Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 81 (1999)

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Autor: Nithikul, Montri / Sujjavanich, Suvimol / Suwanvitaya, Prasert

DOI: https://doi.org/10.5169/seals-61427

Effect of Fly Ash Size and Curing on Concrete Strength

Montri NITHIKUL
Postgraduate student
Kasetsart University
Bangkok, Thailand

Suvimol SUJJAVANICH
Associate Professor
Kasetsart University
Bangkok, Thailand

Prasert SUWANVITAYA
Associate Professor
Kasetsart University
Bangkok, Thailand

Summary

Particle size and curing temperature are important factors influencing mechanical properties of fly ash concrete. This paper reports the strength development of fly-ash concrete using three plant-classified particle sizes from Mae Moh power plant. The effect of two curing temperatures, 40 °C and 60 °C were studied, compared with that of room temperature. Of the three cement replacement percentages used ie 20%, 30% and 40%, the test results indicated that concrete with 20% replacement yielded highest strength gain for all particle sizes and curing temperatures. Within the range studied, size effects appeared to be much higher than temperature effect, particularly for the finest one. The effect of increasing temperature from 40 °C to 60 °C is minimal. However, the effect of curing at 40 °C compared to the room temperature is significant.

1. Introduction

In Thailand, the largest source of fly ash is the electricity generating facility in Mae Moh, Lampang province, in the North of Thailand. The fly ash, some 8,000 tons produced daily, has until recently been regarded as waste and has been treated accordingly. The past several years have seen better results in the attempts at utilization of the fly ash from this source as a pozzolanic material. Although studies have shown good results in terms of contribution to strength development (1,2), several other parameters remain uninvestigated. This study proposed to determine the influence of fly ash particle size and curing temperature on the compressive strength of fly ash concrete.

Two factors that are of current interest with regards to Mae Moh fly ash are the fly ash particle size and the curing temperature of the fly ash concrete. The interest in the particle size arises early in the installation of particle classifier in the plant. Particles are classified into three groups of varying mean particle sizes. The effects of such classified fly ash on concrete properties should be of substantial benefit. The other factor, the curing temperature, is thought to be significant in this region, since large numbers of on site concrete members are cured under temperature in the range of 30-40 C. The effect on the strength development, particularly when fly ash is involved, should lead to better understanding on the use of this material

2. Influence of particle size

Because the pozzolanic reactions that fly ash undergoes are surface reactions, the finer particles (hence, the greater specific surface) has been found to show higher rate of contribution to strength development (3,4). There are several other aspects associated with particle sizes and fly ash specific surface that may influence the pozzolanic activity of the ash. Chemical compositions of fly ash vary with particle sizes. Larger particles tend to have higher carbon content but less alkali, sulphate and chloride than finer ones, even though all particles have been collected from the same source, at the same time. It can be seen that after the particles have been separated into several sizes, the differences among the colllectors are not limited to size only, the chemical compositions are normally different as well. Even with these variances associated with particle sizes, using the fly ash samples collected from the classifier from the same plant at the same time was considered the best alternative in the investigation of the size effect.

3. Influence of curing temperature

Generally, higher temperature increases the rate of strength development of portland cement concrete and portland-fly ash concrete, particularly at early age. At temperature higher than 80 °C, however, portland cement concrete experiences strength reduction while the fly ash concrete still show large increase in strength (5).

4. Test program

Fly ash samples were obtained from Mae Moh electricity generating facility. Four samples were used, all collected from the same generating plant. Fly ash T was collected from unclassified collector. Fly ash A and C were collected after classification with fly ash A being the coarsest and fly ash C being the finest. The samples were tested for chemical composition and particle size distributions. The results are shown in Table 1 and 2.
The fly ash was mixed with Type I Portland cement at the proportion of 0%, 20%, 30% and 40% cement replacement by weight. Each binder was used to manufacture concrete specimens with binder content of 480 kg. per cubic meter of concrete for all mixes. The specimens were 75 mm. cubes. The water to binder ratios were 0.40, 0.45 and 0.50. The specimens were tested for slump and then divided into three sets for curing at room temperature (28 °C) and at 40 °C and 60 °C respectively. They were then tested for compressive strength at 7 and 28 days.

5. Test results

The results of slump tests are shown in Table 3. It can be seen that inclusion of fly ash in the mix sharply increased the slump. For water/binder ratio of 0.45, the increase was from 8.3 cm. for the control mix to an average of 15.0 cm. for mixes with 20% replacement with fly ash. The slump increases were larger with higher replacement percentage. The average slump values of 18.4 cm. and 21.0 cm. were found for 30% and 40% fly ash replacement respectively. The same trends can be seen for water/binder ratio of 0.40 and 0.50. The results were as expected. The spherical shape of the ash is known to help reduce interparticle friction and hence increase the flow of the composite mixtures. However, the finer particle sizes produce an increase in overall specific suface of the binder phase and, in some cases, result in an overall increase in water demand. For

the fly ash used in this study, the latter trend was probably smaller than the lubricating effect of the ash.
The results of effect of curing temperature on the compressive strength of fly ash concrete, for water/binder ratio of 0.45, are shown in figures 1, 2 and 3, for fly ash T, A and C respectively. It can be seen that, as expected, the higher the curing temperature, the more rapid the strength development. This trend is very clear at 7 days age, even for mixes with 40% cement replacement. However, it can be seen that curing at 60 °C resulted in a relative drop in the rate of strength gain at 28 days. This behaviour has been observed in portland cement concrete, and probably results from the same mechanisms. Again, the same trend was observed for water/binder ratio of 0.40 and 0.50.
The effects of particle sizes and their distribution are shown in figures 4, 5 and 6 for replacement percentages of 20, 30 and 40 percent, respectively. It can be seen that fly ash C, the finest sample of the three, contributed most to the strength development of the fly ash concrete. The influence is clear and consistent for all replacement percentages studied. The same influence can be seen for water/binder of 0.40 and 0.50. These trends are as expected, since the smaller size yields larger specific surface, the site for chemical reactions. The larger the site, the faster the reaction rate.

6. Conclusion

1. For the fly ash used in this study, the inclusion of fly ash in the binder phase helps increase slump to a very high degree.
2. Higher temperature increases the rate of strength development. However, at 28 days, relative drop in the rate of strength gain was observed for specimens cured at 60 °C.
3. Small, plant classified, fly ash particle size contributes positively to the rate of strength development, probably because of the larger specific surface.

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Table 1 Chemical composition of fly ash

Type of fly ash	Chemical composition (wt.)								
	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	MgO	SO_3	Na_2O	MnO
T	41.86	25.17	12.84	9.59	3.11	2.03	1.28	1.10	0.06
A	46.46	27.87	11.87	5.98	3.32	1.79	0.95	0.98	0.05
C	36.57	21.68	13.24	14.16	2.97	2.18	3.75	1.32	0.12

Table 2 Physical properties of fly ash

Physical properties	Type of fly ash		
	T	A	C
Specific gravity	1.92	1.63	2.58
Blaine specific surface area (cm^2/g)	3233	3122	7290
Volume weight mean diameter (μm)	67.68	108.1	4.87
% Retained on a 45 μm sieve	39.5	53.3	1.0

Table 3 The result of slump and compressive strength tests

W/B (ages)-Temp	75 mm. Cubes. Compressive strength (ksc)									
	control	fly ash T			fly ash A			fly ash C		
	0%	20%	30%	40%	20%	30%	40%	20%	30%	40%
0.40 (7) - R	470	443	368	323	429	371	322	521	430	388
0.40 (7) - 40	487	485	418	390	472	399	382	544	459	438
0.40 (7) - 60	508	508	454	442	509	432	425	608	516	475
0.40 (28) - R	589	606	533	479	558	512	464	711	679	612
0.40 (28) - 40	607	621	573	517	593	561	517	754	717	666
0.40 (28) - 60	554	534	471	458	532	454	439	619	559	494
slumps (cm.)	3.0	4.5	8.5	12.5	4.3	6.8	11.5	6.0	10.5	14.0
0.45 (7) - R	405	380	328	293	389	339	298	460	381	347
0.45 (7) - 40	446	444	377	337	435	366	351	501	428	404
0.45 (7) - 60	447	471	404	391	482	382	387	519	452	416
0.45 (28) - R	507	533	444	411	519	451	413	632	607	554
0.45 (28) - 40	509	538	489	426	556	487	470	675	655	590
0.45 (28) - 60	480	487	435	408	497	403	395	535	516	440
slumps (cm.)	8.3	15.3	18.3	20.3	15.0	17.8	20.8	14.8	19.0	22.0
0.50 (7) - R	357	350	285	251	335	274	245	377	314	300
0.50 (7) - 40	390	374	308	288	369	300	281	423	389	357
0.50 (7) - 60	414	397	348	324	406	322	309	440	400	372
0.50 (28) - R	462	468	371	342	460	362	337	528	492	454
0.50 (28) - 40	478	494	410	385	472	400	375	559	524	482
0.50 (28) - 60	420	431	362	334	415	338	320	457	419	380
slumps (cm.)	18.5	21.0	23.5	>25	20.8	22.5	25.0	22.0	25.0	>25

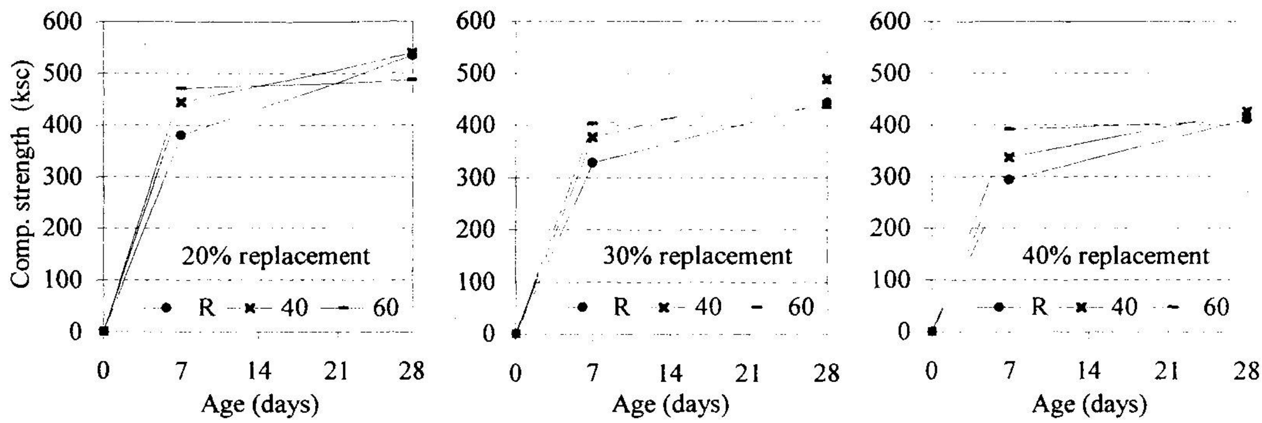

Fig. 1 Effect of temperatures on compressive strength for fly ash T concrete (W/B = 0.45)

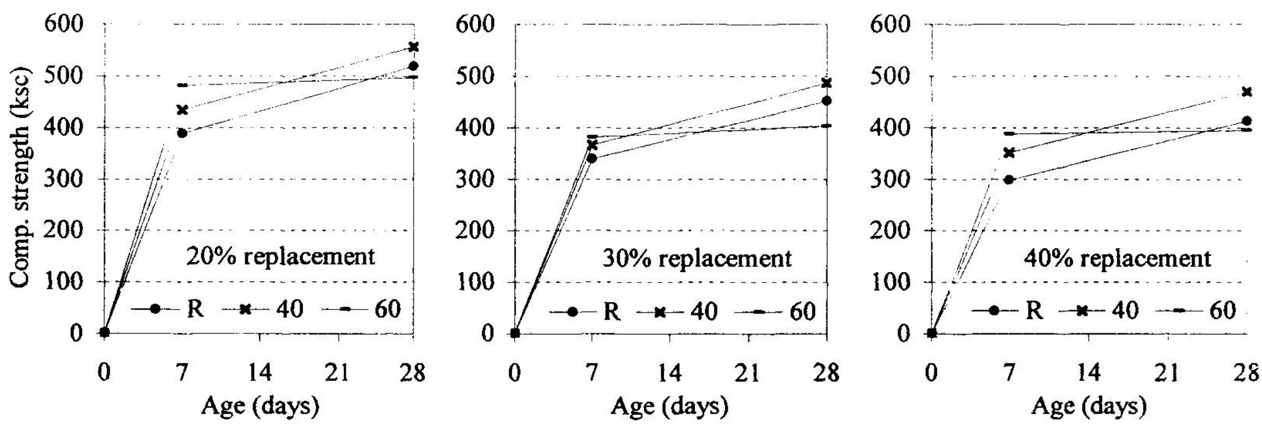

Fig. 2 Effect of temperatures on compressive strength for fly ash A concrete (W/B = 0.45)

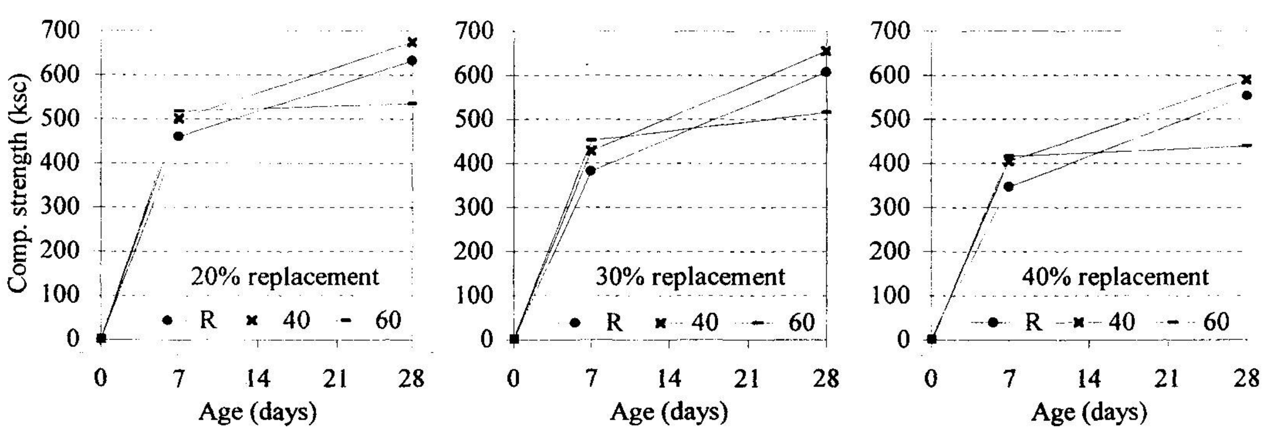

Fig. 3 Effect of temperatures on compressive strength for fly ash C concrete (W/B = 0.45)

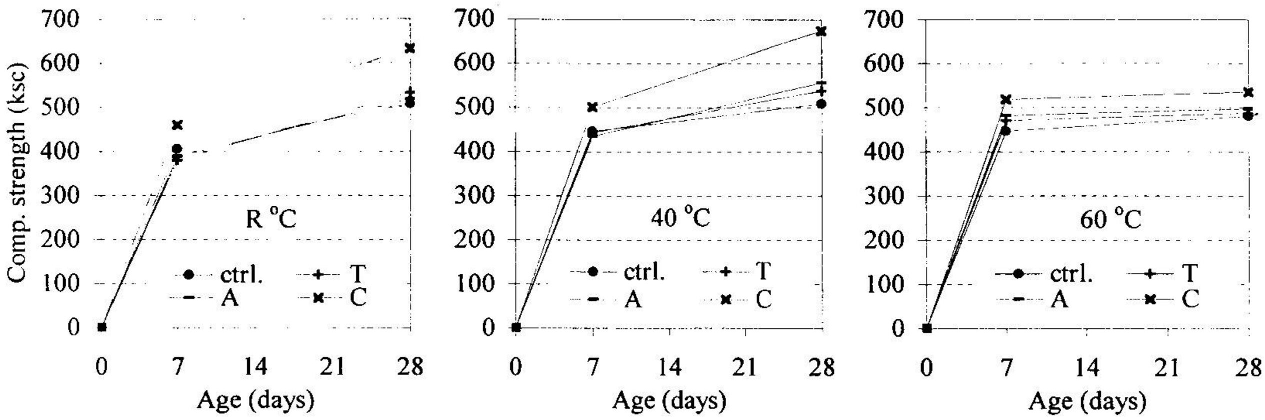

Fig. 4 Type of fly ash on compressive strength at 20% replacement (W/B = 0.45)

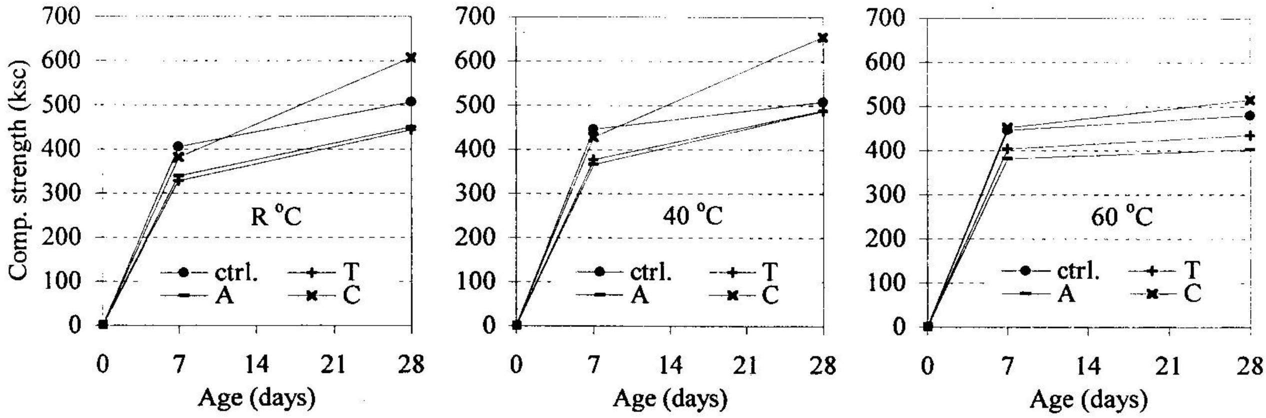

Fig. 5 Type of fly ash on compressive strength at 30% replacement (W/B = 0.45)

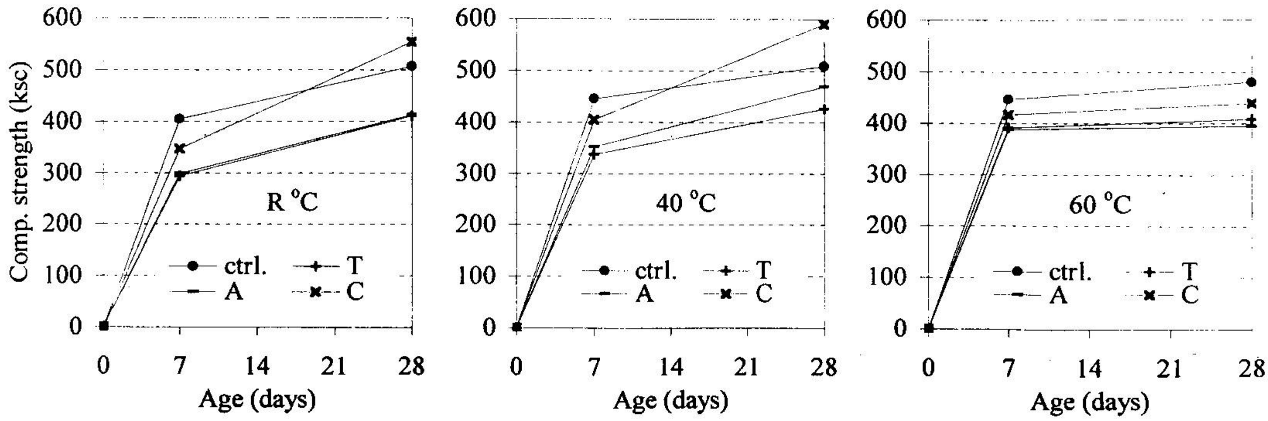

Fig. 6 Type of fly ash on compressive strength at 40% replacement (W/B = 0.45)