvement. Cement hydration proceeds in the case of the polymers. It is presumed the polymers improve mortarflow not by hydration control effect but by another one such as dispersion.

REFERENCES

- Kenichi AIZAWA, et. (1996). "A study about utilization of sludge from concrete using super retarding agent" *Proceeding of JCI*, Vol. 18, No.1, pp.387-392. (In Japanese)
- Naoshi OZAWA, et. (1997). "A Study of Retardation Mechanism of Organic Retarders" *Cement Science and Concrete Technology*, No.51, pp.276-281. (In Japanese)
- Policy Bureau, Ministry of Land, Infrastructure, Transport and Tourism, (2006). "Summary of the result of questionnaire survey about control and utilization of leftover & return concrete" (In Japanese)
- Takashi TANIGUCHI, et. (2010). "Rapid test of drying shrinkage strain of concrete" *Proceedings of the Concrete Structure Scenarios*, Vol. 10, pp.249-254. (In Japanese)
- Young-jin SONG, et. (2007). "Recycling of Sludge Water of Portland Blast Furnace Slag Cement Containing Set-Retarder" *Cement Science and Concrete Technology*, No.61, pp535-541. (In Japanese)