SPECIAL PROJECT REPORT

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FINAL REPORT ON A LABORATORY INVESTIGATION OF THE STRENGTH DEVELOPMENT OF HIGH PFA CONTENT CONCRETE

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FOREWORD

At the request of the Standing Committee on Concrete Technology (SCCT), the Public Works Central Laboratory (PWCL) of the Materials Division carried out an investigation on the strength development of high PFA content concrete. The main objective of the investigation is to compare the strength development of OPC concrete and PFA concrete, subject to various curing environments and durations, and derive correlations between the 28-day strength and the long term strengths.

This final report presents the test results obtained from the concrete mixes investigated, up to a test age of 360 days.

The early stage planning of this investigation was carried out by Mr. P.C. Wong. Mr. W.C. Leung took over the management of the project in January 1993 and prepared this report in conjunction with Mr. W.L. Tse, the project engineer, who organised and supervised the testing with the assistance of Mr. M.Y. Chu, Ms K.Y. Law and Mr. C.C. Kwok. The casting, curing and testing of cubes were carried out by staff of the Concrete Unit in PWCL.

The report was reviewed by members of SCCT.

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ABSTRACT

Pulverized fuel ash (PFA) is a by-product of the combustion of coal used in coal-fired power stations. It is well known that PFA has the advantage of improving the strength and durability properties of concrete when used as a partial replacement of Portland cement in concrete. However, there is a lack of information on the performance of concrete manufactured using locally produced PFA.

In May 1992, the Standing Committee on Concrete Technology (SCCT) awarded a research consultancy to the Hong Kong City Polytechnic to carry out a study on PFA concrete. The study covers the strength development of PFA concretes with 15% to 25% PFA replacement, as well as their shrinkage and creep characteristics. Results have been obtained for the strength development of the PFA concretes up to a period of 90 days.

In late 1992, SCCT requested the Public Works Central Laboratory (PWCL) to conduct a parallel study to compare the strength development of OPC and PFA concretes up to the age of one year. The objective of the study is to derive correlations between the 28-day and the long term strengths of a range of mixes produced with up to 55% PFA replacement. The cubes were cured over a range of temperatures from 10°C to 75°C and with selected curing durations, such that the influence of curing environment can also be assessed.

An interim report on test results obtained from the concrete mixes investigated up to a test age of 90 days was issued in December 1993. This final report presents the test results up to a test age of 360 days.

Based on the results obtained, the replacement of OPC by PFA was found to have a slight retarding effect on the 7-day strengths of the concrete. However, all of the PFA concrete mixes gave strengths of about 14% to 31% higher than the target 28-day strength at the age of 360 days while the OPC concrete gained little strength after 28 days and had roughly the same strength as the target strength at the age of 360 days. The results also indicate that a high initial curing temperature can reduce the strength of OPC concrete significantly but has little effect on PFA concrete strength.

CONTENTS

1. INTRODUCTION

In late 1992, the Public Works Central Laboratory (PWCL) commenced a project to investigate the strength development of high PFA content concrete at the request of the Standing Committee on Concrete Technology (SCCT). The investigation covers the strength development of a range of mixes with up to 55% PFA content. A total of 1260 cubes were made and cured over a range of temperatures from 10°C to 75°C, and with selected durations of curing, so that the influence of the curing environment can also be assessed. An interim report on the investigation was issued in December 1993 (Leung & Tse, 1993). The interim report covers the PWCL's findings on the strength development of the concrete mixes up to an age of 90 days.

This report covers the additional cube test results obtained since October 1993 and summarises the strength development of high PFA as well as OPC mixes up to an age of 360 days.

2. DESCRIPTION OF TEST MATERIALS

The physical and chemical properties of the cement and the physical properties of the aggregates used in the investigation are given in the interim report (Leung & Tse, 1993). These are reproduced in Tables 1 and 2 for easy reference. The physical and chemical properties of the PFA used in this investigation are given in Table 3.

3. LABORATORY INVESTIGATION

3.1 Concrete Mix Design

The mix design for the study comprised the design of an OPC concrete and four PFA concrete mixes with replacement percentages of 25%, 35%, 45% and 55% respectively. Grades 30 and 45 concretes were aimed for in the design as these are the most commonly encountered concrete grades in Hong Kong. The target 28-day strength of the mixes was taken as the grade strength plus 8 MPa, and a target slump value of 75 mm was adopted. The mix proportions adopted are given in Table 4.

3.2 Test Procedures

The testing equipment and apparatus are calibrated to the requirements laid down in CS1 (Hong Kong Government, 1990) and the calibrations are traceable to national standards. The cubes were made in accordance with CS1 .

After the cubes were cast, they were stored for 24 hours in the laboratory at 25° ± 5°C before demoulding. After demoulding, the cubes were stored under various curing environments as described in Table 5.

After curing, the cubes were soaked in water at 27°C ± 3°C for a period of 24 hours immediately before testing. The density and compressive strength of the cubes were determined in accordance with CS1.

For each mix, three cubes were cast and cured under each of the curing environments and these were tested at each of the following test ages: 28, 56, 90, 180 and 360 days. Six additional cubes were cast and cured under standard curing environment E1. Three of these cubes were tested at seven days and the other three at 28 days to provide additional data for the control test age.

For the cubes which were air cured, they were stored in an air curing room where the room temperature was maintained at 25±5°C. Records of the temperature and relative humidity of the air curing room over the test period are shown in Figure 1. It can be seen that over the test period, the mean storage temperature of the cubes is about 25°C and the mean RH was about 75%.

3.3 Test Results

The full density and compressive strength results for cubes in mixes M1 to M10 at the test age of 180 days and 360 days together with the mean compressive strength results for the same mixes at the age of 7, 28, 56 and 90 days are given in Tables 6 to 15 respectively. The full density and compressive strength results for the test age of 7, 28, 56 and 90 days can be found in the interim report (Leung & Tse, 1993).

4. DISCUSSION OF TEST RESULTS

4.1 Normalisation

While the mean 28-day compressive strengths of mixes M1 to M10 under curing environment E1 are very close to the target strengths (as can be seen from the summary in Table 16), it is obviously not possible in practice to achieve the target strengths exactly. In order to permit comparison of the test results amongst the different mixes for each of the two grades of concrete, it is necessary to normalise the mean compressive strengths obtained. The normalisation was carried out by applying a factor N as defined below to each of the mean 28-day strengths under curing environment E1 in Table 16:

$$N = \frac{\text{28-day Target Strength for Environment E1}}{\text{28-day Measured Strength for Environment E1}} \qquad \text{---- (1)}$$

For example, a factor N = 38/39 = 0.974 was applied to the results obtained at the different ages for mix M1. The calculated N factors for all the mixes are given in Table 17.

There is also a need to compare the results obtained under curing environment E1 with results obtained under other curing environments, for each mix. In order to do this, the following principle has been invoked: the strength realisation potential of a particular mix of concrete is the same irrespective of the environment under which curing is carried out. Take, for example, mix M1. There is a potential for the concrete cured under environment E2 to achieve a 28-day strength of 39.0 MPa if curing is carried out to environment E1. Hence, if all results obtained under curing environment E1 are normalised by a factor N = 38/39, then the same factor should be applied to all the results obtained under curing environment E2, if a meaningful comparison is to be carried out. This approach has been adopted and the mean

strengths obtained for the different curing environments have been normalised using the factors given in Table 17. The normalised mean compressive strengths for mixes M1 to M10 are given in Table 18.

4.2 Calculation of Relative Strength Percentages

In order to facilitate comparison further so that the relative speed of strength development of the various mixes in the two concrete grades can be readily appreciated, the normalised mean compressive strengths for each mix in Table 18 have been converted to relative strength percentages by dividing the values by the (28-day) target strength of the same mix:

$$\text{Relative strength percentage for a particular mix of a specified concrete grade} = \frac{\text{Normalised Mean Compressive Strength}}{\text{Target Strength (= Grade Strength + 8MPa)}} \quad \text{------- (2)}$$

The relative strength percentages calculated for mixes M1 to M10 are given in Table 19.

4.3 Strength Development Under Normal Curing

The results from this investigation are consistent with the common observation that PFA has an enhancing effect on the long term strength development of concrete.

Under standard curing environment E1 (27°C water curing for 28 days, then followed by air curing until testing is required), both the Grade 30 and Grade 45 OPC mixes failed to gain further strength after 56 days and the strength of both OPC mixes at 360 days fell to about the same level as the 28-day strength as shown in Figures 2 and 3. As for the PFA mixes, there was a significant gain in strength from 28 days to 360 days, representing a post 28-day strength gain of about 23% to 44%.

4.4 Influence of Initial Curing Temperature on Strength Development

4.4.1 Influence of low initial curing temperature

The concreting in cold weather was simulated as far as possible in curing environments E2 and E3. The cubes in environment E2 were initially water cured for 3 days at 10°C, followed by further water curing at 20°C for another 24 days. Thereafter, the cubes were stored in the air curing room until testing. The cubes in environment E3 were initially water cured at 20°C for 27 days, followed by storage in the air curing room until testing.

The strength development of cubes cured in environments E2 and E3 is shown in Figures 4 and 5. It can be seen that the low temperature curing had a retarding effect on the initial strength development of both the OPC and PFA mixes. The effect was however greater for the PFA mixes.

For both grades of concrete, all of the PFA mixes had strengths slightly lower than the OPC mixes at the age of 28 days. As the PFA concrete matured, the influence of the low

temperature curing reduced with time. At the age of 360 days, all of the PFA mixes had strengths between 14% and 31% higher than the target strength. On comparison, the OPC mixes gained little strength after 28 days, and at the age of 360 days, the OPC mixes had strengths roughly the same as the target strength.

The behaviour of the mixes suggests that in the cold seasons in Hong Kong, the use of high PFA concrete in thin structural sections may lead to an impeding effect on the early age strength development of the concrete. The impediment could be more prominent if there was a prolonged period of low temperature and a longer waiting time may be necessary prior to formwork stripping. The long term strength development of the PFA mixes, however, does not seem to be affected by the initial low curing temperature as evidenced by the above-target concrete strengths at the age of 360 days.

4.4.2 Influence of high initial curing temperature

The curing environments E7 and E8 simulates the conditions in mass concrete pours where the adiabatic temperature may rise to as high as 75°C or above. The cubes in environment E7 were initially water cured for 7 days at 50°C, followed by further water curing at 27°C for another 20 days. Thereafter, the cubes were stored in the air curing room until testing. Similarly, the cubes in environment E8 were initially water cured at 75°C for 7 days, followed by water curing at 20°C for 20 days and then storage in the air curing room until testing.

The results of cubes subjected to high initial temperature curing (i.e. environments E7 and E8) are shown in Figures 6 and 7. It can be seen that the strength development of the OPC mixes was hampered by the high temperature curing. The OPC mixes generally had strengths lower than the target strength, with the exception of Grade 30 cubes cured under environment E7 which reached the target strength. The retarding effect was more prominent in environment E8 (i.e. 75°C curing), where the OPC mixes only reached a strength of about 85% of the target strength at the age of 360 days. This suggests that the OPC concrete in a mass pour may not reach the target strength at all locations even at an age of 360 days.

On comparison, all of the PFA mixes had strengths which were equal to or greater than (by up to 41%) the target strength for all the test ages. At the age of 360 days, the PFA mixes in environment E8 achieved strengths between 11% and 18% above the target strength.

The results lend support to the conclusion given in the interim report that a PFA concrete is less sensitive to a high curing temperature than an OPC concrete of the same design (28-day) strength, with data extending to 360 days.

4.5 Influence of Duration of Curing

It was generally believed that PFA concrete is more sensitive to curing than OPC concrete and if not cured sufficiently, the strength development of PFA concrete will be severely affected. The results of this investigation indicate that this may not be entirely correct. The influence of duration of water curing on the strength development of Grade 30 and Grade 45 mixes is shown in Figures 8 and 9 respectively.

As can be seen from the figures, none of the cubes subjected to air curing only (i.e.

curing environment E4) achieved their target strengths even at the age of 360 days. This clearly supports the conclusion drawn in the interim report that if OPC and PFA concretes are insufficiently cured, their strength potential will not be realised.

For cubes that were subjected to limited curing (viz. 3 or 7 days as in curing environments E5 and E6), the OPC mixes generally had higher strengths than the PFA mixes at 28 days. At the age of 180 and 360 days, this trend is reversed and all of the PFA mixes had higher strengths than the corresponding OPC mixes. Furthermore, PFA mixes that had been subjected to 7 days water curing had strengths exceeding the target strength at the age of 360 days. None of the corresponding OPC mixes achieved the target strength even at the age of 360 days.

The results indicate that the long term strength of PFA concrete is not seriously impaired by insufficient curing. On the other hand, OPC concrete, if not cured properly, appears to suffer more in the long term.

The results also confirm the general belief that the longer is the curing, the higher will be the cube strength.

5. CONCLUSIONS AND RECOMMENDATIONS

In response to SCCT's request, the PWCL carried out a laboratory investigation of the strength development of high PFA content concrete. A total of ten concrete mixes and eight curing environments were included in the study. Altogether 2520 density and compressive strength tests were carried out on concrete cubes. Based on the results up to a test age of 360 days, the following conclusions can be drawn:

(a) For the two concrete grades investigated, the replacement of OPC by PFA has a slight retarding effect on the early age strength of the concrete. The 7-day strengths of the PFA concrete mixes with PFA replacement percentages between 25% and 55% were between 52% and 68% of the 28-day strength, compared to a range of 67% to 76% for the OPC concrete mixes. These results are for the standard (27°C) water curing environment.

(b) Despite the reduction in early age strength, the PFA mixes gained strength rapidly and achieved target strengths equivalent to the OPC mixes at 28 days. Between the ages of 28 days and 360 days, the OPC mixes exhibited little strength gain (in fact a strength reduction after about 90 days), whereas the PFA mixes showed a strength gain between 23% and 44%.

(c) For the OPC concrete mixes, a curing temperature as low as 10°C (applied over a 3-day period) did not have a significant effect on strength compared to standard water curing at 27°C. However, for the PFA mixes, as the PFA replacement percentage was increased, the 28-day strength reduced quickly when the curing temperature dropped below 27°C. The influence of the low curing temperature reduced with time : all of the PFA mixes gave strengths of about 14% to 31% higher than the target strength at the age of 360 days. The OPC mixes gained little strength after 28 days and had roughly the same strength as the target strength at the age of 360 days.

(d) The strength of the OPC mixes reduced significantly (to below the target strength) as the curing temperature was increased from 27°C to 75°C. Even at the age of 360 days, OPC mixes that had been cured at 75°C (over a 7-day period) gave strengths about 15% below the target strength. This suggests that the OPC concrete in a mass pour may not reach the target strength at all locations.

On comparison, all of the PFA mixes had post 28-day strengths which were generally much greater than the target strength. This suggests that a PFA concrete is less sensitive to a high curing temperature than an OPC concrete of the same design strength.

(e) The OPC and PFA mixes which were cured insufficiently showed a reduction in strength by a similar amount at the age of 28 days. However, at the age of 360 days, all the PFA mixes that had been cured for a minimum of 7 days had achieved their target strengths. On comparison, only the OPC mixes with 28 days water curing achieved the target strengths at 360 days.

6. REFERENCES

Hong Kong Government (1990). Construction Standard - Testing Concrete (CS1:1990). Two volumes, Government Printer. Hong Kong.

Leung, W.C. & Tse, W.L. (1993). Interim Report on a Laboratory Investigation of the Strength Development of High PFA Content Concrete. Geotechnical Engineering Office, Hong Kong, 41p.

LIST OF TABLES

Table 1 - Physical and Chemical Properties of Cement

Test	Unit	Sample No.		
		1	2	3
Physical Properties				
Density	kg/m^3	3120	3150	3130
Fineness (specific surface)	m^2/kg	335	360	355
Standard consistence	%	26.0	27.5	28.5
Initial setting time	min.	120	135	105
Final setting time	min.	170	215	105
Soundness (expansion)	mm	1.0	0	1.0
Concrete cube strength (mean 3 days)	MPa	36.5	37.0	40.0
Mortar cube strength (mean 28 days)	MPa	70.5	73.5	69.0
Chemical Properties				
SiO_2	%	20.9	20.7	20.5
CaO	%	65.2	64.3	65.1
Al_2O_3	%	5.5	5.3	5.4
Fe_2O_3	%	3.1	3.1	3.0
MgO	%	0.7	1.5	1.1
K_2O	%	0.33	0.48	0.38
Na_2O	%	0.10	0.14	0.10
SO_3	%	2.4	2.5	2.4
Insoluble residue	%	0.2	0.4	0.2
Loss-on-ignition	%	0.6	1.2	1.1
C_3A	%	9.2	8.8	9.3
Lime saturation factor	-	0.95	0.94	0.96
Total alkali (equivalent Na_20)	%	0.32	0.46	0.35

Table 2 - Physical Properties of Aggregates

Test	Unit	Coarse Aggregates						Fine Aggregates					
		20 mm			10 mm			Rock Fines			River Sand		
		Sample No.			Sample No.			Sample No.			Sample No.		
		1	2	3	1	2	3	1	2	3	1	2	3
1. Particle size distribution (Percentage Passing) Size of BS Sieve (mm)													
37.5	%	100	100	100	--	--	--	--	--	--	--	--	--
20	%	92	95	97	--	--	--	--	--	--	--	--	--
14	%	41	42	64	--	--	--	--	--	--	--	--	--
10	%	12	9	20	100	99	100	--	--	--	--	--	--
5	%	1	1	3	16	27	12	100	100	93	100	98	100
2.36	%	1	0	3	4	2	1	76	81	60	94	85	93
1.18	%	--	--	--	--	--	--	53	60	45	77	66	74
0.6	%	--	--	--	--	--	--	39	44	35	49	40	44
0.3	%	--	--	--	--	--	--	28	32	27	21	13	13
0.15	%	--	--	--	--	--	--	18	22	18	3	2	1
2. Flakiness index		17	17	17	20	--	19	--	--	--	--	--	--
3. Elongation index		38	37	38	9	--	3	--	--	--	--	--	--
4. Ten per cent fines value	kN	150	210	210	*50	--	--	--	--	--	--	--	--
5. Crushing value	%	23	20	--	*21	--	--	--	--	--	--	--	--
6. Water absorption	%	0.6	0.5	0.5	0.7	0.7	0.6	0.8	0.9	0.8	1.1	0.4	0.7

Legend : * The aggreggates used in these tests were of non-standard size with a size range of 6.3 - 10 mm.

Table 3 - Physical and Chemical Properties of PFA

Test	Unit	Sample No.		
		1	2	3
Fineness of PFA residue on 45 μm sieve	%	3.8	3.4	2.9
Moisture Content	%	0.1	0.1	0.1
Water requirement	%	98	99	99
Loss-on-ignition	%	3.7	3.5	3.7
MgO	%	1.1	0.7	0.4
SO_3	%	0.8	0.7	0.9

Table 4 - Mix Proportions

Mix Ref. No.	Grade	Nominal Percentage of PFA Replacement (%)	Total Cementitious Content (kg)	Cement (kg)	PFA (kg)	Water (kg)	Ratios		Admixtures		Slump (mm)
							A/C	W/C	D-17 (c.c.)	Super 20 (c.c.)	
M1	30	0	310	310	0	189	6.13	0.61	0	0	75
M3	30	25	330	248	82	178	5.73	0.54	0	735	80
M5	30	35	340	221	119	177	5.54	0.52	0	2100	70
M7	30	45	390	215	175	176	4.71	0.45	0	2155	75
M9	30	55	460	207	253	184	3.82	0.40	0	2449	65
M2	45	0	375	375	0	195	4.88	0.52	190	0	75
M4	45	25	390	293	97	168	4.72	0.43	0	1684	65
M6	45	35	400	260	140	168	4.58	0.42	0	3325	65
M8	45	45	460	253	207	175	3.84	0.38	0	2938	70
M10	45	55	550	248	302	187	3.03	0.34	0	4114	65

Table 5 - Curing Environments of Cubes after Demoulding

Curing Environment	Description
E1	27°C water curing for 27 days, then air curing
E2	10°C water curing for 3 days, followed by 20°C water curing for 24 days, then air curing
E3	20°C water curing for 27 days, then air curing
E4	Air curing
E5	27°C water curing for 3 days, then air curing
E6	27°C water curing for 7 days, then air curing
E7	50°C water curing for 7 days, followed by 27°C for 20 days, then air curing
E8	75°C water curing for 7 days, followed by 27°C for 20 days, then air curing

Notes: (1) The air cured cubes were stored in a room where the temperature was maintained at 25 $\pm$ 5°C.
(2) The mean relative humidity of the room over the test period was about 75%.

Table 6 - Density and Compressive Strength of Concrete Mix M1 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	26.0	39.0	42.8	42.8	2380 2370 2390	41.0 41.5 39.5	40.7	2380 2360 2360	38.0 37.5 38.5	38.0
E2	--	37.0	43.0	41.2	2375 2365 2370	40.0 42.0 42.5	41.5	2390 2360 2360	39.5 39.0 40.0	39.5
E3	--	37.5	42.0	43.5	2370 2370 2370	42.5 38.5 39.0	40.0	2360 2380 2360	41.0 39.5 38.5	39.7
E4	--	28.7	30.2	28.5	2380 2400 2380	29.0 30.0 27.0	28.7	2390 2400 2390	30.0 31.0 28.5	29.8
E5	--	33.5	35.5	35.3	2380 2385 2385	34.0 33.5 33.5	33.7	2390 2360 2370	32.0 33.0 33.5	32.8
E6	--	36.0	38.0	38.0	2370 2360 2360	38.0 35.0 34.5	35.8	2380 2380 2370	34.5 32.5 31.0	32.7
E7	--	37.5	42.3	42.0	2370 2360 2380	38.5 40.5 43.0	40.7	2370 2360 2360	38.0 43.0 41.0	40.7
E8	--	33.0	35.8	34.5	2375 2365 2360	33.0 35.0 34.5	34.2	2390 2370 2380	33.0 33.0 33.0	33.0

Notes : The details of the densities and individual cube strengths of concrete mix M1 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 7 - Density and Compressive Strength of Concrete Mix M2 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	39.5	52.3	60.5	58.2	2380 2380 2360	54.0 55.5 56.0	55.2	2380 2370 2360	54.0 56.5 53.0	54.5
E2	--	50.8	57.2	55.5	2375 2375 2390	53.0 53.5 53.5	53.3	2370 2360 2370	52.0 48.5 52.5	51.0
E3	--	52.0	57.8	57.7	2370 2365 2365	54.5 53.0 54.0	53.8	2370 2380 2360	53.0 55.0 52.0	53.3
E4	--	39.2	43.8	39.8	2380 2380 2395	42.0 42.5 38.5	41.0	2370 2380 2380	41.5 42.0 41.5	41.7
E5	--	50.2	50.2	50.3	2360 2370 2360	48.0 49.5 47.5	48.3	2380 2360 2380	49.0 45.5 46.5	47.0
E6	--	53.2	54.2	54.8	2370 2360 2360	52.0 52.5 53.5	52.7	2350 2370 2370	48.5 50.0 51.0	49.8
E7	--	47.5	53.0	53.7	2360 2370 2375	51.5 53.0 51.5	52.0	2370 2370 2360	49.5 51.5 50.0	50.3
E8	--	41.3	45.5	43.3	2360 2360 2360	43.5 43.0 43.0	43.2	2360 2370 2350	42.5 43.5 44.0	43.3

Notes : The details of the densities and individual cube strengths of concrete mix M2 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 8 - Density and Compressive Strength of Concrete Mix M3 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	24.5	39.8	46.7	49.5	2380 2370 2360	50.5 50.5 48.5	49.8	2370 2370 2380	49.0 48.5 49.5	49.0
E2	--	35.8	43.7	46.7	2370 2370 2370	47.0 48.5 46.5	47.3	2370 2360 2370	45.0 48.0 46.5	46.5
E3	--	36.7	43.8	45.8	2370 2380 2380	48.0 46.0 48.0	47.3	2370 2370 2360	45.0 46.0 49.5	46.8
E4	--	29.5	32.8	33.2	2380 2390 2380	32.5 33.0 33.0	32.8	2390 2380 2400	35.0 37.0 35.0	35.7
E5	--	35.5	39.2	39.0	2390 2380 2370	40.0 42.0 42.0	41.3	2370 2360 2360	42.0 42.5 42.5	42.3
E6	--	39.2	41.5	43.8	2370 2380 2370	44.5 45.5 42.5	44.2	2370 2380 2380	44.0 49.0 43.0	45.3
E7	--	46.8	48.2	51.3	2380 2370 2380	54.0 55.0 49.5	52.8	2370 2360 2370	54.0 56.5 50.5	53.7
E8	--	38.8	41.5	42.8	2380 2390 2380	46.0 45.0 43.5	44.8	2360 2350 2360	48.0 46.0 44.5	46.2

Notes : The details of the densities and individual cube strengths of concrete mix M3 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 9 - Density and Compressive Strength of Concrete Mix M4 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	39.7	58.0	67.2	68.0	2390 2370 2380	72.5 73.5 70.5	72.2	2390 2370 2380	73.0 71.5 69.5	71.3
E2	--	54.7	62.5	68.2	2390 2390 2380	70.0 70.0 67.5	69.2	2390 2390 2380	69.0 70.0 69.0	69.3
E3	--	53.7	62.2	67.3	2390 2390 2400	68.5 66.5 67.5	67.5	2390 2390 2390	69.0 66.0 66.5	67.2
E4	--	45.3	48.2	49.5	2380 2390 2380	52.5 49.5 50.5	50.8	2390 2400 2380	51.0 51.0 49.5	50.5
E5	--	54.5	56.5	60.0	2390 2380 2380	62.0 62.5 60.5	61.7	2380 2370 2380	64.0 63.0 61.5	62.8
E6	--	55.5	58.7	60.8	2380 2380 2380	64.0 62.5 64.5	63.7	2370 2380 2380	61.5 62.0 64.0	62.5
E7	--	63.0	65.7	67.8	2390 2390 2380	74.0 71.5 72.0	72.5	2390 2390 2380	75.0 72.5 73.5	73.7
E8	--	57.3	58.8	60.5	2390 2390 2390	65.0 62.5 64.5	64.0	2390 2380 2380	65.5 67.5 66.5	66.5

Notes : The details of the densities and individual cube strengths of concrete mix M4 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 10 - Density and Compressive Strength of Concrete Mix M5 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	22.0	38.7	47.7	49.2	2340 2350 2360	51.0 48.5 48.0	49.2	2350 2350 2350	53.5 53.0 51.5	52.7
E2	--	32.5	40.7	44.3	2365 2360 2360	45.0 45.5 44.5	45.0	2350 2350 2360	44.0 46.0 42.5	44.2
E3	--	32.8	40.7	44.2	2350 2350 2355	46.0 45.5 45.0	45.5	2360 2360 2350	46.0 46.0 45.5	45.8
E4	--	28.0	29.7	28.5	2380 2380 2370	27.5 31.0 30.0	29.5	2380 2370 2380	34.0 35.0 32.0	33.7
E5	--	31.2	34.5	36.0	2360 2350 2360	37.5 39.5 36.5	37.8	2350 2360 2360	40.0 37.0 42.0	39.7
E6	--	33.5	36.5	40.3	2360 2360 2370	42.0 39.5 39.5	40.3	2350 2340 2350	37.5 42.5 42.5	40.8
E7	--	43.5	46.2	47.8	2370 2370 2370	49.0 48.5 48.0	48.5	2360 2360 2360	52.5 53.0 49.0	51.5
E8	--	41.2	42.3	43.0	2375 2370 2365	45.5 43.5 46.0	45.0	2370 2360 2370	46.0 45.5 46.0	45.8

Notes : The details of the densities and individual cube strengths of concrete mix M5 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 11 - Density and Compressive Strength of Concrete Mix M6 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	32.0	51.5	60.2	63.2	2360 2360 2360	67.5 67.0 61.5	65.3	2360 2360 2360	69.0 67.5 67.0	67.8
E2	--	45.8	57.0	60.5	2370 2380 2360	62.0 62.5 62.5	62.3	2360 2360 2390	66.0 68.0 69.0	67.7
E3	--	47.3	58.3	62.3	2360 2380 2360	61.5 64.0 65.0	63.5	2380 2360 2370	61.5 65.5 59.5	62.2
E4	--	39.8	39.0	43.3	2390 2380 2380	49.5 45.5 43.0	46.0	2370 2380 2380	47.0 45.0 44.5	45.5
E5	--	43.3	46.7	50.2	2360 2350 2370	54.0 52.5 50.0	52.2	2370 2360 2370	54.0 48.5 50.5	51.0
E6	--	45.7	47.5	50.8	2370 2360 2350	52.5 53.5 54.0	53.3	2370 2370 2370	53.0 54.5 53.0	53.5
E7	--	56.3	61.5	62.8	2380 2390 2370	65.0 65.0 67.5	65.8	2370 2370 2380	69.0 68.0 68.5	68.5
E8	--	55.5	58.0	58.3	2370 2380 2370	58.5 61.5 59.5	59.8	2380 2380 2380	59.5 61.5 61.5	60.8

Notes : The details of the densities and individual cube strengths of concrete mix M6 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 12 - Density and Compressive Strength of Concrete Mix M7 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	22.3	41.2	51.2	52.0	2380 2370 2370	56.0 58.0 55.0	56.3	2360 2370 2360	58.0 60.0 59.0	59.0
E2	--	31.8	45.0	46.5	2370 2370 2370	51.0 53.0 52.0	52.0	2360 2370 2370	54.0 54.0 50.5	52.8
E3	--	31.3	46.2	47.5	2360 2360 2370	50.0 51.0 52.0	51.0	2370 2380 2370	51.5 52.0 52.5	52.0
E4	--	27.0	32.8	30.8	2360 2370 2360	34.0 33.5 32.0	33.2	2380 2380 2370	36.5 33.5 34.5	34.8
E5	--	33.2	38.2	39.5	2380 2360 2360	41.0 43.5 43.5	42.7	2380 2370 2360	42.5 44.5 44.0	43.7
E6	--	36.0	41.7	43.2	2360 2370 2370	46.0 47.0 49.5	47.5	2360 2370 2360	48.0 51.5 42.0	47.2
E7	--	50.0	54.3	53.8	2370 2390 2360	55.5 61.0 54.0	56.8	2360 2360 2370	55.0 60.0 54.5	56.5
E8	--	41.5	43.2	43.3	2370 2360 2350	45.0 46.5 46.5	46.0	2370 2370 2360	46.5 46.0 46.0	46.2

Notes : The details of the densities and individual cube strengths of concrete mix M7 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 13 - Density and Compressive Strength of Concrete Mix M8 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	32.5	55.0	63.5	69.8	2320 2370 2370	72.5 74.0 74.5	73.7	2370 2380 2360	76.5 73.5 76.0	75.3
E2	--	43.5	59.2	64.0	2370 2370 2370	66.5 67.0 68.0	67.2	2370 2360 2360	70.0 72.0 71.5	71.2
E3	--	44.3	58.2	65.2	2370 2370 2370	70.5 68.5 67.0	68.7	2360 2360 2370	71.5 68.5 71.5	70.5
E4	--	35.0	38.3	41.5	2370 2385 2385	43.5 41.5 40.0	41.7	2380 2390 2390	45.0 41.0 42.0	42.7
E5	--	45.3	51.5	54.5	2360 2380 2360	57.0 59.0 56.0	57.3	2370 2360 2360	61.5 57.5 58.0	59.0
E6	--	48.5	54.8	58.2	2370 2370 2370	60.5 65.5 58.5	61.5	2370 2370 2370	61.0 68.0 61.0	63.3
E7	--	62.5	65.3	67.2	2370 2370 2360	69.0 74.0 66.0	69.7	2370 2370 2370	73.0 78.5 69.0	73.5
E8	--	56.0	56.7	57.5	2370 2370 2370	61.0 56.5 58.5	58.7	2360 2360 2370	62.0 61.5 64.5	62.7

Notes : The details of the densities and individual cube strengths of concrete mix M8 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 14 - Density and Compressive Strength of Concrete Mix M9 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	22.5	42.9	49.5	54.3	2350 2350 2340	57.5 60.5 61.5	59.8	2340 2350 2350	58.5 64.0 62.5	61.7
E2	--	31.0	44.3	50.3	2360 2350 2350	57.0 56.5 56.5	56.7	2350 2350 2340	56.5 56.5 53.5	55.5
E3	--	29.3	40.7	47.2	2350 2340 2350	51.5 52.0 50.0	51.2	2340 2350 2330	49.5 52.0 50.5	50.7
E4	--	30.2	33.3	35.7	2360 2350 2360	35.5 35.5 37.5	36.2	2370 2360 2360	35.5 36.5 36.0	36.0
E5	--	35.5	38.7	44.2	2350 2360 2350	46.0 44.5 43.5	44.7	2350 2350 2350	45.0 43.5 42.5	43.7
E6	--	37.0	40.5	44.7	2360 2350 2340	43.0 45.0 44.0	44.0	2350 2340 2340	46.5 44.0 44.5	45.0
E7	--	51.5	51.7	54.5	2360 2350 2340	60.0 60.5 60.5	60.3	2360 2340 2340	62.0 60.5 58.5	60.3
E8	--	48.2	47.7	49.5	2360 2340 2350	48.0 48.5 51.5	49.3	2360 2360 2340	50.0 51.0 51.5	50.8

Notes : The details of the densities and individual cube strengths of concrete mix M9 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 15 - Density and Compressive Strength of Concrete Mix M10 under Various Curing Environments

Curing Environment	Age at Test									
	7 Days	28 Days	56 Days	90 Days	180 Days			360 Days		
	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)	Density (kg/m^3)	Compressive Strength (MPa)	Mean Strength (MPa)
E1	30.2	54.8	63.3	66.8	2350 2340 2330	70.0 70.5 72.0	70.8	2340 2350 2340	71.0 71.0 72.5	71.5
E2	--	42.2	54.1	59.8	2350 2330 2340	62.5 63.5 66.5	61.2	2350 2340 2320	66.0 65.5 67.0	66.2
E3	--	40.8	54.7	60.2	2350 2350 2340	67.0 61.5 64.0	64.2	2340 2340 2340	66.5 66.0 65.5	66.0
E4	--	35.3	39.5	42.2	2330 2330 2340	44.0 43.5 41.0	42.8	2330 2340 2350	47.5 48.5 45.5	47.2
E5	--	46.8	48.7	54.0	2330 2340 2330	54.0 57.0 57.5	56.2	2340 2330 2330	57.0 60.0 56.0	57.7
E6	--	47.5	51.5	56.0	2340 2340 2330	60.5 60.0 56.0	58.8	2330 2330 2340	62.5 62.0 58.5	61.0
E7	--	61.0	62.8	63.0	2350 2350 2350	69.5 66.5 69.5	68.5	2350 2340 2350	73.5 70.0 68.5	70.7
E8	--	56.7	57.8	59.7	2340 2340 2350	59.5 60.0 61.5	60.3	2360 2340 2340	60.5 61.0 61.0	60.8

Notes : The details of the densities and individual cube strengths of concrete mix M10 between the ages of 7 days and 90 days under the various curing environments are given in the interim report (Leung & Tse, 1993).

Table 16 - Mean Compressive Strengths for Mixes M1 to M10

Curing Environment	Age (days)	Grade 30 Concrete					Grade 45 Concrete				
		M1	M3	M5	M7	M9	M2	M4	M6	M8	M10
E1	7	26.0	24.5	22.0	22.3	22.5	39.5	39.7	32.0	32.5	30.2
	28	39.0	39.8	38.7	41.2	42.9	52.3	58.0	51.5	55.0	54.8
	56	42.8	46.7	47.7	51.2	49.5	60.5	67.2	60.2	63.5	63.3
	90	42.8	49.5	49.2	52.0	54.3	58.2	68.0	63.2	69.8	66.8
	180	40.7	49.8	49.2	56.3	59.8	55.2	72.2	65.3	73.7	70.8
	360	38.0	49.0	52.7	59.0	61.7	54.5	71.3	67.8	75.3	71.5
E2	28	37.0	35.8	32.5	31.8	31.0	50.8	54.7	45.8	43.5	42.2
	56	43.0	43.7	40.7	45.0	44.3	57.2	62.5	57.0	59.2	54.1
	90	41.2	46.7	44.3	46.5	50.3	55.5	68.2	60.5	64.0	59.8
	180	41.5	47.3	45.0	52.0	56.7	53.3	69.2	62.3	67.2	64.2
	360	39.5	46.5	44.2	52.8	55.5	51.0	69.3	67.7	71.2	66.2
E3	28	37.5	36.7	32.8	31.3	29.3	52.0	53.7	47.3	44.3	40.8
	56	42.0	43.8	40.7	46.2	40.7	57.8	62.2	58.3	58.2	54.7
	90	43.5	45.8	44.2	47.5	47.2	57.7	67.3	62.3	65.2	60.2
	180	40.0	47.3	45.5	51.0	51.2	53.8	67.5	63.5	68.7	64.2
	360	39.7	46.8	45.8	52.0	50.7	53.3	67.2	62.2	70.5	66.0
E4	28	28.7	29.5	28.0	27.0	30.2	39.2	45.3	39.8	35.0	35.3
	56	30.2	32.8	29.7	32.8	33.3	43.3	48.2	39.0	38.3	39.5
	90	28.5	33.2	28.5	30.8	35.7	39.8	49.5	43.3	41.5	42.2
	180	28.7	32.8	29.5	33.2	36.2	41.0	50.8	46.0	41.7	42.8
	360	29.8	35.7	33.7	34.8	36.0	41.7	50.5	45.5	42.7	47.2
E5	28	33.5	35.5	31.2	33.2	35.5	50.2	54.5	43.3	45.3	46.8
	56	35.5	39.2	34.5	38.2	38.7	50.2	56.5	46.7	51.5	48.7
	90	35.3	39.0	36.0	39.5	44.2	50.3	60.0	50.2	54.5	54.0
	180	33.7	41.3	37.8	42.7	44.7	48.3	61.7	52.2	57.3	56.2
	360	32.8	42.3	39.7	43.7	43.7	47.0	62.8	51.0	59.0	57.7
E6	28	36.0	39.2	33.5	36.0	37.0	53.2	55.5	45.7	48.5	47.5
	56	38.0	41.5	36.5	41.7	40.5	54.2	58.7	47.5	54.8	51.5
	90	38.0	43.8	40.3	43.2	44.7	54.8	60.8	50.8	58.2	56.0
	180	35.8	44.2	40.3	47.5	44.0	52.7	63.7	53.3	61.5	58.8
	360	32.7	45.3	40.8	47.2	45.0	49.8	62.5	53.5	63.3	61.0
E7	28	37.5	46.8	43.5	50.0	51.5	47.5	63.0	56.3	62.5	61.0
	56	42.3	48.2	46.2	54.3	51.7	53.0	65.7	61.5	65.3	62.8
	90	42.0	51.3	47.8	53.8	54.5	53.7	67.8	62.8	67.2	63.0
	180	40.7	52.8	48.5	56.8	60.3	52.0	72.5	65.8	69.7	68.5
	360	40.7	53.7	51.5	56.5	60.3	50.3	73.7	68.5	73.5	70.7
E8	28	33.0	38.8	41.2	41.5	48.2	41.3	57.3	55.5	56.0	56.7
	56	35.8	41.5	42.3	43.2	47.7	45.5	58.8	58.0	56.7	57.8
	90	34.5	42.8	43.0	43.3	49.5	43.3	60.5	58.3	57.5	59.7
	180	34.2	44.8	45.0	46.0	49.3	43.2	64.0	59.8	58.7	60.3
	360	33.0	46.2	45.8	46.2	50.8	43.3	66.5	60.8	62.7	60.8

Notes : (1) The details of the concrete mixes M1 to M10 and the curing environments are given in Tables 4 and 5 respectively.

(2) The mean compressive strengths in this Table are taken from Tables 6 to 15 of this Report and are in units of MPa.

Table 17 - Normalisation Factors for Mixes M1 to M10

Concrete Mix	Grade 30 Concrete					Grade 45 Concrete				
	M1	M3	M5	M7	M9	M2	M4	M6	M8	M10
Normalisation Factor	0.974	0.955	0.982	0.922	0.886	1.013	0.914	1.029	0.964	0.967

Note : (1) The normalisation factors were calculated using equation (1).

Table 18 - Normalised Mean Compressive Strengths for Mixes M1 to M10

Curing Environment	Age (days)	Grade 30 Concrete					Grade 45 Concrete				
		M1	M3	M5	M7	M9	M2	M4	M6	M8	M10
E1	7	25.3	23.4	21.6	20.6	19.9	40.0	36.3	32.9	31.3	29.2
	28	38.0	38.0	38.0	38.0	38.0	53.0	53.0	53.0	53.0	53.0
	56	41.7	44.6	46.8	47.2	43.8	61.3	61.4	62.0	61.2	61.2
	90	41.7	47.3	48.3	48.0	48.1	58.9	62.1	65.0	67.3	64.6
	180	39.7	47.5	48.3	51.9	53.0	55.9	66.0	67.2	71.0	68.5
	360	37.0	46.8	51.7	54.4	54.7	55.2	65.2	69.8	72.6	69.2
E2	28	36.1	34.2	31.9	29.3	27.5	51.5	50.0	47.1	41.9	40.8
	56	41.9	41.7	40.0	41.5	39.2	58.0	57.1	58.7	57.0	52.3
	90	40.1	44.6	43.5	42.9	44.6	56.2	62.3	62.3	61.7	57.8
	180	40.4	45.2	44.2	48.0	50.2	54.0	63.2	64.1	64.8	62.1
	360	38.5	44.4	43.4	48.7	49.2	51.7	63.3	69.7	68.6	64.0
E3	28	36.5	35.0	32.2	28.9	26.0	52.7	49.1	48.7	42.7	39.5
	56	40.9	41.8	40.0	42.6	36.1	58.6	56.8	60.0	56.1	52.9
	90	42.4	43.7	43.4	43.8	41.8	58.5	61.5	64.1	62.8	58.2
	180	39.0	45.2	44.7	47.0	45.4	54.5	61.7	65.3	66.2	62.1
	360	38.7	44.7	45.0	48.0	44.9	54.0	61.4	64.0	67.9	63.8
E4	28	28.0	28.2	27.5	24.9	26.8	39.7	41.4	41.0	33.7	34.1
	56	29.4	31.3	29.2	30.3	29.5	43.9	44.0	40.1	36.9	38.2
	90	27.8	31.7	28.0	28.4	31.6	40.3	45.2	44.6	40.0	40.8
	180	28.0	31.3	29.0	30.6	32.1	41.5	46.4	47.3	40.2	41.4
	360	29.0	34.1	33.1	32.1	31.9	42.3	46.1	46.8	41.1	45.6
E5	28	32.6	33.9	30.6	30.6	31.4	50.9	49.8	44.6	43.7	45.3
	56	34.6	37.4	33.9	35.2	34.3	50.9	51.6	48.1	49.6	47.1
	90	34.4	37.2	35.3	36.4	39.1	51.0	54.8	51.7	52.5	52.2
	180	32.8	39.4	37.1	39.4	39.6	48.9	56.4	53.7	55.2	54.4
	360	32.0	40.4	39.0	40.3	38.7	47.6	57.4	52.5	56.9	55.8
E6	28	35.1	37.4	32.9	33.2	32.8	53.9	50.7	47.0	46.7	45.9
	56	37.0	39.6	35.8	38.5	35.9	54.9	53.6	48.9	52.8	49.8
	90	37.0	41.8	39.6	39.8	39.6	55.5	55.6	52.3	56.1	54.2
	180	34.9	42.2	39.6	43.8	39.0	53.4	58.2	54.9	59.3	56.9
	360	31.9	43.3	40.1	43.5	39.9	50.5	57.1	55.1	61.0	59.0
E7	28	36.5	44.7	42.7	46.1	45.6	48.1	57.6	57.9	60.2	59.0
	56	41.2	46.0	45.4	50.1	45.8	53.7	60.0	63.3	62.9	60.7
	90	40.9	49.0	46.9	49.6	48.3	54.4	62.0	64.6	64.8	60.9
	180	39.7	50.4	47.6	52.4	53.4	52.7	66.3	67.7	67.2	66.3
	360	39.7	51.3	50.6	52.1	53.4	51.0	67.3	70.5	70.8	68.4
E8	28	32.2	37.0	40.5	38.3	42.7	41.9	52.4	57.1	54.0	54.8
	56	34.9	39.6	41.5	39.8	42.3	46.1	53.7	59.7	54.6	55.9
	90	33.6	40.9	42.2	39.9	43.8	43.9	55.3	60.0	55.4	57.7
	180	33.3	42.8	44.2	42.4	43.7	43.8	58.5	61.5	56.6	58.3
	360	32.2	44.1	45.0	42.6	45.0	43.9	60.8	62.6	60.4	58.8

Notes : (1) The notes of Table 16 also apply to this Table.
(2) The normalised mean compressive strengths were calculated in accordance with Section 4.1.

Table 19 - Relative Strength Percentages for Mixes M1 to M10

Curing Environment	Age	Relative Strength Percentage (%)									
		Grade 30 Concrete					Grade 45 Concrete				
	(days)	M1	M3	M5	M7	M9	M2	M4	M6	M8	M10
E1	7	67	62	57	54	52	76	68	62	59	55
	28	100	100	100	100	100	100	100	100	100	100
	56	110	117	123	124	115	116	116	117	115	116
	90	110	124	127	126	127	111	117	123	127	122
	180	104	125	127	137	139	106	124	127	134	129
	360	97	123	136	143	144	104	123	132	137	130
E2	28	95	90	84	77	72	97	94	89	79	77
	56	110	110	105	109	103	109	108	111	108	99
	90	106	117	114	113	117	106	118	117	116	109
	180	106	119	116	126	132	102	119	121	122	117
	360	101	117	114	128	129	98	119	131	129	121
E3	28	96	92	85	76	68	99	93	92	81	74
	56	108	110	105	112	95	111	107	113	106	100
	90	112	115	114	115	110	110	116	121	119	110
	180	103	119	118	124	119	103	116	123	125	117
	360	102	118	118	126	118	102	116	121	128	120
E4	28	74	74	72	66	70	75	78	77	64	64
	56	77	82	77	80	78	83	83	76	70	72
	90	73	83	74	75	83	76	85	84	75	77
	180	74	82	76	81	84	78	88	89	76	78
	360	76	90	87	84	84	80	87	88	78	86
E5	28	86	89	81	81	83	96	94	84	82	85
	56	91	98	89	93	90	96	97	91	94	89
	90	91	98	93	96	103	96	103	97	99	99
	180	86	104	98	104	104	92	106	101	104	103
	360	84	106	103	106	102	90	108	99	107	105
E6	28	92	98	87	87	86	102	96	89	88	87
	56	97	104	94	101	94	104	101	92	100	94
	90	97	110	104	105	104	105	105	99	106	102
	180	92	111	104	115	103	101	110	103	112	107
	360	84	114	105	115	105	95	108	104	115	111
E7	28	96	118	112	121	120	91	109	109	114	111
	56	108	121	119	132	121	101	113	119	119	115
	90	108	129	124	131	127	103	117	122	122	115
	180	104	133	125	138	141	99	125	128	127	125
	360	104	135	133	137	141	96	127	133	134	129
E8	28	85	97	106	101	112	79	99	108	102	103
	56	92	104	109	105	111	87	101	113	103	105
	90	88	108	111	105	115	83	104	113	105	109
	180	88	113	116	112	115	83	110	116	107	110
	360	85	116	118	112	118	83	115	118	114	111

Notes : (1) The details of the concrete mixes M1 to M10 and the curing environments are given in Tables 4 and 5 respectively.

(2) The relative strength percentages were calculated using equation (2).

LIST OF FIGURES

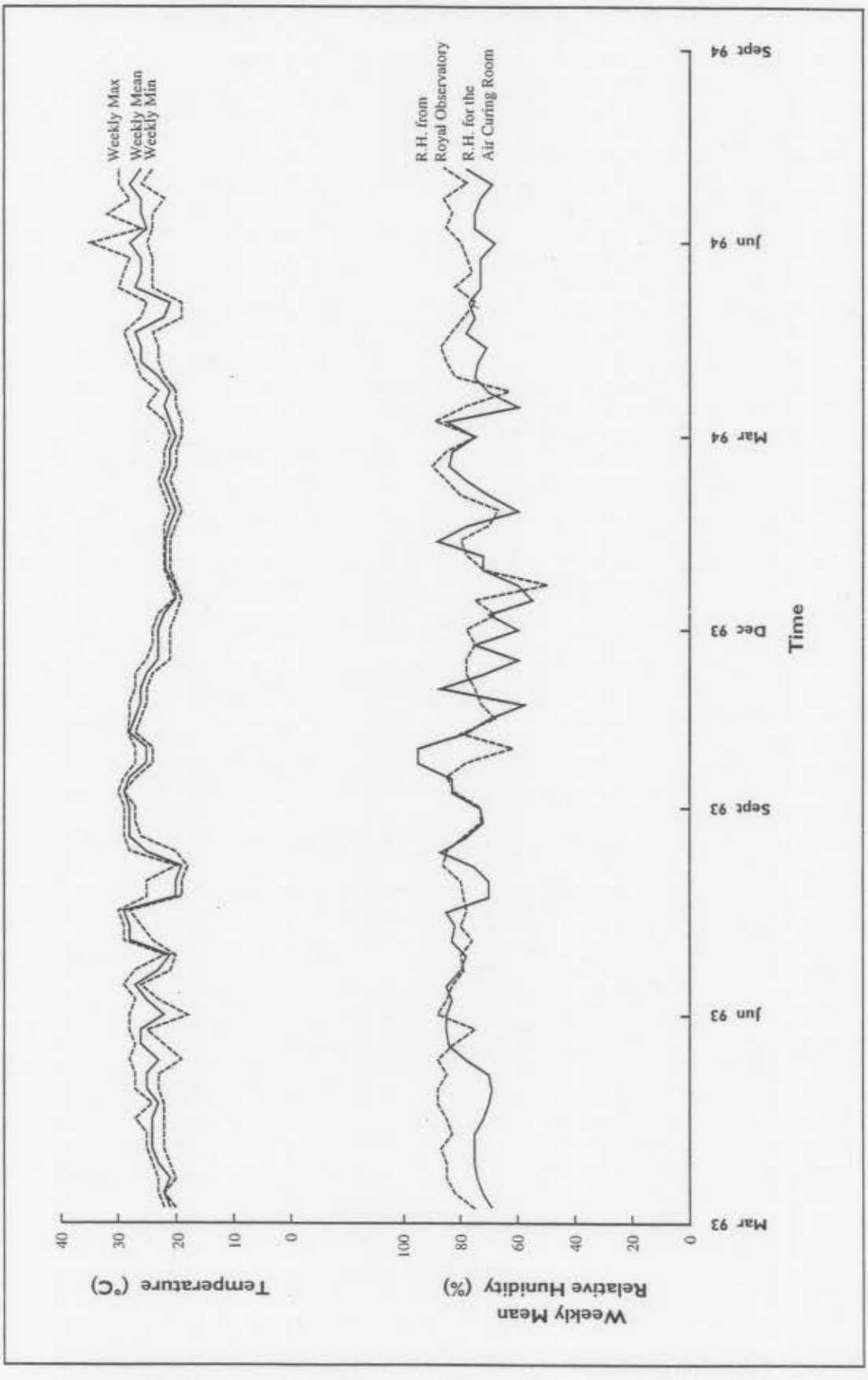

Figure 1 - Weekly Environmental Records of the Air Curing Room

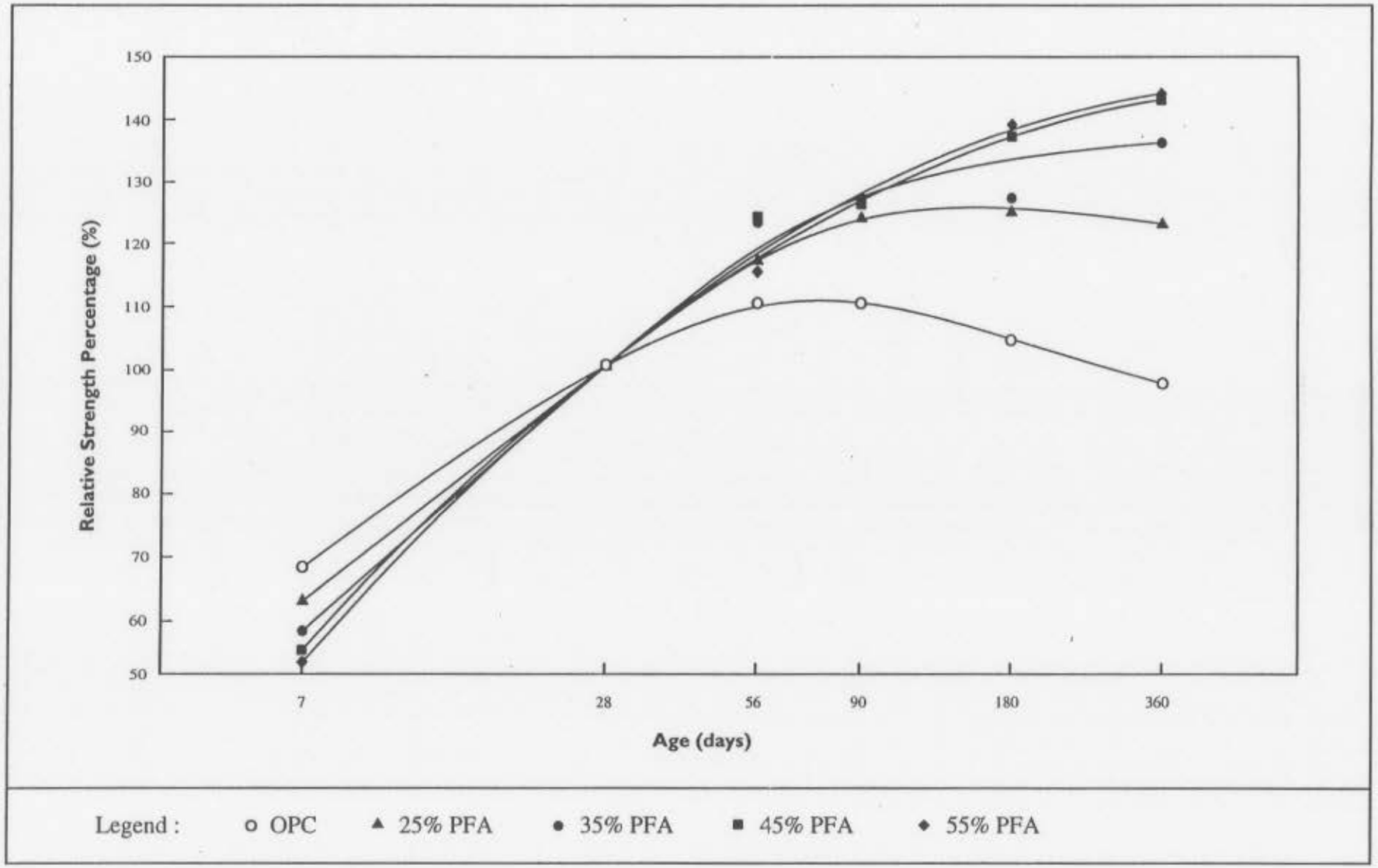

Figure 2 - Strength Development of Grade 30 OPC and PFA Concretes Cured under Environment E1

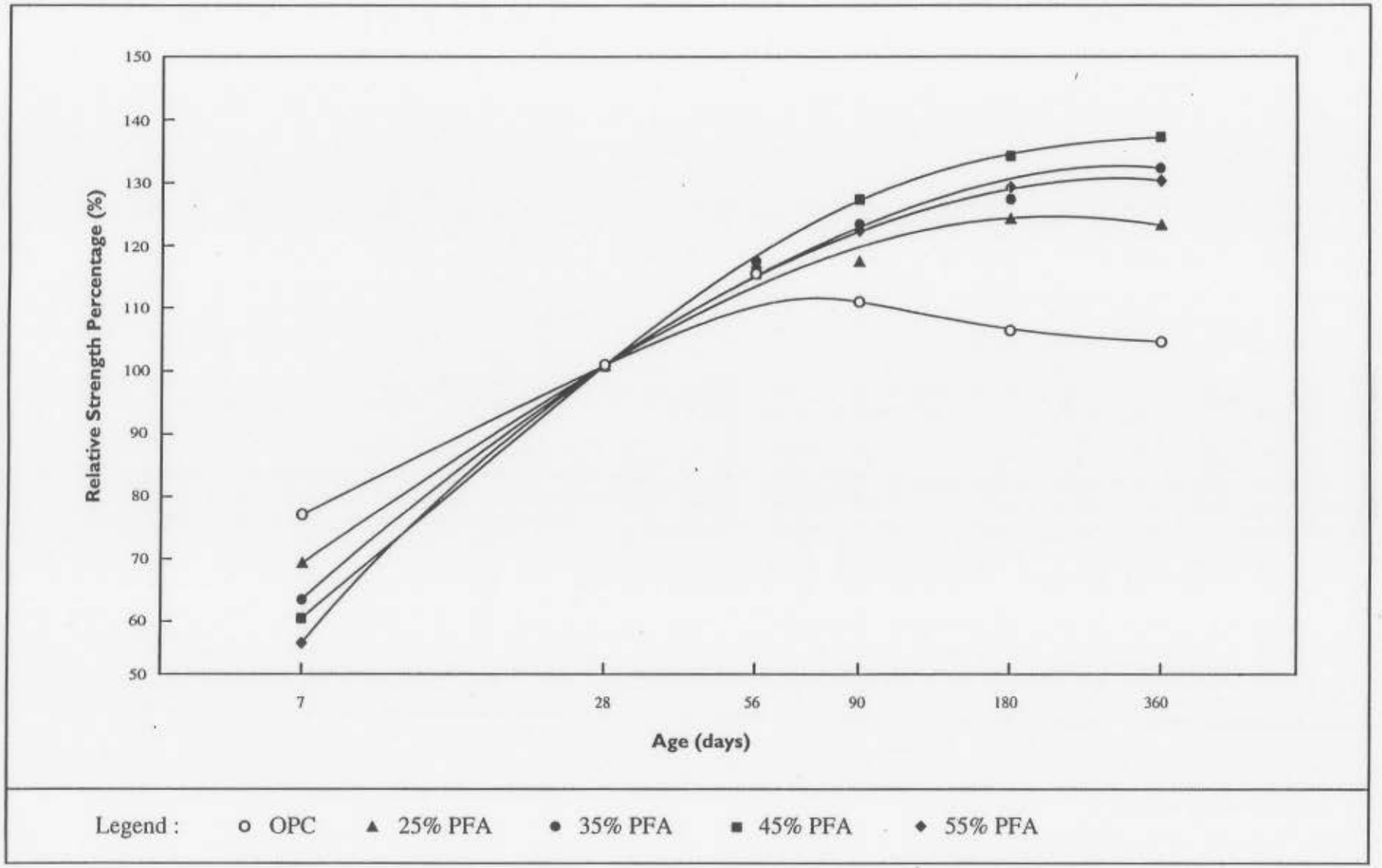

Figure 3 - Strength Development of Grade 45 OPC and PFA Concretes Cured under Environment E1

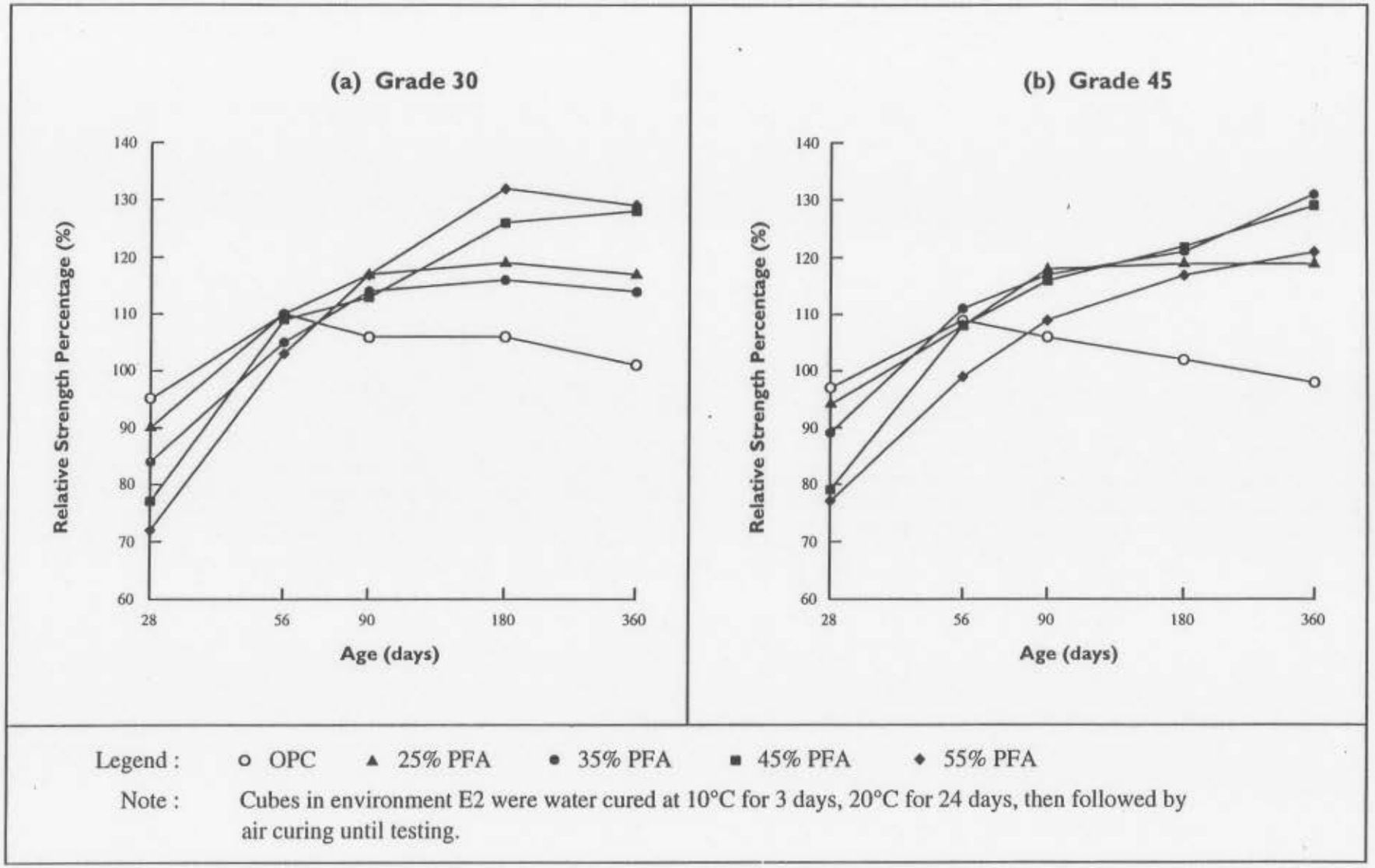

Figure 4 - Strength Development of OPC and PFA Concretes Cured under Environment E2

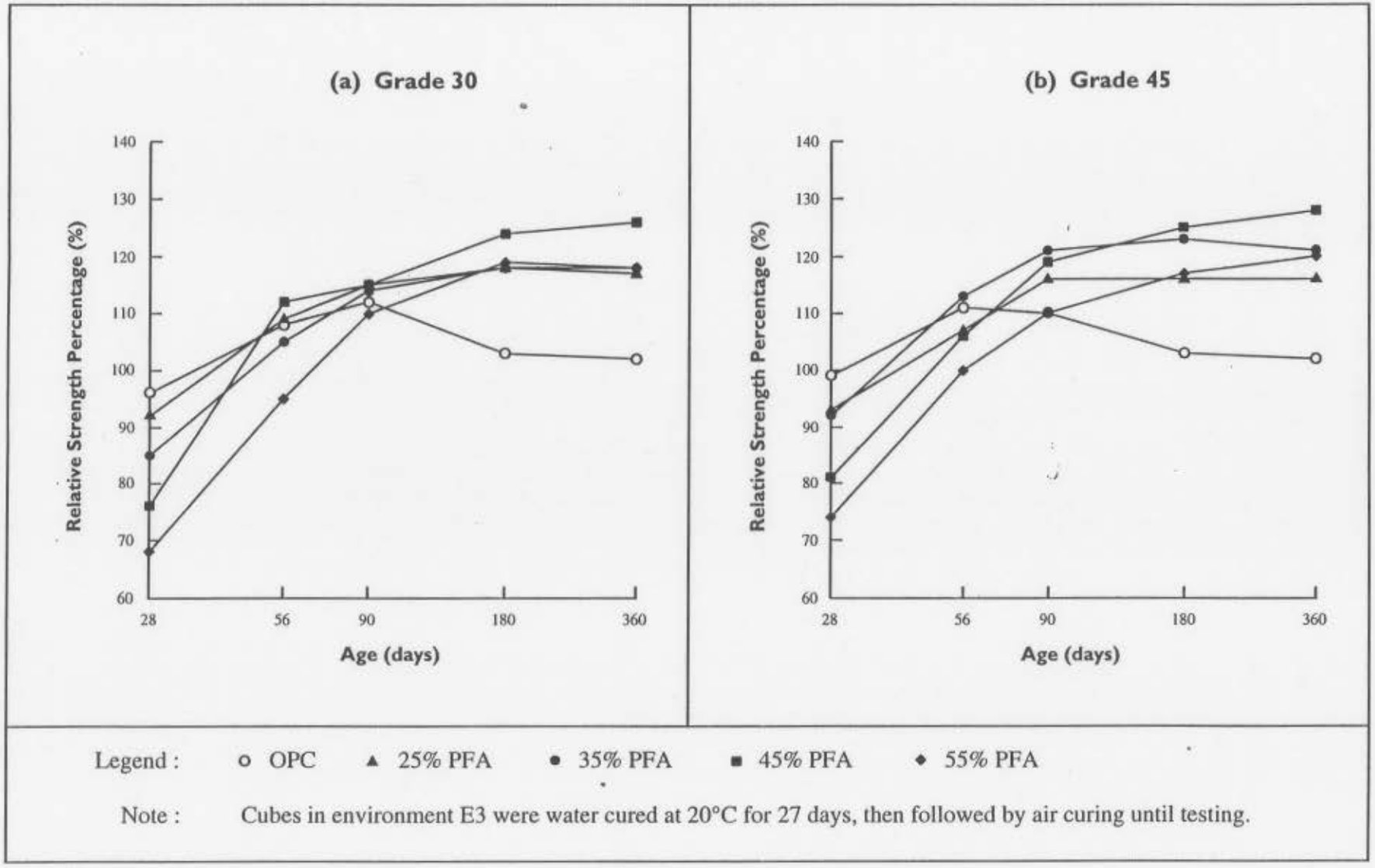

Figure 5 - Strength Development of OPC and PFA Concretes Cured under Environment E3

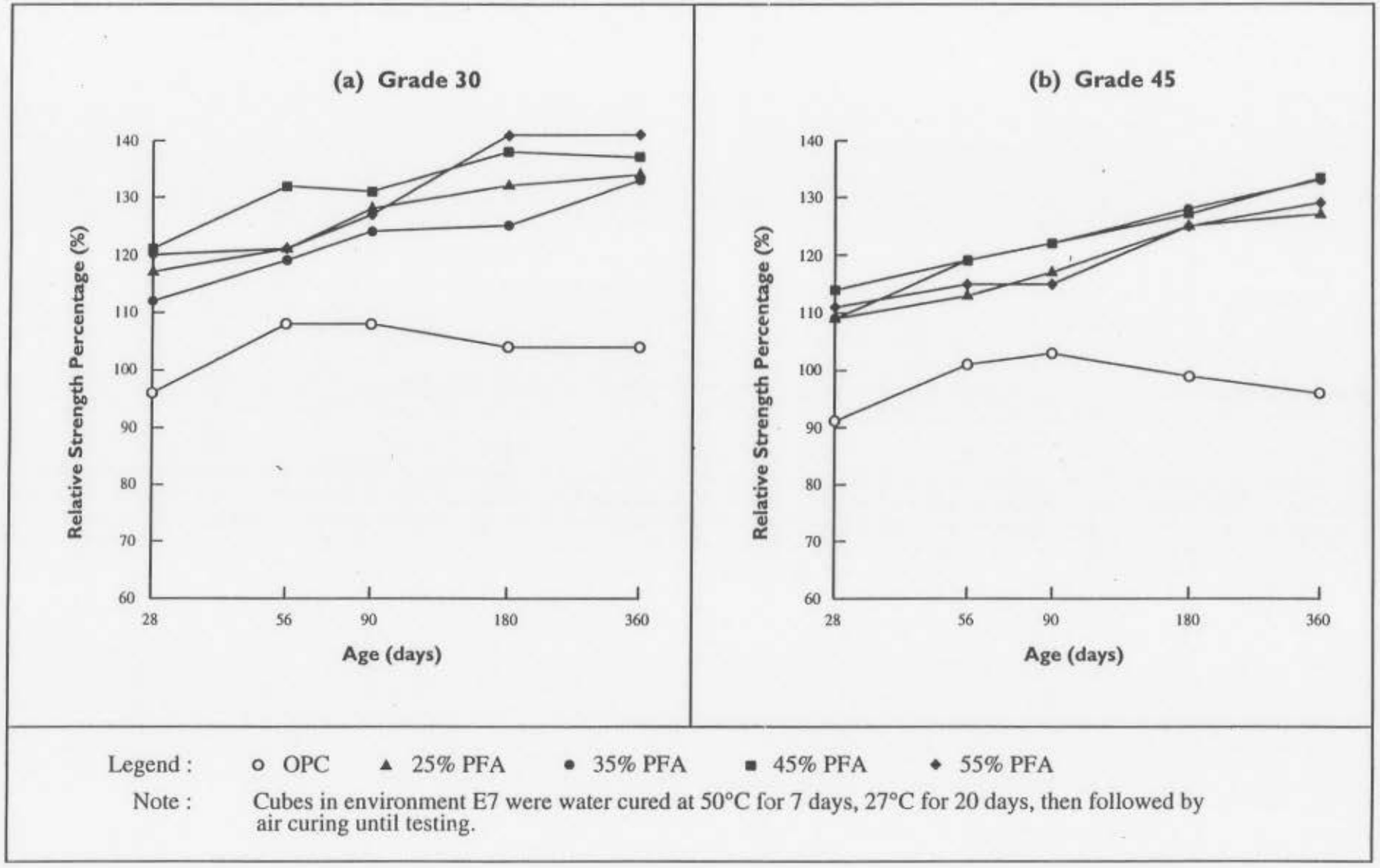

Figure 6 - Influence of High Initial Curing Temperature (Environment E7) on the Strength Development of OPC and PFA Concretes

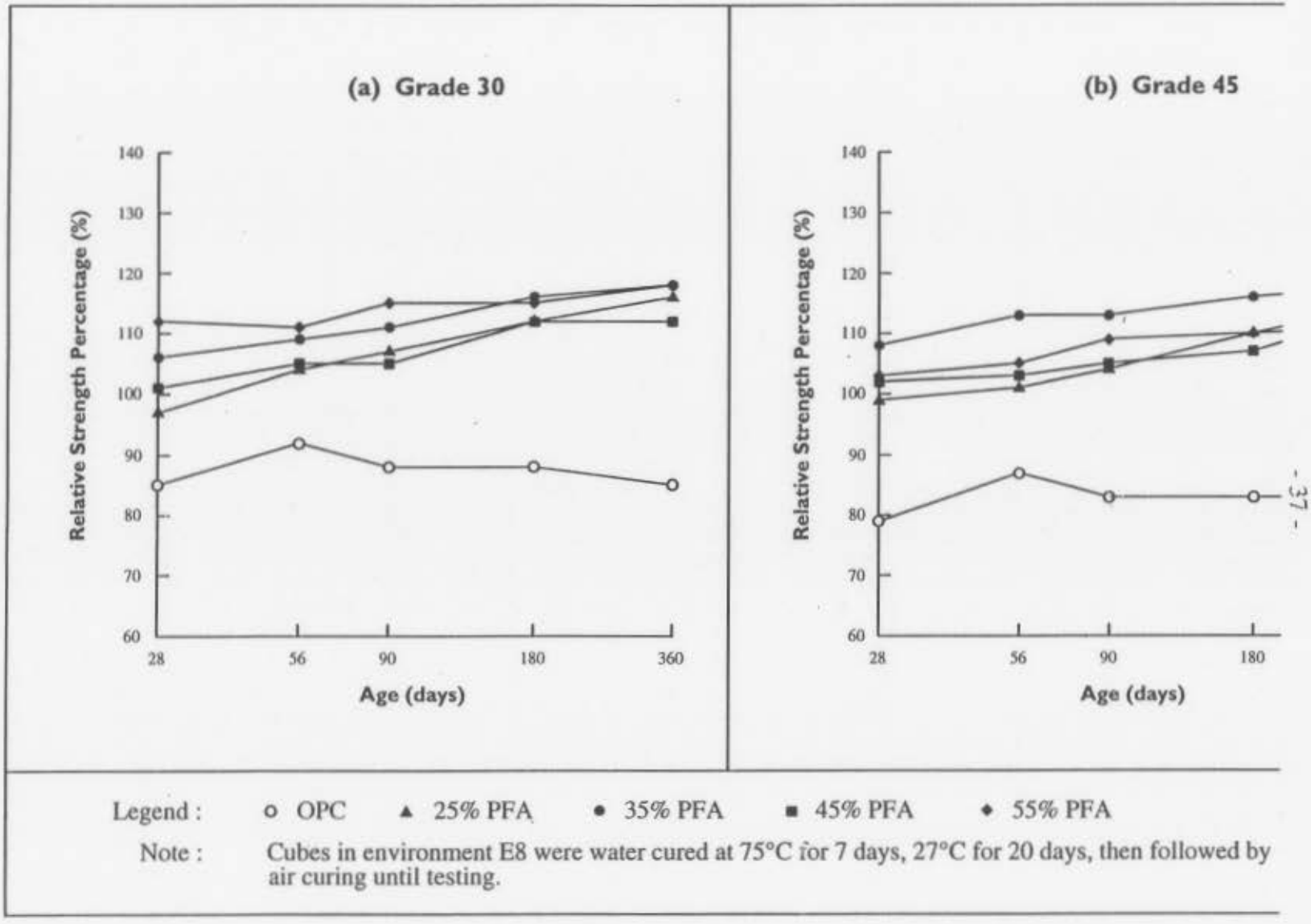

Figure 7 - Influence of High Initial Curing Temperature (Environment E8) on the Strength Development of OPC and PFA Concretes

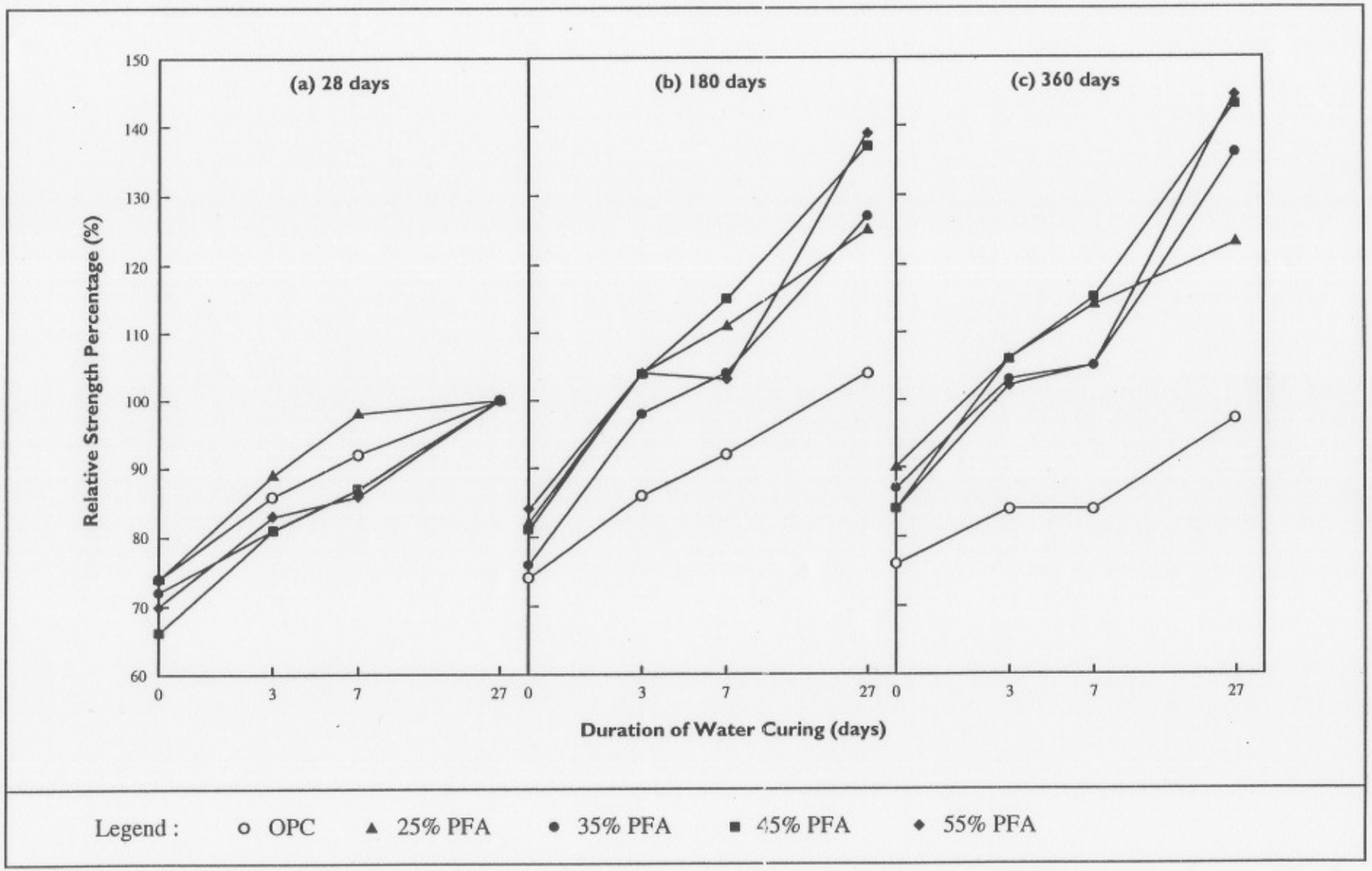

Figure 8 - Influence of Duration of Curing on the Strength Development of Grade 30 OPC and PFA Concretes

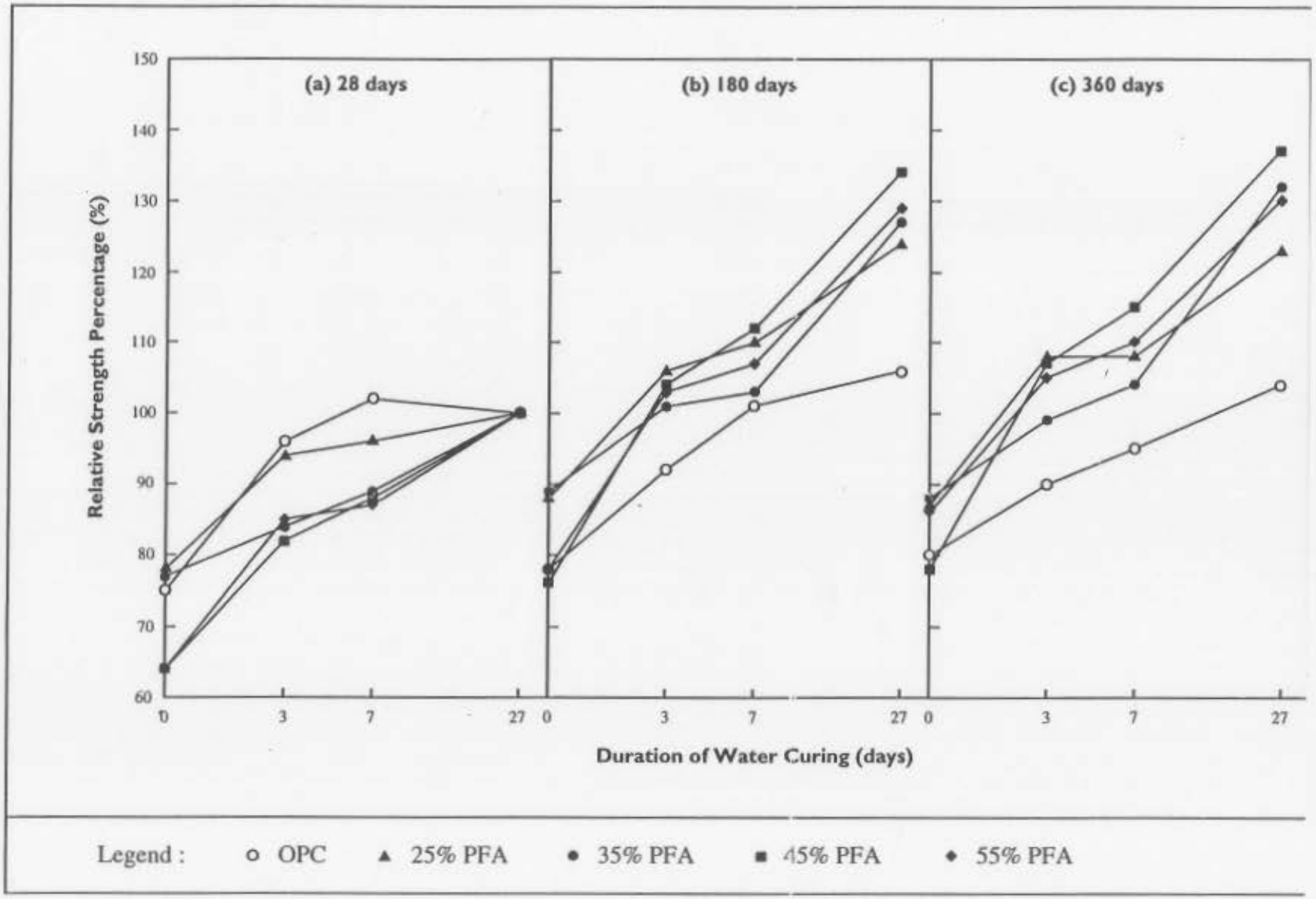

Figure 9 - Influence of Duration of Curing on the Strength Development of Grade 45 OPC and PFA Concr