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Examination of improvement of early age strength of fly ash concrete
フライアッシュコンクリートの早期強度の改善に関する検討

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1.Introduction:

Fly Ash is a by-product of thermal power station which is now a most available supplementary cementing material world wide. There are many practical reasons to add some fly ash (if not a lot of) to concrete not just in addition to Portland cement, but in replacement of it. To considerably increase the utilization of fly ash that is other wise being wasted, and to have a significant impact on the production of cement, it is necessary to advocate the use of concrete that will incorporate large amounts of fly ash as a replacement for cement. However, due to the slow rate of hydration of fly ash, the concrete with high volume fly ash has lower strength at early ages. This limits the wide use of high volume fly ash concrete in construction works.

In this paper, the prediction of strength of fly ash concrete at the early age and different examinations concerning the improvement of early age strength of fly ash concrete are made.

2. Experimental Details:

2.1 Materials:

1. Cement: Ordinary Portland cement (density 3.16gm/cm^3) and rapid hardening Portland cement (density 3.14gm/cm^3) , 2. The fly ash (density 2.24gm/cm^3), 3. Sand (density 2.57gm/cm^3), 4. Aggregate (density 2.6gm/cm^3, max. size: 20mm), 5. AE water reducing agent, air entraining and high range water reducing agent, AE supplementary agent, 6.Admixtures: Blast furnace slag, slaked lime, $CaSO_4$ and $CaSO_4.2H_2O$, silica fume

2.2 Test procedure:

Test 1: In this test, the early age strength of fly ash concrete in comparison to plain cement concrete was tried to investigate. Cylindrical test specimen (ø10 x 20cm) of materials and proportions as shown in table 1 was prepared. After 24 hours of the cast, the sealed curing was done in the constant temperature water of about 20°c. The compression strength of the specimen was examined at seven different ages varying from 2 days to 28 days.

Test 2: This test was aimed to improve the early age strength of fly ash. In this test, according to the presumption of the researches in the past[1),2)], mortar test specimens (diameter 5 cm and length 10 cm) of cement, fly ash, fine aggregate and variety of admixtures were prepared (as shown in table 2). After 24 hours of the cast, the specimen was taken out from the mould and curing was done in the constant water temperature of about 20°c. The compressive strength of the test piece was examined at 3 days and 7 days.

Table 1 mix proportions of concrete

Water cement ratio (%)	Fly Ash mixture ratio F/(F+C) (%)	Sand-aggregate ratio (%)	Amount of unit (kg/m^3)					Amount of air Adjustment medicine (%)	AE Water reducing agent (%)	Slump value (cm)	Amount of air (%)
			Water	Cement	Fly Ash	Crushed sand	Aggregate				
40	0	45	170	425	0	747	924	0.35	0.35	6.0	4.1
	10	45	170	383	42	740	915	0.45	0.35	9.4	4.5
	20	45	167	334	84	740	915	0.45	0.35	6.0	4.1
	30	45	165	289	124	738	912	0.55	0.35	6.3	4.2
65	0	50	170	262	0	896	907	0	0.35	6.0	4.0
	10	50	165	229	25	901	911	0.25	0.35	8.0	4.7
	20	50	170	210	52	887	897	0.35	0.35	12.0	4.2
	30	50	170	183	79	883	893	0.37	0.35	8.0	4.0
50(R.H.C))	20	47	172	275	69	797	910	0.7	0.35	9.4	4.7

Table 2 mix proportions of mortar

Water	Cement	Crushed sand	Fly Ash	$CaSo_4$	$CaSo_4.2H_2O$	Blast furnace slag	Lime	Silica Fume	AE
1.5	3	6							
1.5	2.1	6	0.9						
1.5	2.1	5.85	0.9	0.15					
1.5	2.1	5.7	0.9	0.3					
1.5	2.1	5.85	0.9		0.15				
1.5	2.1	5.7	0.9		0.3				
1.5	2.1	6	0.6			0.3			
1.5	1.8	6	0.6			0.3	0.3		
1.4902	1.95	6	0.9					0.15	0.0098

3. Early age strength presumption:

The presumed early age strength of fly ash concrete is proposed from the research in the past by combining the age of the equivalent materials based on the maturity and the strength curve using the Gorral curve[3)].

$$f_{c,t} = \frac{a \cdot f_{c,28} \cdot t_m}{b + t_m} \quad \cdots \quad (1)$$

Here, $f_{c,t}$, $f_{c,28}$: Compressive strength of concrete at required age and strength of concrete at 28th day

t_m : Age of equivalence material in maturity

$t_m = \sum \{(T+10)/30\}\Delta t$

(T : Curing temperature, Δt : time of curing temperature T)

a, b : Coefficient $a = (b+28)/28$

$b = c(W/C) + d$

c, d :constant, ordinary Portland cement c=7.55, d=-0.10,
rapid Portland cement c=5.19, d=-0.74

By the research in the past, the accurate method of using substantial water cement ratio can be presumed from the above expression of W/C. In this research, as the curing temperature was kept 20°c, $t_m = \Delta t$.

The compressive strength of fly ash concrete (W/C 40%and 65%) with three different replacement ratios of fly ash and the compressive strength of rapid hardening Portland cement (W/C 50%) with replacement ration of fly ash 20% was presumed.

Fig.2-1 to 2-3 shows the result of specimen with W/C=40% and ordinary Portland cement shows the result of rapid hardening Portland cement. From these result, it can be concluded that the presumed early age strength is accurate. Therefore the above expression is applicable with the mentioned materials and W/C ratio.

4.Improvement of early age strength :

Fig.3 shows the compressive strength of concrete with rapid hardening Portland cement (20%fly ash) and ordinary Portland cement (0%and 20% fly ash) .The result shows that the early strength of the fly ash concrete increases with rapid hardening Portland cement.

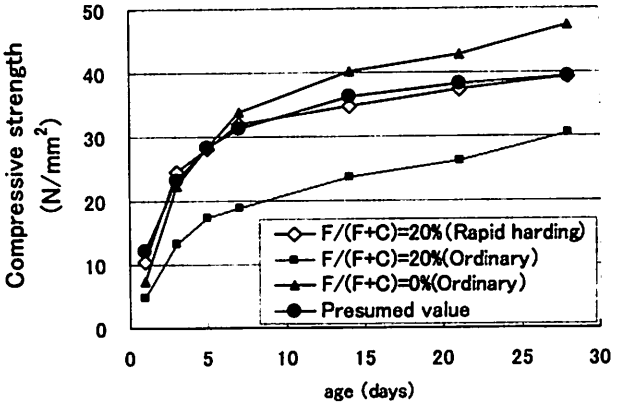


Fig.3 Comparison of compressive strength

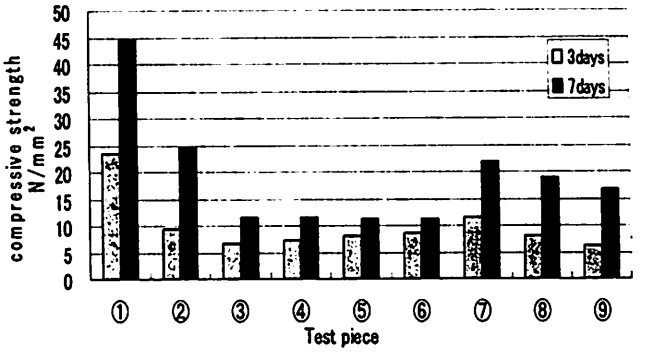


Fig.4 Comparasion of comp. strength of test piece

Fig.4 shows the compressive strength of mortar specimen with different materials as shown in table 2.The result shows that there is not any improvement in the early age strength of fly ash concrete with the addition of the admixtures. Further, the compressive strength decreases in most of the cases.

5. Conclusion:

- Early age strength of fly ash concrete with ordinary and rapid hardening Portland cement can be presumed
- With the use of rapid hardening Portland cement, the early age strength of fly ash concrete can be improved.
- The early age strength of fly ash concrete could not be increased with the addition of the given materials with given conditions in table 2.

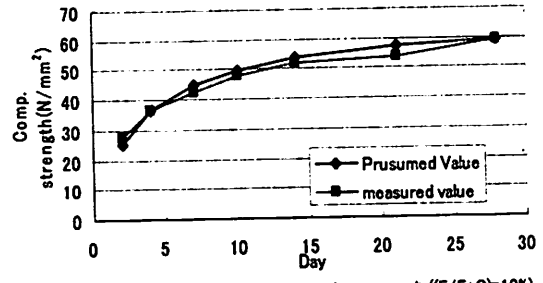


Fig.2-1 Compressive strength test result ((F/F+C)=10%) W/C=40%

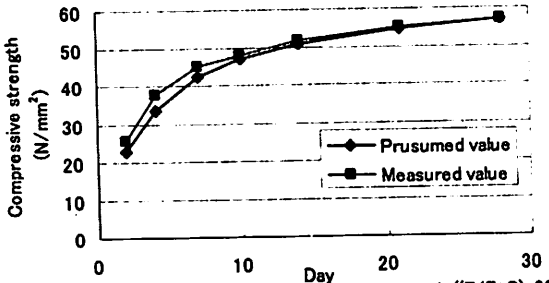
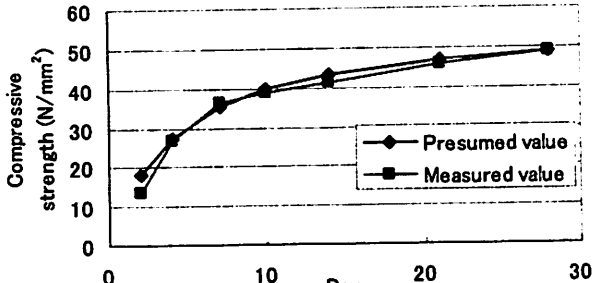


Fig2-2. Compressive strength test result ((F/F+C)=20%) W/C=40%



Gig2-.3 Compressive strength test result ((F/F+C)=30%) W/C =40%

References:

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2)Gengying Li and Xiaohua Zhao: Properties of concrete incorporating fly ash and ground granulated blast-furnace slag. Cement and Concrete Composites, Vol.25, 3, pp.293-299, 2003.4

3) Isao Ujike and Koji OOno : A Study on Prediction of Early-Stage Strength of Concrete Due to Various Growth Curve, Juranal of Materials, Concrete Structures and Pavement, No.798/ VI -68, pp.51-61, 2005.9.