

PORTLAND-CEMENT BASED SIMPLE REPAIRING MORTAR WITH MODIFIED INORGANIC ADMIXTURES AND SAP

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ABSTRACT

Polymer cement mortar (PCM) is widely used for repair and strengthening of concrete, due to its high performance in workability, strength and durability. But, it would be uneconomical to use it in the usual environment, because the cost of PCM is about 10 times of ordinary Portland cement (OPC). In this study, as material for repair and strengthening of concrete, OPC based silica fume or fly ash modified test mortar without dry polymer powder was manufactured, and the property of test mortar was compared with PCM on the market. In order to confirm the inhibiting effect of drying shrinkage with super absorbent polymer (SAP), SAP modified mortar was also manufactured and examined its properties.

Keywords: silica fume; fly ash; polymer cement mortar; super absorbent polymer

INTRODUCTION

Extension of life-span of structure is an important worldwide problem. And the development of low-cost and high-quality repair and strengthening techniques become still more important. Polymer cement mortar (PCM) is popular as the material for repair and strengthening of concrete. Due to its high performance in workability, strength and durability, it became widely used for sprayed mortar. But it would be uneconomical to use it in the usual environment, because the cost of PCM is about 10 times of ordinary Portland cement. In this study, as material for repair and strengthening of concrete, Portland cement based and modified with silica fume or fly ash test mortar without dry polymer powder was manufactured, and the property of test mortar was compared with PCM on the market. The inhibiting effect for drying shrinkage of super absorbent polymer(SAP) was also examined[1].

OUTLINE OF EXPERIMENTS

Used materials and Mixture proportion Ordinary Portland cement, silica fume, fly ash, tap water, fine aggregate, surperplaticizer and SAP were used in test mortar. PCM on the market was also used to compare with test mortar. The detail of used materials and the image of dry SAP are shown in Table 1, Table 2 and Fig.1.

Table 1. Used Materials of Test Mortar

	material		properties
Powder	ordinary Portland cement	OPC	density 3.16g/cm ³
	silica fume	SF	density 2.33g/cm ³
	Fly ash	FA	density 2.36g/cm ³
Water	tap water	W	density 1.00g/cm ³
Aggregate	mixed quartz sand	S	No.4, density 2.65g/cm ³
			No.6, density 2.65g/cm ³
Addmixture	surperplaticizer	SP	polycarboxylic acid type
	defoaming agent	DA	polyalkylene glycol derivatives
	SAP	SAP	SAP-A, water absorption ratio 7.5g/g
SAP-B, water absorption ratio 22.5g/g			

Table 2. The Composition of PCM

Symbol	materials	properties
PCM-A	special cement, fine aggregate, organic admixture, organic fiber	density 2.65g/cm ³
PCM-B	cement, fine aggregate, admixture, fiber, acrylic powder resin	density 2.33g/cm ³

Figure 1. The image of dry SAP



(a) SAP-A

(b) SAP-B

Mixture proportion of PCM-A and test mortar are shown in Table 3 and Table 4. W/PCM=17.0% in Table 3 is fixed from the recommended value by cement maker, and targeted flow value of 160±10mm is decided from experimental result. In Table 4, W1,W2 and W3 express tap water, 1% of de-foaming agent diluted water and absorbed water of SAP respectively.

Table 3. The Mixture Proportion of PCM-A

Symbol	W/PCM (%)	SAP/P (%)	Mass of one batch(g)				
			PCM-A	PCM-B	W		SAP
					W1	W2	
M1	17.0	0	3000		510	0	0
M2	17.0	0.2	3000		510	45	A: 6.0
M3	17.0	0.2	3000		510	135	B: 6.0
M4	18.0	0		3000	540		0

Table 4. The Mixture Proportion of Test Mortar

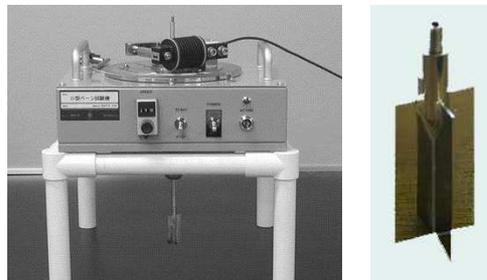
Symbol	W/P (%)	SAP/P (%)	Mass of one batch(g)								
			P			W		W3	S	SP	SAP
			OPC	SF	FA	W1	W2				
M5	27.3	0	1050	105	0	315.0	0	2010	21.5	0	
M6		0.27				0	283.5			31.5	23.6
M7							70.9			B:3.15	
M8		0		0	106	315.0	0			0	0
M9						283.5	31.5			23.6	A:3.15
M10		0.27		0	0	0	283.5			31.5	70.9
M11			70.9				14.3	B:3.15			
M12											

Evaluation method of property: The property just after mixing was evaluated by flow value, air content and setting time. Setting time test is provided for cement paste in case of test mortar, on the other hand, it was adapted for mortar in case of PCM, because fine aggregate was premixed. The consistency was measured with vane-type viscometer as shown in Fig.2. The device was developed by one of authors to evaluate the material and spraying quality of PCM[2]. It consists of torque meter, drive motor, vane and connecting shaft. Evaluation factor: shear stress: τ is measured by this device and calculated by Equation(1). The vane of 2cm in total width and 4cm in height was used. The rotational velocity for the rheometric test was 60 degree/min, and test was started just after mixing of mortar.

$$\tau = \frac{M}{\pi D^2 (H/2 + D/6)} \quad (1)$$

where τ : shear stress(Pa), M : torque(Nm), D : total width of vane(m), H : height of vane(m)

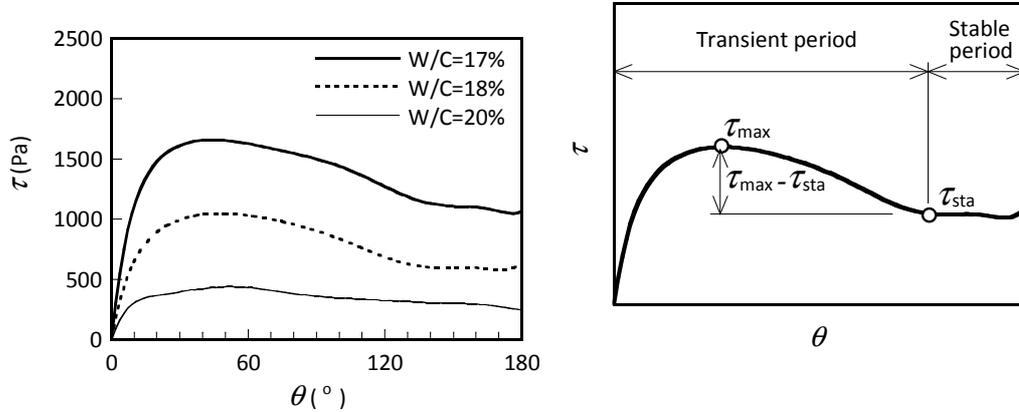
Figure 2. Vane-type viscometer and vane



The relation between τ and the rotation angle of vane: θ which is named $\tau - \theta$ curve is illustrated in Fig.3. The sample $\tau - \theta$ curves of PCM-A with different W/C are illustrated in Fig.3(a). $\tau - \theta$ curve of PCM has two phases: transient period and stable period, and

three parameters: τ_{\max} , τ_{sta} and $\tau_{\max} - \tau_{\text{sta}}$ can express the characteristics of PCM.

Figure 3. The Sample $\tau - \theta$ curve of PCM-A and Evaluation indexes in $\tau - \theta$ curve



(a) The Sample $\tau - \theta$ curve of PCM-A (b) Evaluation indexes in $\tau - \theta$ curve

The hardened properties such as mortar strength (JIS R 5201), the bond strength between base plate and PCM or test mortar(JSCE-K 531-2010) and length change(JIS A 1129) were measured. In bond strength test, the base plate which size is 300mm x 300mm x 30mm and made of mortar on the market was used. The surface of base plate was ground by sandpaper, and cleaned with acetone absorbed cotton. The surface of all base plates were sprayed liquid primer for PCM-A with a spray. After primer dried, fresh mortar was plastered on base plate with a trowel and covered with lap film to prevent evaporation from mortar. In order to act constant pressure between plastered mortar and base plate, the same plate as base plate was put on plastered mortar. The pressing weight and lap film were removed at the day after placing, and the specimen was stored in curing room of 20°C and 60%RH. Bond strength was measured with the testing apparatus shown in Fig.4 at 28 days.

Figure 4. Bond strength testing apparatus

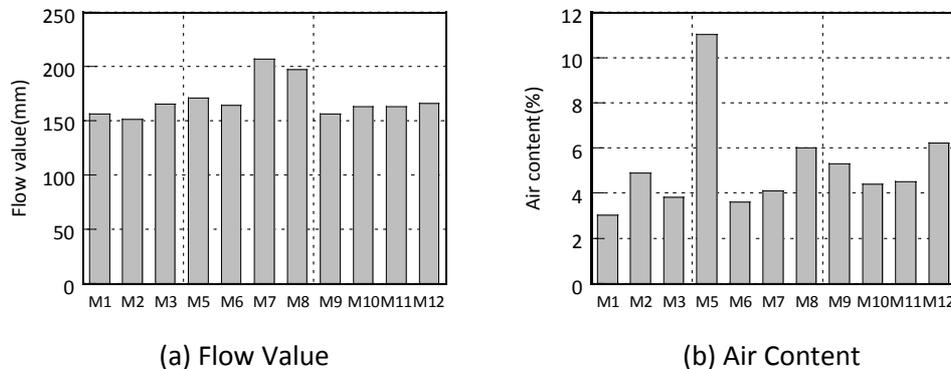


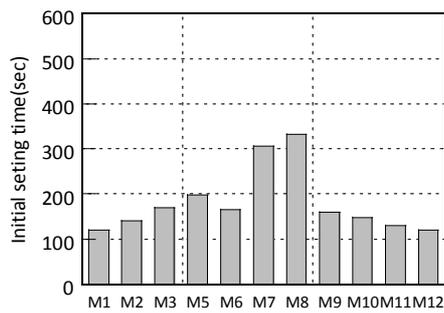
EXPERIMENTAL RESULTS AND DISCUSSION

The properties of fresh mortar are shown in Fig.5. Flow value, in fig.5 (a), are in the range of 160 ± 10 mm except M7 and M8. Because in the series of OPC+SF; M5, M6.M7

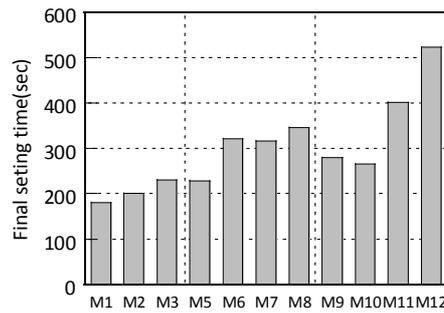
and M8 used same mass of SP and same total water of SAP modified mixture: M7 and M8 is larger than non-SAP mixture: M5 and M6. In case of OPC+FA, flow value is same level, because mass of SP in M12 which modified SAP-B is smaller than other mixture shown in Table 4. In comparison of reference mixture, air content of M4 which modified SF is larger than M8 which modified FA. These results would be caused by the characteristics of each material; smaller particle admixture takes much entrapped air and FA cannot take entrapped air easily. There is certain advantage in high air content for sprayed mortar, because pumpability is improved when air content is high. And after sprayed, air content drops to reasonable value with impact by spraying. Actually there are two type of PCM: one is a PCM-A of a low air content type, the other is a PCM-B of a high air content type. Fig.5(c) and (d) are Initial setting time and final setting time. The setting time of reference mixture:M1 is 160min for initial time and 280min for final time, and almost mixture has longer setting time than M1 except initial setting time of M11 and M12. This result shows test mortar and SAP modified mixture needs accelerating admixture and accelerating admixture which act only on final setting is needed in case of FA modified mixture. $\tau - \theta$ curve of four types mixture are shown in Fig.6. PCM-A and PCM-B has different shape of $\tau - \theta$ curves; PCM-A has clear peak, but PCM-B has no clear peak. On the other hand, τ_{sta} during stable period is same level. The shape of $\tau - \theta$ curve of test mortar is across between PCM-A and PCM-B, and has many points of similarity to PCM on the market. Although experiment in the field is eventually required, test mortar could have normal consistency as wet type sprayed mortar. Fig.7 shows the relation between weight loss and drying age. The weight loss ratio measurements start after seven days water curing. Fig.7(a) shows large weight loss ratio, in order, M3,M2 and M1, and the water absorption effect of SAP is confirmed from this result. The weight loss ratio of M5, M7 and M8 in Fig.7(b) is similar to M1, M2 and M3 in Fig.7(a). M6 which is mixed with de-foaming agent is the smallest weight loss ratio. The result in Fig.7(b) express total void volume is large M8, M7, M5 and M6 in that order. FA modified mixture has different tendency from SF modified mixture and PCM. In comparison Fig.7(c) with Fig.7(b), M6 and M10 is the same level, however, M9, M11 and M12 corresponds to M5, M7 and M8 which are smaller than SF modified mixture, and there is no difference between M9, M10 and M11.

Figure 5. The Comparison of fresh properties





(c) Initial Setting Time



(d) Final Setting Time

Figure 6. $\tau - \theta$ curve of different mixture

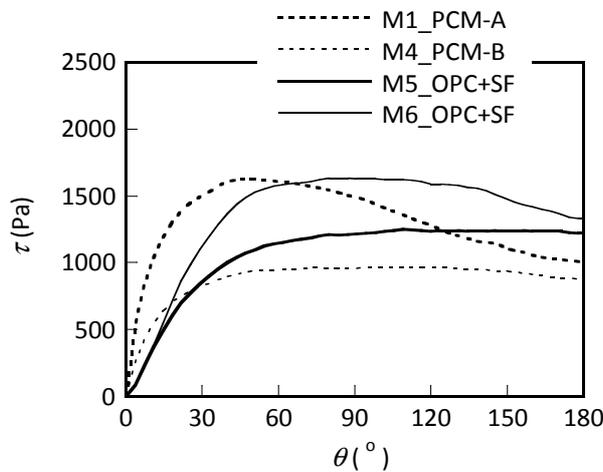
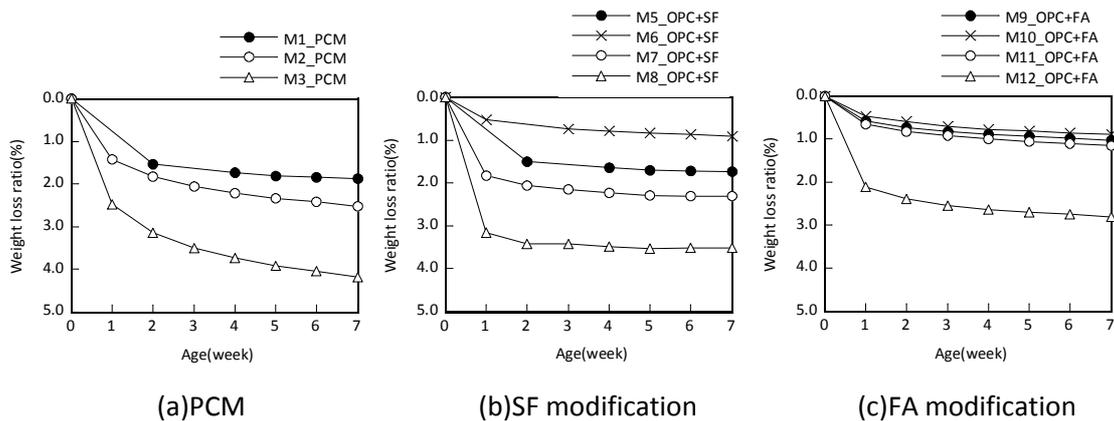


Figure 7. Weight loss ratio vs. Drying Age



(a)PCM

(b)SF modification

(c)FA modification

Fig.8 shows the relation between compressive strength and curing days. In comparison between reference mixture:M1, M5 and M9, compressive strength at 28 days are nearly equal. The same relation is observed in SAP-B modified mixture:M3, M8 and M12. The influence of SAP-A admixing is different from the type of mixture:M2<M1, M7>M5 and M11=M9. M6 which modified SF and de-foaming agent has the maximum compressive strength, 120N/mm² at 28 days, in this experiment. This mixture is effective for strengthening of concrete. Fig.9 shows the relationship between drying

shrinkage and drying age. The drying shrinkage measurements start after seven days water curing. As a rule, specimen which has large weight loss caused by drying shows large shrinkage. In comparison between reference mixture:M1, M5 and M9, the basic knowledge is applicable to this results, however, it is not applied to same case:M2, M3 and M12. The drying shrinkage of SAP modified PCM is worth notice:M2=M3<M1, that is, SAP mixing is effective method for control of drying shrinkage of PCM.

Figure 8. Compressive Strength vs. Water Curing Age

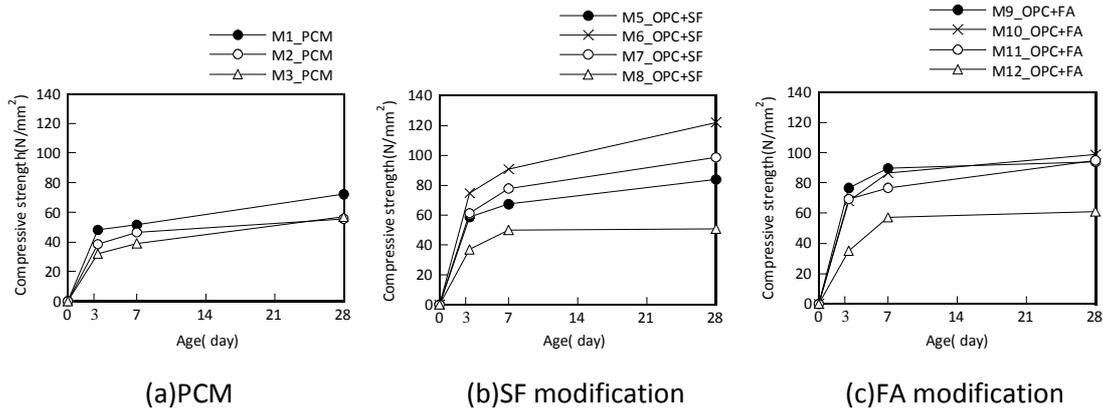
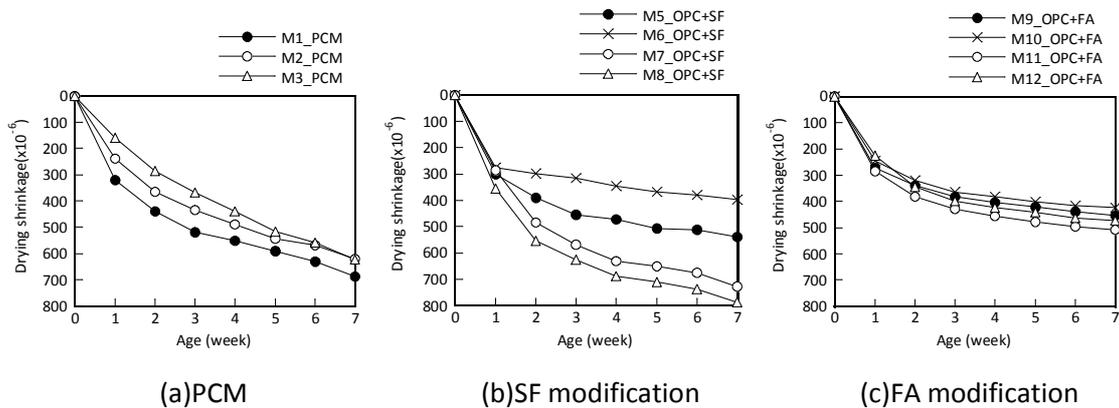
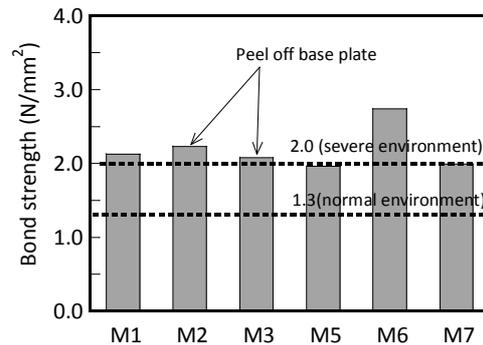


Figure 9. Drying Shrinkage vs. Drying Age



The bond strength between base mortar plate and plastered mortar is shown in Fig.10. The standard value provided by Japan Society of Civil Engineers is also shown in this figure. The bond strength of all specimens is in excess of the standard value in normal environment. However, the bond strength of test mortar is less than the standard value in severe environment. And there are two fracture patterns; the fracture layer of M2 and M3 is the surface of base plate, that is plastered mortar is peeled off base plate, while that of M1, M4, M5 and M6 is the inner parts of base plate. Normally bond strength in case of interface fracture is less than that in case of internal fracture, however the results of this experiment are the different results which we expected. Although the cause of different fracture pattern is unknown, it is confirmed that test mortar has enough bond strength in ordinary environment.

Figure 10. The comparison of bond strength among different mixtures of mortar



CONCLUSIONS

The setting time of SF and FA modified mortar is longer than that of PCM, and mixing in SAP delays setting time. Due to the consistency of test mortar, which is similar to PCM, test mortar could be used as wet type sprayed mortar. Test mortar has enough compressive strength and bond strength as mortar for repair and strengthening. SAP modified PCM has inhibited drying shrinkage. On the other hand, the result of test mortar is different between OPC+SF and OPC+FA: SAP modification cause negative effect in case of OPC+SF and no effect in case of OPC+FA.

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LIST OF REFERENCES

1. Jensen, O.M., *Water-entrained cement-based materials*, *Cement and Concrete Research*, No.32, 2002, pp.973–978.
2. Ichimiya, K., Zaitso, K., and Etoh, M., *Measurement method for consistency of polymer-modified sprayed mortar with vane-type viscometer*, *Advances in Construction Materials through Science and Engineering*, RILEM Publications s.a.r.l. PRO 79, Bagnaux, 2011, p. 60 (abstract book). Full text on CD-ROM.