CHAPTER 6

EXPERIMENTAL INVESTIGATION

6.1 Experimental Program

6.1.1 Conventional Concrete

From the scope of study, the models for predicting 28-day compressive strength will be constructed to consider low unit CaO content in mix proportion and the effect of curing temperature. Two types of fly ash were used in the experiment as follows:

1. Low Calcium Fly Ash (FA1)
2. High Calcium Fly Ash (FA2)

For the low unit CaO content mixtures, the experiment was done by controlling curing temperature at 30±3°C and s/a equal to 0.43, which gave a minimum void. The mix proportion is shown in Table 6.1.

Table 6.1 The mix design taking into account the effect of the low unit CaO content

Mix	Type of fly ash	w/b	γ	replacement (%)	Number of specimens for each testing days			
					7	28	91	365
N1	FA1	0.6	1.4	40	3	3	3	3
N2		0.6	1.4	60	3	3	3	3
N3		0.5	1.4	40	3	3	3	3
N4		0.5	1.4	60	3	3	3	3
N5		0.4	1.1	70	3	3	3	3
N6		0.5	1.24	70	3	3	3	3
N7		0.6	1.22	70	3	3	3	3
N8	FA2	0.6	1.41	40	3	3	3	3
N9		0.6	1.42	60	3	3	3	3
TOTAL					108			

Remark: These data are used to modify model in Appendix A

The influence of fly ash on the cement hydration and the compressive strength development was determined in order to investigate the effect of curing temperature. The concrete specimens were prepared with an ordinary Portland cement and two different types of fly ash. In order to evaluate the effect of fly ash on cement hydration, fly ash was used to replace cement by 20%, 40% and 60% by the total mass of binder. Then the specimens were cured in water at constant temperature of 50°C and 65°C. The mix proportion is shown in Table 6.2.

Table 6.2 The mix design taking into account the effect of curing temperature

Mix	Temp (°C)	Replacement (%)	w/b	Number of specimens for each testing days				
				1-day	3-day	7-day	28-day	91-day
1	30	0	0.4	3	3	3	3	3
2			0.6	3	3	3	3	3
3		20	0.4	3	3	3	3	3
4			0.6	3	3	3	3	3
5		40	0.4	3	3	3	3	3
6			0.6	3	3	3	3	3
7		60	0.4	3	3	3	3	3
8			0.6	3	3	3	3	3
9	50	0	0.4	3	3	3	3	3
10			0.6	3	3	3	3	3
11		20	0.4	3	3	3	3	3
12			0.6	3	3	3	3	3
13		40	0.4	3	3	3	3	3
14			0.6	3	3	3	3	3
15		60	0.4	3	3	3	3	3
16			0.6	3	3	3	3	3
17	65	0	0.4	3	3	3	3	3
18			0.6	3	3	3	3	3
19		20	0.4	3	3	3	3	3
20			0.6	3	3	3	3	3
21		40	0.4	3	3	3	3	3
22			0.6	3	3	3	3	3
23		60	0.4	3	3	3	3	3
24			0.6	3	3	3	3	3

Remark: The details of mix proportion are shown in Table B1 in Appendix B

6.2 Materials

6.2.1 Portland cement

Ordinary Portland cement type I, Elephant brand, was used for all mix proportions.

6.2.2 Fly ash

Fly ash was obtained from Mae-Moh electric power plant, the Electrical Generating Authority of Thailand (EGAT). All fly ash was kept in sealed plastic bags.

6.2.3 Water

Ordinary tap water, supplied in Thammasat University, was used for all mix proportion.

6.2.4 Fine aggregate

Natural river sand passing sieve #4 was prepared in saturated-surface dry (SSD) condition and used in mix proportion. The prepared sand was kept in clean and closed buckets. The gradation of river sand complied with ASTM C33-93.

6.2.5 Coarse aggregate

Crushed limestone was used as coarse aggregate for all type of mix design. Coarse aggregate had been prepared also in SSD condition and kept in clean and closed buckets. The sieve analysis was performed according to ASTM C33-93.

6.3 Moisture Content of Aggregate

A problem, thought by many to be trivial, is the control of the moisture content of aggregate. Not infrequently, it has come across situations where the variability of concrete, in terms of workability and strength, is due to inadequate allowance for the variation in the moisture content of the aggregate. Sure enough, the situation is quickly remedied by adjustments to the water put into the mixer, but not quickly enough to avoid several batches of unsatisfactory and non-compliant concrete.

If the total free water content of every batch of concrete is known reliably, then the water to binder ratio of all the concrete is likely to be properly constant, and thus compliance with the specified value will probably be ensured.

6.4 Curing of Concrete

In order to obtain good concrete, the placing of an appropriate mix should be followed by curing in a suitable environment particularly during the early stages of hardening. Curing is the process of maintaining a satisfactory moisture content and a favorable temperature in concrete during hydration of the cementitious material so that desired properties of the concrete is developed.

The necessity of curing arises from the fact that hydration of cement can take place only in water filled capillaries. That is why evaporation from the capillaries must be prevented. Moreover, water lost by self-desiccation has to be replaced by water from outside.

In this research, the three constant curing temperatures were approximately 30, 50 and 65 °C. Efforts were made to ensure that the initial temperatures of the mixtures were close to the intended curing temperature, because the initial temperature significantly affects the initial rate of strength development.

6.5 Experimental Procedures

All mixtures were prepared, kept and mixed at room temperature about 30°C. At the end of mixing period, the specimens were cast in ϕ100x200mm-steel moulds. After final setting time, all specimens were demoulded in order to be cured in the controlled temperature as fast as possible, because the initial curing temperature significantly affects the initial rate of strength development.

Due to the different controlled-curing temperature, the specimens will be stored and cured in the curing tank as shown in Fig. 6.1.

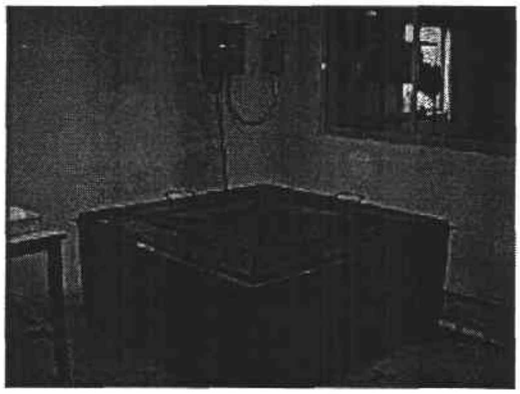

Fig. 6.1 Curing tank

The curing temperatures are shown in Fig. 6.2. Three specimens were removed and tested for compressive strength at 1, 3, 7, 28 and 91 days respectively by using rubber capping. The test schedule was selected so that specimens cured at different temperatures were tested at approximately the same age. The age at time of test was considered from the time when the mixing water was added.

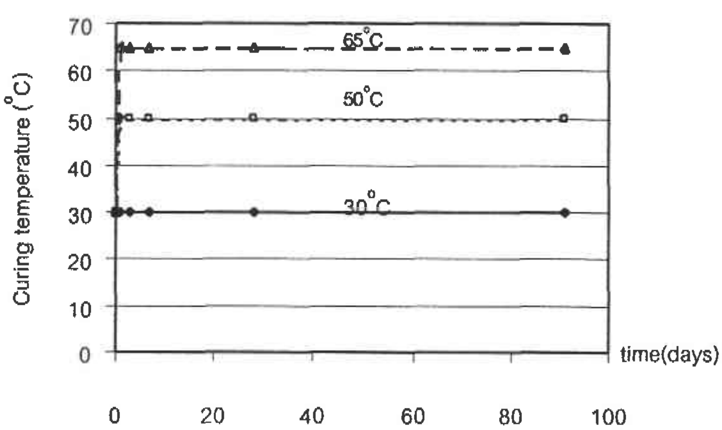

Fig. 6.2 Controlled temperatures from start mixing until the end of testing days

6.6 Experimental Results

As stated at first, the experiments are controlled by percentage replacement (0, 20, 40 and 60%), curing temperatures (30±3, 50±3 and 65±3°C), water to binder ratio (0.4 and 0.6) and γ (1.15 and 1.29).

The compressive strength of fly ash concrete cured at elevated temperature is shown in Fig. 6.3 to Fig. 6.9. Each figure shows two graphs. The left-hand graph shows compressive strength at early age while the right-hand graph shows compressive strength from start of mixing to 91 days.

From experimental results, it was found that curing temperatures significantly influenced the compressive strengths of fly ash concrete. The higher curing temperature developed higher compressive strength than the lower one at early ages. On the other hand, it gained and developed lower compressive strength in longer ages when compared with concrete cured in lower temperature as shown in Fig. 6.3-6.4.

Fig. 6.5-6.9 illustrated that the higher water to binder ratio (w/b) result in the lower compressive strength in any isothermal controlled temperature. This effect is similar to the concrete cured at room temperature. The lower strength is the result of exceed water that creates high amount of capillary pore in concrete.

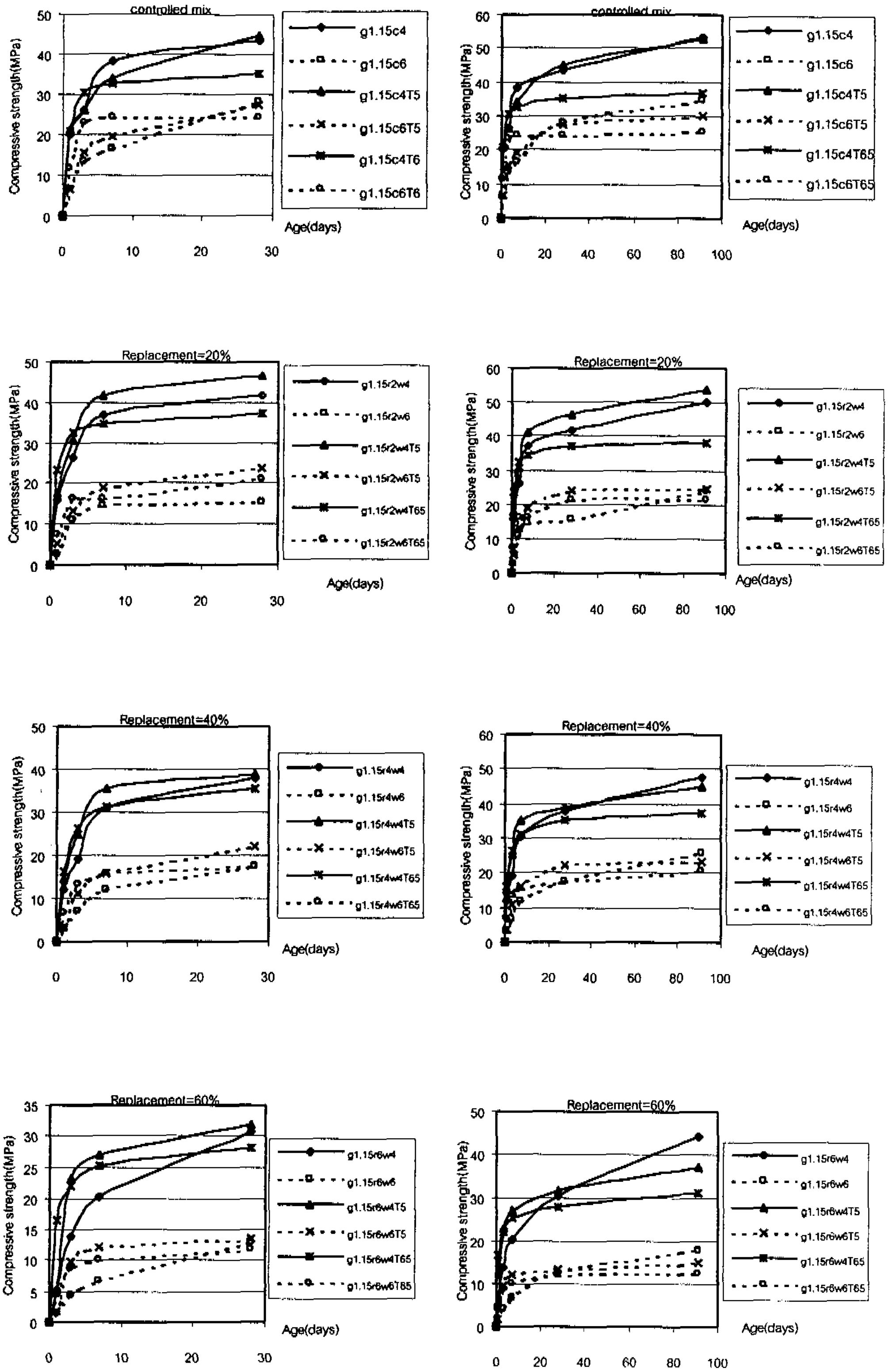

Fig. 6.3 Compressive strength of fly ash concrete cured in various temperatures (30, 50 and 65°C) and w/b (0.4, 0.6) by controlling $\gamma = 1.15$

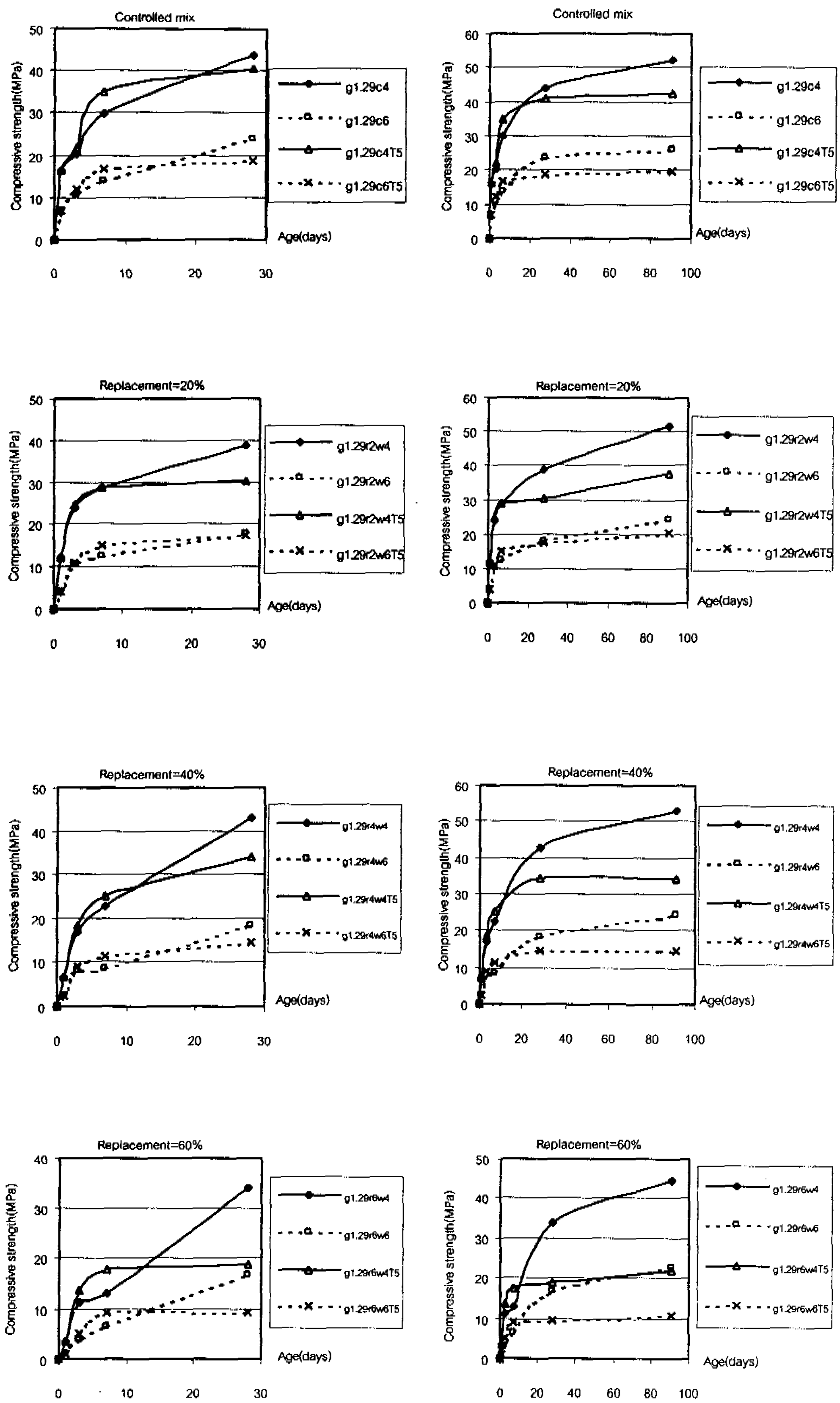

Fig. 6.4 Compressive strength of fly ash concrete cured in various temperatures (30 and 50°C) and w/b (0.4 and 0.6) by controlling $\gamma = 1.29$

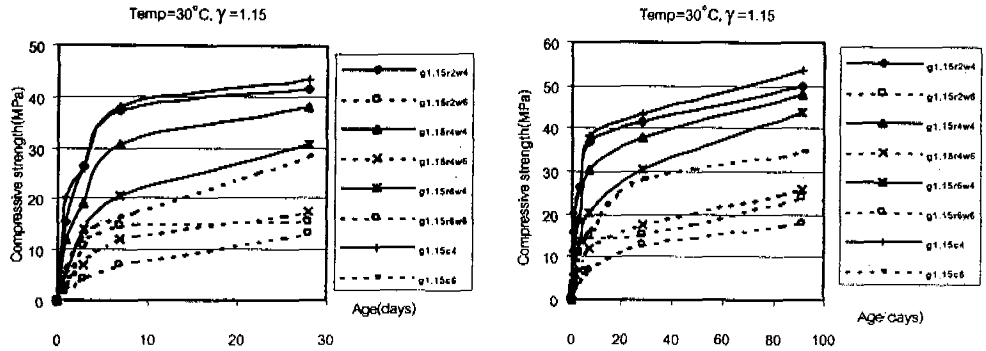

Fig. 6.5 Compressive strength of fly ash concrete which has variation in percentage replacement (0, 20, 40 and 60%) and w/b (0.4 and 0.6) cured in room temperature by controlling γ = 1.15

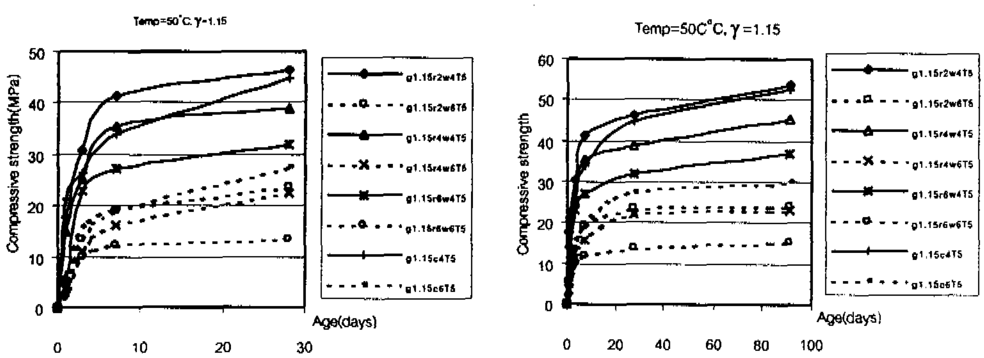

Fig. 6.6 Compressive strength of fly ash concrete which has variation in percentage replacement (0, 20, 40 and 60%) and w/b (0.4 and 0.6)cured 50°C by controlling γ = 1.15

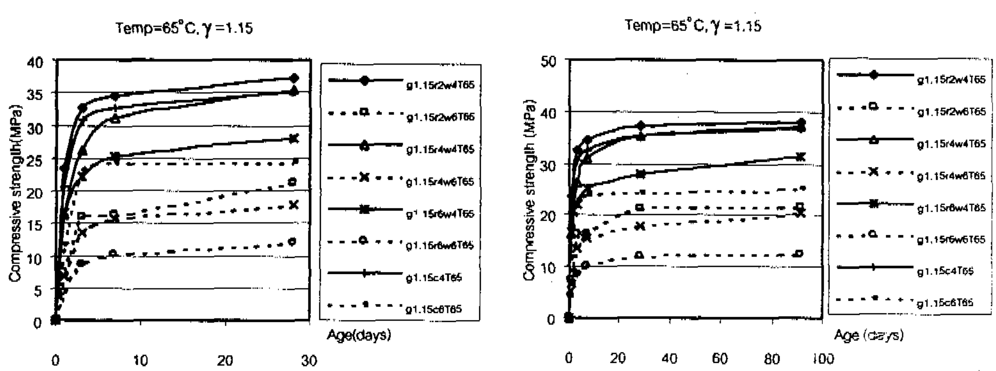

Fig. 6.7 Compressive strength of fly ash concrete which has variation in percentage replacement (0, 20, 40 and 60%) and w/b (0.4 and 0.6)cured at 65°C by controlling γ = 1.15

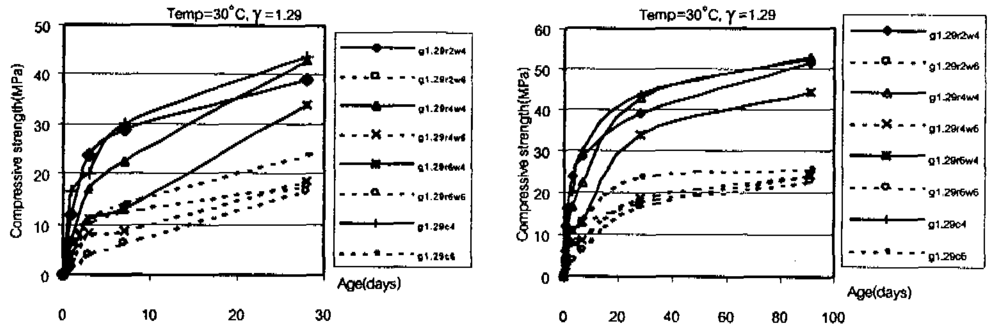

Fig. 6.8 Compressive strength of fly ash concrete which has variation in percentage replacement (0, 20, 40 and 60%) and w/b (0.4 and 0.6)cured at room temperature by controlling γ = 1.29

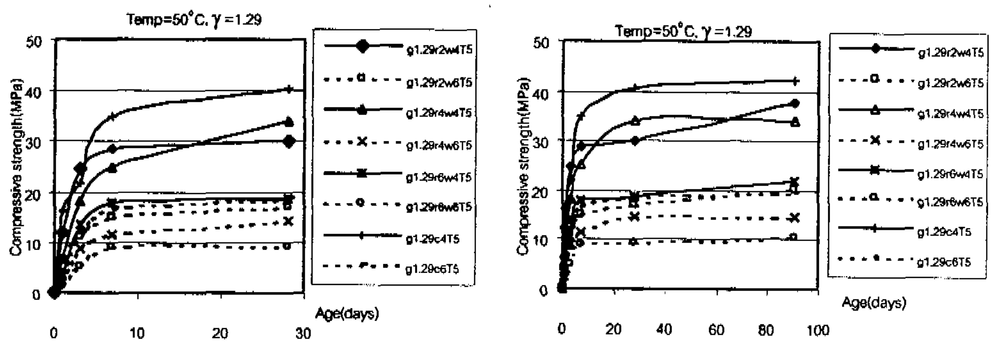

Fig. 6.9 Compressive strength of fly ash concrete which have variation in percentage replacement (0, 20, 40 and 60%) and w/b (0.4 and 0.6)cured at50°C by controlling γ = 1.29