

## Some Effects on Datum Temperature for Maturity Application on Fly Ash Concrete

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### ABSTRACT

This paper reports the effects of water binder ratio (w/b), curing temperature and fly ash content on datum temperature for maturity applications on fly ash concrete. This chosen temperature is used to predict the potential characteristics of fly ash concrete within a short time after placing for quality control purpose. It was found that these factors strongly and differently affected the datum temperature of fly ash concrete with different workability. From the three chosen curing temperatures, 26, 40 and 60°C, the datum temperature of no slump roller compacted concrete was -3.2°C, while those of normal slump fly ash concrete appeared to be higher. The w/b ratios of 0.40-0.45 and fly ash content of 20-30% yielded a small difference in datum temperature while the higher w/b and higher fly ash content resulted in higher datum temperature. However, the latter was derived from the limited available data and further investigations were suggested.

**Key words:** datum temperature, maturity, fly ash concrete

### INTRODUCTION

The advantage of long-term strength prediction within a short time after placing concrete is widely recognized for quality control purpose. This paper reports the study which provide the necessary information for maturity concept, the means to predict the potential characteristics of different workability fly ash concrete. The aim is to support the rapidly increasing uses of fly ash concrete in Thailand. The current major uses of fly ash concrete in Thailand are in two directions: normal workability fly ash concrete for structural purpose and no slump fly ash concrete for mass construction. From the good performance of fly ash concrete, low cost of material and less generated heat, the rapid growth in use of fly ash concrete is

a result. The present construction of Tha Dan Dam in Nakorn Nayok province, employs about 5.5 million cubic meters of Roller Compacted Concrete (RCC) which is the current world's biggest application of no slump concrete. The rapid construction schedule and cost effective aspects might provide the new venue of mass concrete construction in Thailand in the future.

The strength gain of fly ash concrete is a result of hydration and pozzolanic reactions. Both reactions are also directly influenced by time and temperature conditions. Even under different single temperature, strength development of normal concrete has been reportedly different (Price, 1951). The maturity concept of strength gain which is a function of time interval and temperature has been of interest since 1951 (Saul, 1951). Lew and

Reichard (1978) reported that acceptable compressive strength prediction could be obtained from the non-linear strength-logarithm of maturity relationship of concrete using the same constituents as of the developed curve. The key factor is datum temperature, below which it is assumed that no hydration occurs and  $-10^{\circ}\text{C}$  is normal used for normal concrete (Neville, 1997). However, this datum temperature is affected from the actual service condition and the higher value is recommended for the higher temperature (William and Owen, 1982).

It is recognized that the effect of temperature on both pozzolanic reactions in fly ash concrete may differ from normal concrete (William and Owen, 1982), and different conditions of fly ash concrete may result in different effects on the strength prediction. Therefore, this paper which is a part of the study aimed to investigate the effect of high temperature and apply maturity concept on fly ash concrete, reports the effect of some factors on datum temperature of fly ash concrete with different workability. No slump concrete, RCC, was mainly investigated and compared to the normal slump concrete under the same temperature condition from previous study. The results may provide information for maturity's applications for quality control purpose in the future.

## MATERIALS AND METHOD

Local lignite fly ash from the major and largest source, Mae-Moh, was used in this study.

Properties of fly ash in this study were as follows. Fly ash particles were spherical, the Blaine specific surface area varied in the range of  $3200\text{--}3900\text{ cm}^2/\text{g}$ . and the mean diameter was  $68\text{--}108\text{ micron}$  with the total amount of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$  and  $\text{Fe}_2\text{O}_3$  70-85%,  $\text{CaO}$  4-15% and  $\text{LOI}$  0.4-6.9%. Four levels of cement replacement (0,20,30,40%) were used for normal fly ash concrete and one level of replacement (45%) was used for no slump concrete, as the actual working condition at Tha Dan Dam. This no slump fly ash concrete for RCC is compacted by earth compacting machine; steel roller. Vebe time is used as the measure of workability.

For RCC, in situ crushed rock and crushed sand from the local source were used. The major classifications are Andesite, Basalt and Rhyolite. The vebe time in this project was 30-40 seconds.

For normal slump fly ash concrete, coarse river sand and type I Portland cement were used in this study. Three curing temperatures; room temperature,  $40^{\circ}\text{C}$  and  $60^{\circ}\text{C}$  were applied to three sets of specimens. The accelerated curing condition was applied after removing molds at 24 hours, in the controlled temperature water tank. The mix proportions in this study are shown in Table 1.

As the major source of local fly ash, the microstructure of cement paste with Mae-Moh fly ash was investigated. The SEM and XRD Analysis Techniques were conducted on cement paste samples, both with and without fly ash under normal curing conditions. The specimens were casted in  $7.5\times 7.5\times 7.5\text{ cm}$ . mold, similar to the

**Table 1** Proportions for fly ash concrete mixes.

Type	W/b	Cement ( $\text{kg}/\text{m}^3$ )	Fly ash ( $\text{kg}/\text{m}^3$ )	Coarse agg. ( $\text{kg}/\text{m}^3$ )	Fine agg. ( $\text{kg}/\text{m}^3$ )	Water ( $\text{kg}/\text{m}^3$ )
RCC	0.50	90	110	1250	850	100-140
NC	0.40	288-480	0-192	948	613-713	203-205
NC	0.45	288-480	0-192	948	552-602	226-227
NC	0.50	288-480	0-192	948	491-518	251

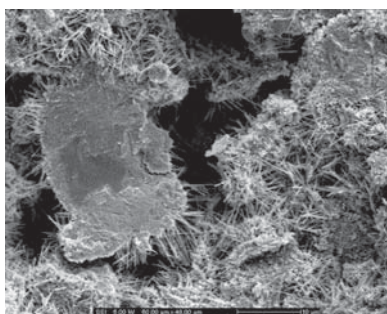
compression specimens, to reduce the size effect on the temperature gradient.

The temperatures, 40°C and 60°C, were chosen to determine datum temperature, based on two reasons. First, the internal temperature in the dam, from test section measurement and the model thermal analysis (not shown in this paper) was about 40°C. Therefore this temperature would simulate the actual condition for RCC while the 60°C provided the far end condition. Second, for the normal slump concrete, this temperature range was used to study the temperature effect on strength gain of fly ash concrete with high cement content.

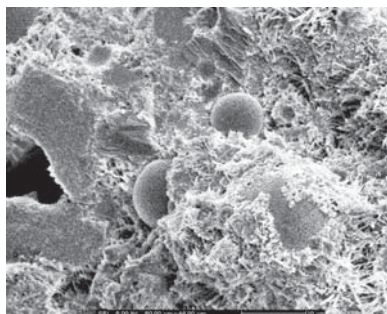
## RESULTS AND DISCUSSION

### Fly ash

Microstructure of cement paste without and with fly ash under moist cure condition, at age 7 days are shown in Figure 1. Needle-like formation of ettringite and big crystal of C-H or  $\text{Ca}(\text{OH})_2$  as well as some poor crystal of C-S-H and voids were observed in cement paste (in Figure 1a). In Figure 1b, same evidences were still observed around smooth-surface fly ash particles. In Figure 2 a and 2b the neat cement paste without and with fly ash at age 8 month are shown. For paste without fly

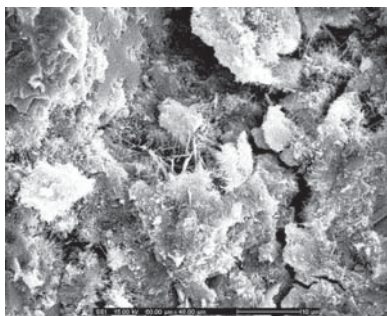


a. Cement paste without flyash

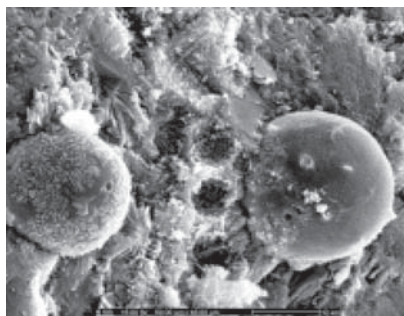


b. Cement paste with flyash

**Figure 1** Microstructure comparison of cement paste with and without fly ash under normal moist cure at 7 day.



a. Cement paste without flyash



b. Cement paste with flyash

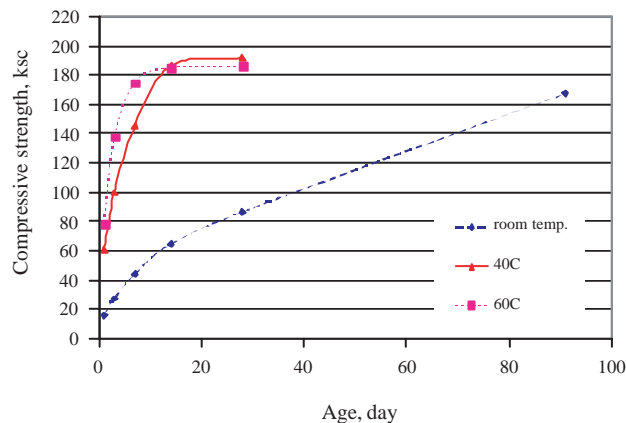
**Figure 2** Microstructure comparison of cement paste without fly ash under under normal moist cure at 8 months.

ash, less needle-like formation of ettringite and agglomeration of  $\text{Ca}(\text{OH})_2$  crystal were found with less amount of voids but micro cracks were observed, comparing to the normal cure at 7 days. For cement- fly ash paste at the later age, the developed pozzolanic products on the surface of fly ash particles was observed in the larger amount and more uniform, compared to those of the early age. Under high temperature curing regime, some micro cracks were still observed in the samples at 3.5 hours curing, compared to which of 28 days (not shown in this paper). The results of XRD analyses (not shown in this paper) indicated the

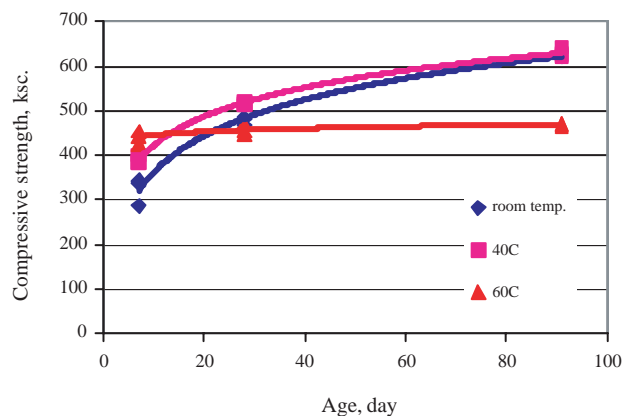
reduction in amount of C-H of the mixture with fly ash compared to those without fly ash.

### No slump concrete, RCC and normal slump concrete

The strength development of RCC and normal slump concrete, cured at different temperature, are shown in Figure 3 and 4. For RCC, the strength from higher curing temperatures, 40°C and 60°C, appeared to be higher and reached the constant level of strength gain faster, compared to which of the normal curing at room temperature. However, strength gain of the latter tended to



**Figure 3** Strength development of RCC under curing conditions.

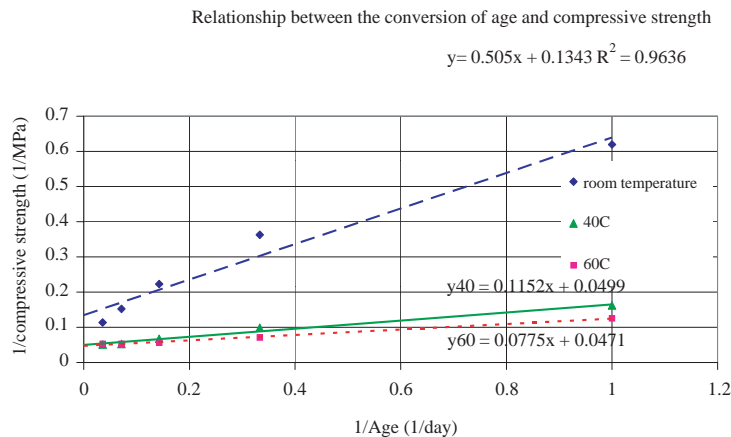


**Figure 4** Strength development of normal slump fly ash concrete (w/b0.4 40%) under different curing conditions.

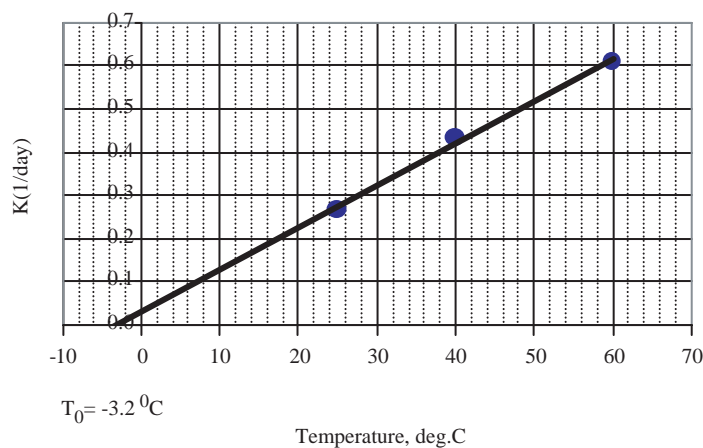
continue increasing which indicated the remaining reaction, especially the pozzolanic reaction. For the normal slump fly ash concrete, the rate of strength gain at the early age strongly depended on both percentage replacement and curing temperature. The higher percentage, the lower early age strength. The higher temperature yielded the higher early age strength, but not for the later age strength, especially for 60°C. The strength of 60°C cured-specimen at 28 and 91 days was lower than that of the other temperatures, although it was higher than that of controlled specimens without fly ash. These may indicate the effect of high temperature on accelerated strength gain at the

early age, the possible microcracks development and poorer microstructure development.

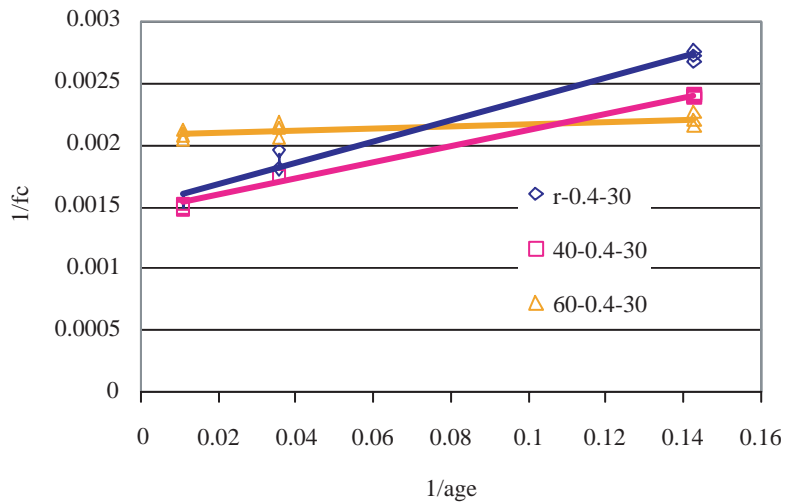
The reciprocal of strength and age from strength development of RCC are plotted in Figure 5. The relationship was quite close for both high temperatures, 40 and 60°C while the difference was shown for specimens cured at room temperature. This was due to the less pozzolanic effect at early age for low binder content admixture. The intercept and slope of this reciprocal relationship were used in datum temperature determination, which yielded the value of  $-3.2^{\circ}\text{C}$  as shown in Figure 6. The value was slightly higher than the usual value of  $-10^{\circ}\text{C}$  as for normal



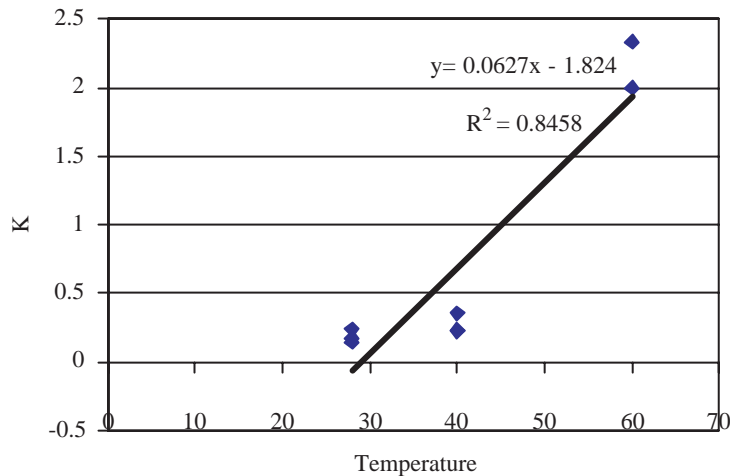
**Figure 5** Reciprocal of strength and age from strength development of RCC.



**Figure 6** Datum temperature determination of RCC.



**Figure 7** Reciprocal of strength and age of normal slump fly ash concrete (w/b 0.4 40%)



**Figure 8** Datum temperature determination normal slump fly ash concrete (w/b 0.4 40%)

concrete (William and Owen, 1982). This may be from the chosen temperature to simulate the actual application conditions and the different influences of temperature on reactions.

However, compared to RCC, the available data of high binder mixture from the previous study (Nittikul, 1999) appeared to be different for all binder content and percentage replacement, as shown in Figure 7 (for w/b 0.40, 40% fly ash). The stronger influence of high temperature (60°C) on

both hydration and pozzolanic reaction yielded higher strength gain at 7 days, but lower at 28 and 91 days. The influences appeared to be different, depended on w/b, percentage replacement and age. Therefore, while the reciprocal relationship was different from RCC, it appeared to be different among normal fly ash concrete with different conditions. There was a trend indicating of higher datum temperature, in the range of 10-20°C. However, the results were drawn from the limited

data of early age concrete from previous study, only at the age from 7 day (Nittikul, 1999). Further study is needed, especially the information during the first few days after casting.

### CONCLUSIONS

From this study, the drawn conclusions are as following:

1. Effect of the high temperature was different for different workability fly ash concrete.
2. Mix proportions and percentage replacement as well as temperature levels strongly influence datum temperature which is the key factor for the application of the maturity concept on fly ash concrete.
3. Datum temperature of no slump RCC was  $-3.2^{\circ}\text{C}$  while the value from the limited data of normal slump fly ash concrete was higher, in the range of  $10\text{-}20^{\circ}\text{C}$ .
4. Information of very early age strength development of normal slump fly ash concrete under the high curing temperature needs to be investigated in the further study for maturity applications.

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