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Table 1 Experimental Program

TEST SERIES	I	II
DESCRIPTION	Rate of Strength Gain	Mechanical Properties
PROPERTIES	Compressive Strength Tensile Strength Modulus of Rupture	Compressive Strength Tensile Strength Modulus of Rupture Modulus of Elasticity
AGE AT TEST (days)	1 2 3 7 28	28

Table 2 Mix Designation

INITIAL W/C	CEMENT CONTENT (kg./cu.m.) 250	300	350	REMARKS
0.48		30A		Conventional,Air-cured
		30AW		Conventional,Moist-cured
		D30A		Dewatered,Air-cured
		D30AW		Dewatered,Moist-cured
0.55	25B	30B	35B	Conventional,Air-cured
	25BW	30BW	35BW	Conventional,Moist-cured
	D25B	D30B	D35B	Dewatered,Air-cured
	D25BW	D30BW	D35BW	Dewatered,Moist-cured
0.62		30C		Conventional,Air-cured
		30CW		Conventional,Moist-cured
		D30C		Dewatered,Air-cured
		D30CW		Dewatered,Moist-cured

Table 3 Typical Mix Proportions to make 1 cu.m. of Concrete

MIX CODE	MIX PROPORTION by wt.	INITIAL W/C	CEMENT CONTENT (kg.)	AGGREGATE CONTENT (kg.)	WATER CONTENT (l.)
30A	1:2.67:4	0.48	300	2,000	144.0
25B	1:3.2:4.8	0.55	250	2,000	137.5
30B	1:2.67:4	0.55	300	2,000	165.0
35B	1:2.29:3.4	0.55	350	2,000	192.5
40B	1:2:3	0.55	400	2,000	220.0
30C	1:2.67:4	0.62	300	2,000	186.0

Table 4 Details of Vacuum Dewatering Process

MIX CODE	AVERAGE CEMENT CONTENT (kg./cu.m.)	AVERAGE WATER CONTENT (l./cu.m.)	WATER EXTRACTED		FINAL W/C
			(l.)	(l./cu.m.)	
30A,30C	300	165	22	65.48	0.33
35B,40B	375	206.25	22.1	65.77	0.37
25B,30B	275	151.25	19	56.55	0.34

Table 5 Development of Compressive Strength with Age.

MIX CODE	COMPRESSIVE STRENGTH (ksc.) AGE (days) 1	2	3	7	28
30A	103.3	140.0	147.5	206.3	238.3
	(43.4)	(58.8)	(61.9)	(86.6)	(100.0)
D30A	142.9	171.7	193.8	248.8	270.0
	(60.0)	(72.1)	(81.3)	(104.4)	(113.3)
25B	96.7	140.8	147.9	182.5	217.5
	(44.5)	(64.7)	(68.0)	(83.9)	(100.0)
D25B	129.2	162.1	186.3	217.1	250.4
	(59.4)	(74.5)	(85.7)	(99.8)	(115.1)
30B	80.0	112.5	141.9	169.2	200.8
	(39.8)	(56.0)	(70.7)	(84.3)	(100.0)
D30B	105.8	145.4	156.7	193.8	275.8
	(52.7)	(72.4)	(78.0)	(96.5)	(137.4)

Table 5 (cont.) Development of Compressive Strength with Age.

COMPRESSIVE STRENGTH (ksc.)					
MIX CODE	AGE (days)				
	1	2	3	7	28
35B	94.6	101.7	122.0	162.1	179.2
	(52.8)	(56.8)	(68.0)	(90.5)	(100.0)
D35B	130.4	178.3	184.6	249.6	293.3
	(72.8)	(99.5)	(103.0)	(139.3)	(163.7)
30C	70.0	115	125.4	155.4	169.2
	(41.4)	(68.0)	(74.1)	(91.8)	(100.0)
D30C	134.2	162.5	188.8	217.5	256.6
	(79.3)	(96.0)	(111.6)	(128.6)	(151.7)

Table 6 Development of Splitting Tensile Strength with Age.

SPLITTING TENSILE STRENGTH (ksc.)					
MIX	AGE (days)				
CODE	1	2	3	7	28
30A	12.5	16.5	23.6	31.6	36.3
	(5.3)	(6.9)	(9.9)	(13.3)	(15.2)
D30A	21.0	27.3	31.3	36.3	42.5
	(8.8)	(11.5)	(13.1)	(15.2)	(17.8)
25B	14.9	20.7	22.0	31.0	36.1
	(6.9)	(9.5)	(10.1)	(14.3)	(16.6)
D25B	23.6	27.6	32.4	34.0	38.4
	(10.9)	(12.7)	(14.9)	(15.6)	(17.7)
30B	12.1	13.8	19.1	27.9	33.7
	(6.0)	(6.9)	(9.5)	(13.9)	(16.8)
D30B	21.8	29.2	36.6	38.4	41.9
	(10.9)	(14.5)	(18.2)	(19.1)	(20.9)

Table 6 (cont.) Development of Splitting Tensile Strength with Age.

SPLITTING TENSILE STRENGTH (ksc.)					
MIX	AGE (days)				
CODE	1	2	3	7	28
35B	14.6	17.0	21.8	31.8	33.7
	(8.2)	(9.5)	(12.2)	(17.8)	(18.8)
D35B	24.9	28.7	37.9	40.3	42.8
	(13.9)	(16.0)	(21.2)	(22.5)	(23.9)
30C	11.7	15.4	18.8	32.6	38.2
	(6.9)	(9.1)	(11.1)	(19.3)	(22.6)
D30C	20.2	24.9	31.0	35.0	41.6
	(11.9)	(14.7)	(18.3)	(20.7)	(24.6)

Table 7 Development of Modulus of Rupture with Age.

MODULUS OF RUPTURE (ksc.)					
MIX CODE	AGE (days)				
	1	2	3	7	28
30A	15.9 (6.7)	18.0 (7.6)	24.3 (10.2)	33.3 (14.0)	37.8 (15.9)
D30A	24.2 (10.2)	32.9 (13.8)	34.5 (14.5)	40.4 (17.0)	44.7 (18.8)
25B	17.3 (8.0)	21.5 (9.9)	24.3 (11.2)	33.1 (15.2)	39.6 (18.2)
D25B	28.4 (13.1)	34.2 (15.7)	40.1 (18.4)	45.2 (20.8)	46.5 (21.4)
30B	15.0 (7.5)	18.0 (9.0)	20.7 (10.3)	32.3 (16.1)	39.3 (19.6)
D30B	25.4 (12.7)	36.5 (18.2)	41.1 (20.5)	43.2 (21.5)	46.8 (23.3)

Table 7 (cont.) Development of Modulus of Rupture with Age.

MODULUS OF RUPTURE (ksc.)					
MIX	AGE (days)				
CODE	1	2	3	7	28
35B	20.7 (11.6)	22.4 (12.5)	24.8 (13.8)	32.3 (18.0)	38.1 (21.3)
D35B	26.4 (14.7)	32.2 (18.0)	38.6 (21.5)	43.2 (24.1)	47.6 (26.6)
30C	15.5 (9.2)	16.7 (9.9)	22.4 (13.2)	33.6 (19.9)	40.1 (23.7)
D30C	23.0 (13.6)	26.6 (15.7)	35.9 (21.2)	39.0 (23.1)	42.3 (25.0)

Table 8 Development of Compressive Strength with Age

(under Curing Conditions)

COMPRESSIVE STRENGTH (ksc.)			
MIX CODE	AGE (days)		
	3	7	28
30A	147.5	206.3	238.3
30AW	181.7	219.2	257.1
D30A	193.8	248.8	270.0
D30AW	219.6	274.2	323.3
25B	147.9	182.5	217.5
25BW	154.2	204.4	220.8
D25B	186.3	217.1	250.4
D25BW	207.9	233.8	267.5
30B	141.9	169.2	200.8
30BW	153.8	183.8	211.7
D30B	156.7	193.8	275.8
D30BW	200.0	232.1	293.3

Table 8 (cont.) Development of Compressive Strength with Ag

(under Curing Conditions)

MIX CODE	COMPRESSIVE STRENGTH (ksc.) AGE (days) 3	7	28
35B	122.0	162.1	179.2
35BW	162.1	181.7	213.3
D35B	184.6	249.6	293.3
D35BW	190.8	251.3	323.3
30C	125.4	155.4	169.2
30CW	138.3	169.2	181.7
D30C	188.8	217.5	256.6
D30CW	192.5	227.9	308.3

Table 9 Development of Splitting Tensile Strength with Age (under Curing Conditions)

MIX CODE	SPLITTING TENSILE STRENGTH (ksc.) AGE (days) 3	7	28
30A	23.6	31.6	36.3
30AW	24.7	32.6	42.7
D30A	31.3	36.3	42.5
D30AW	35.5	48.5	49.2
25B	22.0	31.0	36.1
25BW	28.1	32.4	41.4
D25B	32.4	34.0	38.4
D25BW	38.7	41.7	42.7
30B	19.1	27.9	33.7
30BW	25.5	28.7	43.0
D30B	36.6	38.4	41.9
D30BW	38.2	45.6	47.1

Table 9 (cont.) Development of Splitting Tensile Strength with Age (under Curing Conditions)

MIX CODE	SPLITTING TENSILE STRENGTH (ksc.) AGE (days) 3	7	28
35B	21.8	31.8	33.7
35BW	23.9	32.6	40.3
D35B	37.9	40.3	42.8
D35BW	38.5	41.4	49.1
30C	18.8	32.6	38.2
30CW	31.3	38.2	41.4
D30C	31.0	35.0	41.6
D30CW	34.0	44.8	45.9

Table 10 Development of Modulus of Rupture with Age

(under Curing Conditions)

MIX CODE	MODULUS OF RUPTURE (ksc.) AGE (days) 3	7	28
30A	24.3	33.3	37.8
30AW	27.3	37.3	42.9
D30A	34.5	40.4	44.7
D30AW	37.1	49.4	52.4
25B	24.3	33.1	39.6
25BW	29.9	41.4	46.7
D25B	40.1	45.2	46.5
D25BW	40.4	45.9	47.6
30B	20.7	32.3	39.3
30BW	28.5	36.2	44.7
D30B	41.1	43.2	46.8
D30BW	42.0	46.7	47.3

Table 10 (cont.) Development of Modulus of Rupture with Age (under Curing Conditions)

MODULUS OF RUPTURE (ksc.)			
MIX CODE	AGE (days)		
	3	7	28
35B	24.8	32.3	38.1
35BW	26.3	33.2	42.6
D35B	38.6	43.2	47.6
D35BW	41.1	45.2	49.4
30C	22.4	33.6	40.1
30CW	33.1	38.4	41.7
D30C	35.9	39.0	42.3
D30CW	37.8	46.7	48.2

Table 11 Summary of the Ultimate Strength

MIX CODE	f'_c (ksc.)	f'_t (ksc.)	f'_r (ksc.)	f'_t (% of f'_c)	f'_r (% of f'_c)
30A	238.3	36.6	37.8	15.2	15.9
30AW	257.1	42.7	42.9	16.6	16.7
D30A	270.0	42.5	44.7	15.7	16.6
D30AW	323.3	49.2	52.4	15.2	16.2
25B	217.5	36.1	39.6	16.6	18.2
25BW	220.8	41.4	46.7	18.8	21.2
D25B	250.4	38.4	46.5	15.3	18.6
D25BW	267.5	42.7	47.6	16.0	17.8
30B	200.8	33.7	39.3	16.8	19.6
30BW	211.7	43.5	44.7	20.6	21.1
D30B	275.8	41.9	46.8	15.2	17.0
D30BW	293.3	47.1	47.3	16.1	16.1

Table 11 (cont.) Summary of the Ultimate Strength

MIX CODE	f'_c (ksc.)	f'_t (ksc.)	f'_r (ksc.)	f'_t (% of f'_c)	f'_r (% of f'_c)
35B	179.2	33.7	38.1	18.8	21.3
35BW	213.3	40.3	42.6	18.6	20.0
D35B	293.3	42.8	47.6	14.6	16.2
D35BW	323.3	49.1	49.4	15.2	15.3
30C	169.2	38.2	40.1	22.6	23.7
30CW	181.7	41.4	41.7	22.8	23.0
D30C	256.6	41.6	42.3	16.2	16.5
D30CW	308.3	45.9	48.2	14.9	15.6

Table 12 Summary of Secant Modulus of Elasticity at 50-ksc. Compressive Stress

MIX CODE	ULTIMATE COMPRESSIVE STRENGTH (ksc.)	COMPRESSIVE STRAIN at 50 ksc. ($*10^{-6}$)	SECANT MODULUS OF ELASTICITY (ksc.)
30AW	250	195	256,400
D30AW	315	180	277,800
25BW	215	230	217,400
D25BW	280	205	243,900
30BW	205	235	212,800
D30BW	300	185	270,300
35BW	215	220	227,300
D35BW	295	200	250,000
30CW	170	260	192,300
D30CW	320	190	263,200

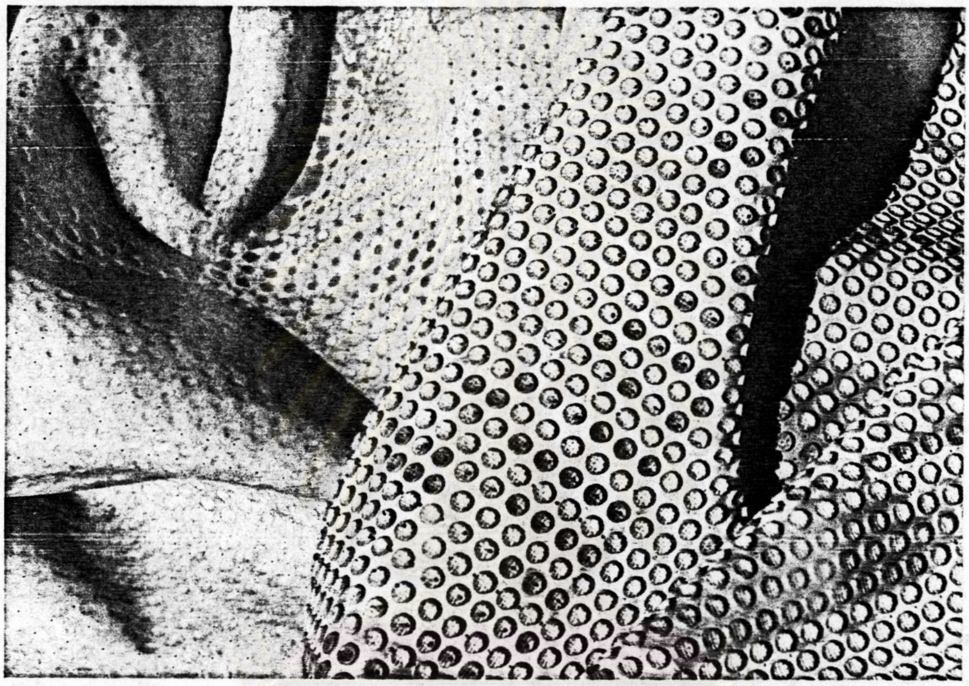


Fig. 1 The Filter Pad

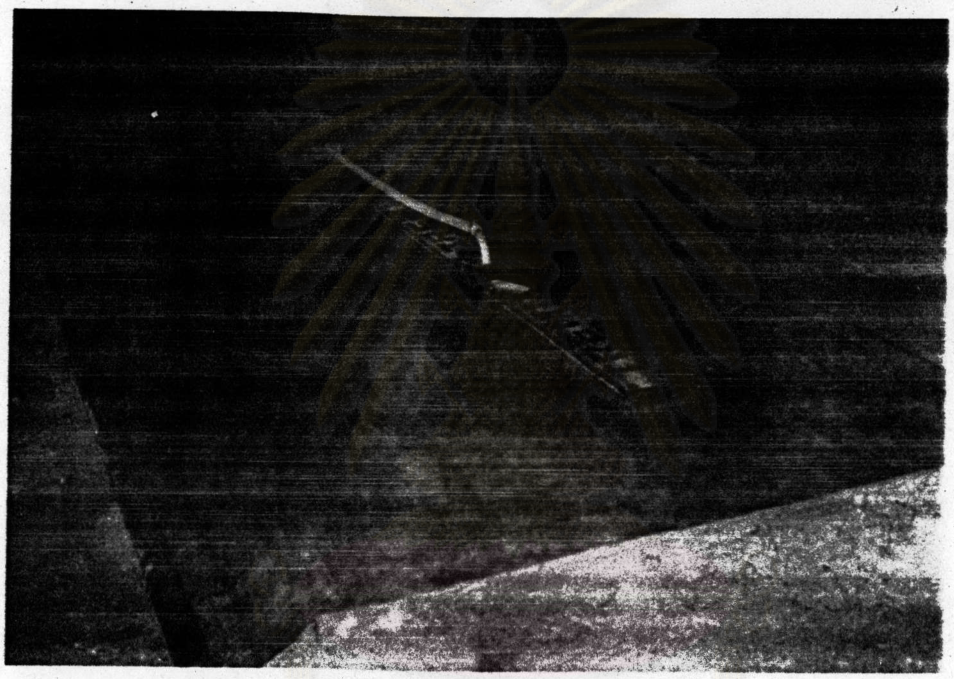


Fig. 2 The Top Cover Connected with the Manifold

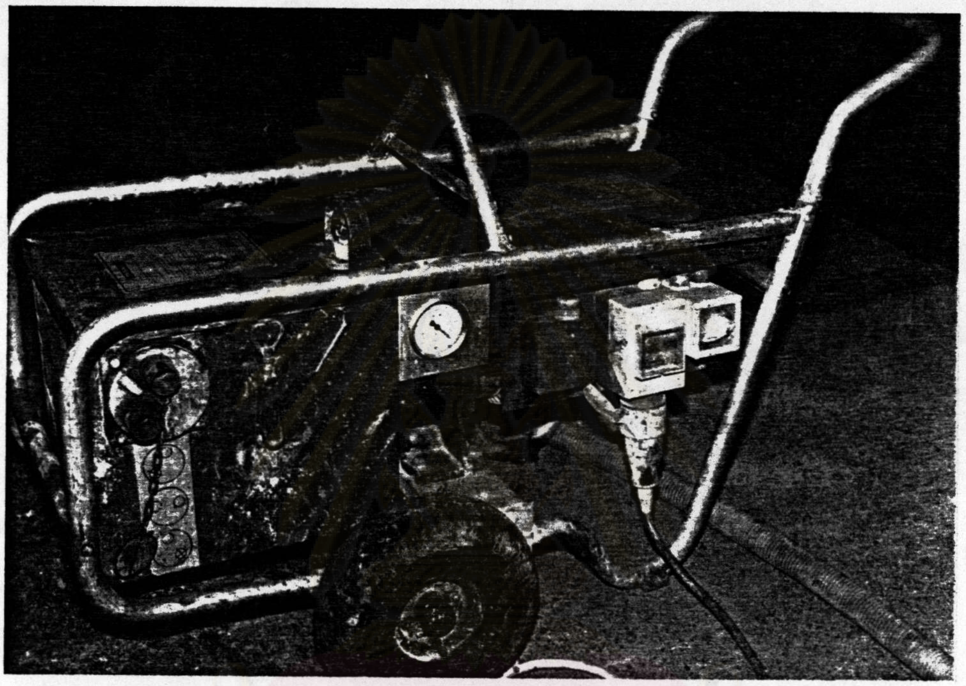


Fig. 3 The Vacuum Pump Unit

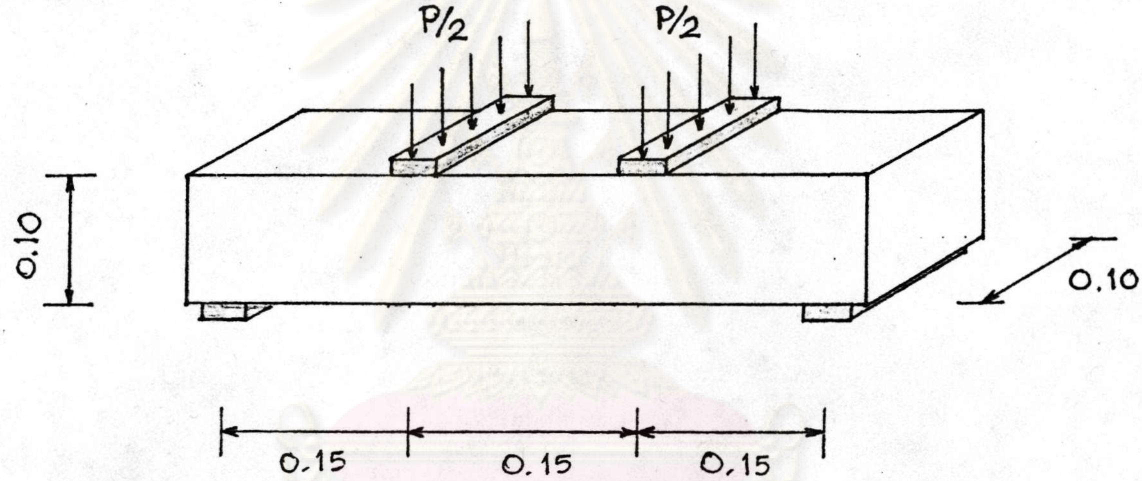


Fig. 4 Schematic Diagram of Test Setup for Modulus of Rupture

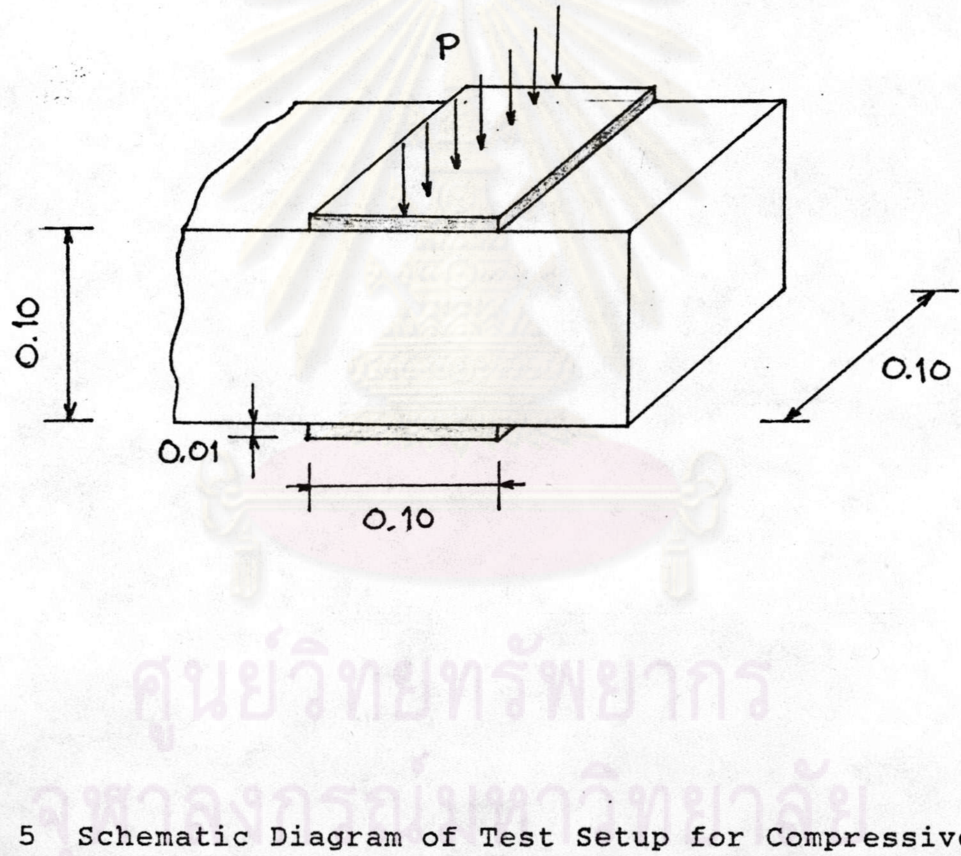


Fig. 5 Schematic Diagram of Test Setup for Compressive Strength

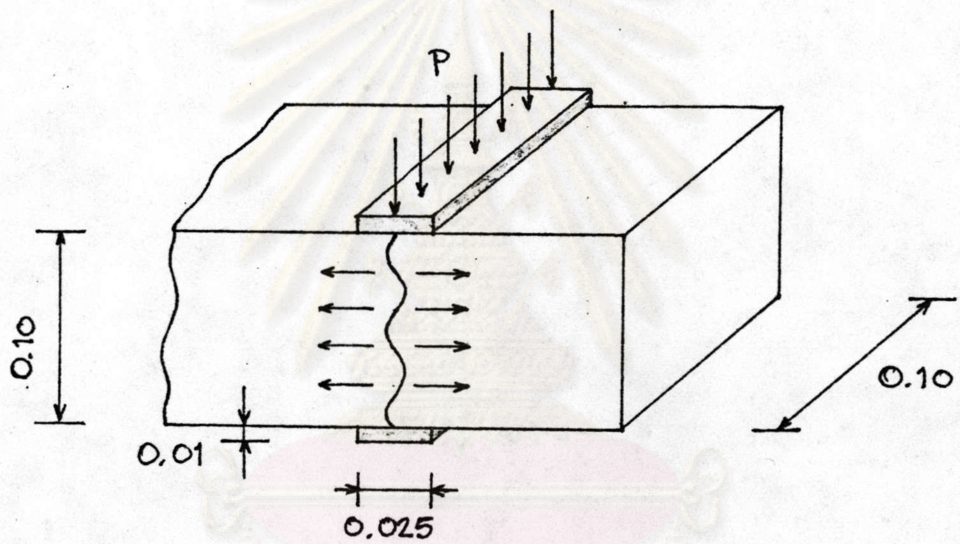


Fig. 6 Schematic Diagram of Test Setup for Splitting Tensile Strength

Fig. 7 Typical Arrangement of Pre-fabricated Formwork for Each Mix

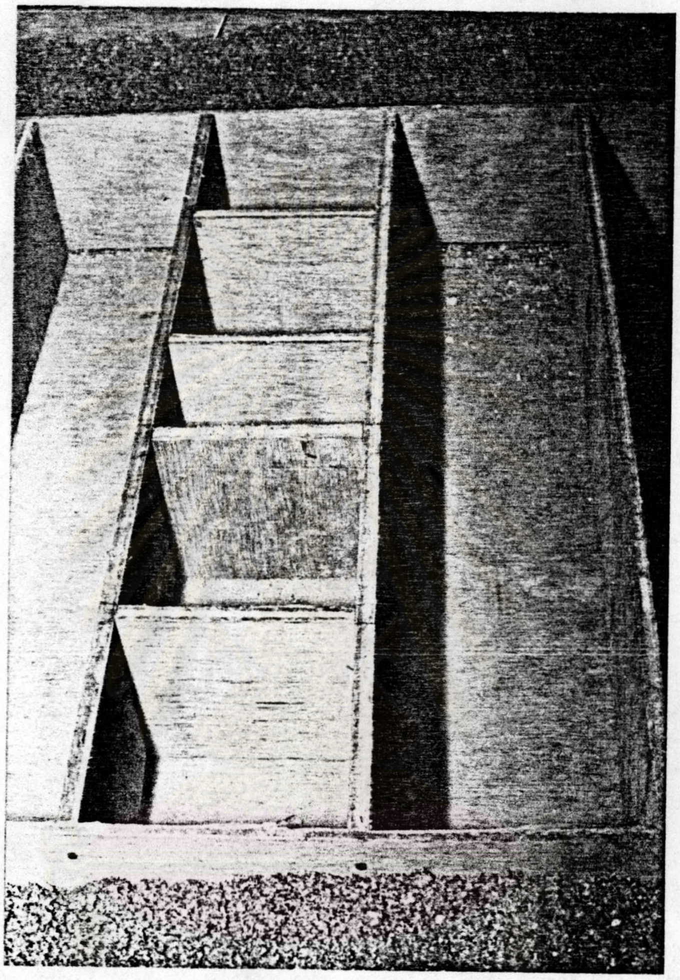


Fig. 8 Detail of the Cube Specimen Formwork

Fig. 9 The Filter Pad Being Laid Over the Concrete Surface

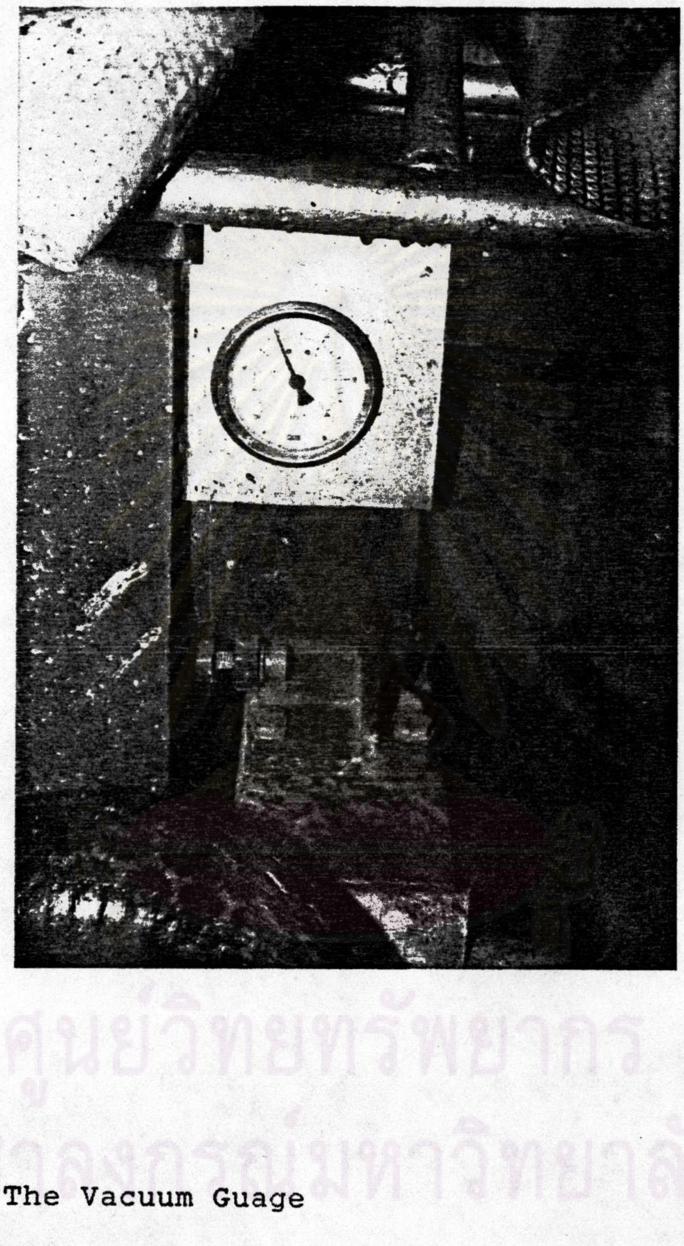


Fig. 10 The Vacuum Guage

Fig. 11 The Water Extracted

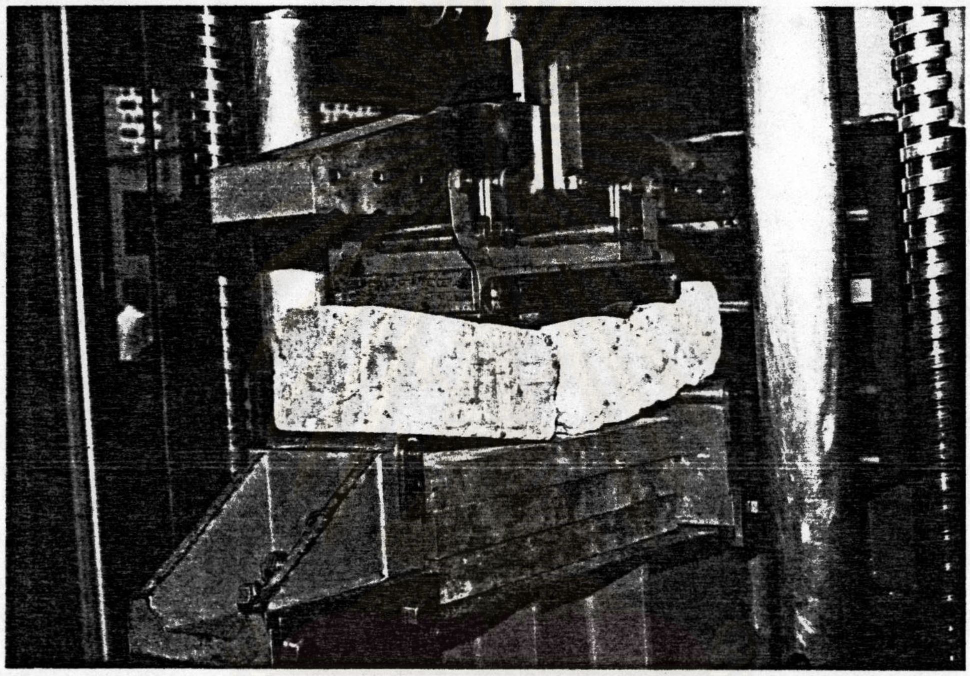


Fig. 12 Test Setup for Modulus of Rupture

Fig. 13 Test Setup for Compressive Strength

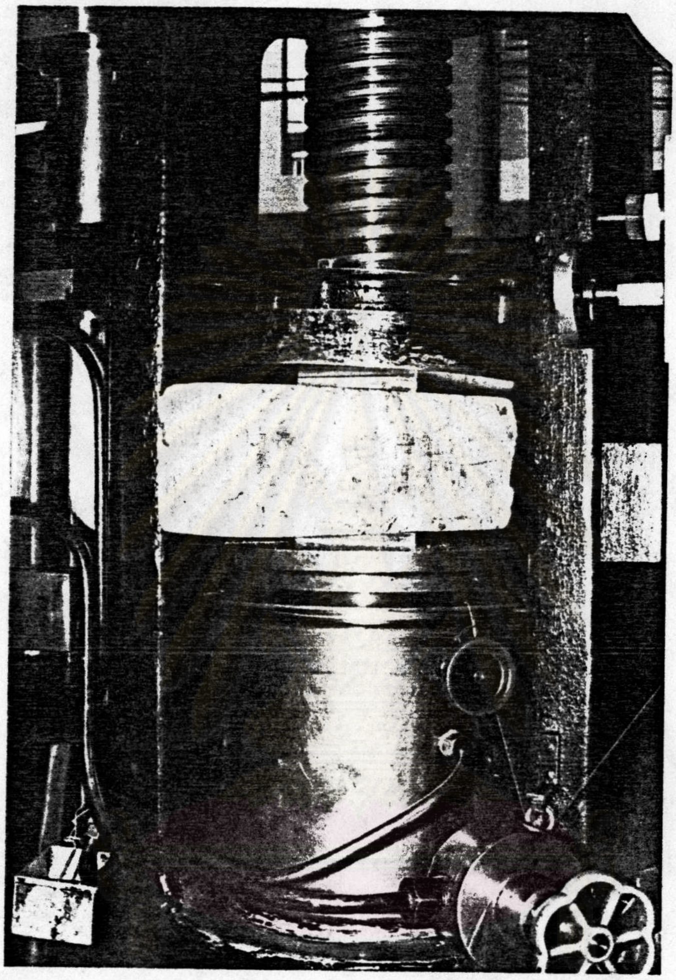


Fig. 14 Test Setup for Modulus of Rupture

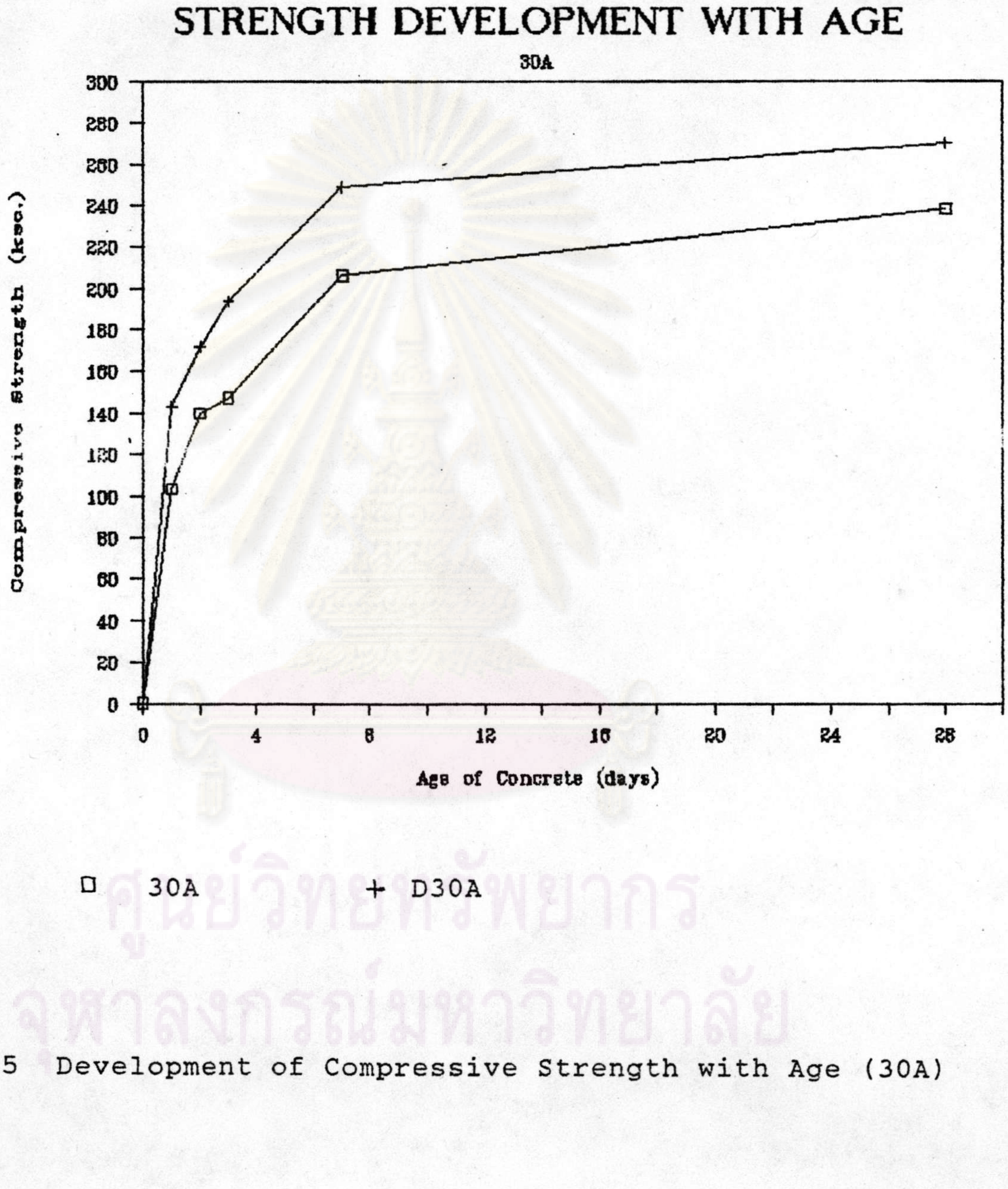


Fig. 15 Development of Compressive Strength with Age (30A)

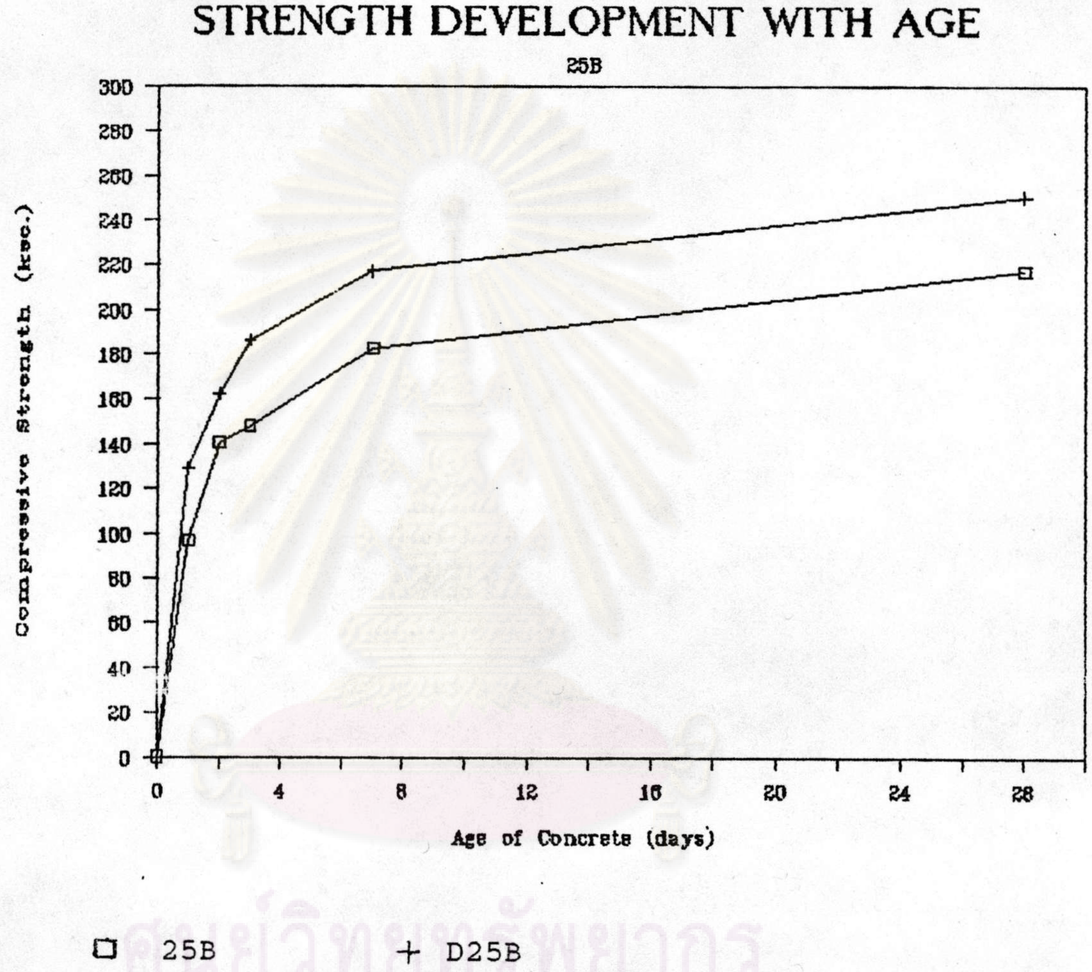


Fig. 16 Development of Compressive Strength with Age (25B)

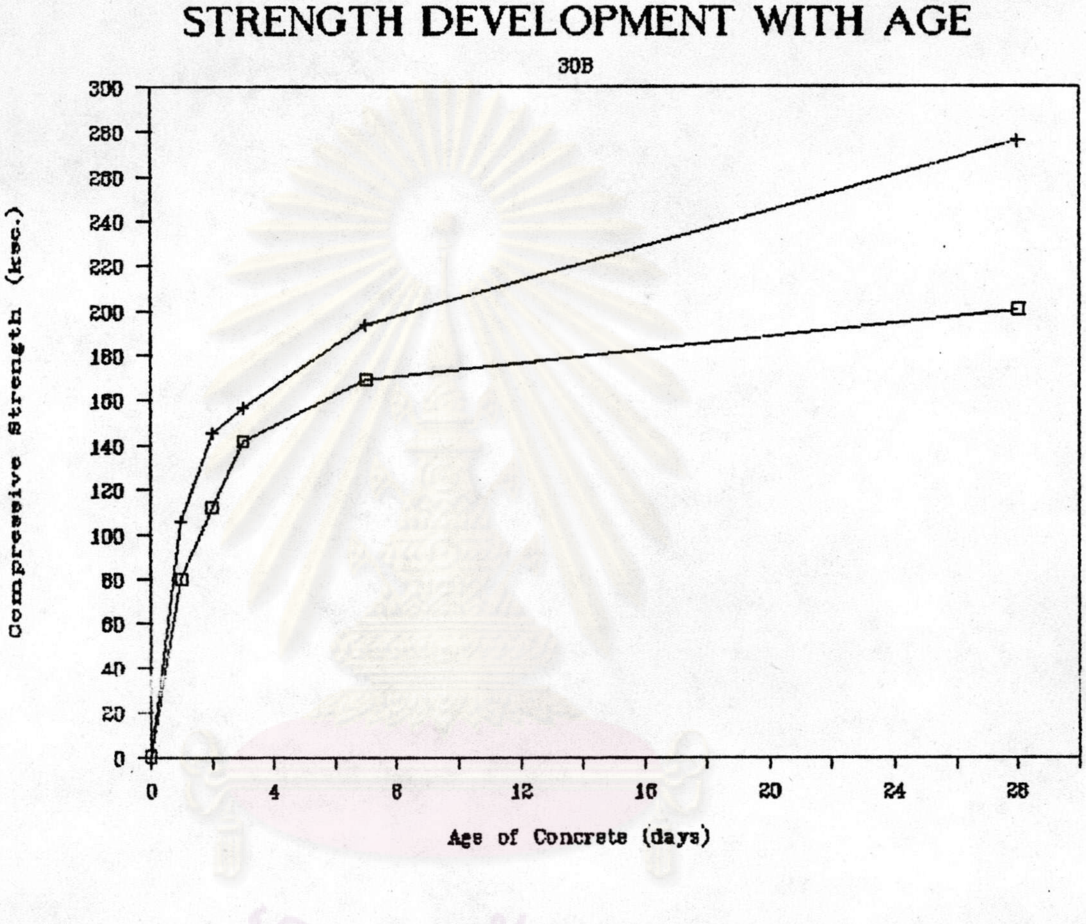


Fig. 17 Development of Compressive Strength with Age (30B)

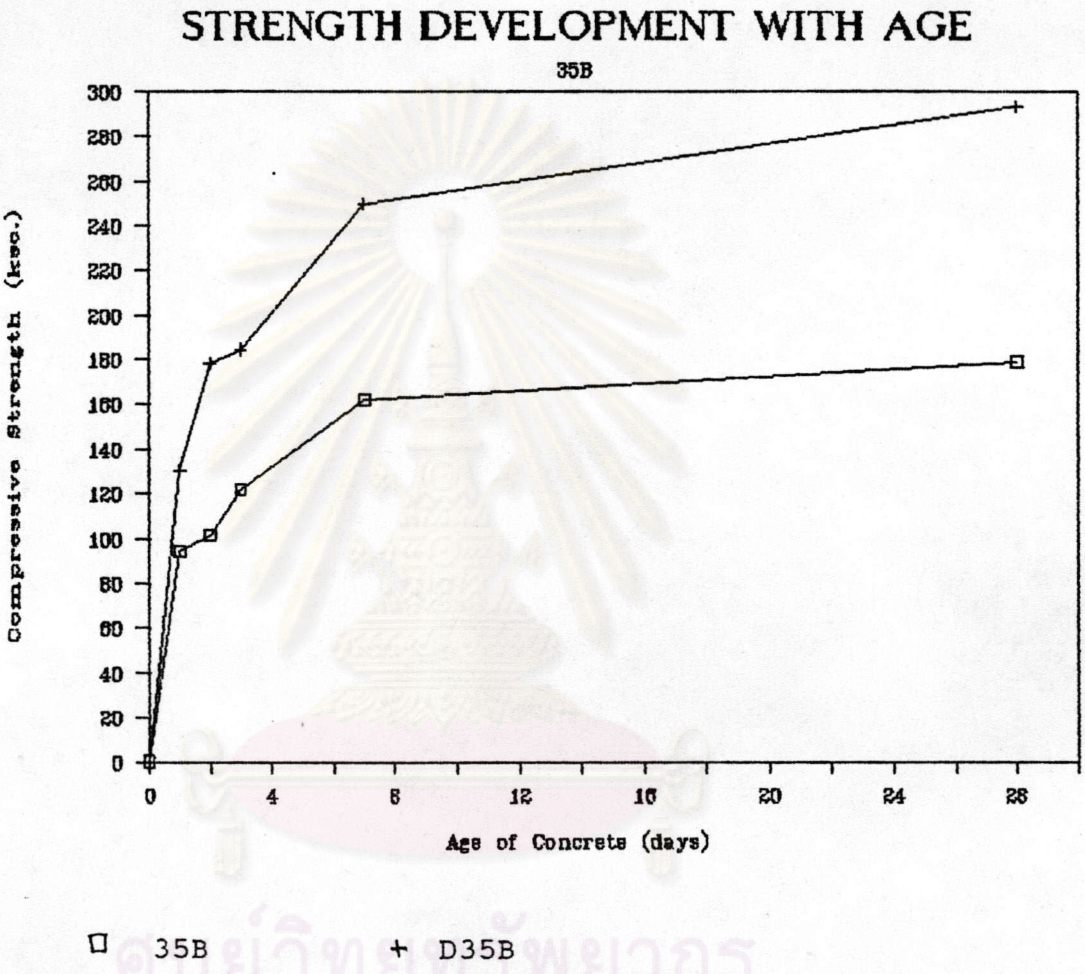


Fig. 18 Development of Compressive Strength with Age (35B)

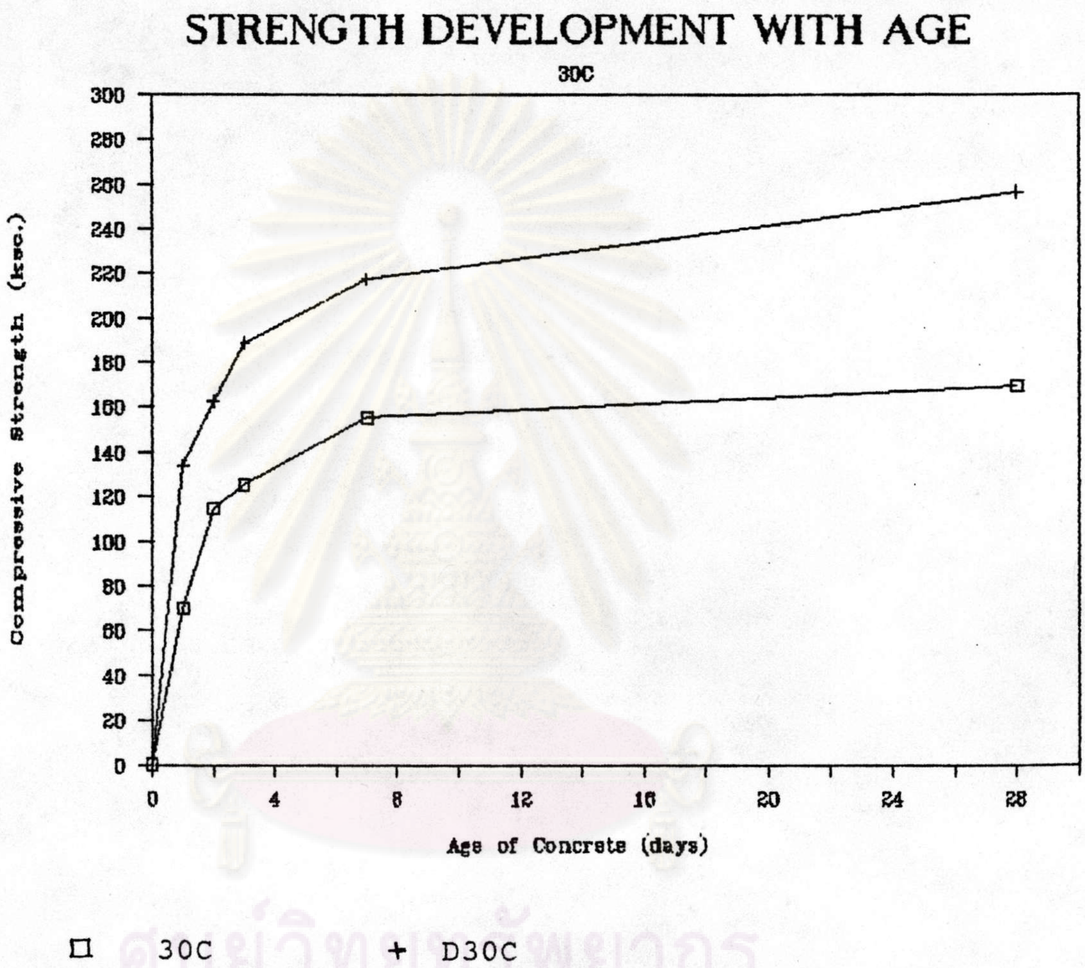
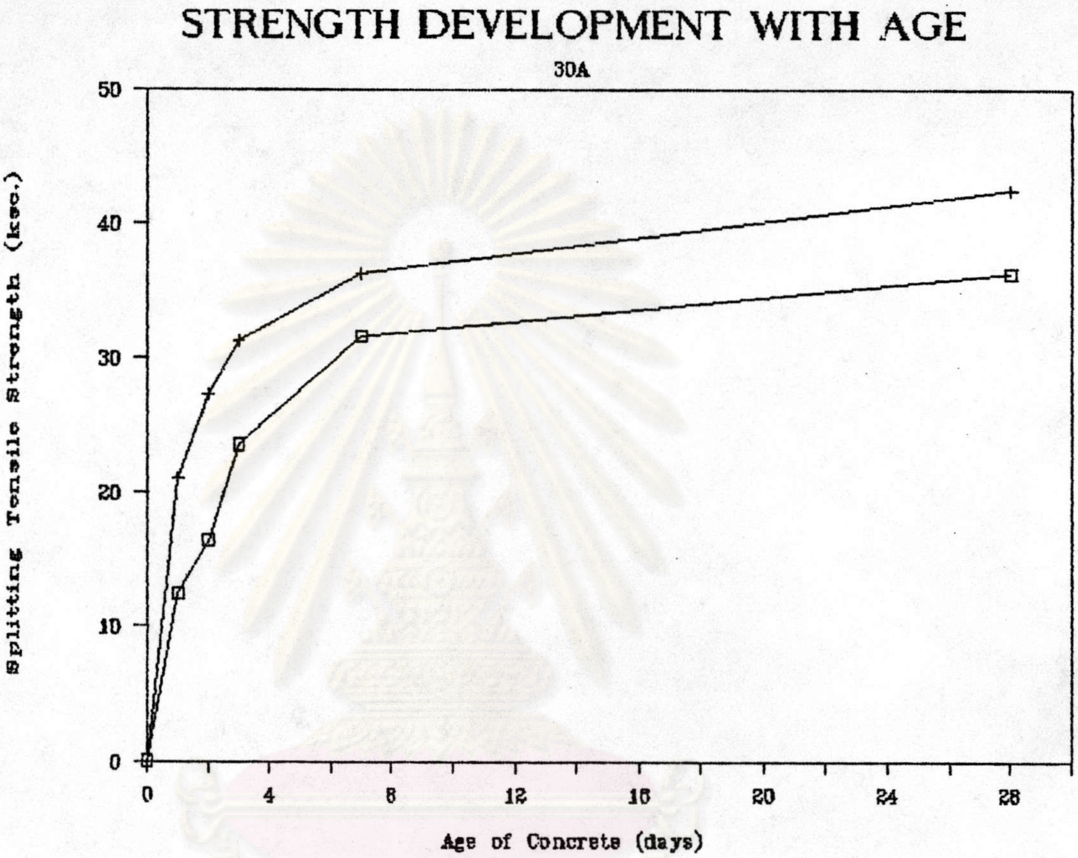


Fig. 19 Development of Compressive Strength with Age (30C)



□ 30A + D30A

Fig. 20 Development of Splitting Tensile Strength with Age (30A)

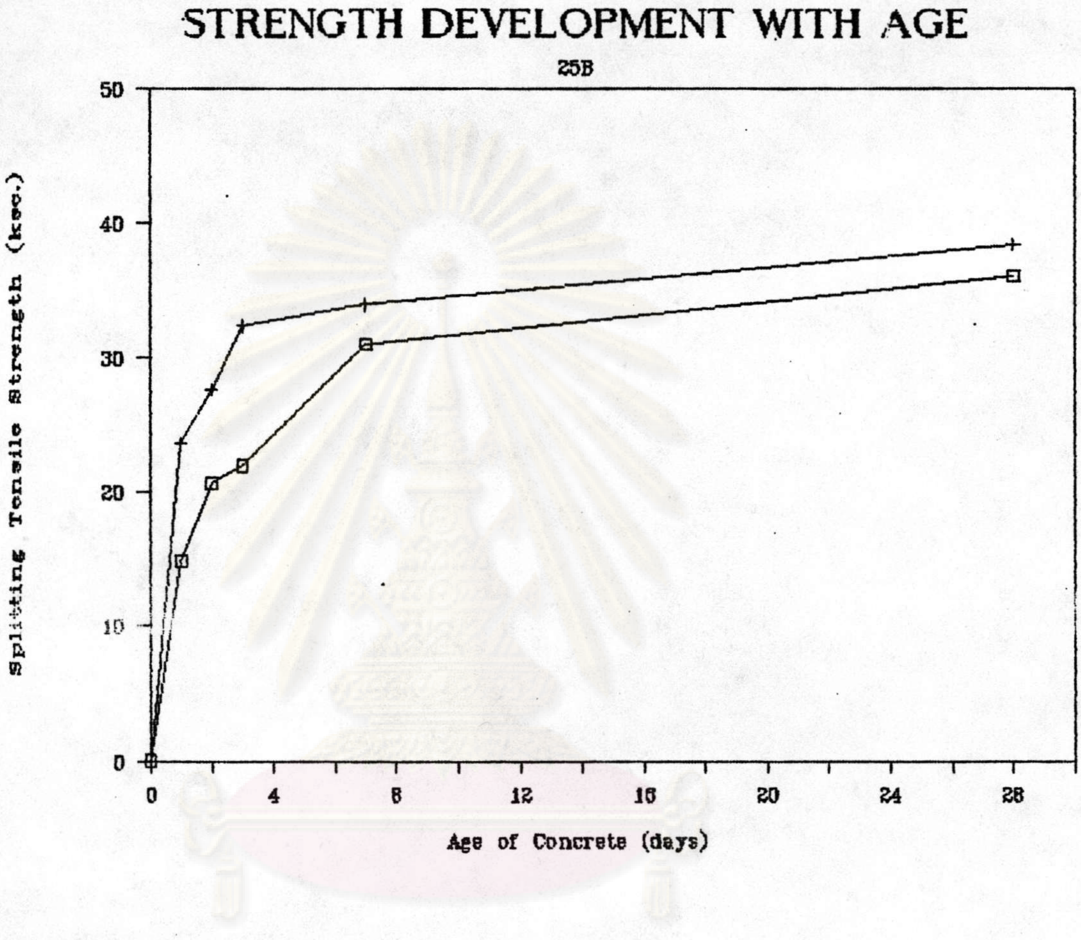


Fig. 21 Development of Splitting Tensile Strength with Age (25B)

Fig. 22 Development of Splitting Tensile Strength with Age (30B)

Fig. 23 Development of Splitting Tensile Strength with Age (35B)

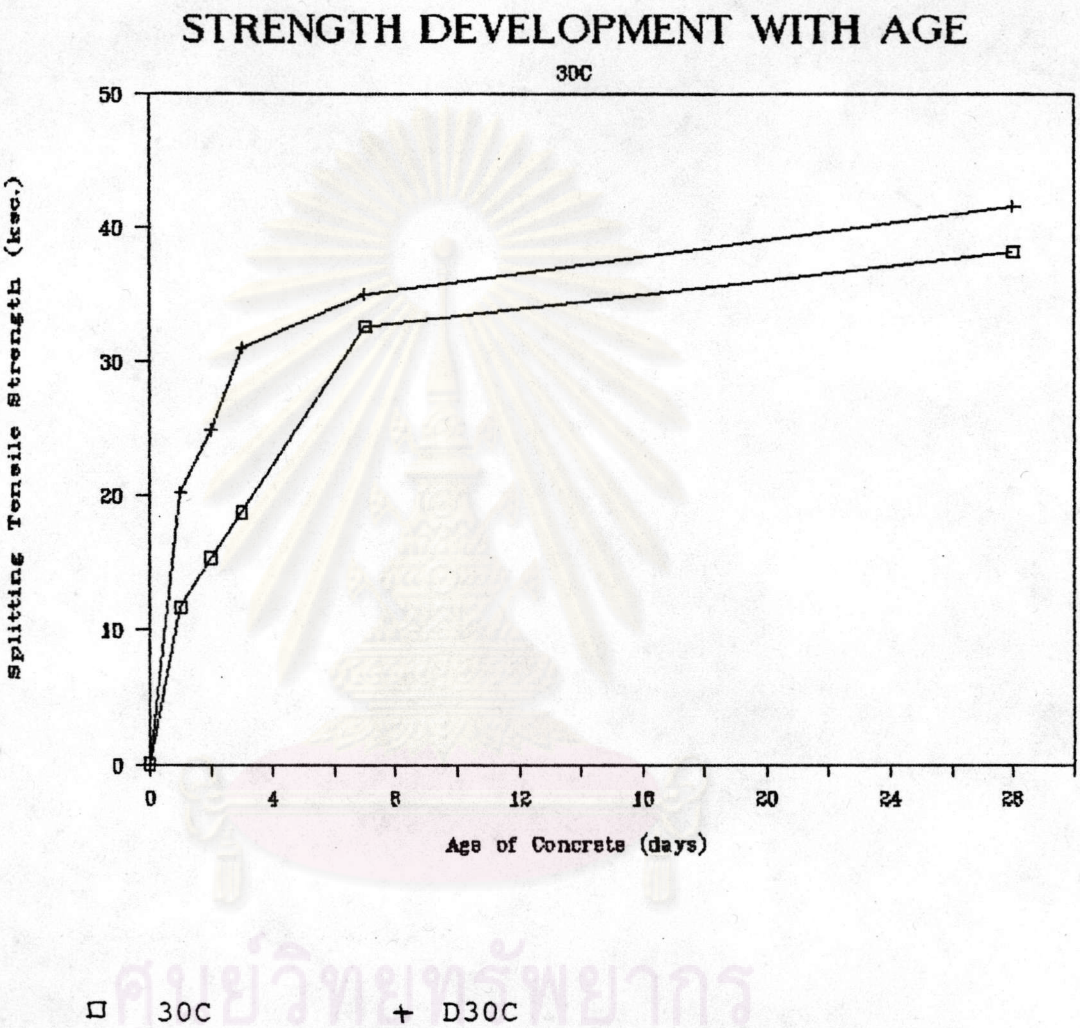


Fig. 24 Development of Splitting Tensile Strength with Age (30C)

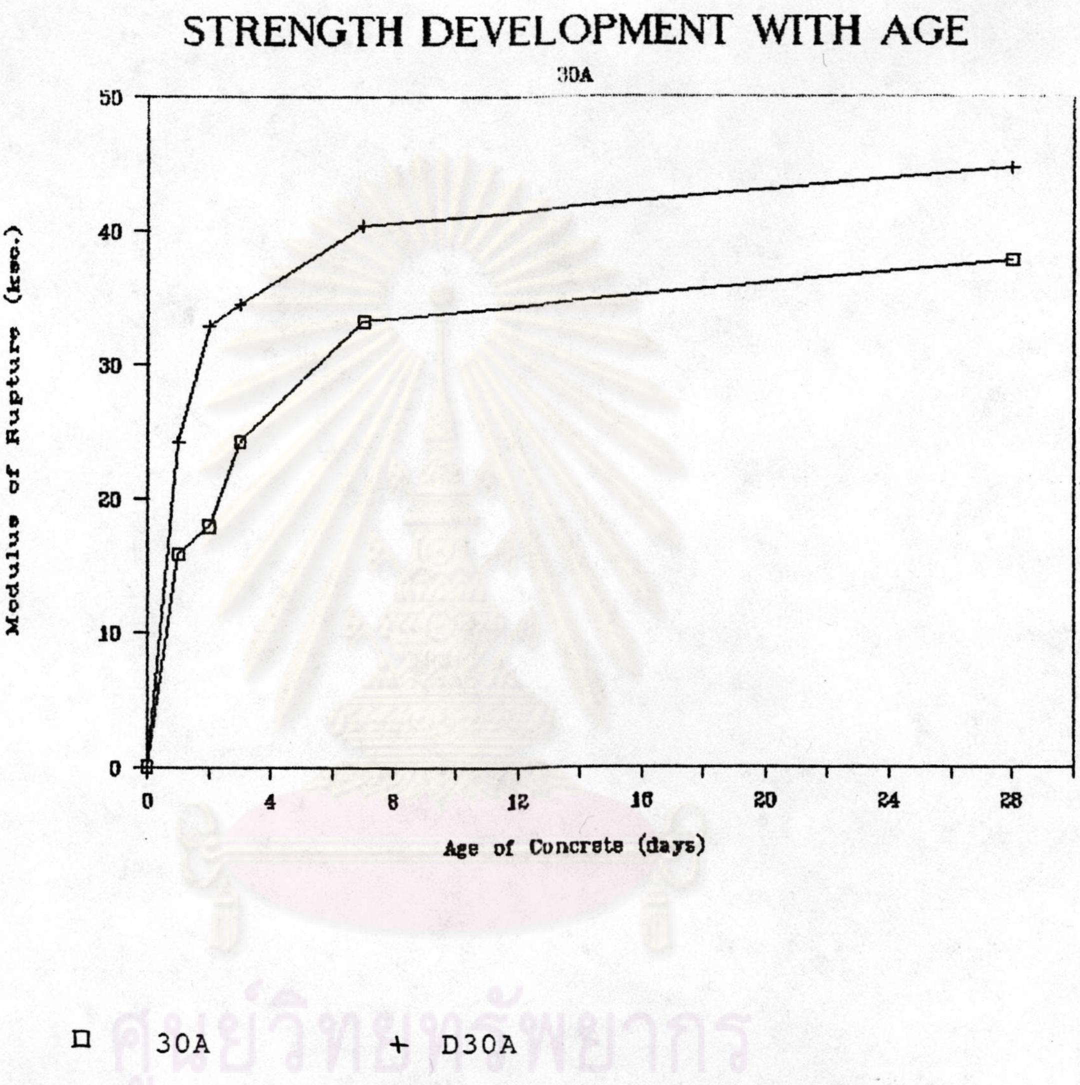
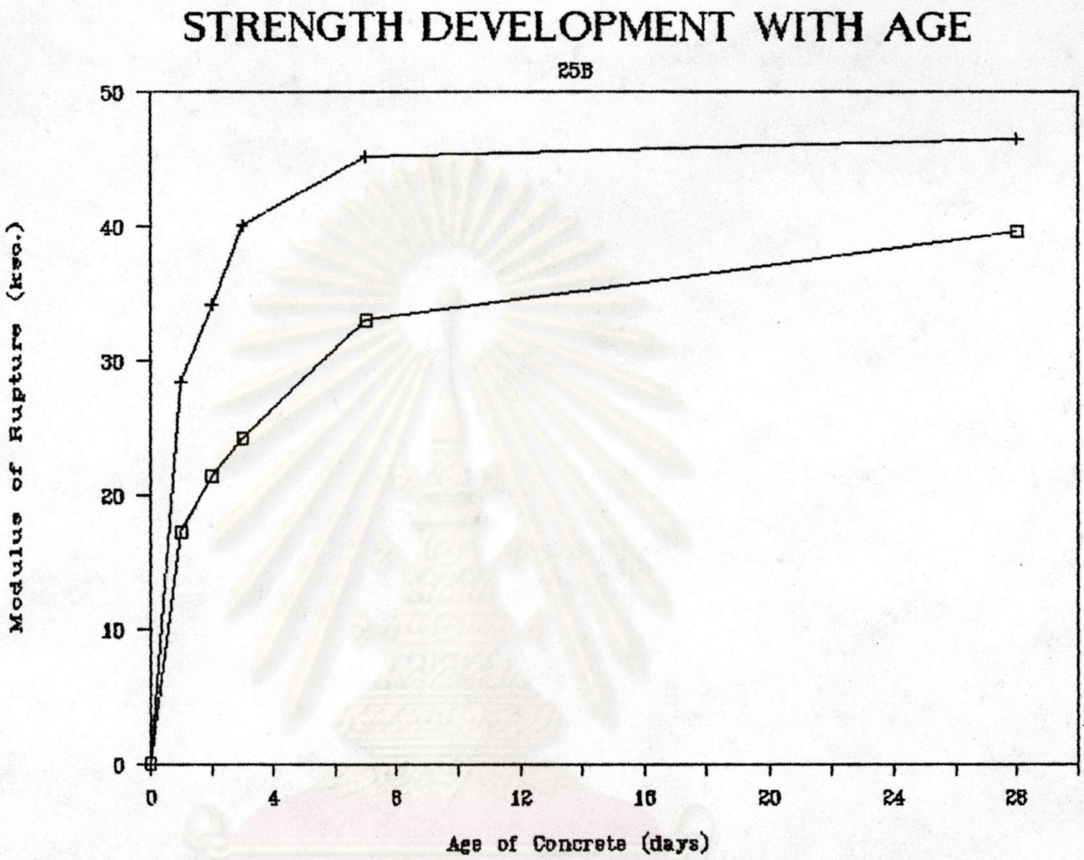


Fig. 25 Development of Modulus of Rupture with Age (30A)



□ 25B + D25B

Fig. 26 Development of Modulus of Rupture with Age (25B)

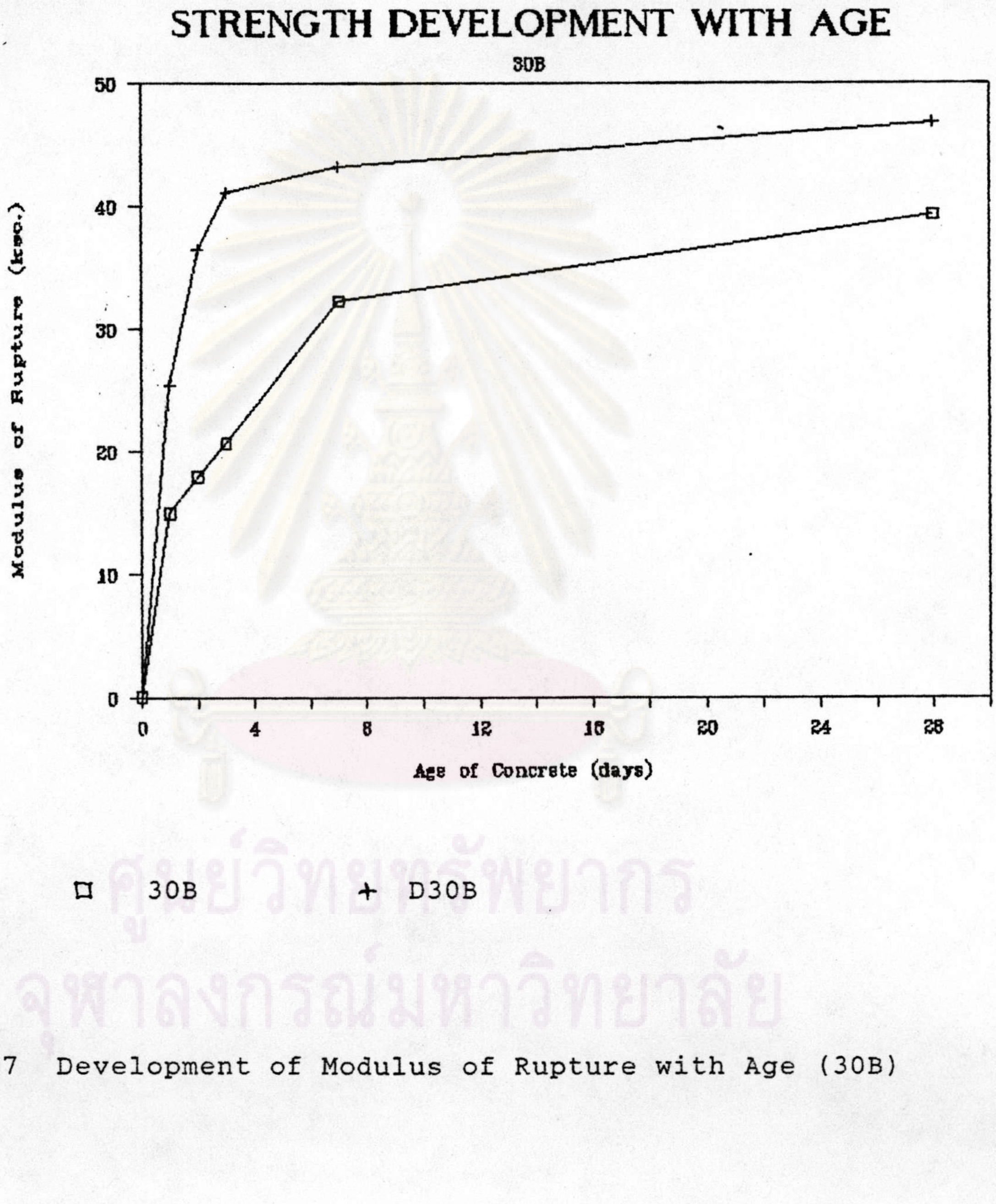


Fig. 27 Development of Modulus of Rupture with Age (30B)

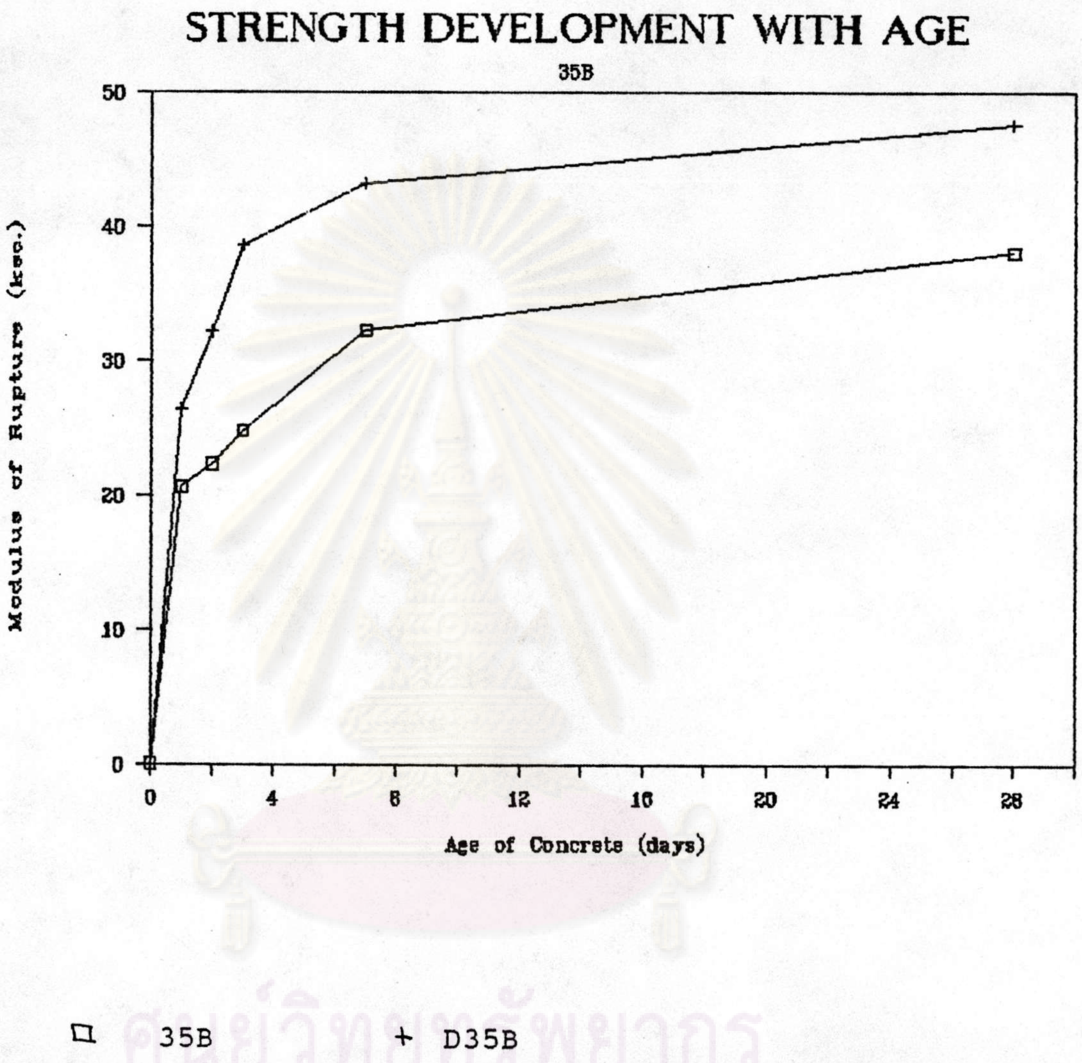
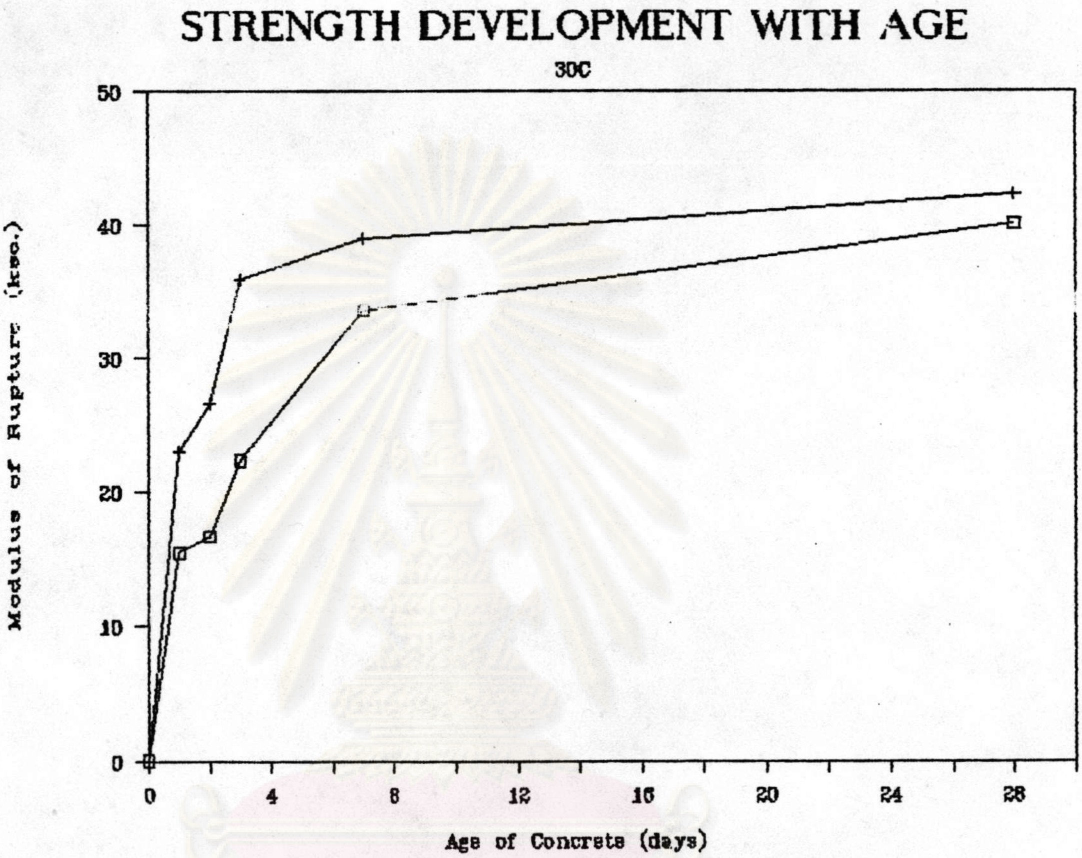


Fig. 28 Development of Modulus of Rupture with Age (35B)



□ 30C + D30C

Fig. 29 Development of Modulus of Rupture with Age (30C)

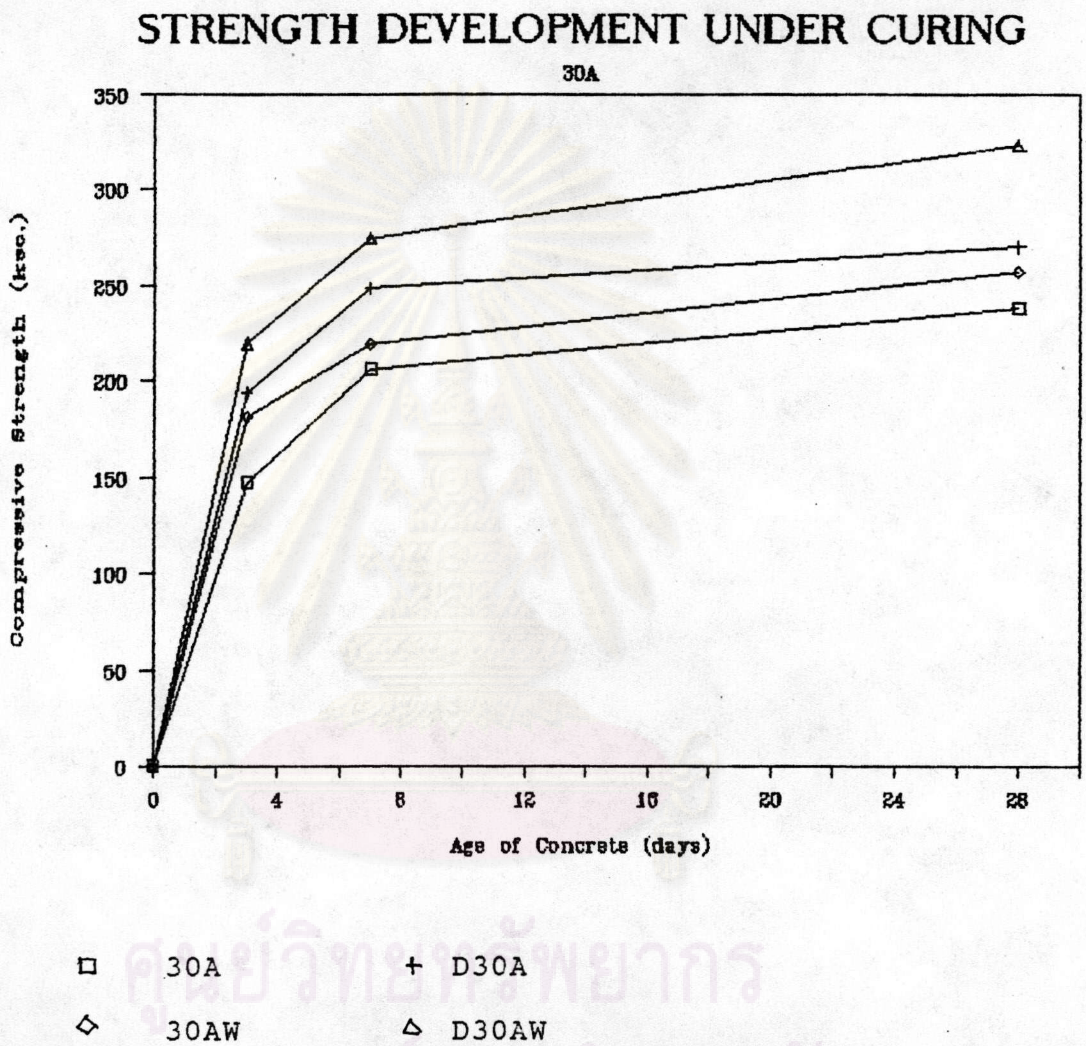
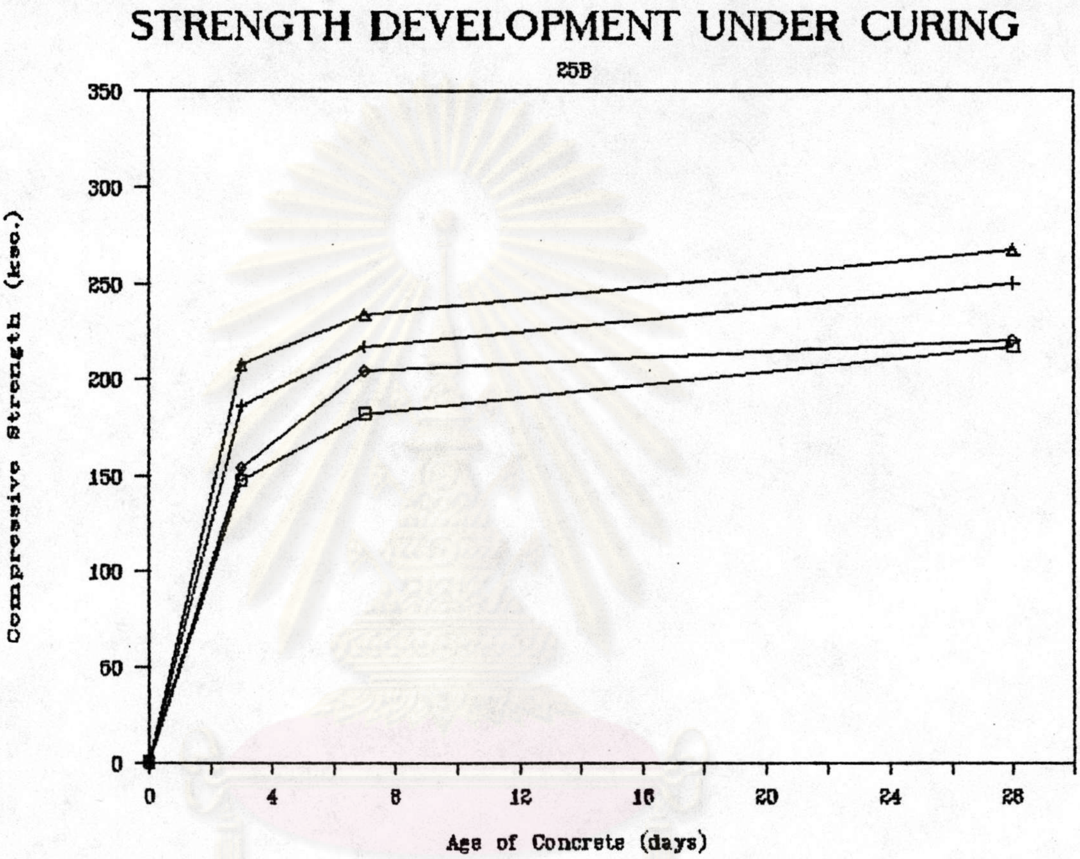


Fig. 30 Effect of Curing Condition on Compressive Strength Development with Age (30A)



□ 25B + D25B

◇ 25BW △ D25BW

Fig. 31 Effect of Curing Condition on Compressive Strength Development with Age (25B)

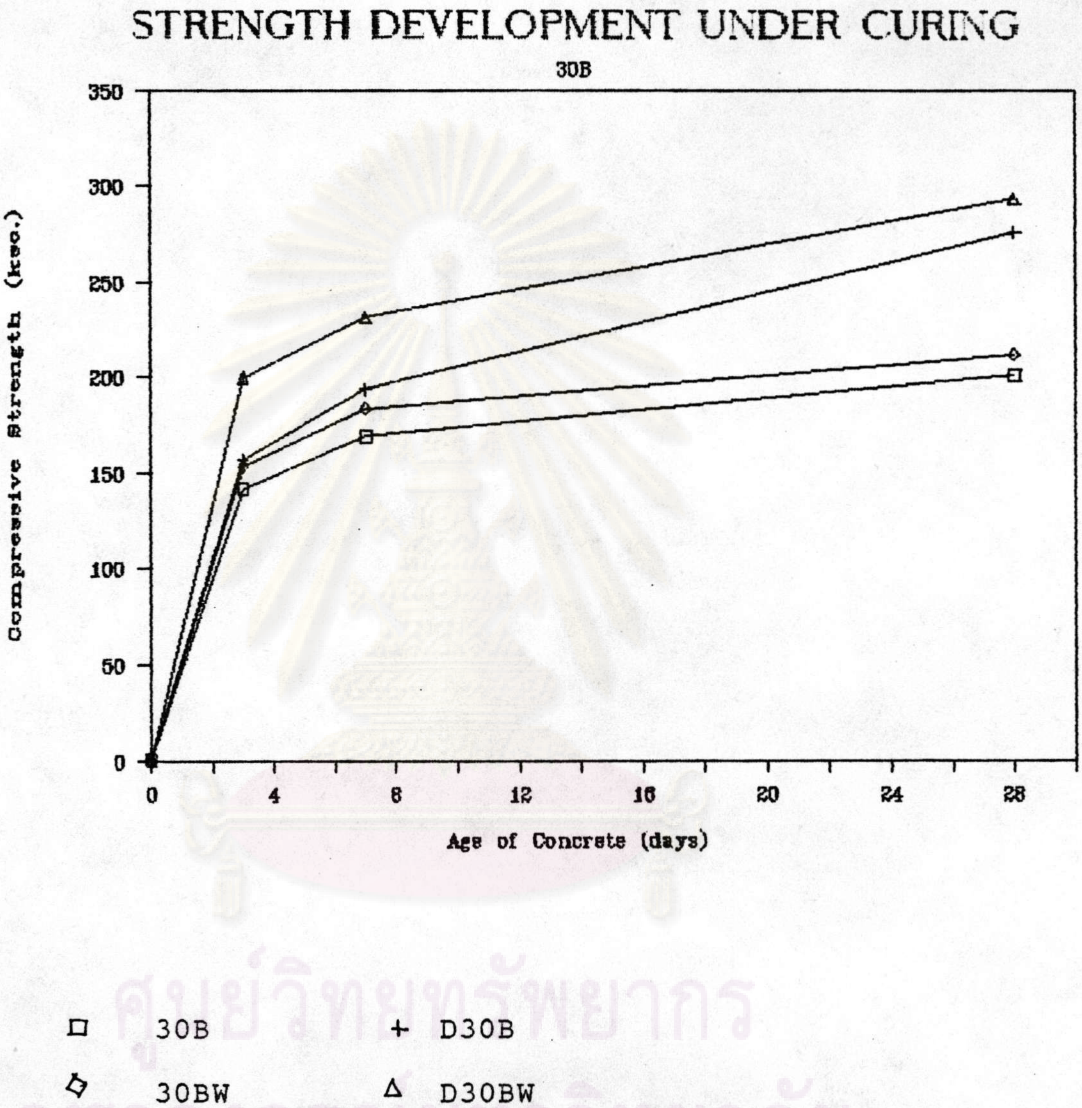
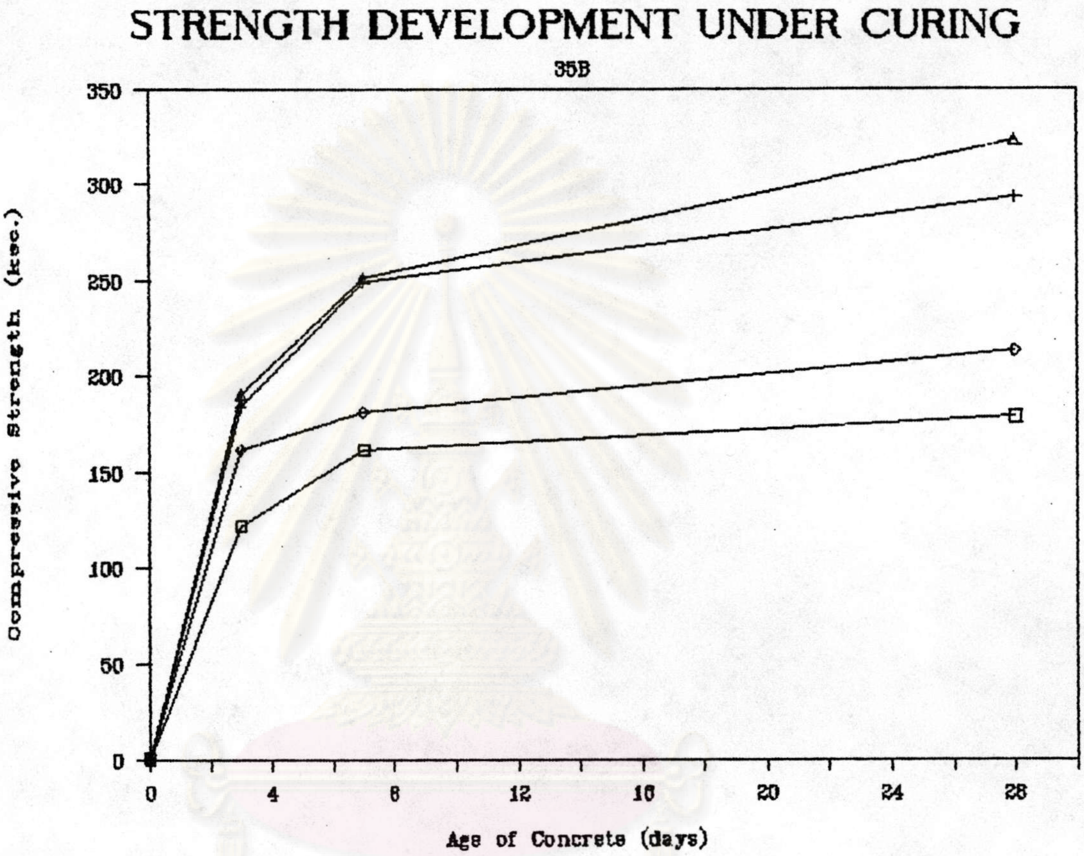


Fig. 32 Effect of Curing Condition on Compressive Strength Development with Age (30B)



□ 35B + D35B

◊ 35BW Δ D35BW

Fig. 33 Effect of Curing Condition on Compressive Strength Development with Age (35B)

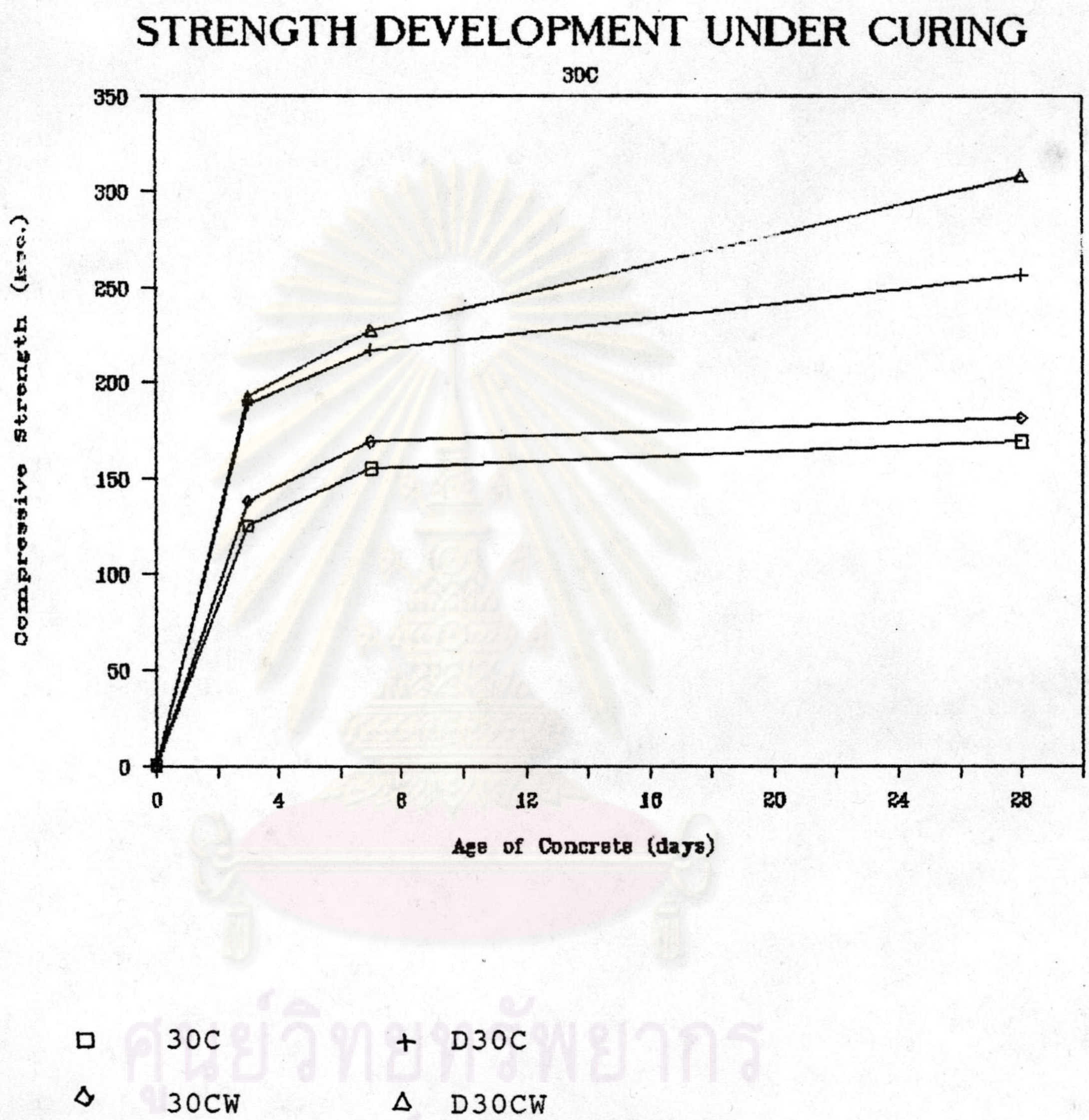
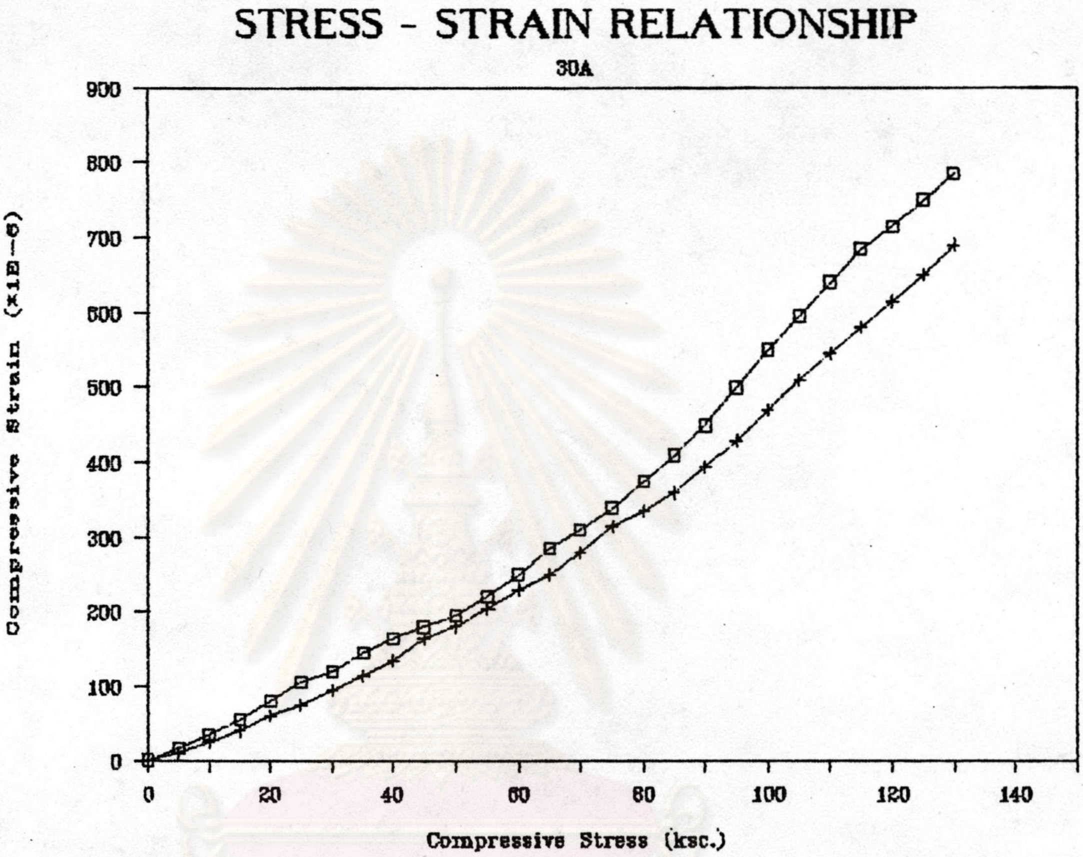
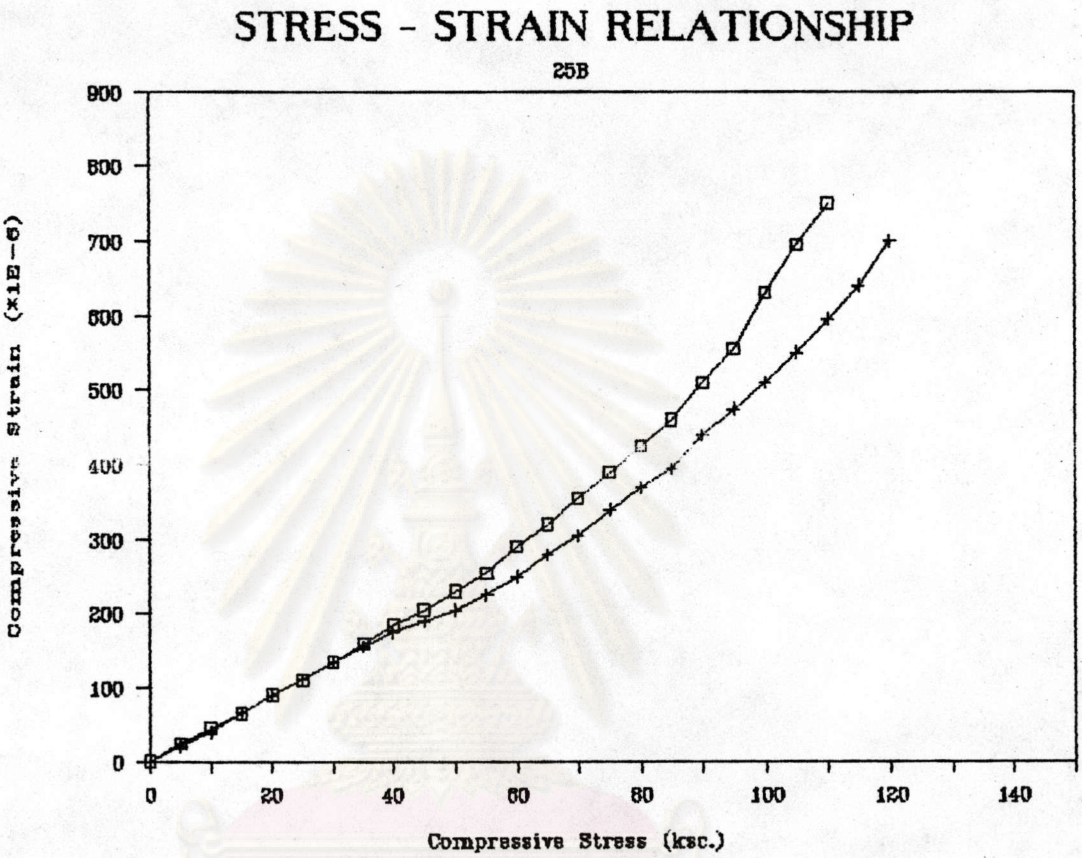


Fig. 34 Effect of Curing Condition on Compressive Strength Development with Age (30C)



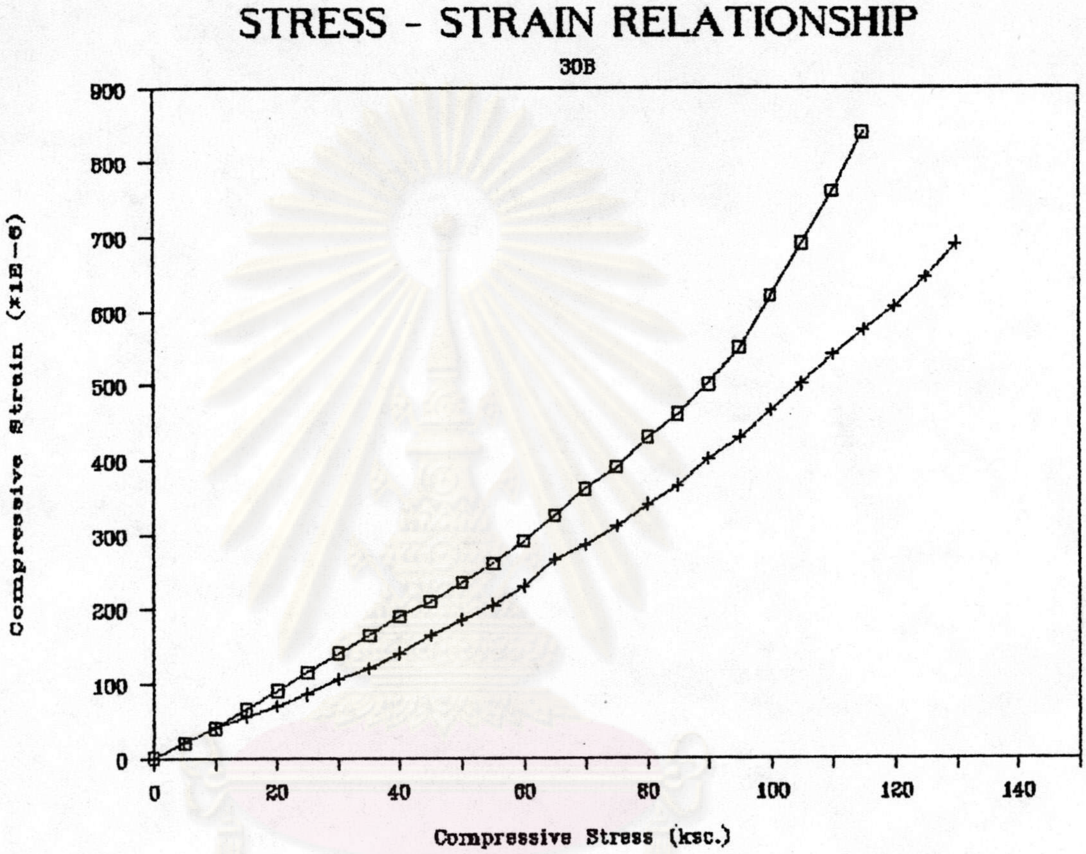
□ 30AW + D30AW

Fig. 35 Relationship between Compressive Stress and Compressive Strain (30A)



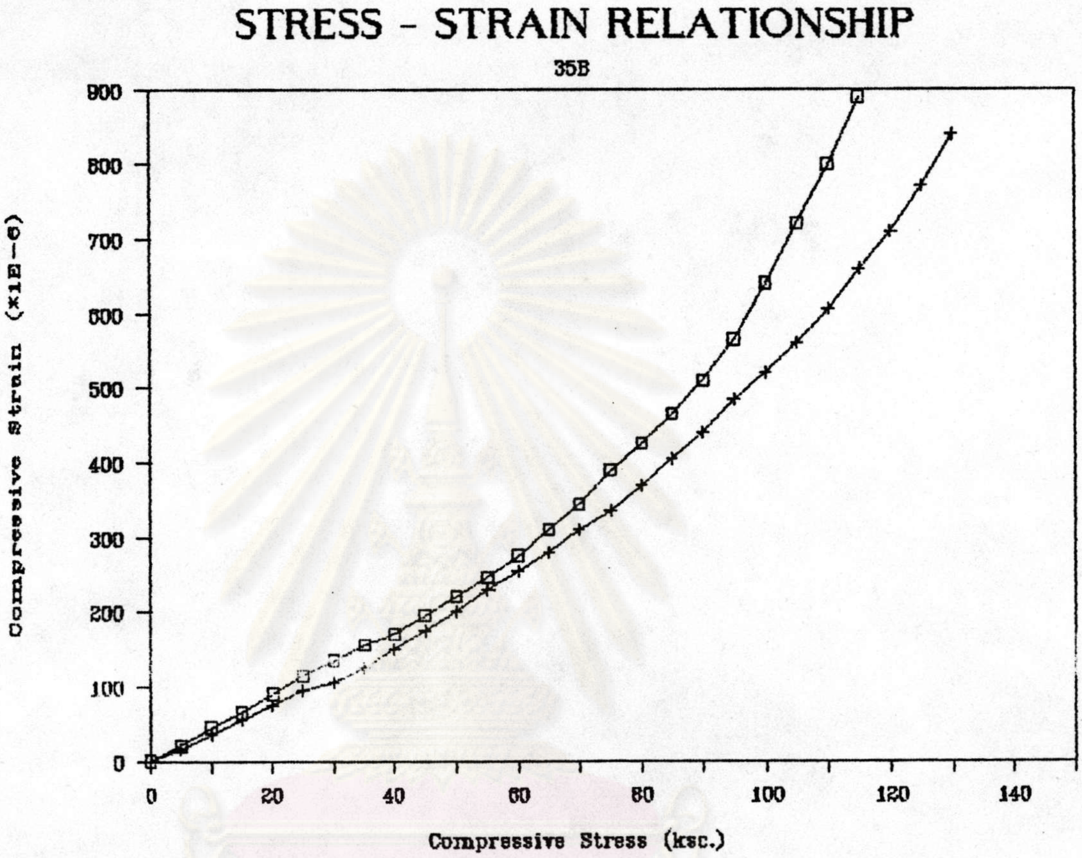
□ 25BW + D25BW

Fig. 36 Relationship between Compressive Stress and Compressive Strain (25B)



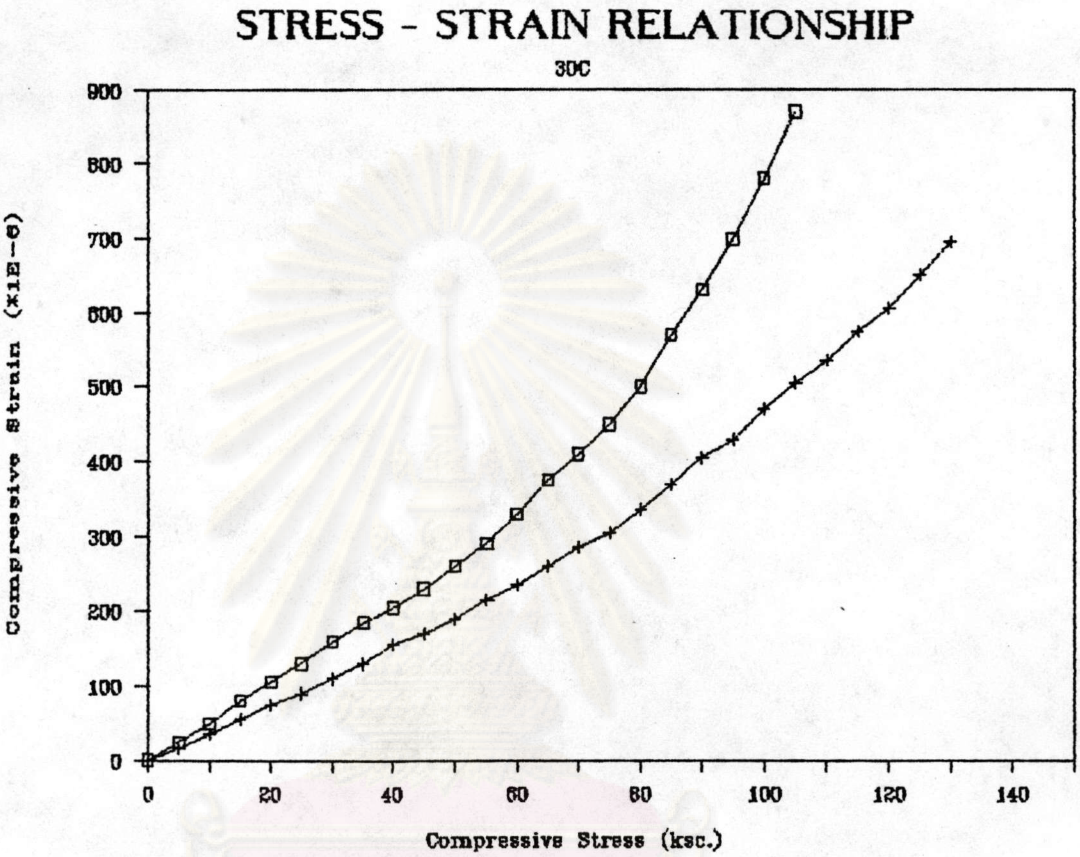
□ 30BW + D30BW

Fig. 37 Relationship between Compressive Stress and Compressive Strain (30B)



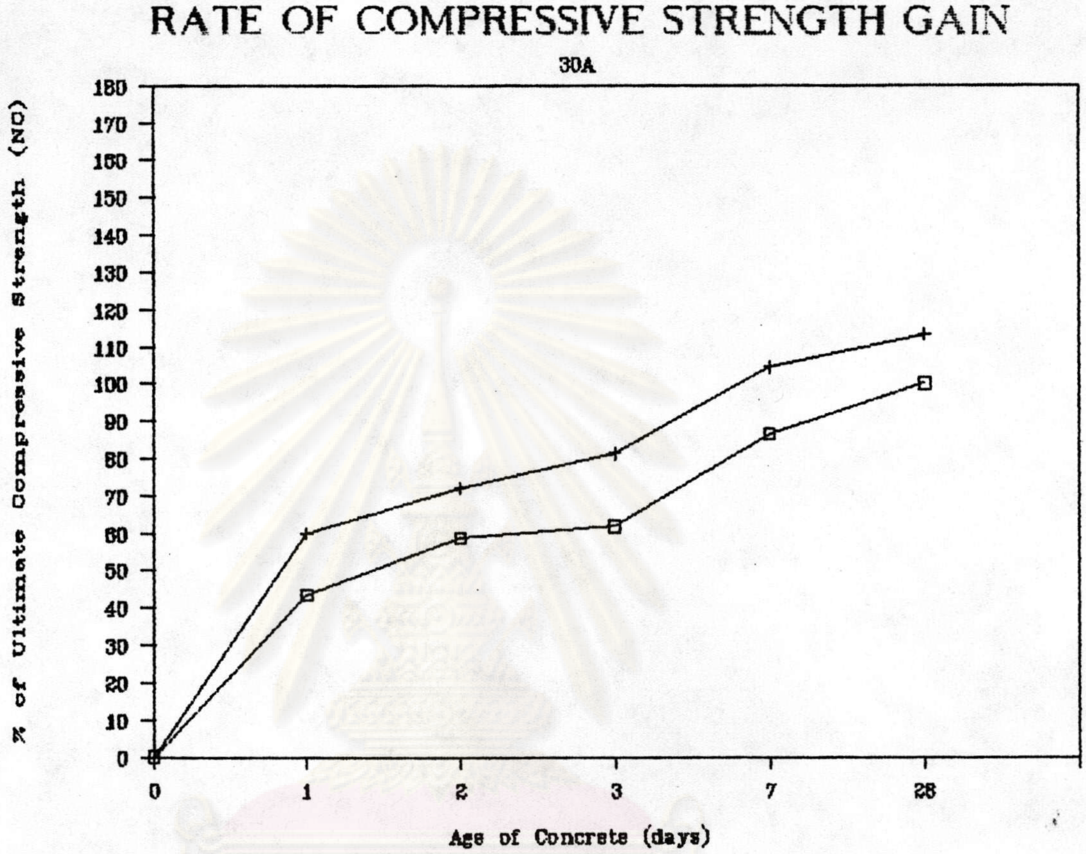
□ 35BW + D35BW

Fig. 38 Relationship between Compressive Stress and Compressive Strain (35B)



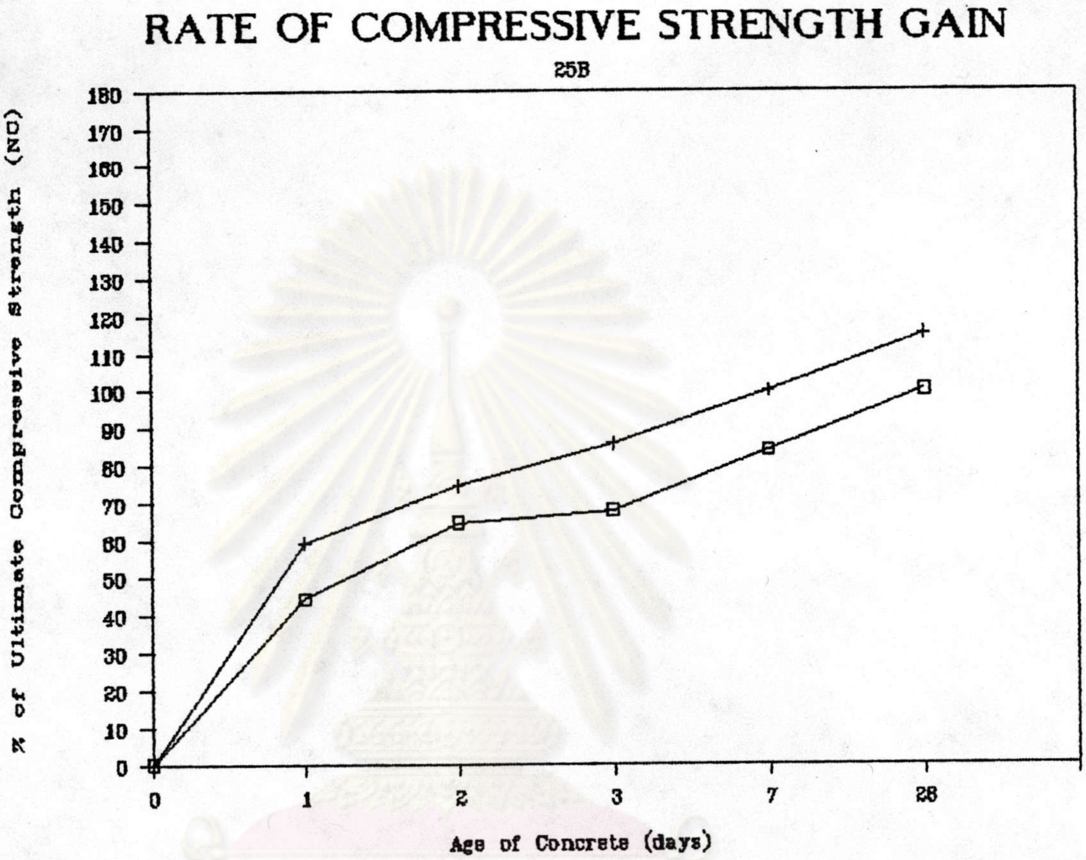
□ 30CW + D30CW

Fig. 39 Relationship between Compressive Stress and Compressive Strain (30C)



□ 30A + D30A

Fig. 40 Rate of Compressive Strength Gain (30A)



□ 25B + D25B

Fig. 41 Rate of Compressive Strength Gain (25B)

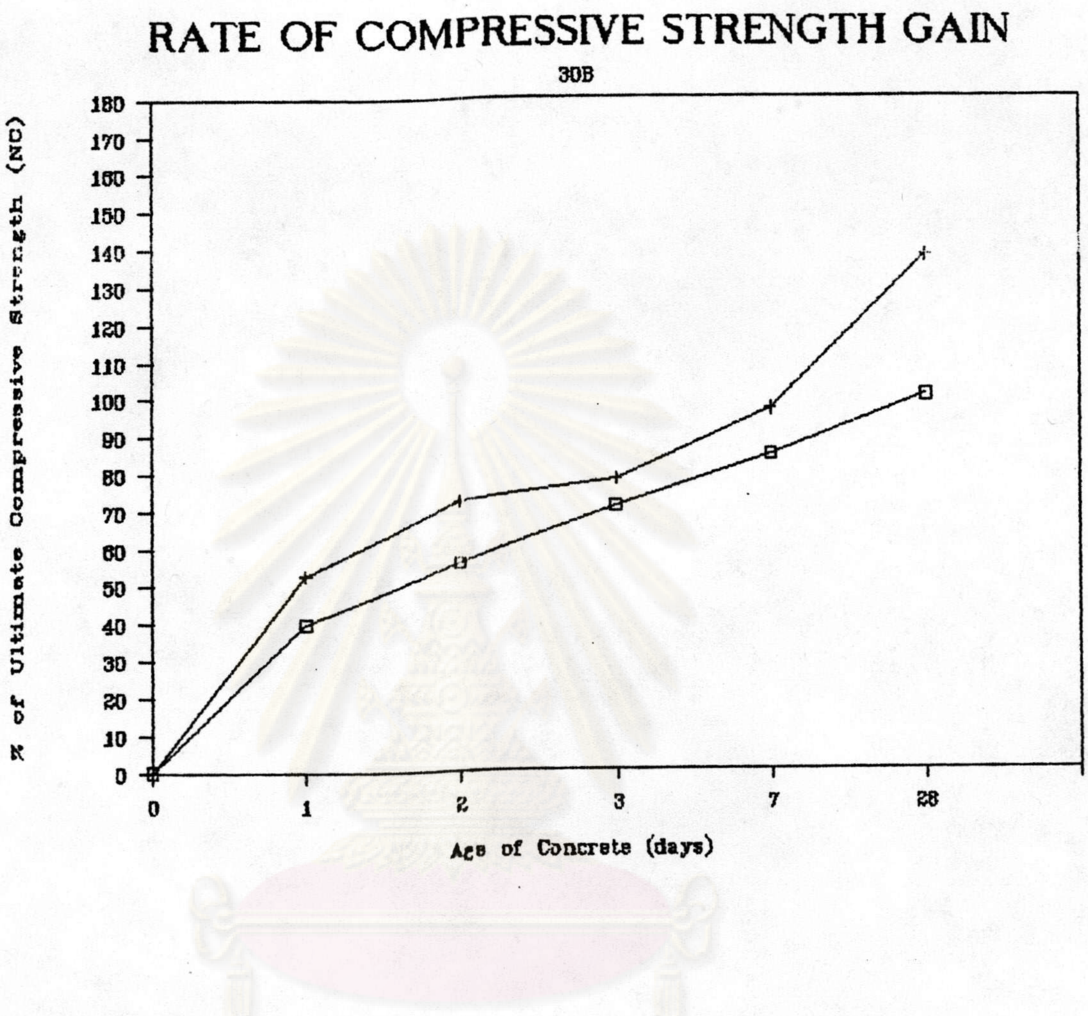


Fig. 42 Rate of Compressive Strength Gain (30B)

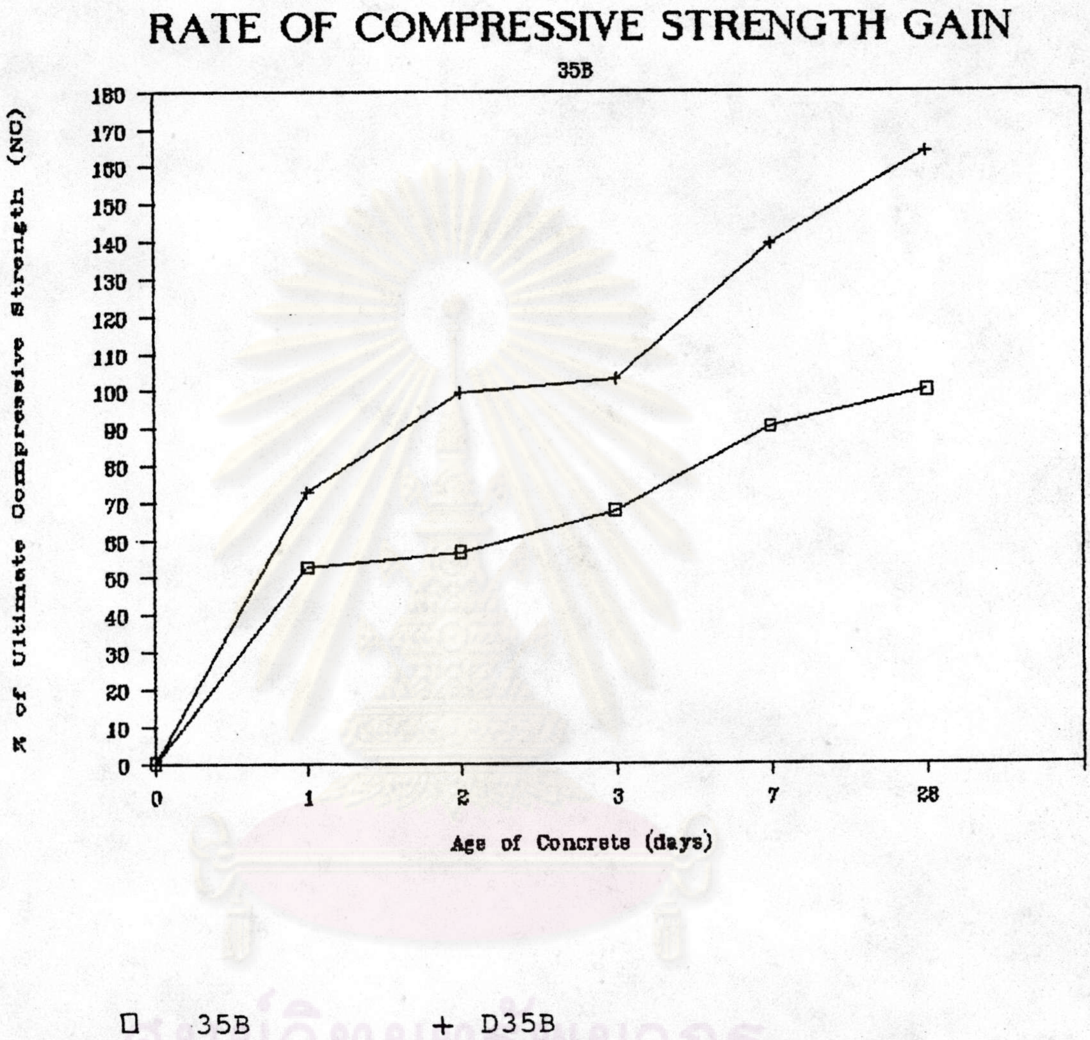


Fig. 43 Rate of Compressive Strength Gain (35B)

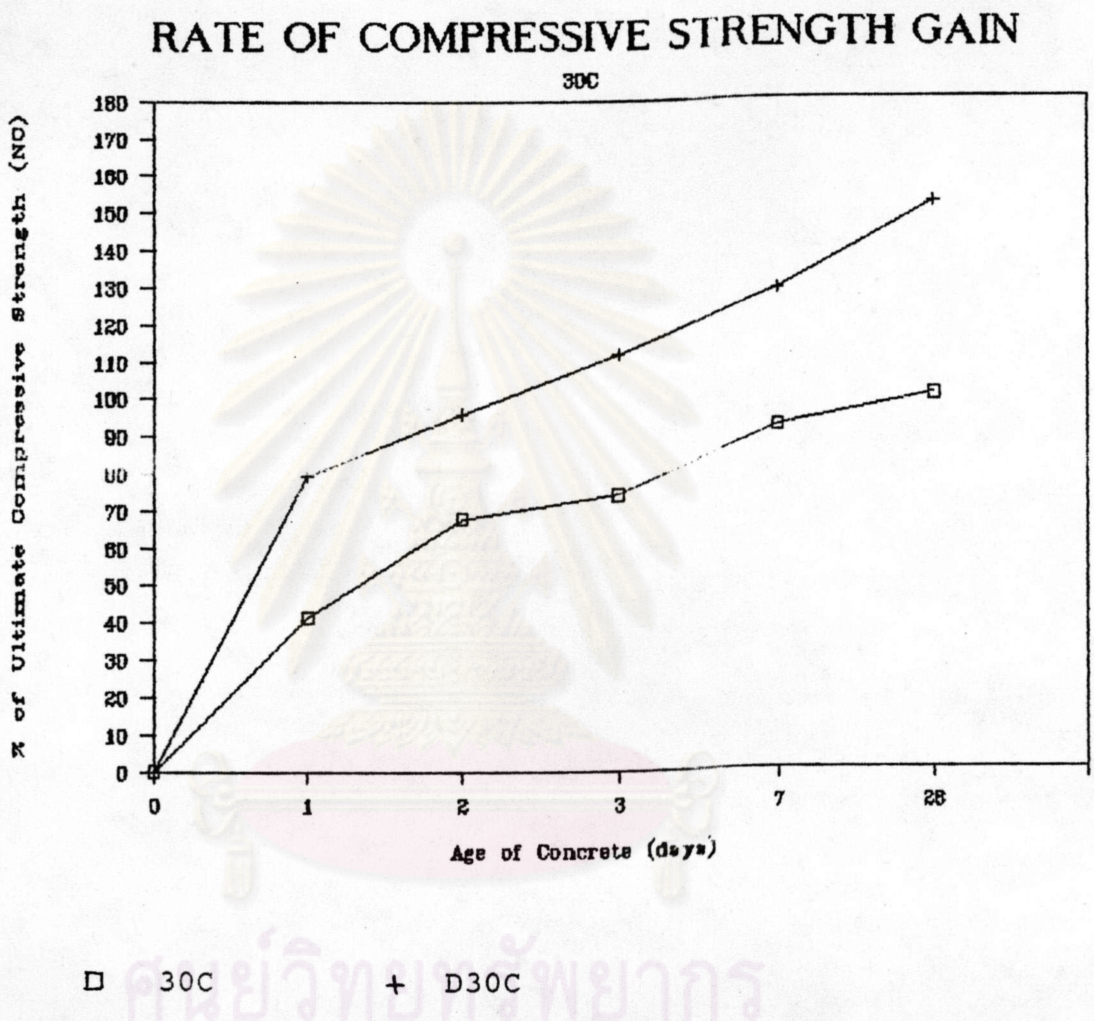
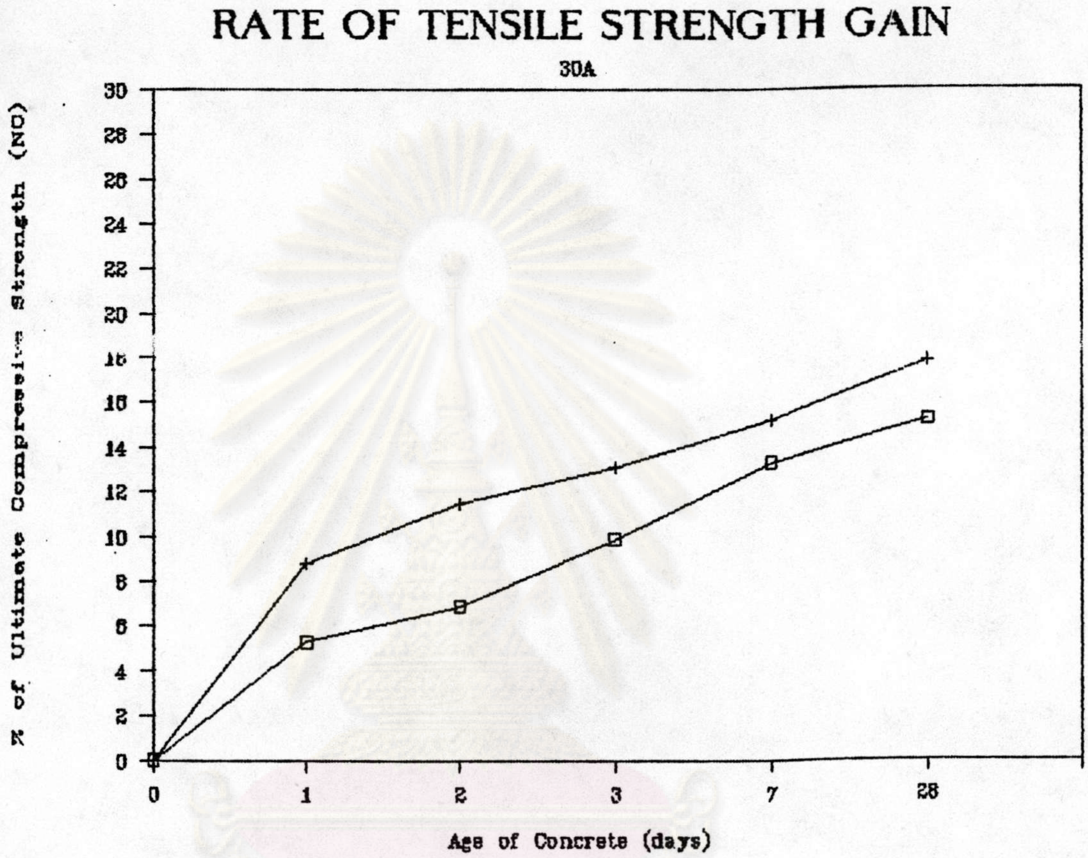


Fig. 44 Rate of Compressive Strength Gain (30C)



□ 30A + D30A

Fig. 45 Rate of Splitting Tensile Strength Gain (30A)

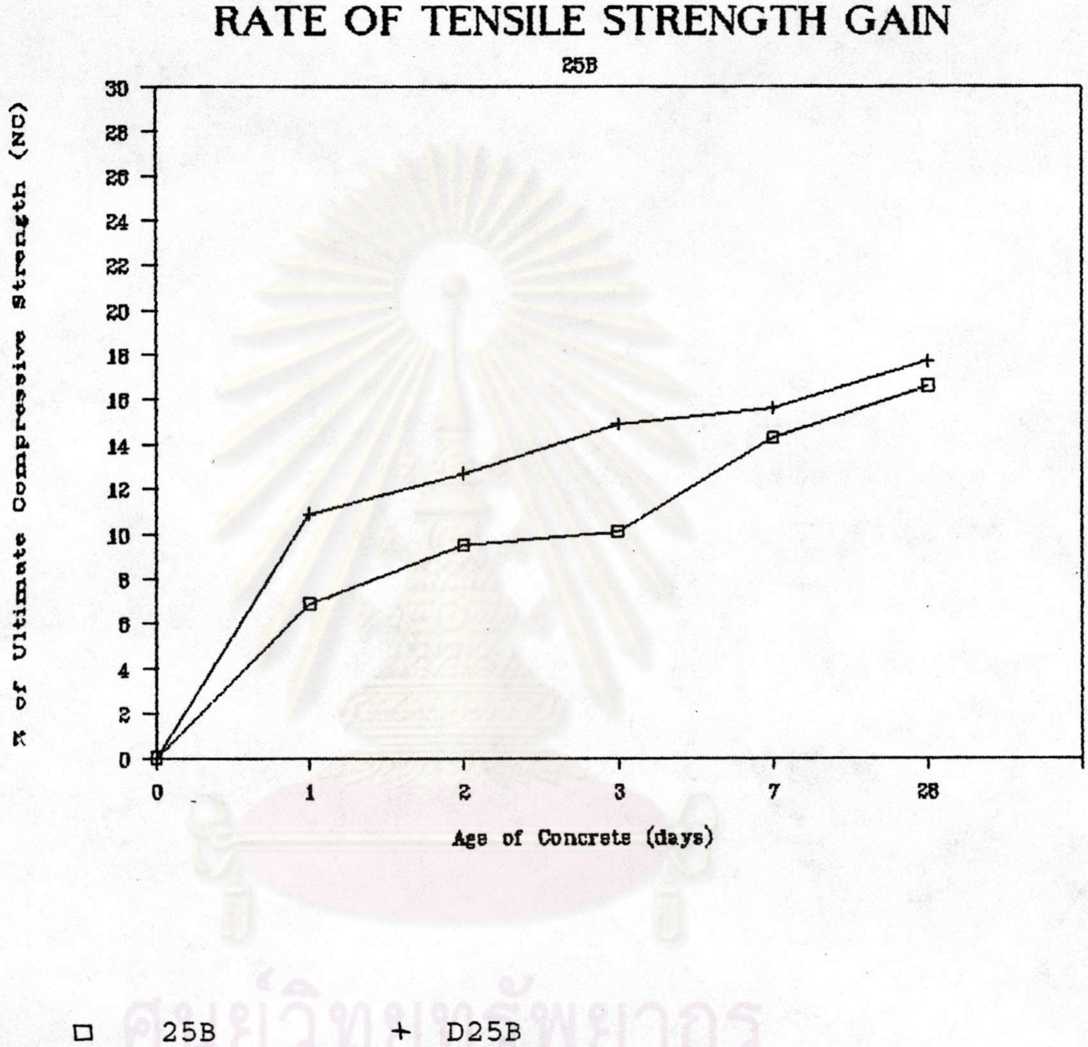
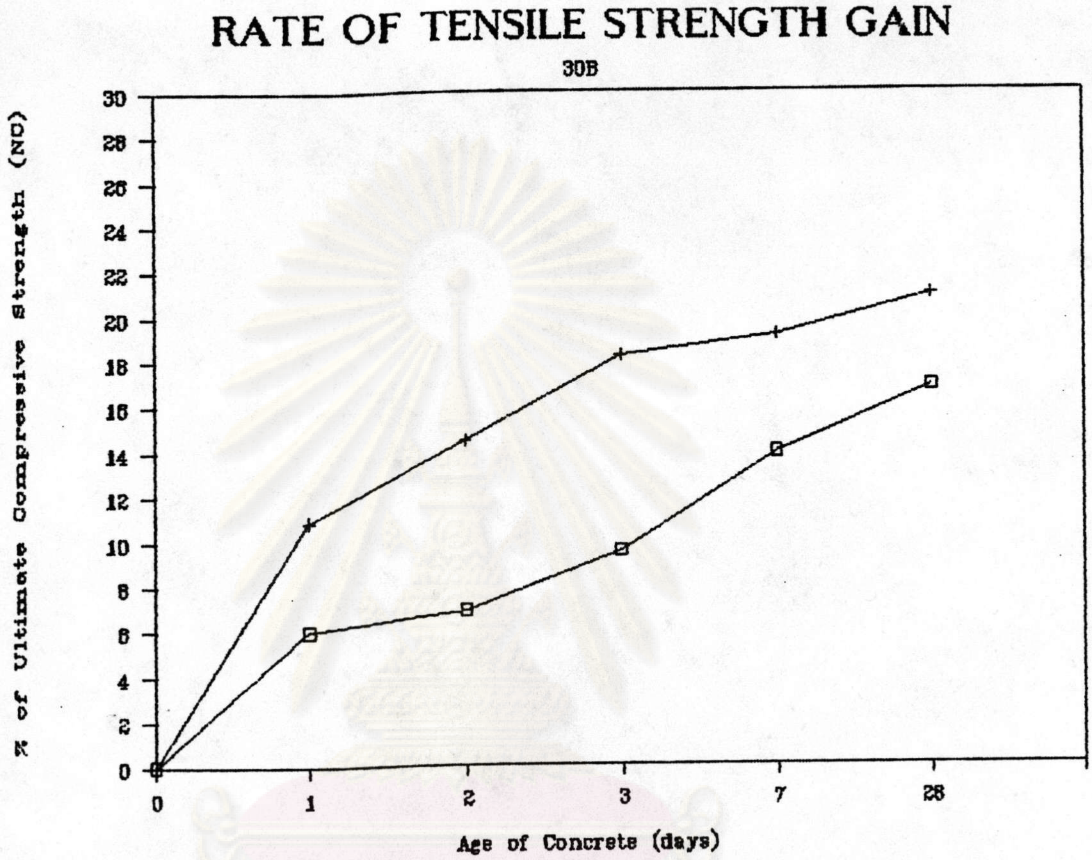
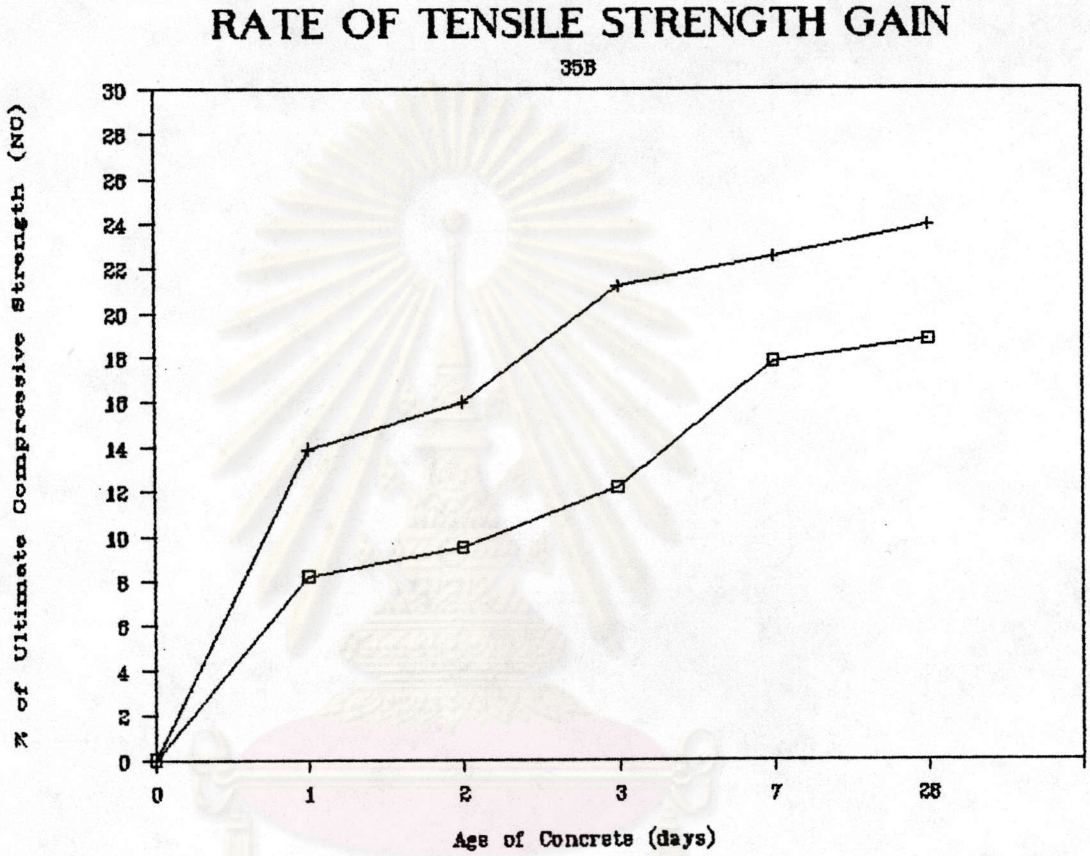


Fig. 46 Rate of Splitting Tensile Strength Gain (25B)



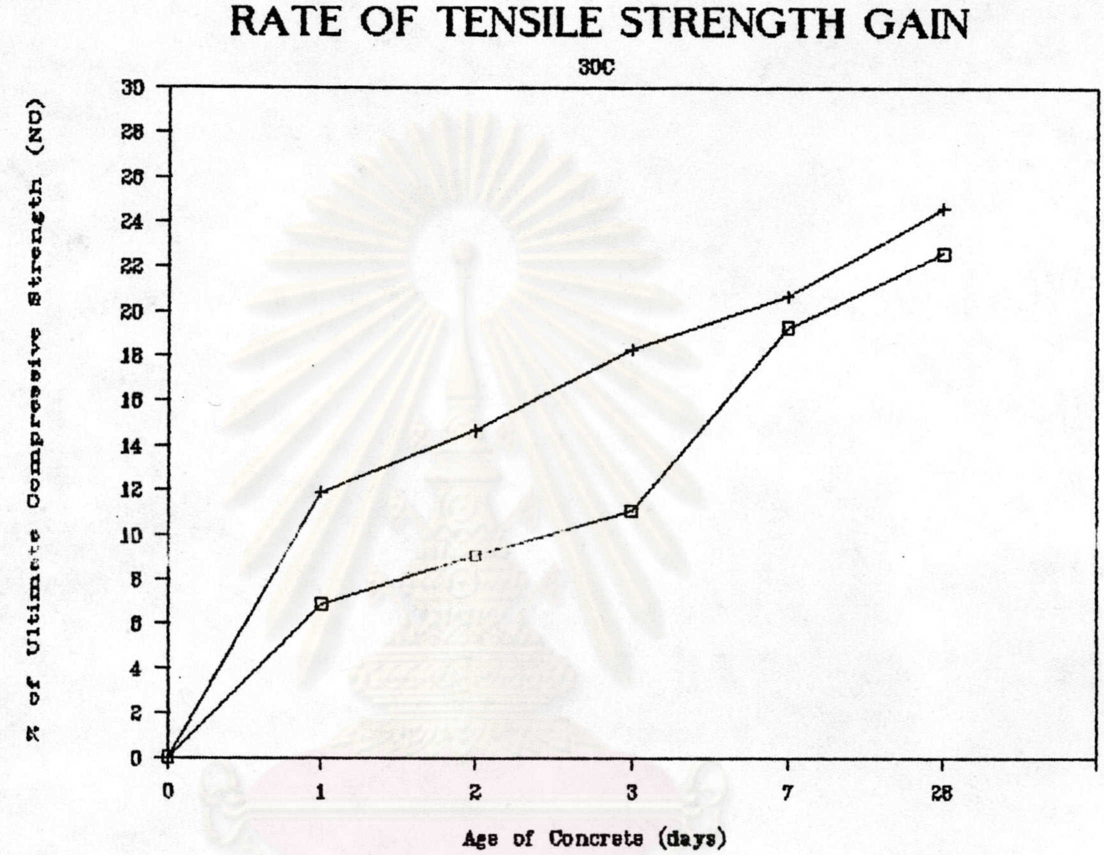
□ 30B + D30B

Fig. 47 Rate of Splitting Tensile Strength Gain (30B)



□ 35B + D35B

Fig. 48 Rate of Splitting Tensile Strength Gain (35B)



□ 30C + D30C

Fig. 49 Rate of Splitting Tensile Strength Gain (30C)

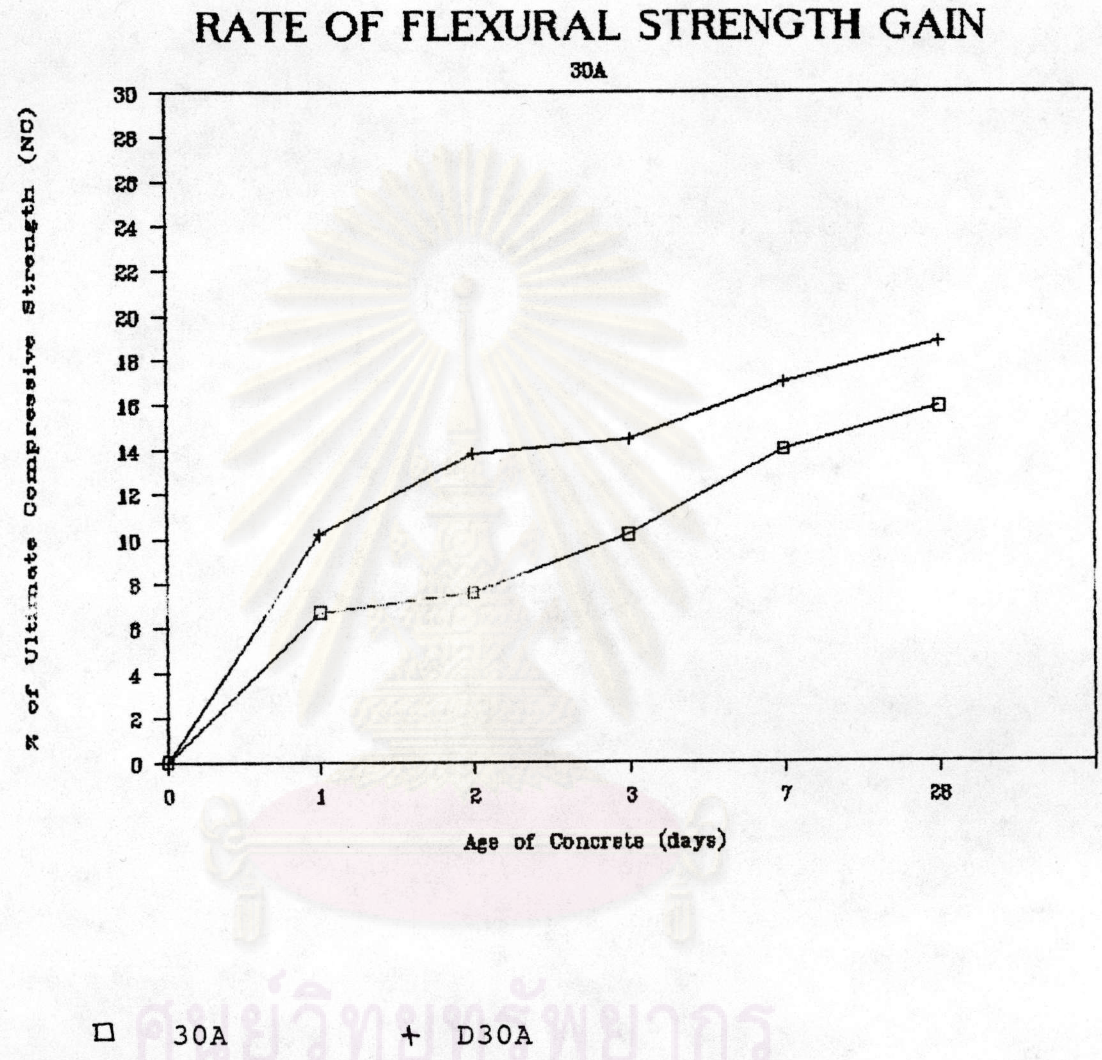
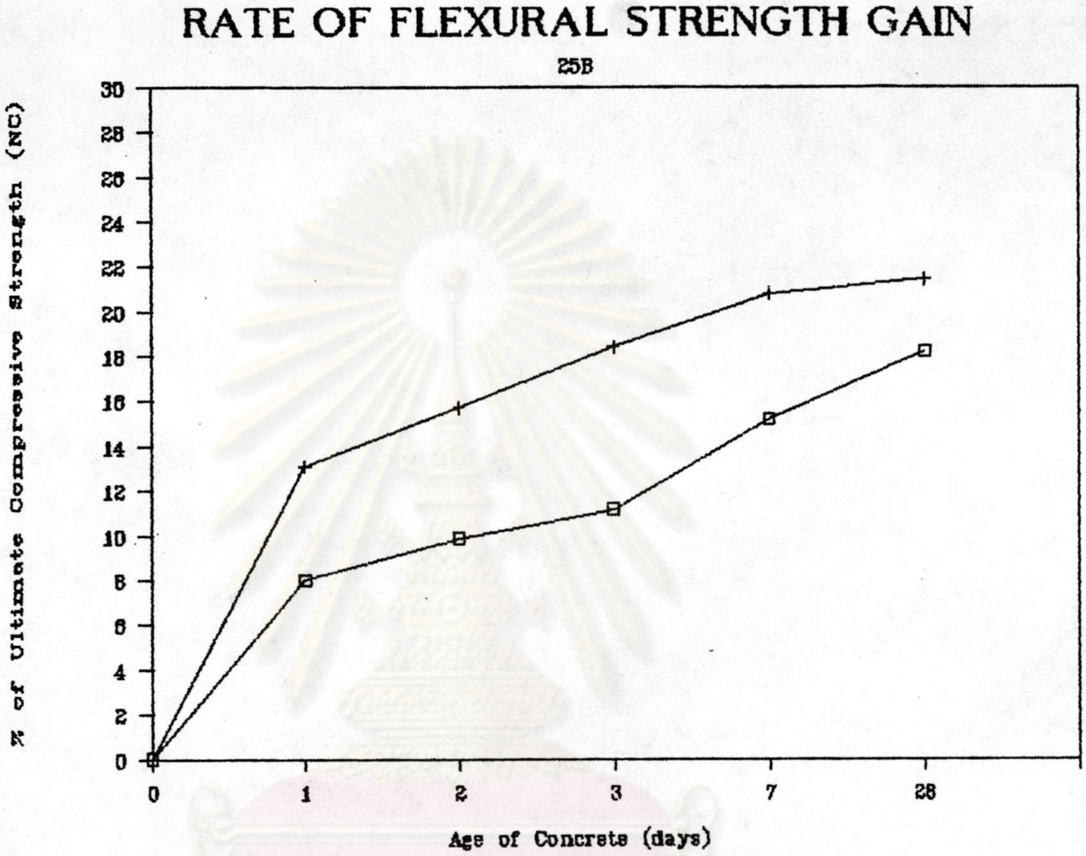
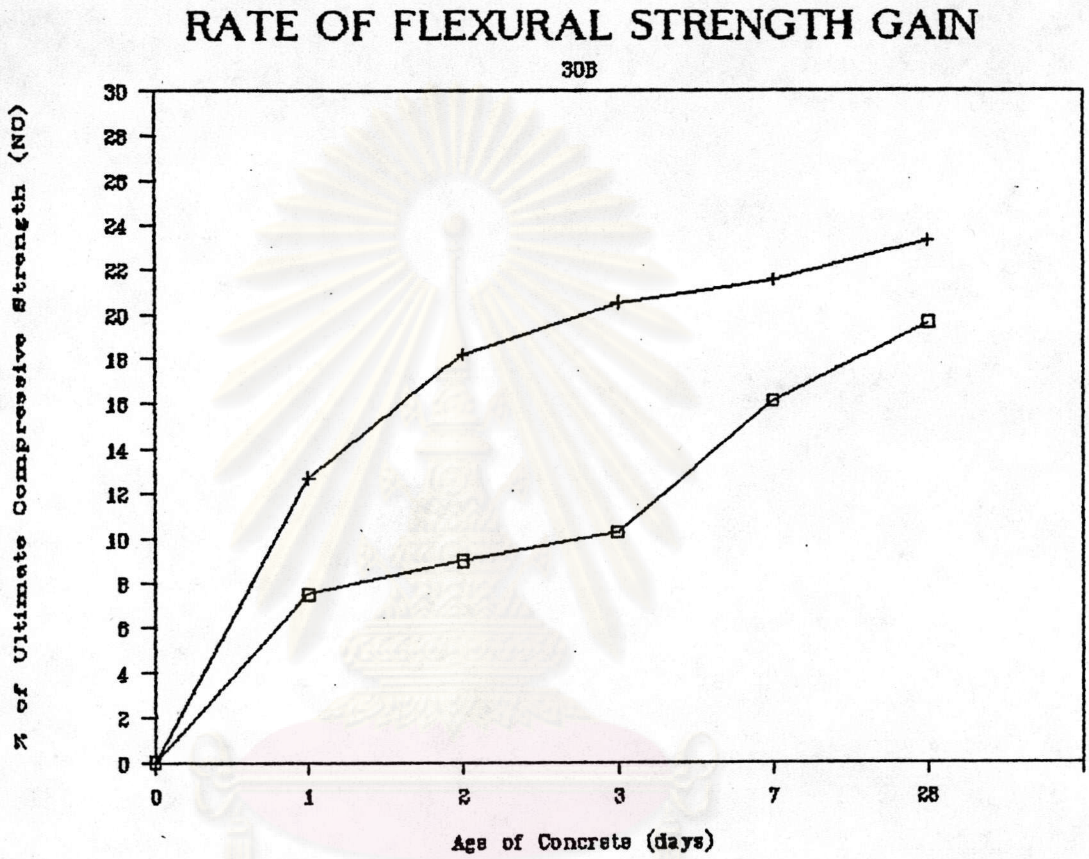


Fig. 50 Rate of Flexural Strength Gain (30A)



□ 25B + D25B

Fig. 51 Rate of Flexural Strength Gain (25B)



□ 30B + D30B

Fig. 52 Rate of Flexural Strength Gain (30B)

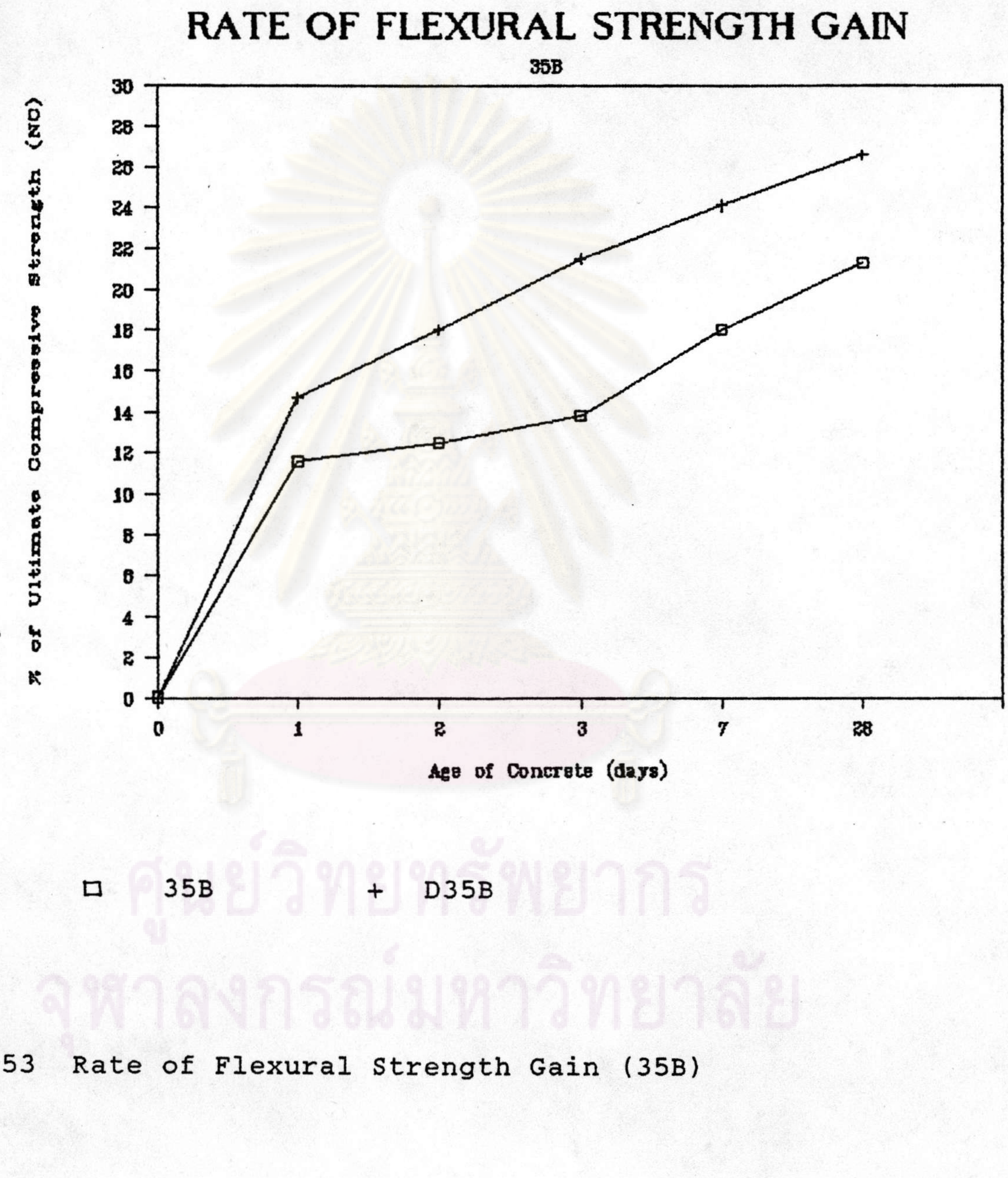


Fig. 53 Rate of Flexural Strength Gain (35B)

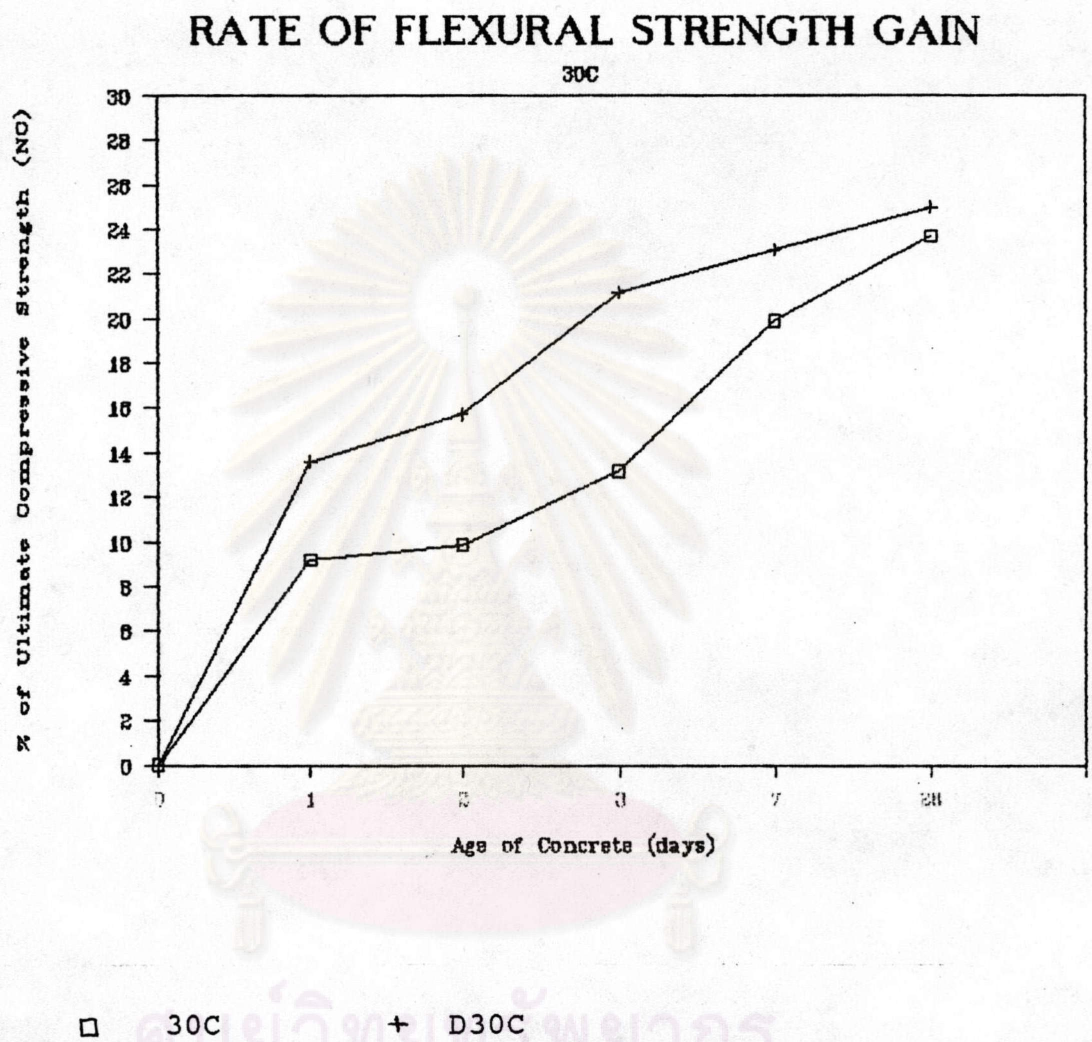
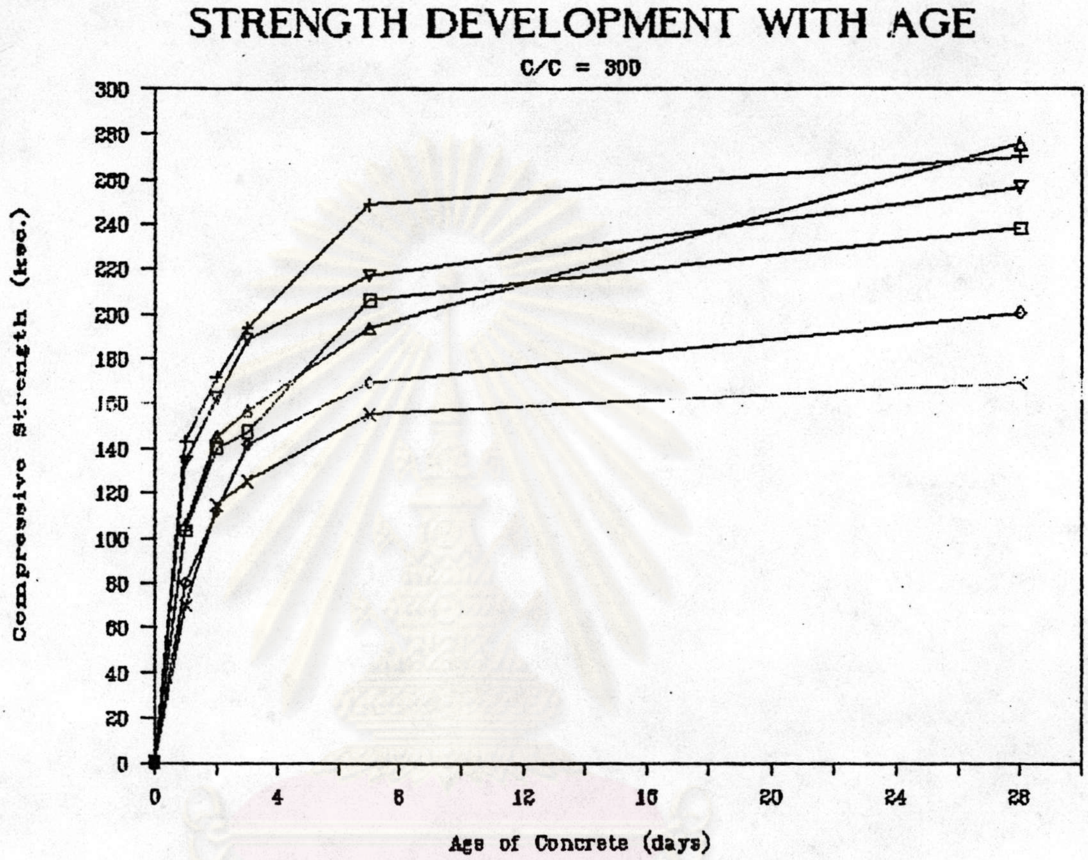


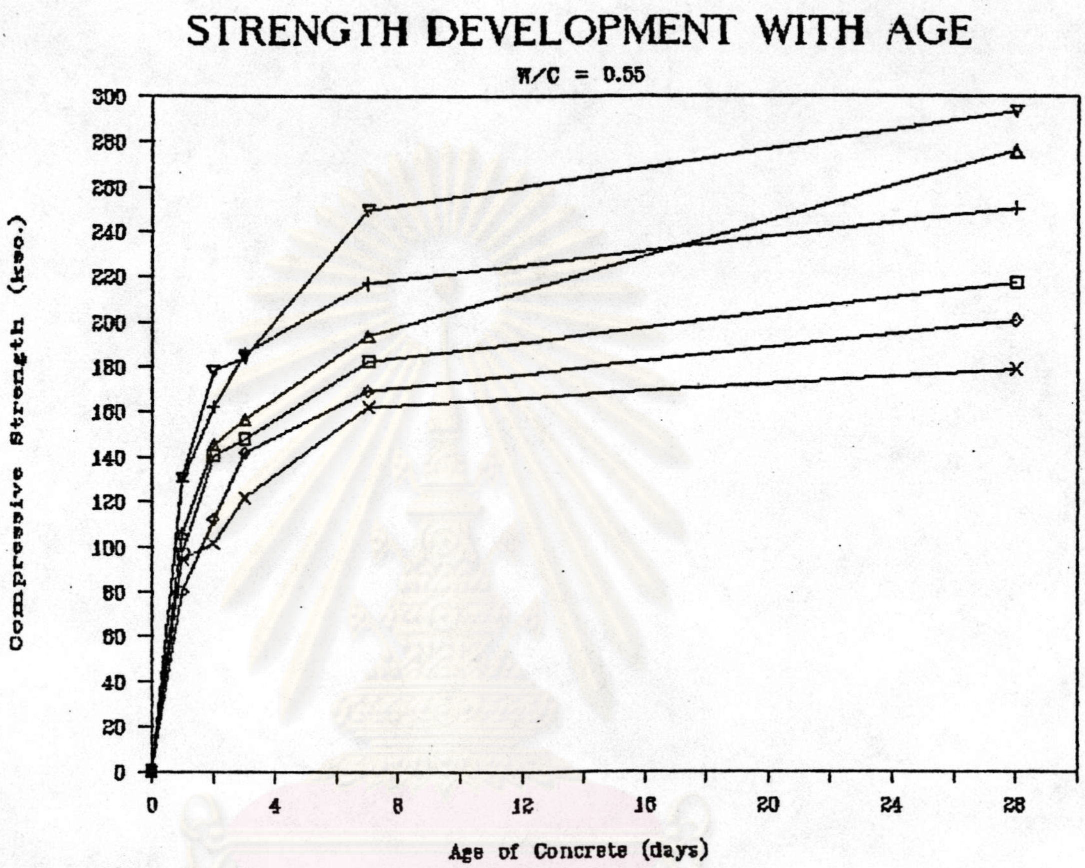
Fig. 54 Rate of Flexural Strength Gain (30C)



□ 30A ◇ 30B × 30C

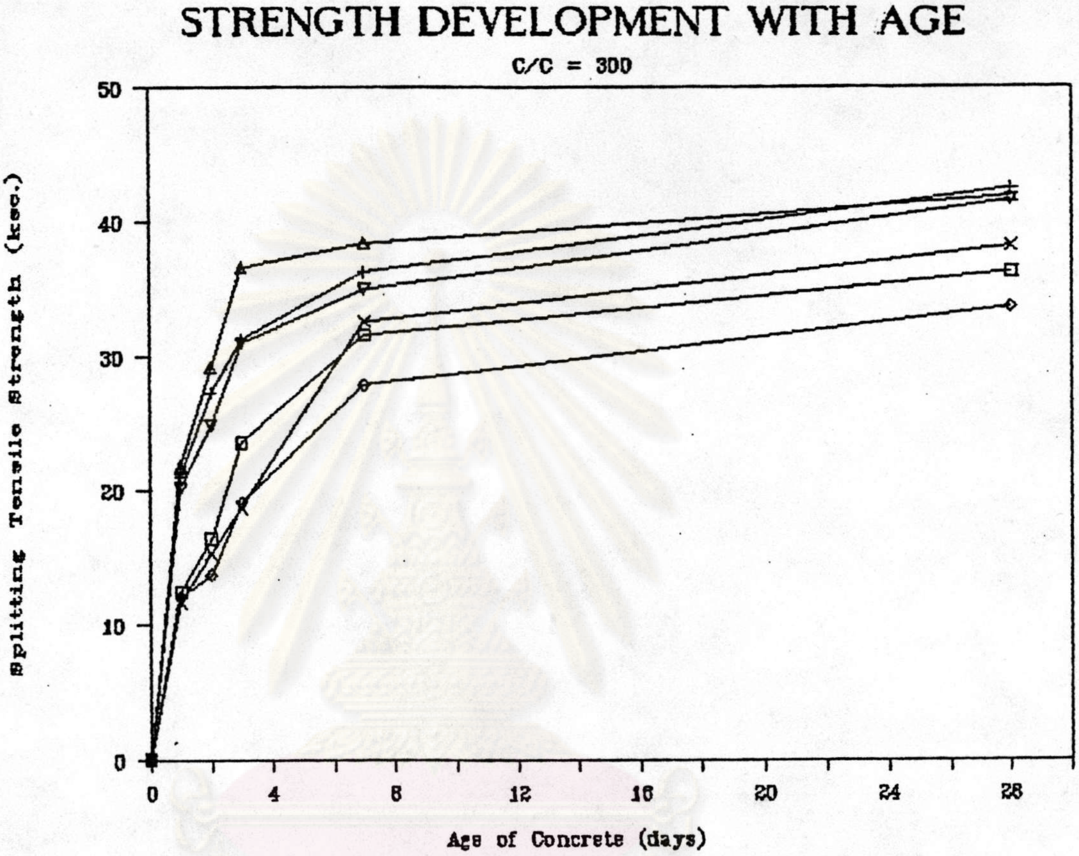
\+ D30A △ D30B ▽ D30C

Fig. 55 Development of Compressive Strength with Age, Varying Initial Water-Cement Ratio



□ 25B ◇ 30B × 35B
+ D25B △ D30B ▽ D35B

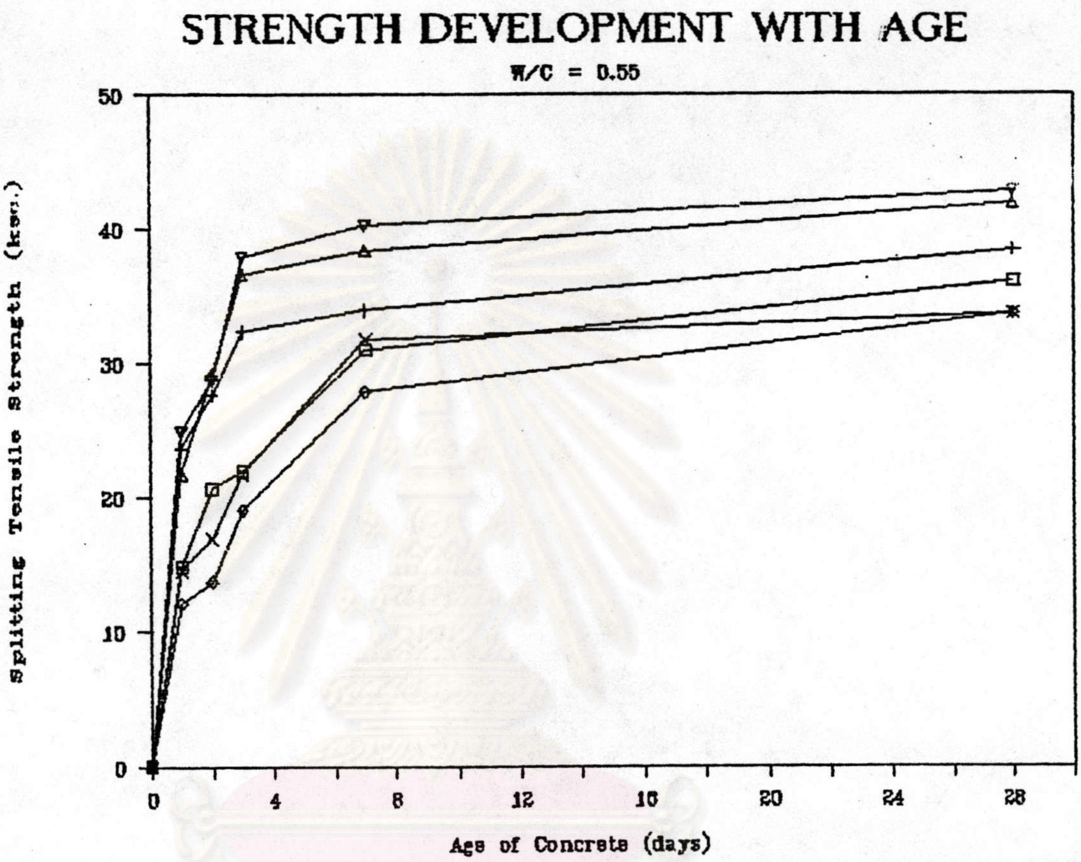
Fig. 56 Development of Compressive Strength with Age, Varying Cement Content



□ 30A ◇ 30B × 30C

\+ D30A △ D30B ▽ D30C

Fig. 57 Development of Splitting Tensile Strength with Age, Varying Initial Water-Cement Ratio



□ 25B ◇ 30B × 35B

\+ D25B △ D30B ▽ D35B

Fig. 58 Development of Splitting Tensile Strength with Age, Varying Cement Content

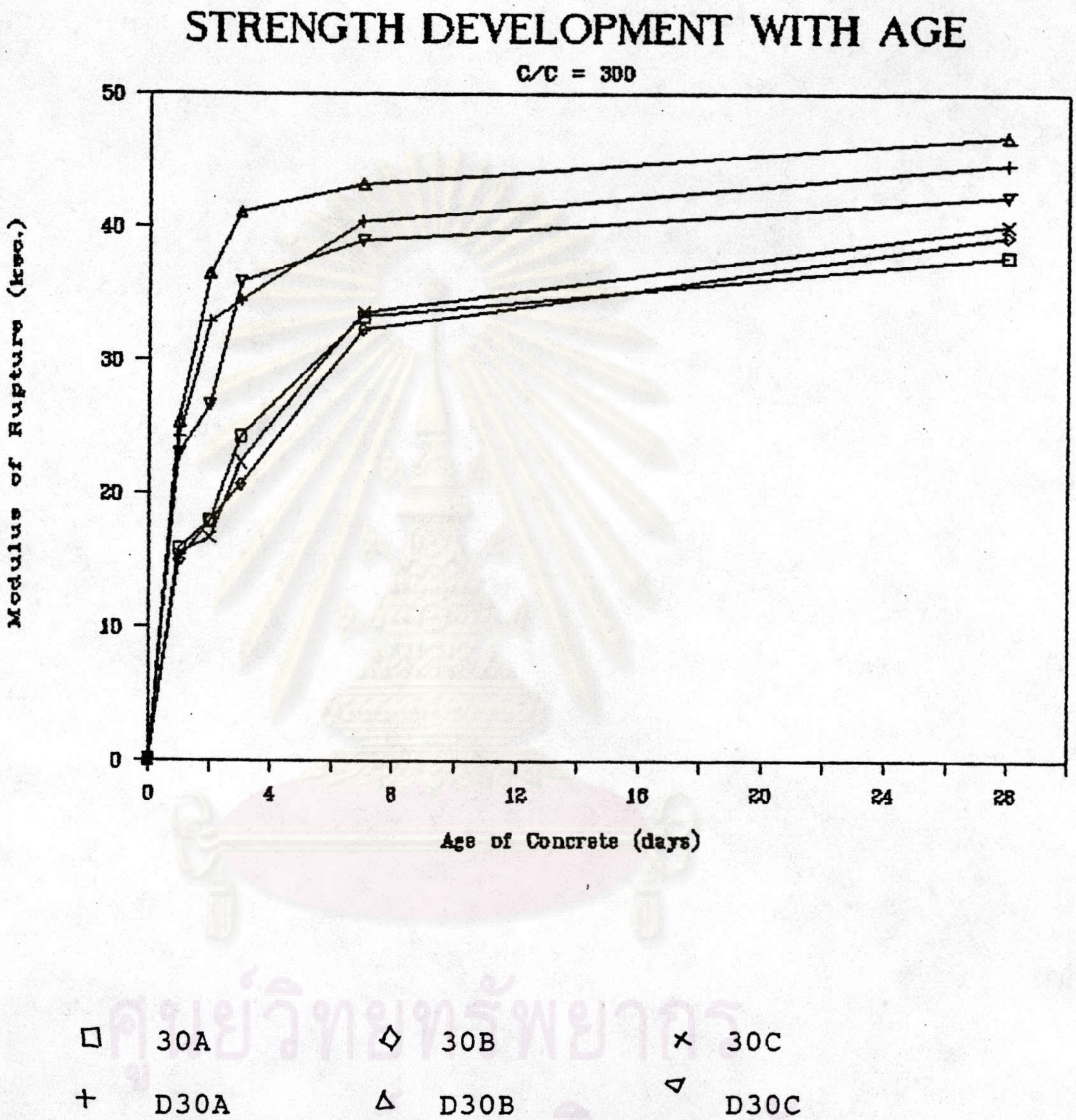


Fig. 59 Development of Modulus of Rupture with Age, Varying Initial Water-Cement Ratio

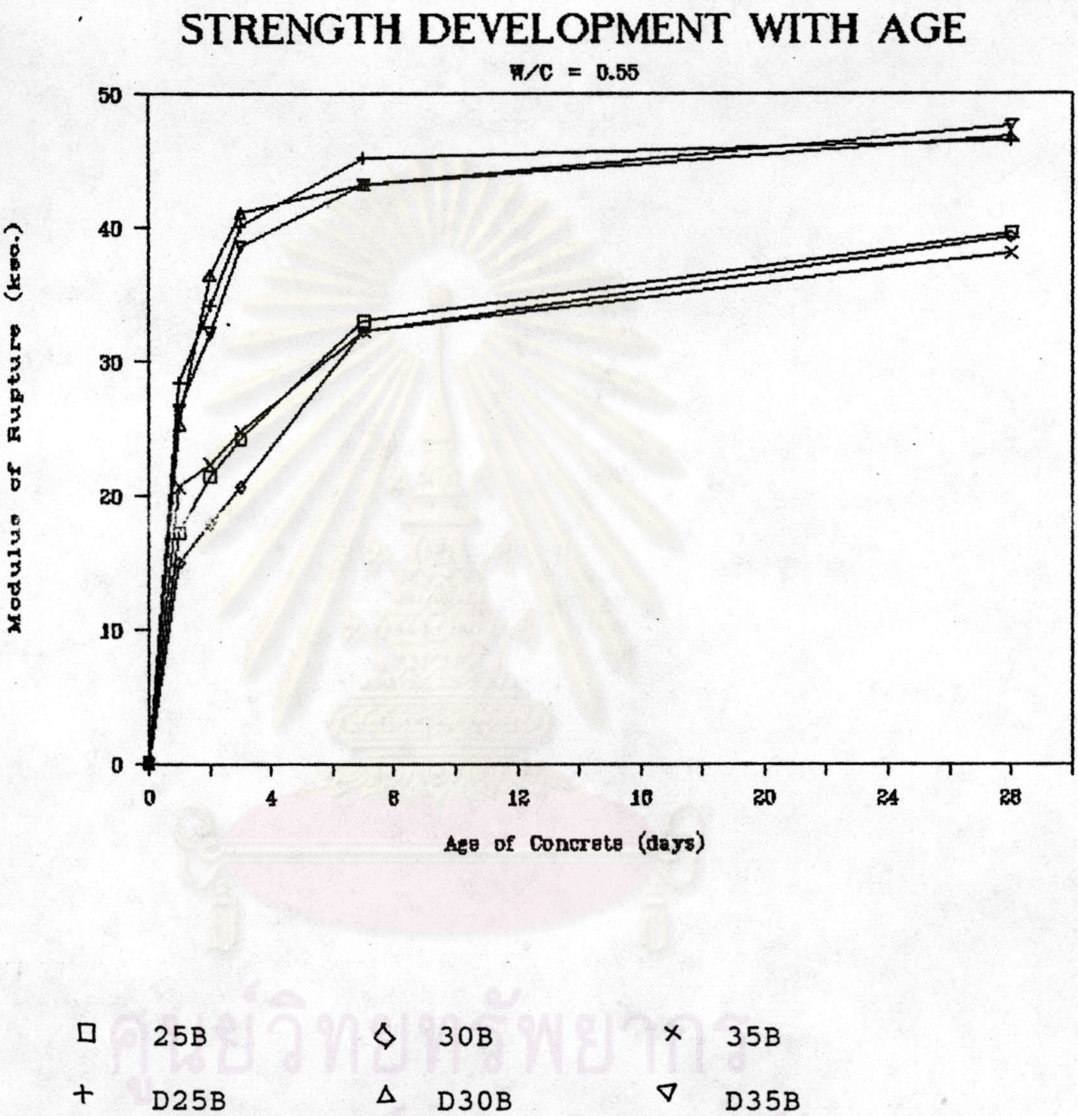
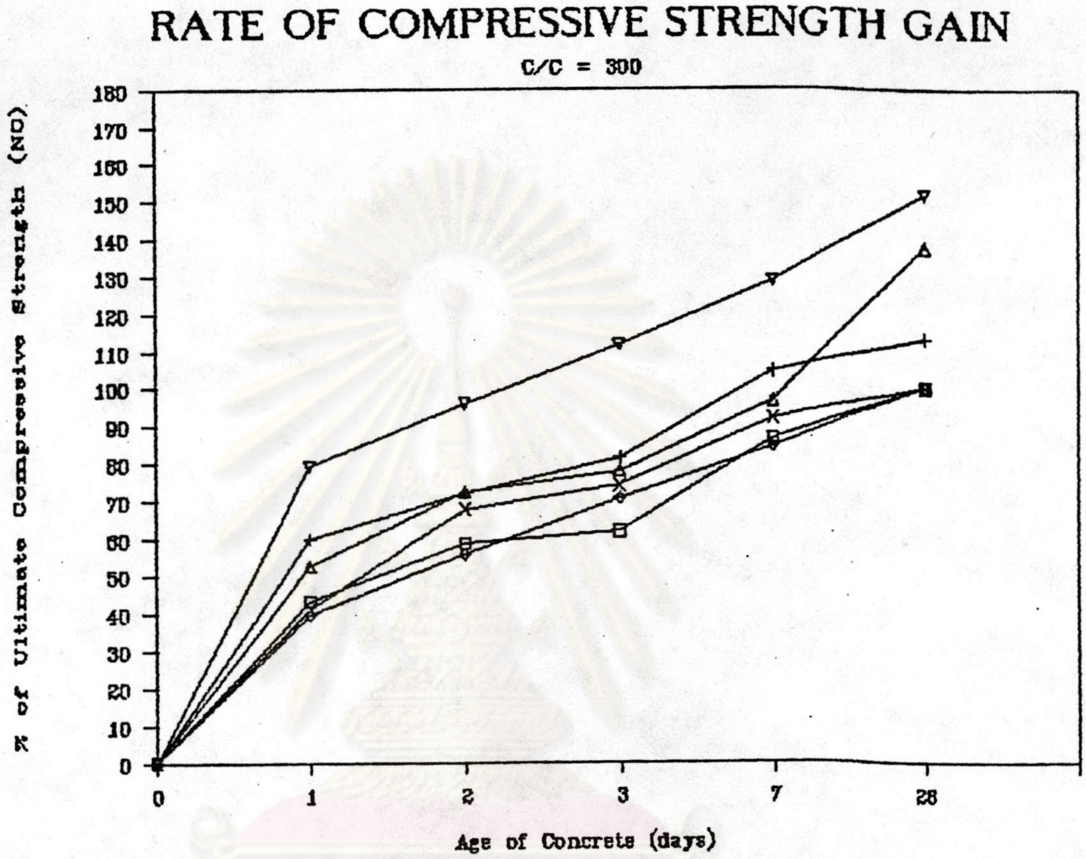


Fig. 60 Development of Modulus of Rupture with Age, Varying Cement Content



□ 30A ◇ 30B × 30C

+ D30A △ D30B ▽ D30C

Fig. 61 Rate of Compressive Strength Gain, Varying Initial Water-Cement Ratio

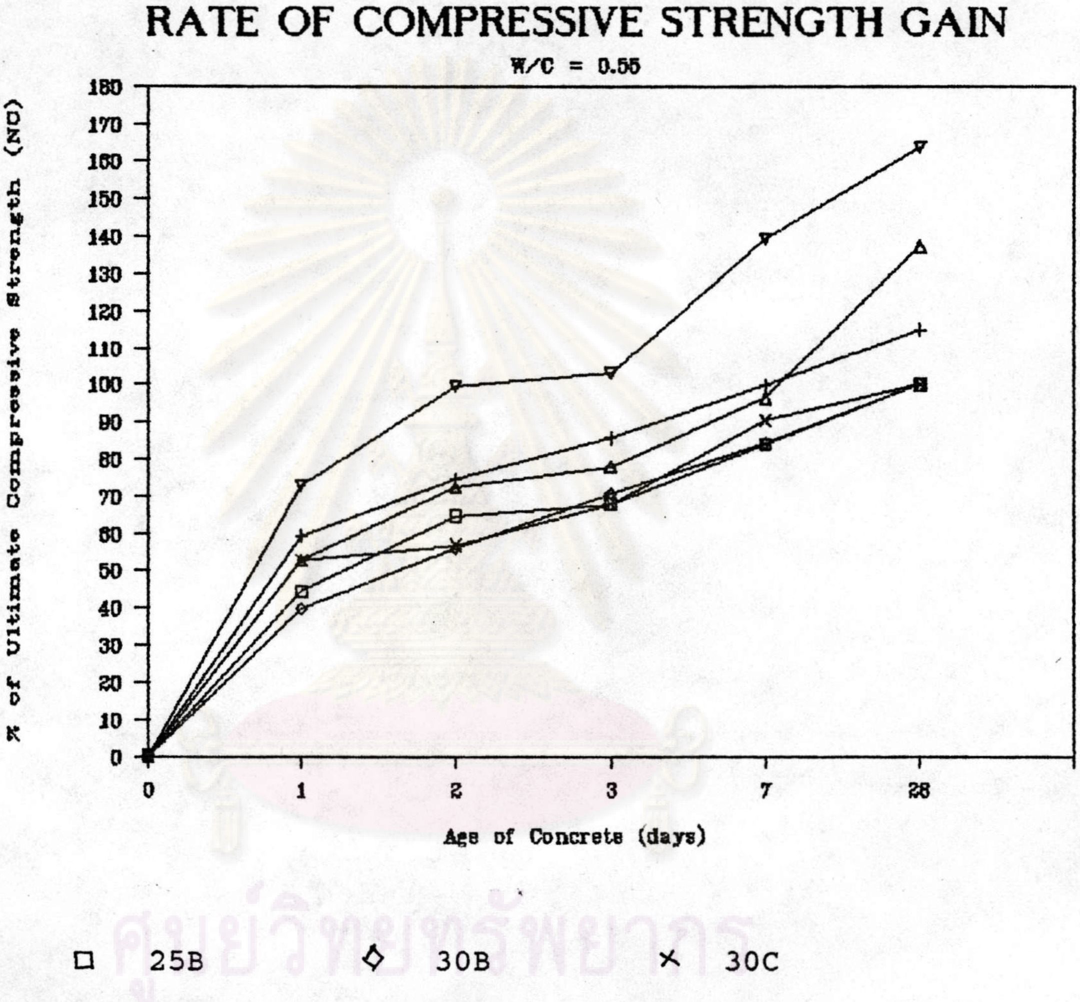


Fig. 62 Rate of Compressive Strength Gain, Varying Cement Content

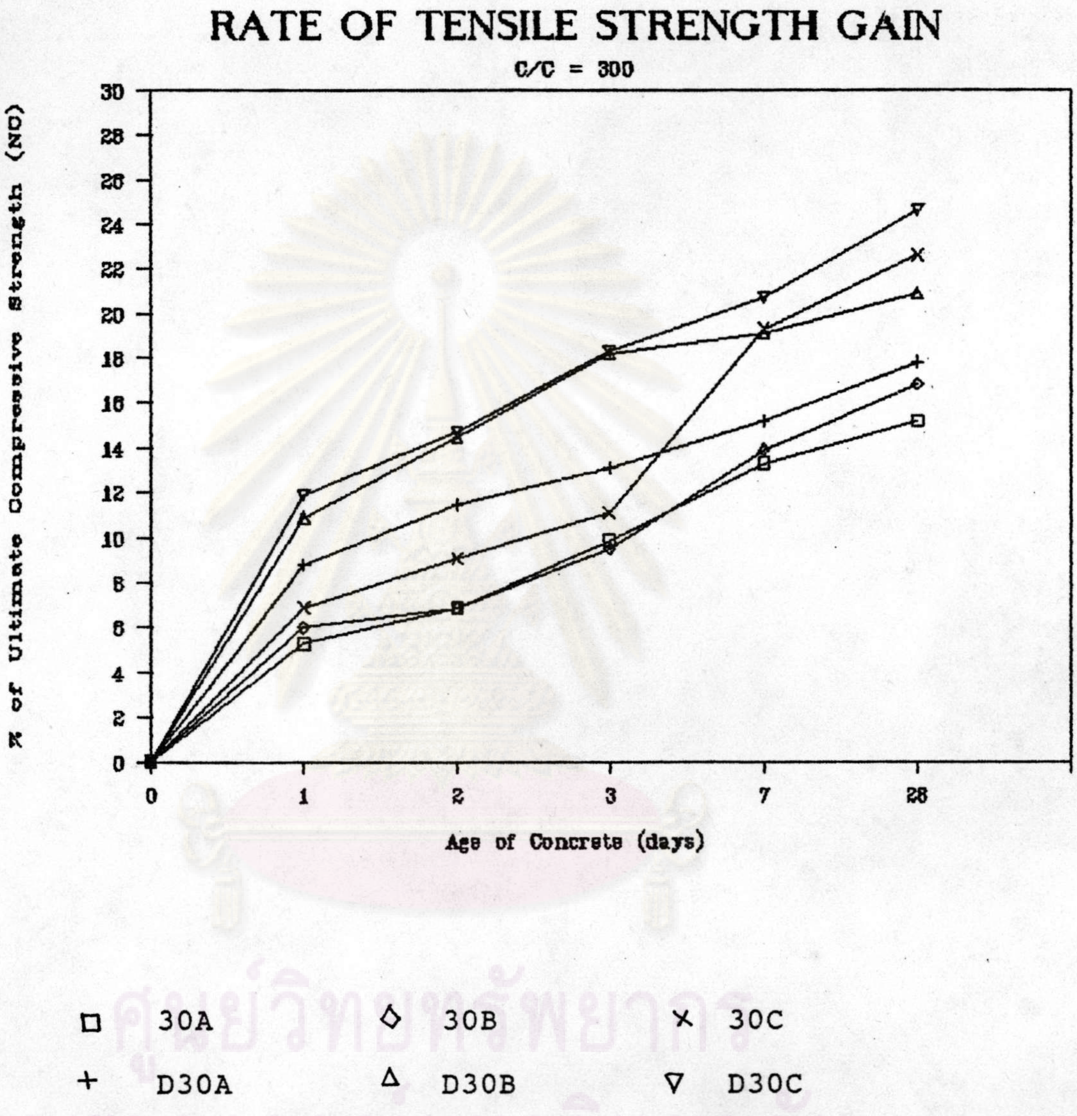


Fig. 63 Rate of Splitting Tensile Strength Gain, Varying Initial Water-Cement Ratio

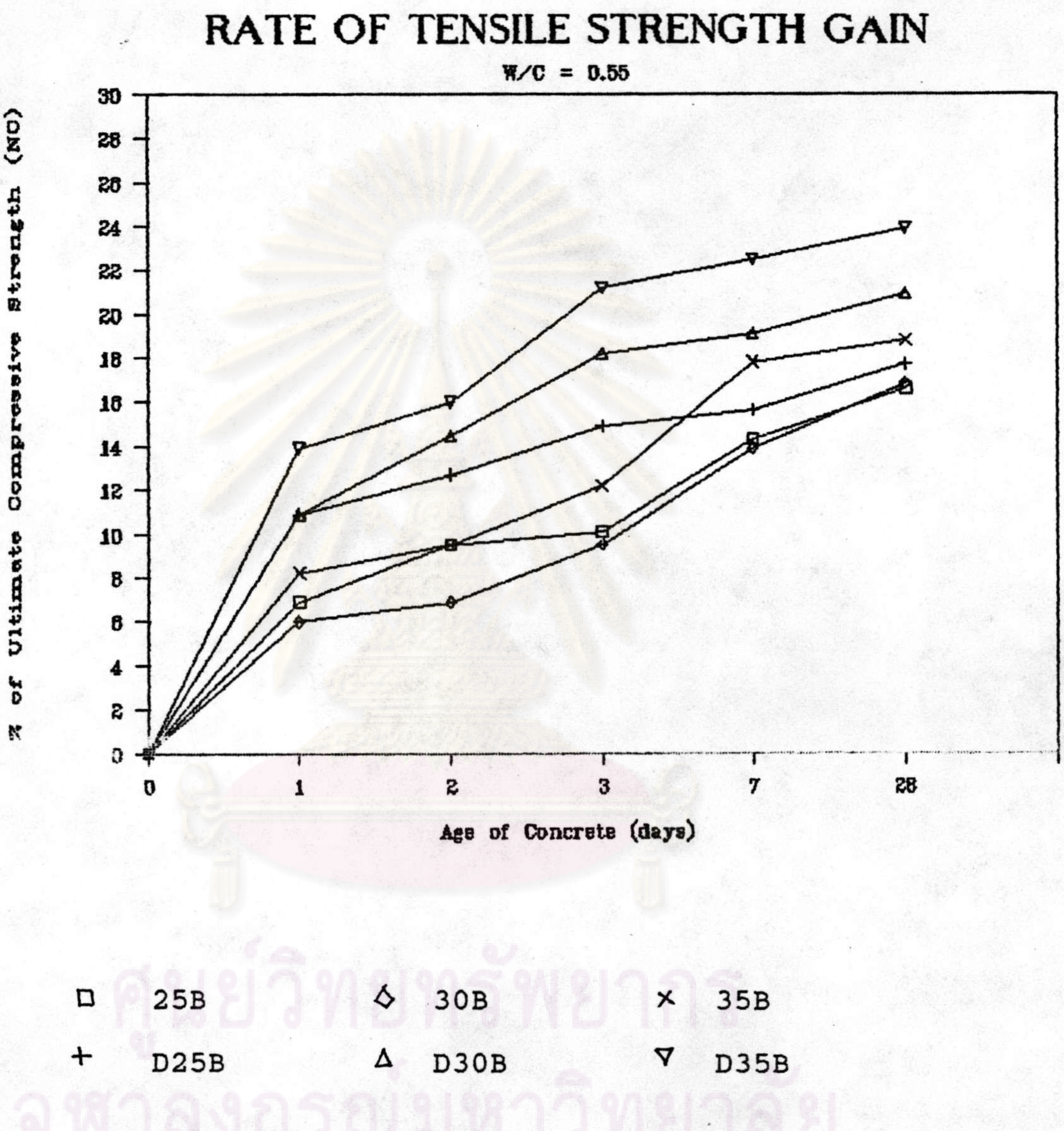
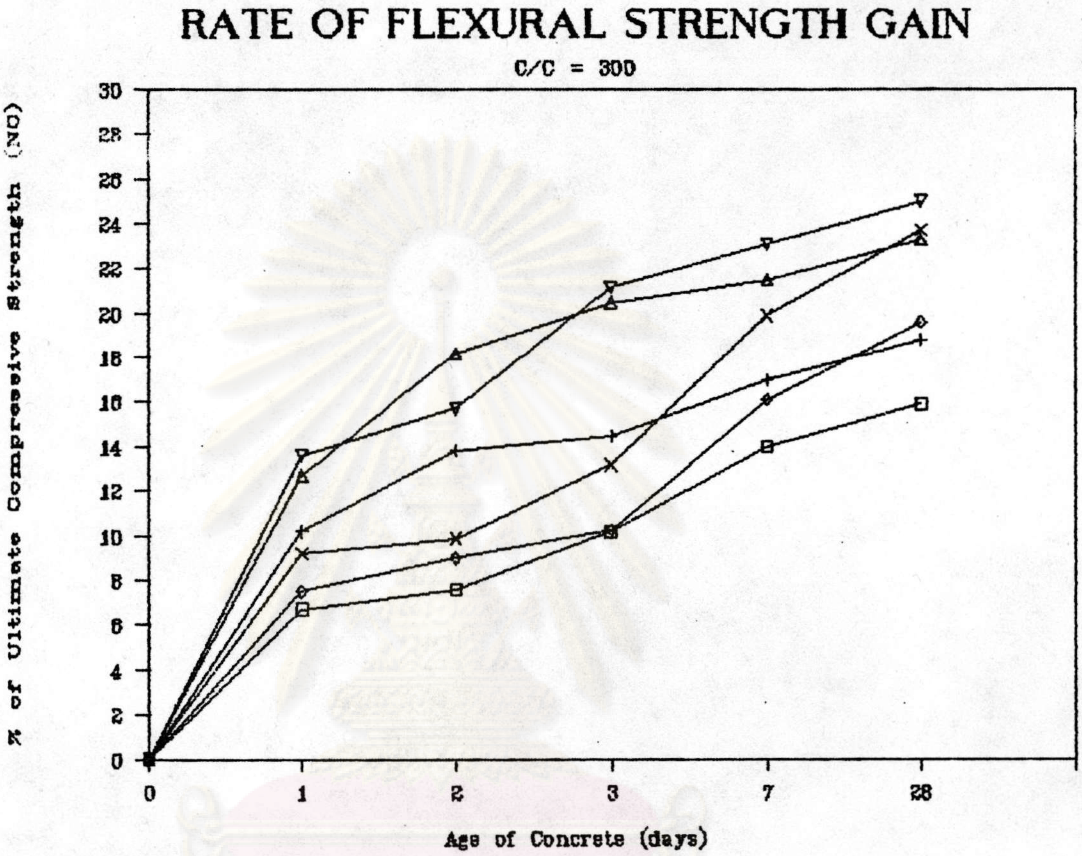


Fig. 64 Rate of Splitting Tensile Strength Gain, Varying Cement Content



□ 30A ◇ 30B × 30C

\+ D30A △ D30B ▽ D30C

Fig. 65 Rate of Flexural Strength Gain,
Varying Initial Water-Cement Ratio

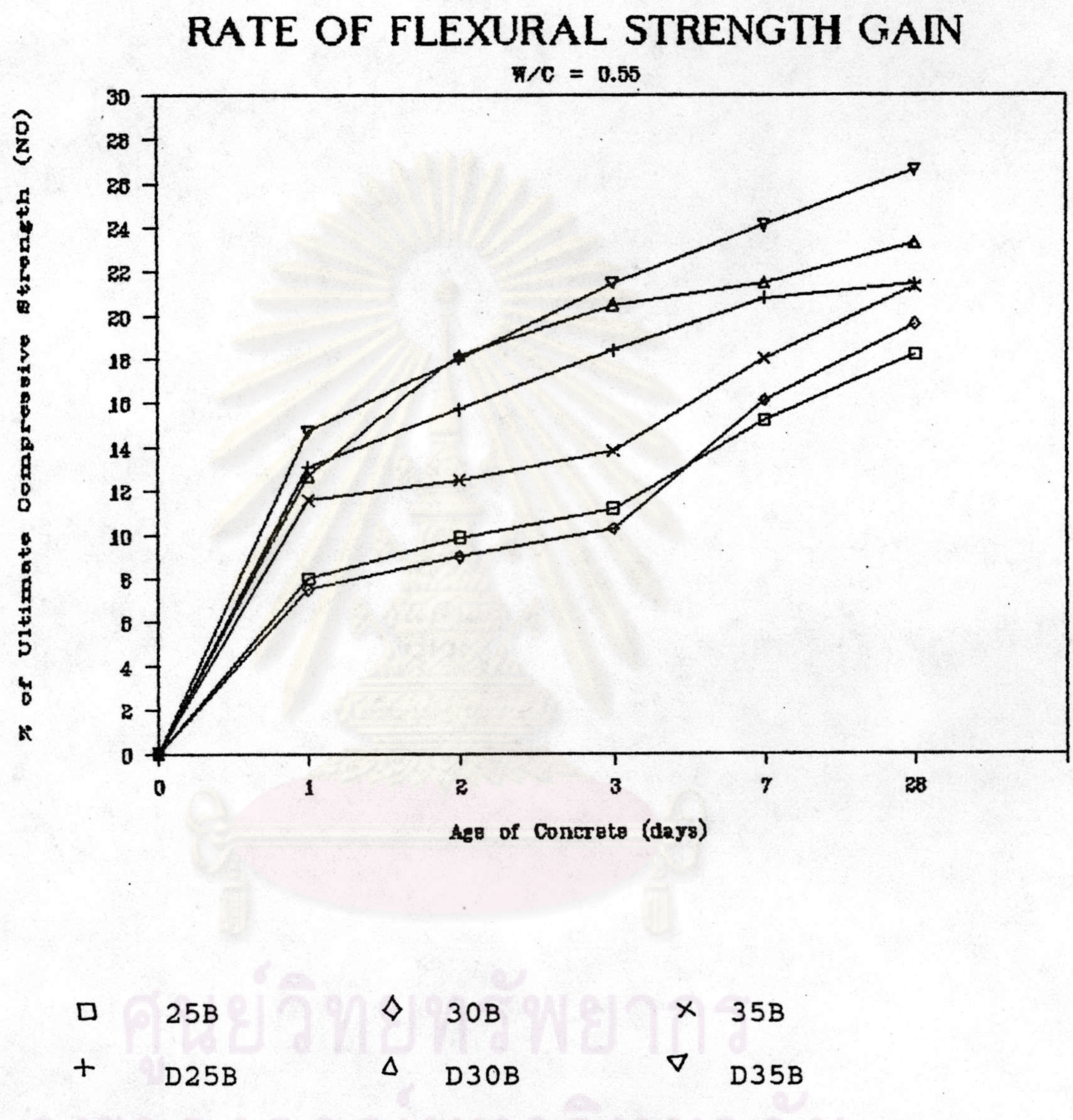


Fig. 66 Rate of Flexural Strength Gain,
Varying Cement Content

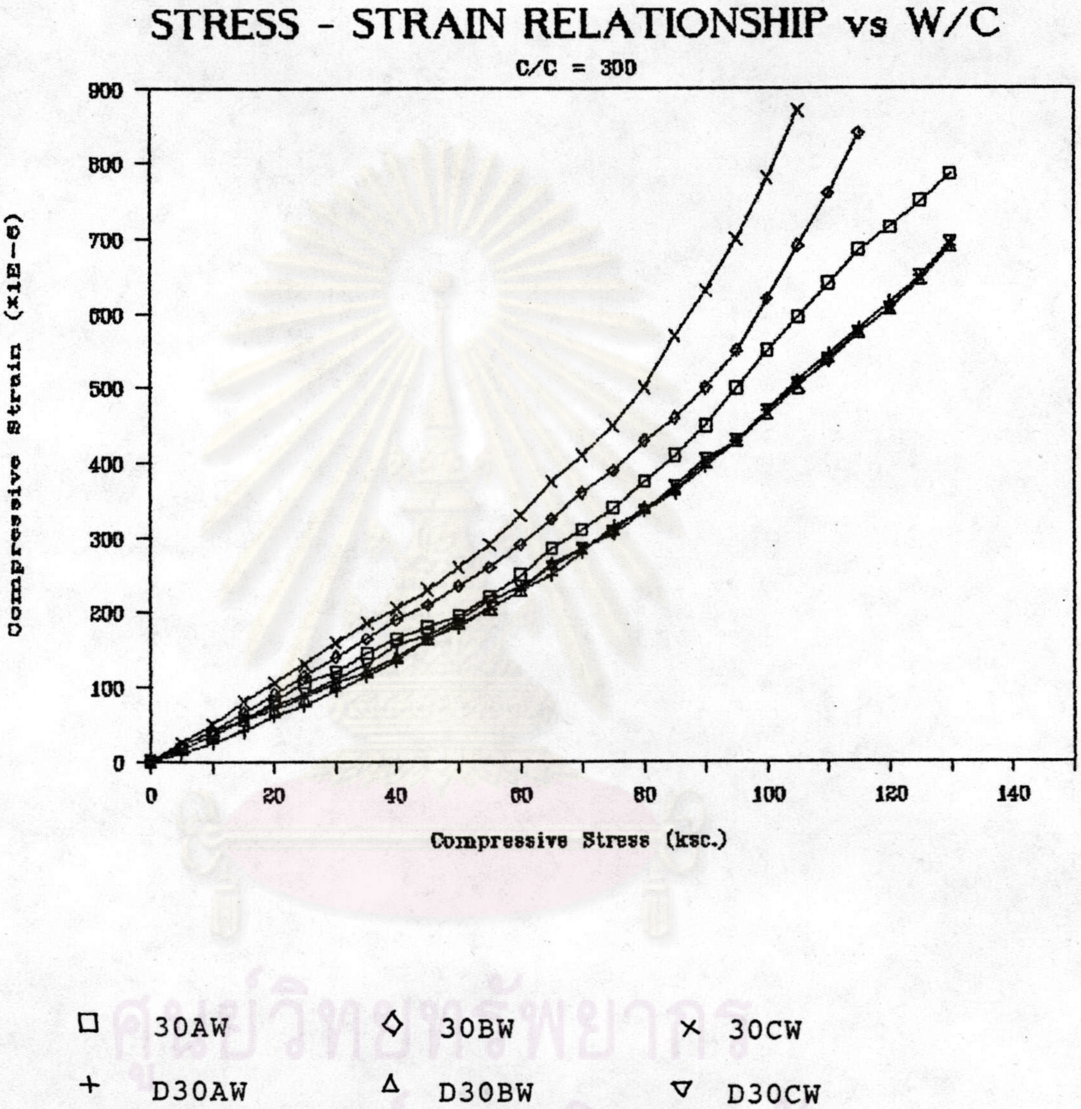


Fig. 67 Effect of Initial Water-Cement Ratio on Relationships between Compressive Stress and Compressive Strain

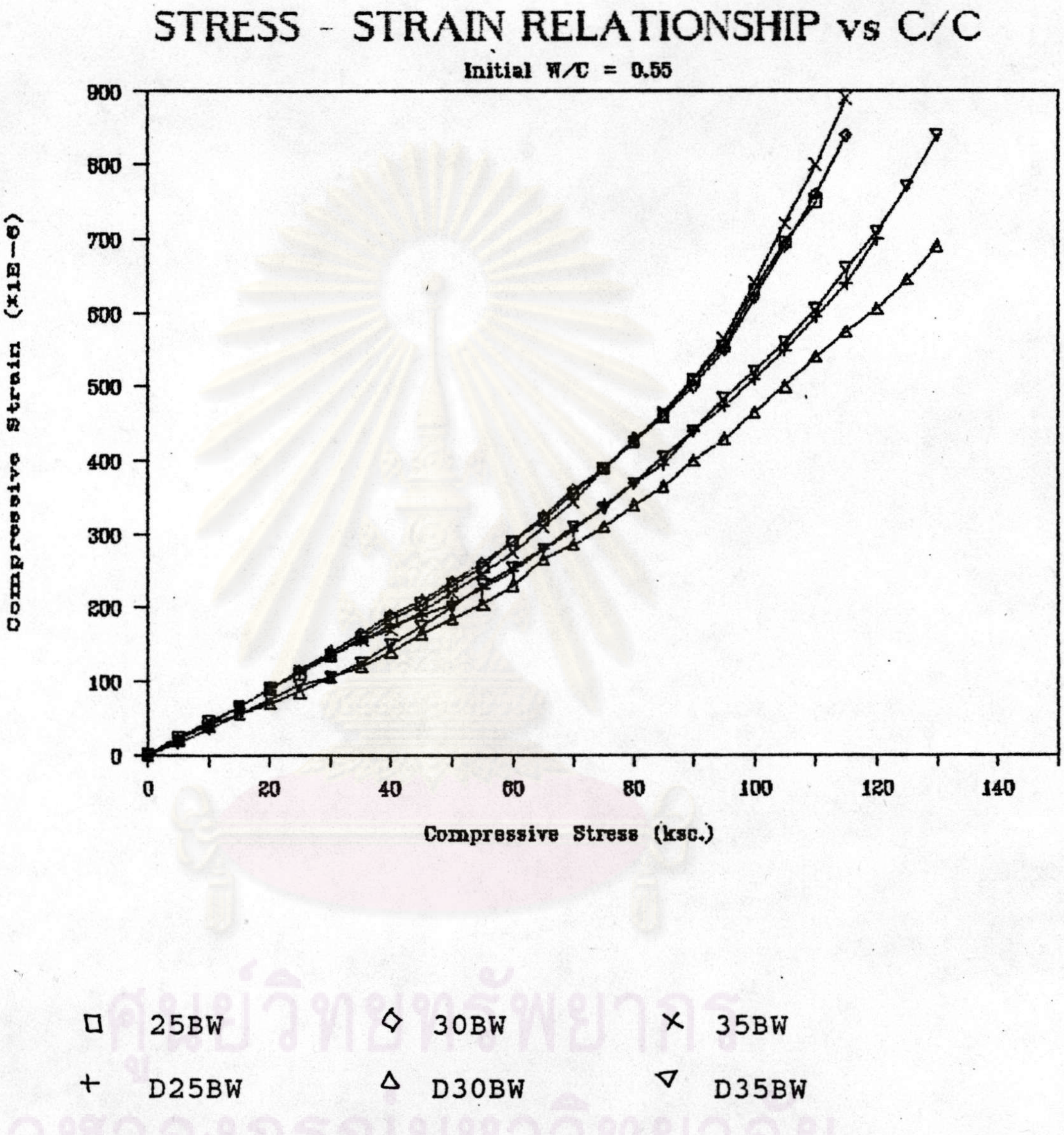
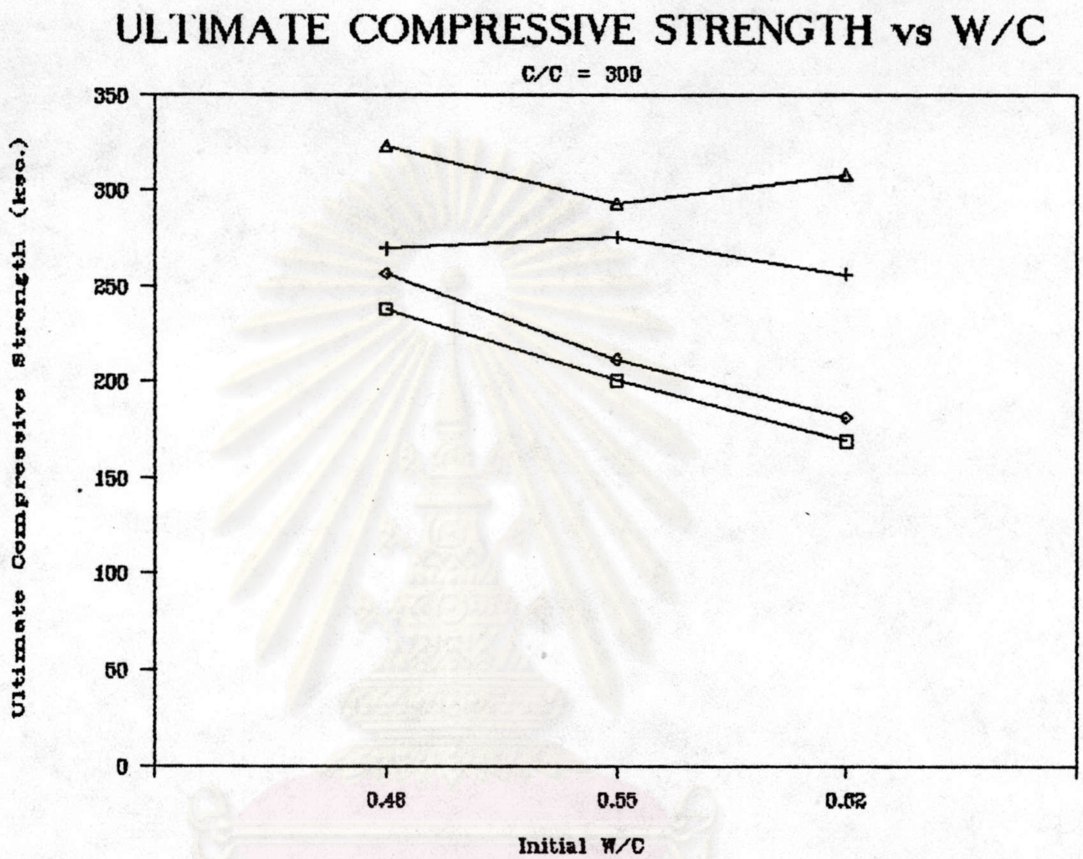


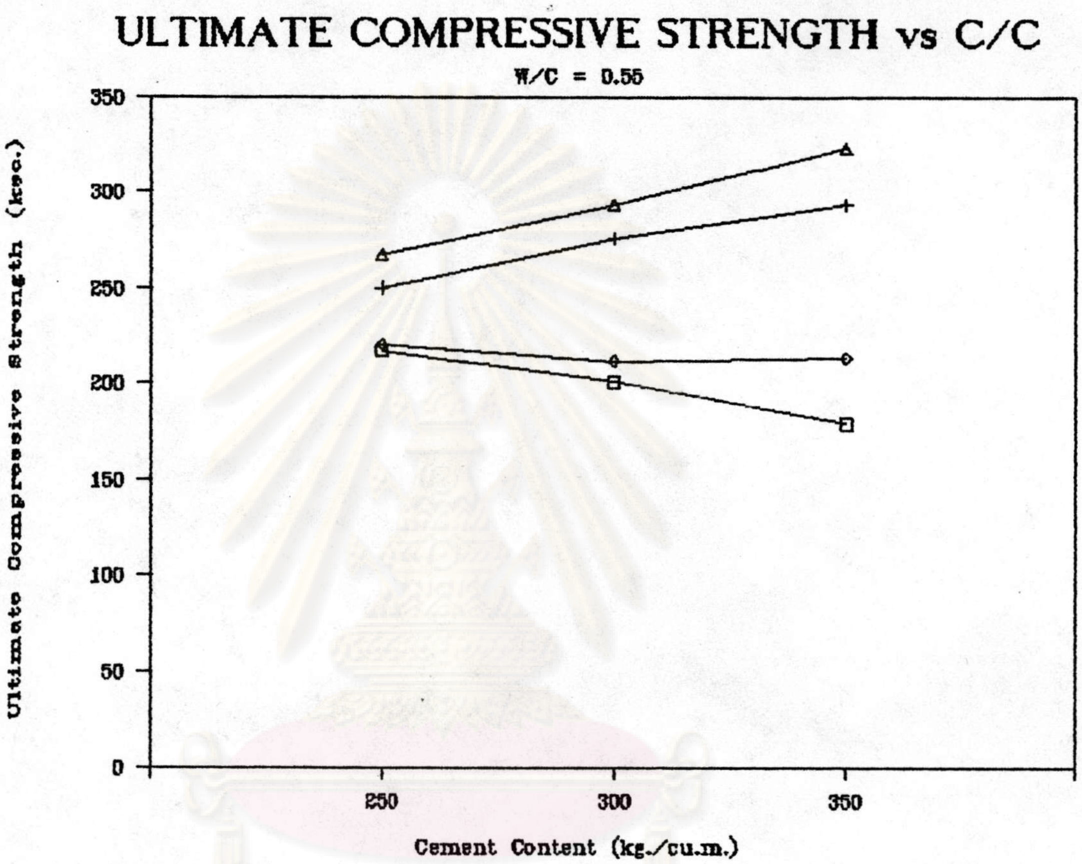
Fig. 68 Effect of Cement Content on Relationships between Compressive Stress and Compressive Strain



□ Conventional,Air-cured + Vacuum-dewatered,Air-cured

◇ Conventional,Moist-cured △ Vacuum-dewatered,Moist-cured

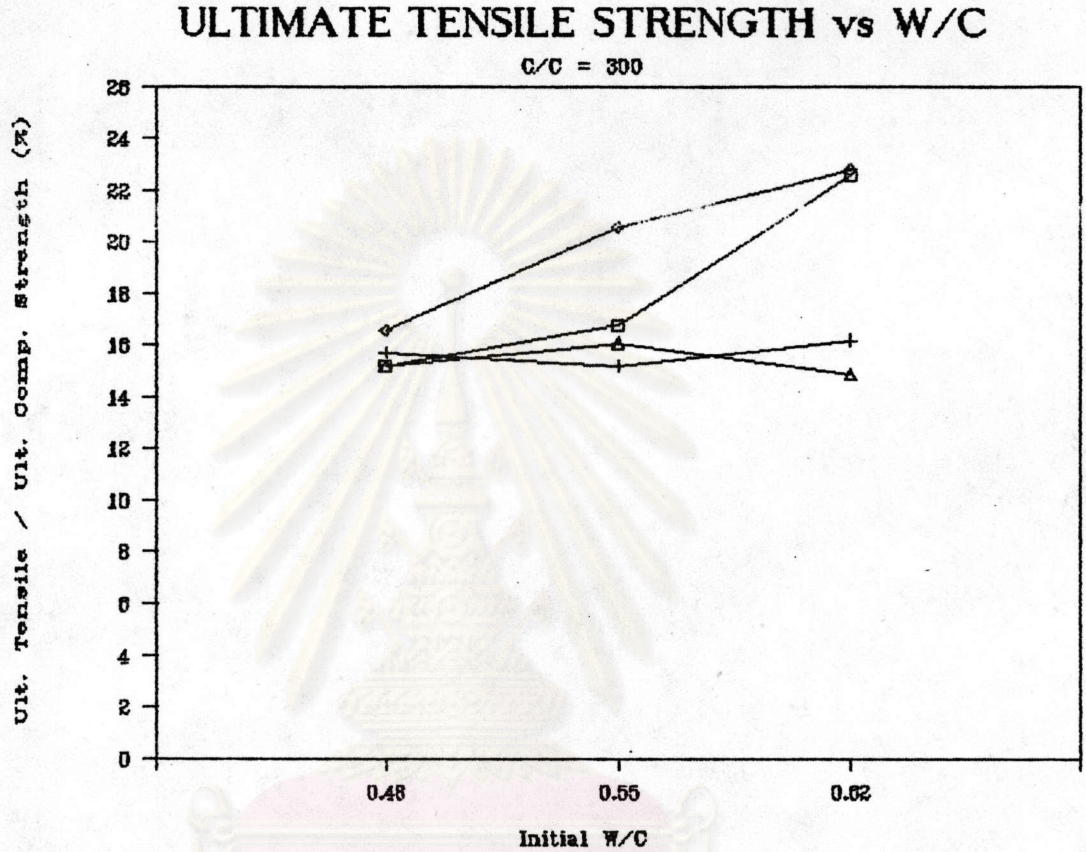
Fig. 69 Effect of Initial Water-Cement Ratio on Ultimate Compressive Strength



□ Conventional, Air-cured + Vacuum-dewatered, Air-cured

◇ Conventional, Moist-cured △ Vacuum-dewatered, Moist-cured

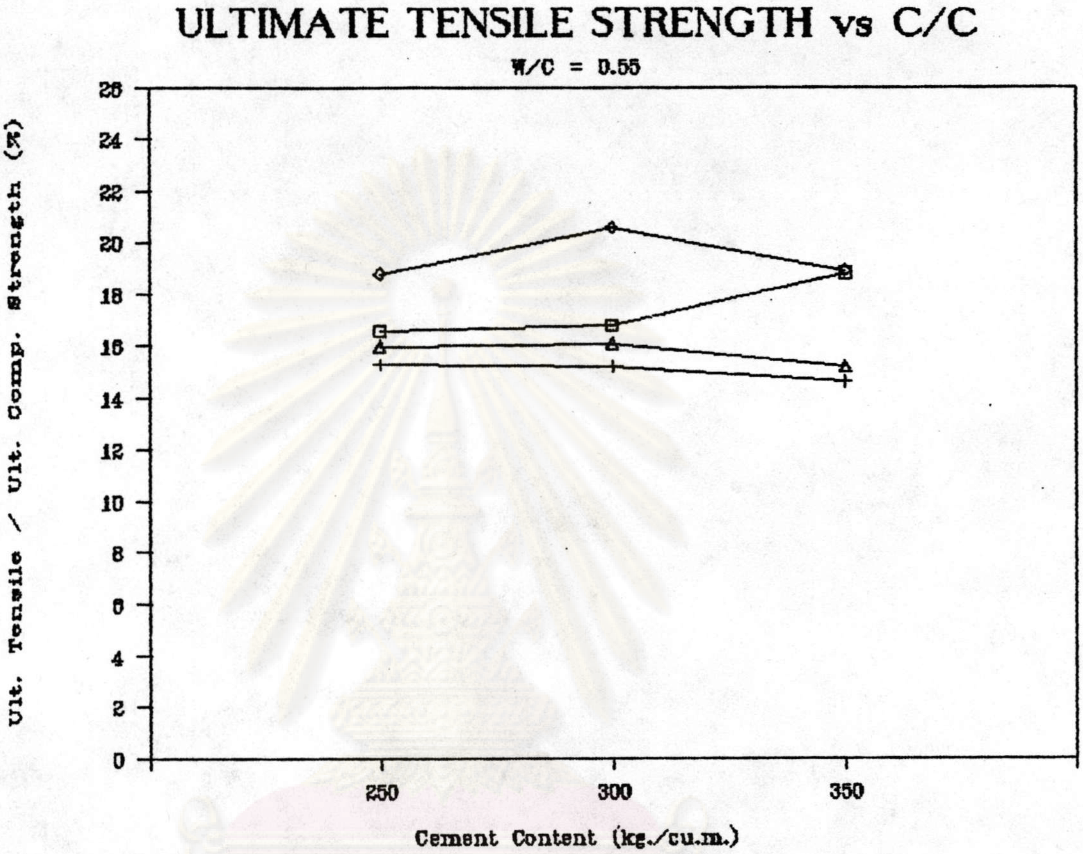
Fig. 70 Effect of Cement Content on Ultimate Compressive Strength



□ Conventional,Air-cured + Vacuum-dewatered,Air-cured

◇ Conventional,Moist-cured △ Vacuum-dewatered,Moist-cured

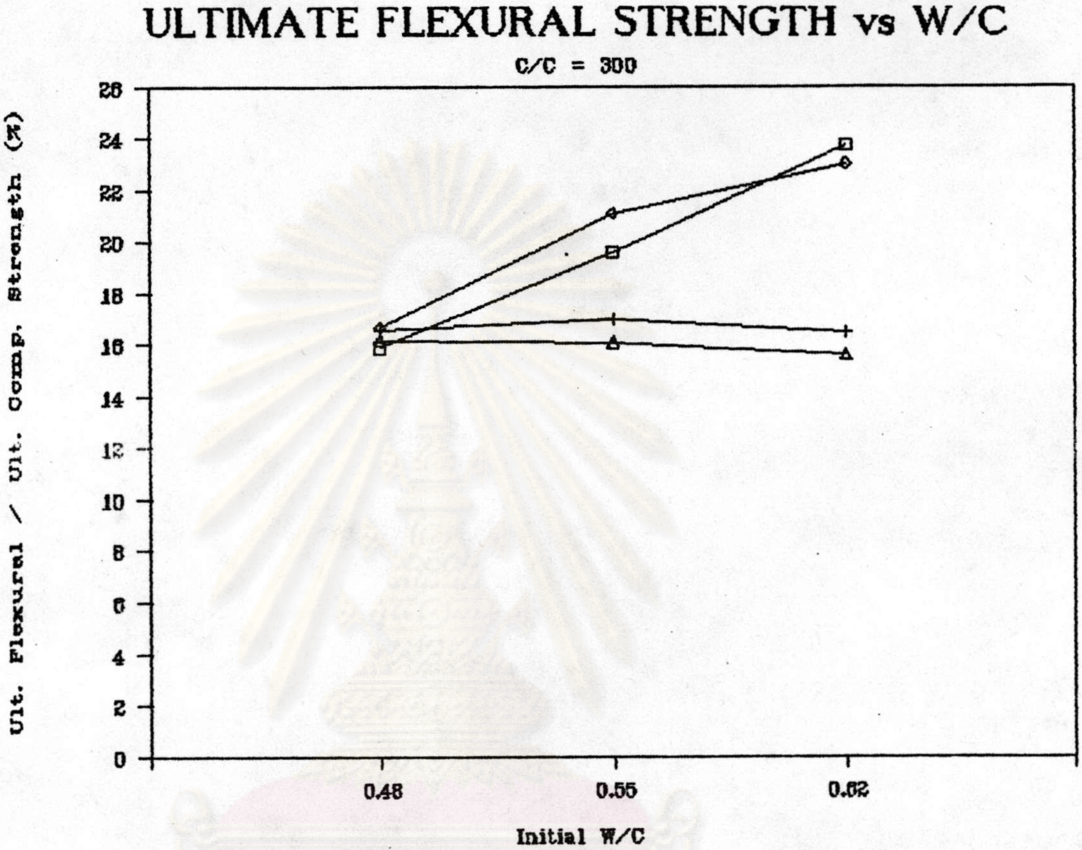
Fig. 71 Effect of Initial Water-Cement Ratio on Ultimate Splitting Tensile Strength



□ Conventional, Air-cured + Vacuum-dewatered, Air-cured

◇ Conventional, Moist-cured △ Vacuum-dewatered, Moist-cured

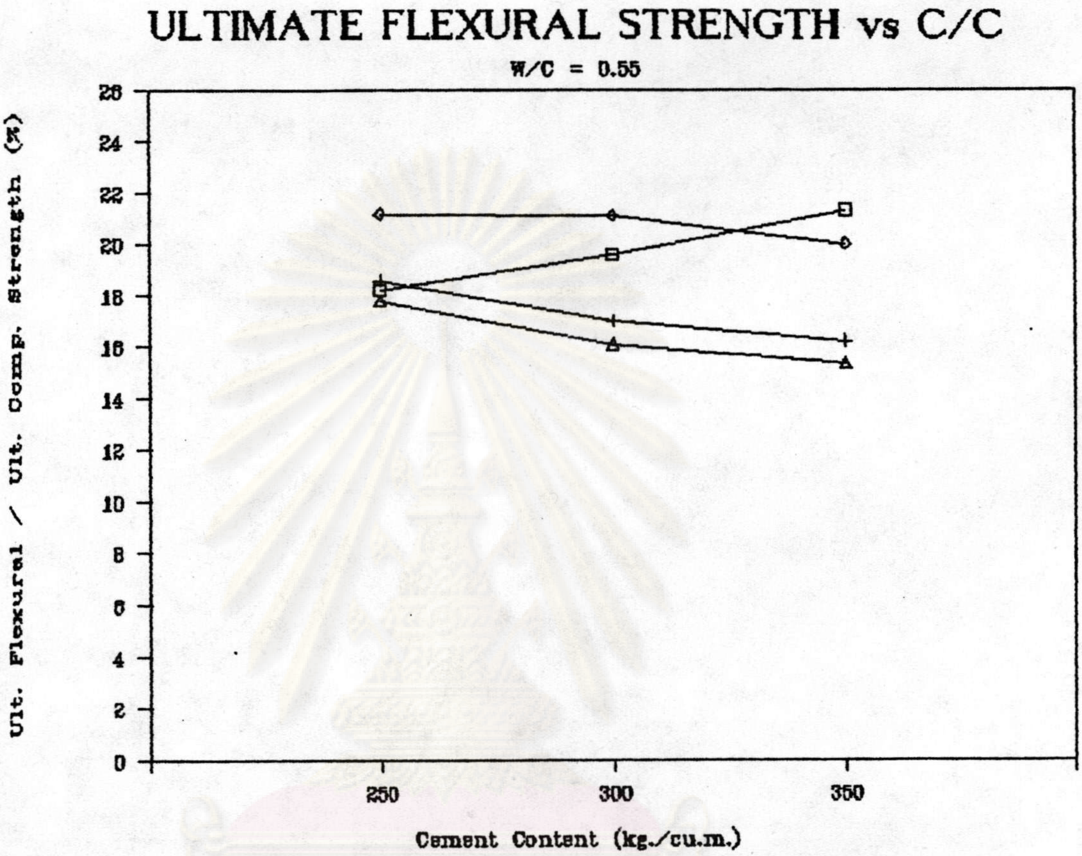
Fig. 72 Effect of Cement Content on Ultimate Splitting Tensile Strength



□ Conventional,Air-cured + Vacuum-dewatered,Air-cured

◇ Conventional,Moist-cured Δ Vacuum-dewatered,Moist-cured

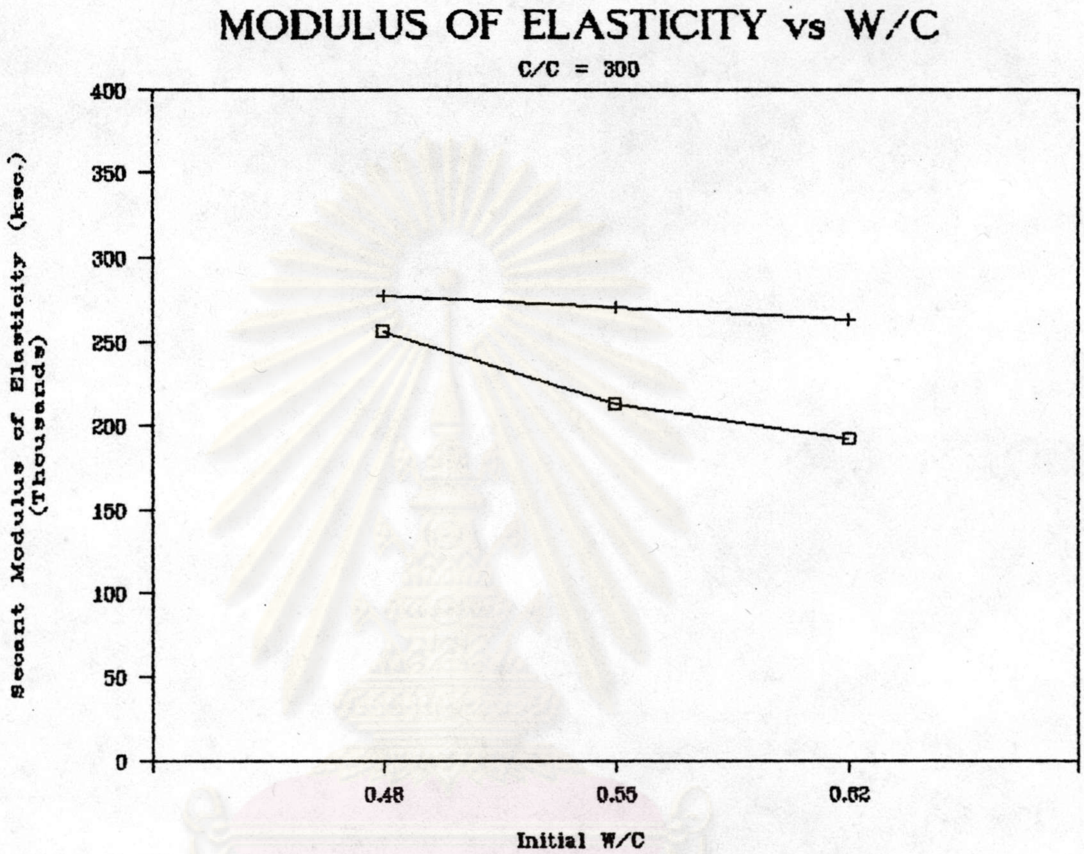
Fig. 73 Effect of Initial Water-Cement Ratio on Ultimate Flexural Strength



□ Conventional,Air-cured + Vacuum-dewatered,Air-cured

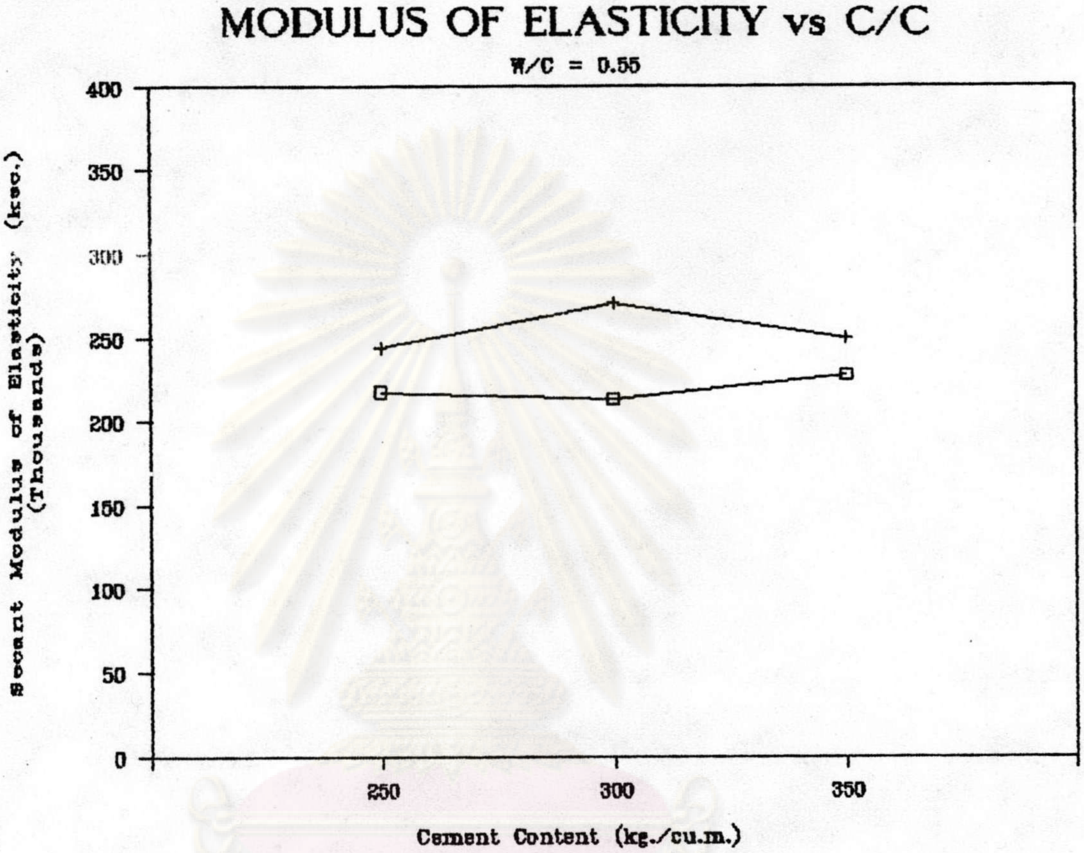
◇ Conventional,Moist-cured △ Vacuum-dewatered,Moist-cured

Fig. 74 Effect of Cement Content on Ultimate Flexural Strength



□ Conventional,Moist-cured + Vacuum-dewatered,Moist-cured

Fig. 75 Effect of Initial Water-Cement Ratio on Secant Modulus of Elasticity



□ Conventional,Moist-cured + Vacuum-dewatered,Moist-cured

Fig. 76 Effect of Cement Content on Secant Modulus of Elasticity

VITA

The author is a civil engineer since his graduation from the department of Civil Engineering, Chulalongkorn University in 1981. He first experienced himself as one of the construction team in the OCEAN INSURANCE HEAD OFFICE BUILDING project, concentrated on the intricate field of post-tensioned flat plate. After the termination of the project, he applied this course of the Master Degree in Structural Engineering to fulfill his knowledge. He also had been the significant member of the post-tensioning team at the SILOM PALACE CONDOMINIUM project during his course.