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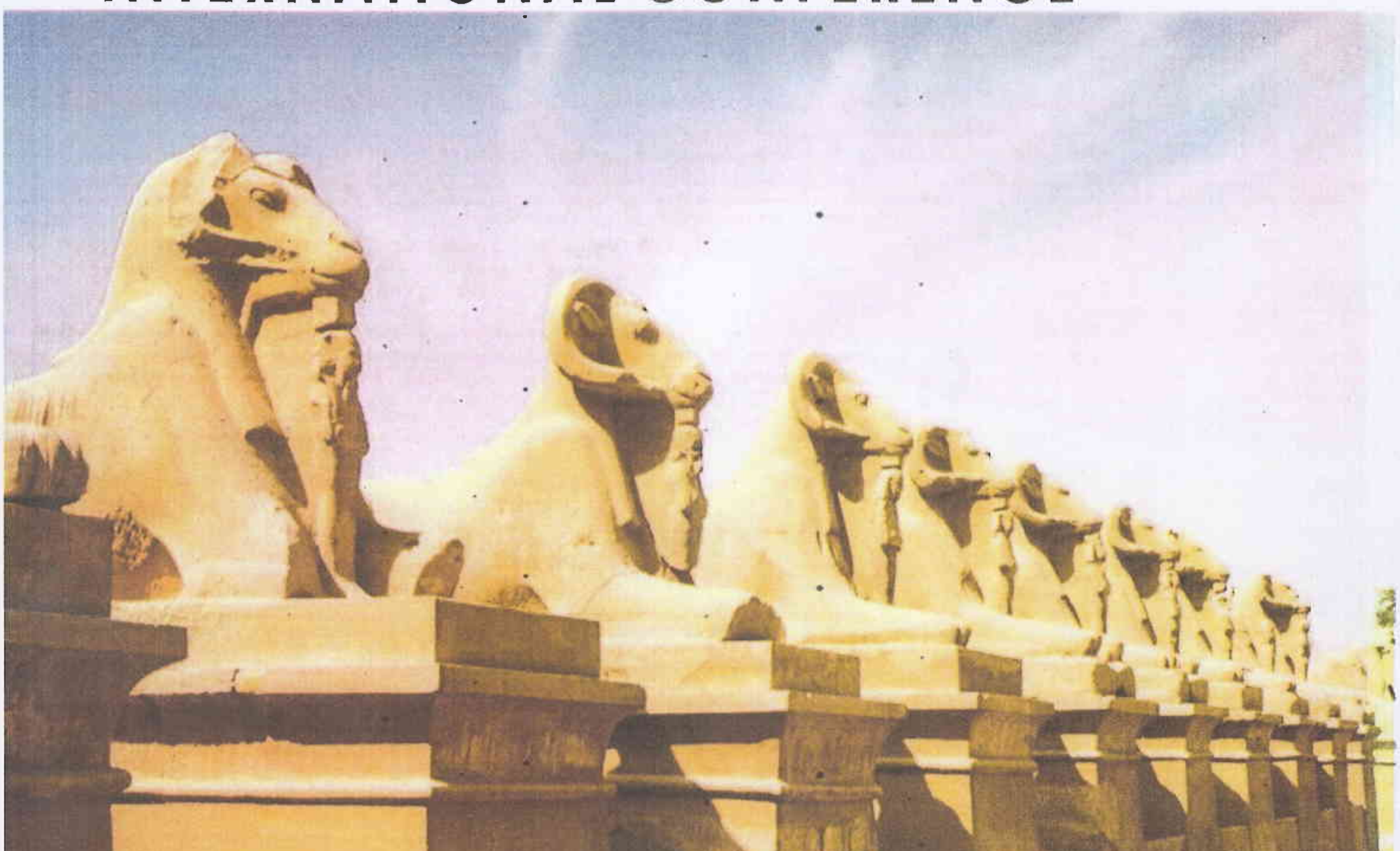

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ESTIMATING OF COMPRESSIVE STRENGTH OF DIFFERENT TYPES OF CONCRETE BY NONDESTRUCTIVE TESTS

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Abstract— The objective of this research is to investigate the effect of the coarse aggregate content, type of coarse aggregate (normal weight and light weight), and amount of steel fiber in concrete on compressive strength, both rebound number and ultra-sonic pulse velocity. Moreover, the relationship between compressive strength and rebound number, ultra-sonic pulse velocity (UPV) was discussed. The experimental work included testing of twenty-four mixes of concrete. The mixes were divided into two groups; each group consisted of twelve mixes, first group mixes consisted of normal weight coarse aggregate, second group mixes consisted of lightweight coarse aggregate, in each group, three contents of coarse aggregate and four percents of steel fiber (0, 0.25, 0.5, 0.75% of concrete volume) were used. It has been noticed that, the UPV increases with increasing coarse aggregate content in normal weight coarse aggregate concrete and vice versa in lightweight coarse aggregate concrete. The increment of age (from 7 to 28 days) leads to higher compressive strength, rebound number and UPV. The steel fiber content showed pronounced effect on the values of UPV. The results also show that, there is a good correlation between compressive strength and rebound number as well as UPV for the two types of concrete.

I. INTRODUCTION

Several national and international standards recognize the various non-destructive test methods as suitable and indicative [1]. Basically, most test methods measure some other properties of concrete than its strength, but the evaluation of in-situ concrete strength is carried out by means of an established correlation of these properties with strength. Therefore, the reliability of the strength estimation primarily depends upon the precision of the established calibration.

Rebound hardness and ultrasonic pulse velocity techniques are commonly used tests for the estimation of concrete strength. The compressive strength of concrete is related to the surface hardness of the concrete in the case of rebound hammer test and to the velocity of a pulse propagated through the full thickness of a concrete element in the pulse velocity technique. The merits and limitations of those techniques are discussed by Bungay [2] and Tann [3]. The relationship between the compressive strength and rebound number or pulse velocity is known to be influenced by several intrinsic and extrinsic factors. Among those factors, the aggregate type and moisture content of concrete, which have a significant effect on the correlation [3,4].There is no standard correlation between concrete compressive strength and the ultrasonic pulse velocity and many aspects controlled this matter. The nature of the aggregates which is one of the major aspects that is generally more plentiful, rigid,and resistant part in concrete, influences this correlation and changes the elastic properties of the concrete.

In this investigation the influence of normal strength and lightweight coarse aggregate with and without fibers on the correlations between compressive and both rebound number and pulse velocity has been studied.

II. EXPERIMENTAL PROGRAM

In order to achieve the aim of the study, 24 mixes (144 specimens) are designed, prepared and tested for fresh and hardened normal weight and light weight concrete.

A. Materials

Ordinary Portland cement with specific gravity of 3.15 and Blaine fineness 3200 cm2/g was used. Table (1) presents the physical properties and chemical compositions of the cement. A local natural coarse (with maximum size of 20mm) and fine aggregate from Zubair, Basrah (south of Iraq), that meet the requirement of ASTM C33-03[5] were used. In this study one type of lightweight coarse aggregate, crushed thermostone was used. The shape of crushed lightweight coarse aggregate was normally in angular with adequate amount of elongated of and flaky particles, for this type of coarse aggregate. The maximum size was 20mm; the part of the excess fine was removed so as to satisfy the ASTM C-330 specification [6]. The sieve analysis of all aggregates is presented in Table (2). Some properties of the lightweight coarse aggregate of each type are given in Table (3). The coarse and fine aggregate each had a specific gravity of 2.62, water absorption of 0.8 and 1.4% respectively.Polycarpoxy superplasticizer as per ASTM C494 type G specification [7] having a specific gravity of 1.05 and a total solid content of 30% was used. Ordinary tap water is used for mixing and curing.

B. Mix Proportions

Details of the mixes are shown in Table (4). The coarse aggregate contents were 1000, 1050 and 1100 kg/m3 for normal weight concrete and 295, 310, 323 kg/m3 for light weight concrete. The W/C ratios were 0.4 for each value of coarse aggregate content. The steel fiber ratios were 0, 0.25, 0.5 and 0.75% of concrete volume.

C. Preparation Specimens and Test Methods

Standard 150mm cubes were used to determine compressive strength at ages 7 and 28 days. The compressive strength for each specimen represents the average of compressive strength of 3 cubes. All samples were demolded after 24hrs, marked and cured in water until testing age.

The rebound number was measured by Schmidt hammer and according to ASTMC805-02 [8]. Each cube was fixed by applying (6) MPa in a compression machine to avoid any movement during this test as shown in Fig.(1). Five readings were taken on each two opposite smooth surfaces of the cube, thus a total of 10 readings were taken on each cube. The final reading of rebound number of each mix was therefore the average of 60 readings. The ultra-sonic pulse velocities of the concrete cubes were measured according to ASTMC597-02 [9] using transducers with frequency (54) kHz, as shown in Fig.(2).Two readings on each cube were measured(using the opposite smooth surfaces of the cube). Thus each mix result of ultrasonic pulse velocity represents an average of twelve readings.

Table (1): Physical properties and chemical composition of cement

PHYSICAL PROPERTIES	
Sitting time(min)	
Initial	150
Final	240
Compressive strength (MPa)	
7days	22.7
28days	30.3
Specific surface, blaine,cm²/g	3200
CHEMICAL ANALYSIS %	
Lime (CaO)	62.00
Silica (SiO_2)	21.00
Alumina (Al_2O_3)	5.26
Iron Oxide (Fe_2O_3)	3.00
Magnesia (MgO)	2.70
Sulfate (SO_3)	2.10
Loss on ignition (LOI)	1.10
Insoluble residue (I.R.)	0.70
Lime saturation factor (L.S.F)	0.92

Figure (1): Schmidt hammer test

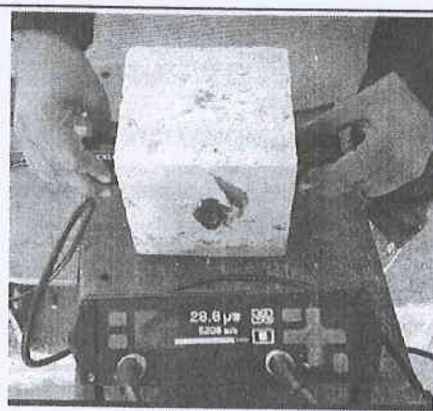


Figure (2): UPV test

III. RESULTS AND DISCUSSION

The test results obtained from this investigation are summarized in Tables (5) and (6). The discussion of the effect of studied parameters on the compressive strength, rebound number and ultra-sonic pulse velocity is presented in the following articles:

A. Rebound number results

Test results show the effect of coarse aggregate content and fiber content on the rebound number of NWC and LWC in addition to the relationship between rebound number and compressive strength is investigated as described in following sections:

B. Effect of fibers content on rebound number

From Fig. (3), it can be noted that increase in the fiber content causes an increase in the rebound number clearly in the lightweight concrete more than it is in normal concrete. The increase in the rebound number due to fibers in the 28 days was more than in the 7 days.

Table (2): Grading of the coarse and fine aggregate used

Sieve size mm	Coarse aggregate				Fine aggregate		
	Gravel Passing %	ASTM C33	Thermostone Passing (%)	ASTM C330	Sieve mm	Passing (%)	ASTM C33 limits
25	100	100	100	100	9.5	100	100
19	97	90-100	94	90-100	4.75	97	95–100
9.5	37	20-55	45	10-50	2.36	88	80–100
4.75	2	0-10	11	15-0	1.18	71	50-85
2.36	1	0-5			0.60	45	25-60
					0.30	11	5–30
					[illegible]	[illegible]	[illegible]

Table(3) Physical properties of lightweight coarse aggregate

Absorption %	17.4
Bulk specific gravity (SSD)	2.11
Dry density (kg/m³)	442

Table (4): Mix proportions of all mixtures (light weight& normal weight coarse aggregate)

Type of concrete	Max No.	Coarse aggregate kg/m³	Cement kg/m³	Sand kg/m³	W/C kg/m³	Water kg/m³	SP of cement %	Fiber content %
NSC	1	1000	521.4	670	0.4	208	0	0
	2							0.25
	3							0.5
	4							0.75
	5	1050	462	703	0.4	184	0.55	0
	6							0.25
	7							0.5
	8							0.75
	9	1100	402	737.0	0.4	160	1.5	0
	10							0.25
	11							0.5
	12							0.75
LWC	13	295	521	670	0.4	208	0.5	0
	14							0.25
	15							0.5
	16							0.75
	17	310	462	703	0.4	184	0.8	0
	18							0.25
	19							0.5
	20							0.75
	21	323	402	737	0.4	160	1.7	0
	22							0.25
	23							0.5
	24							0.75

C. Effect of coarse aggregate content on rebound number

From Fig. (4), it can be observed that, for all fibers content in NWC, the rebound number increases as coarse aggregate content increases but for LWC, the rebound number decreases as coarse aggregate content increases. This is due to the hardness of the concrete surface depends on the hardness of coarse aggregate used in a mixture.

D. The proposed Rebound number – compressive strength relationship

Figure (5) reveals the rebound number – compressive strength relationship for NWC and LWC at ages of 7 and 28 days. It is observed a good correlation between compressive strength and rebound number for NWC and LWC mixes containing fibers regardless of the difference in coarse aggregate content. The proposed relationship between cube compressive strength and the rebound number is expressed as given in equations "(1)" to "(4)" below.

For NWC containing fibers, the Equation "(1)" and "(2)" were proposed to estimate the compressive strength at 7 and 28days from rebound number value respectively

Fcu: compressive strength of concrete(Mpa)

RN: Rebound number

Fcu = 1.286RN - 12.93 (7 days) ……………(1)

Fcu =1.368RN-12.98 (28 days)……………(2)

Figures (6-a) and (6-b) show the relationship between the measured versus the estimated values for the NWC compressive strength with different rebound numbers. The plotted data confirm the reliability of the proposed method for the estimation of the concrete compressive strength with different rebound numbers.

For LWC containing fibers, the Equation "(3)" and "(4)" were proposed to estimate the compressive strength at 7 and 28days from rebound number value respectively as follows:

Fcu: compressive strength of concrete(Mpa)

RN: Rebound number

Fcu = 0.983RN +3.242 (7 days) …………...(3)

Fcu = 1.061RN +5.127 (28 days) …………(4)

Figs.(6-c) and (6-d) shows the relationship between the measured versus the estimated values for the LWC compressive strength with different rebound numbers at ages 7 and 28 days respectively . The plotted data confirm the reliability of the proposed method for the estimation of the concrete compressive strength with different rebound numbers. The predicted compressive strength values are in a good agreement with those obtained from test.

E. Ultrasonic pulse velocity result

Test results presented in Tables (5) and (6) show the effect of coarse aggregate content and fibers content on the ultrasonic pulse velocity of NSC and LWC. In addition to the relationship between ultrasonic pulse velocity and compressive strength is investigated as described in following subsections:

F. Effect of fiber content

From Fig. (7) shows that, increase in the fiber content causes an increase in the ultrasonic pulse velocity in the light concrete and normal strength concrete. The increase in the ultrasonic pulse velocity is same for the 28 days and the 7 days.

G: Effect of coarse aggregate content

From Fig. (8) it can be observed that for all fiber contents in NWC, the ultrasonic pulse velocity increases as coarse aggregate content increases but for LWC the ultrasonic pulse velocity decreases. The increase in the ultrasonic pulse velocity in the 7days is more than in the 28 days. Figures (10-a) and (10-b) show the relationship between the measured versus the estimated values for the compressive strength NWC containing fibers with different UPV. The plotted data confirm the reliability of the proposed method for the estimation of the concrete compressive strength with different UPV. For LWC containing fibers, the Equations "(7)" and "(8)" were proposed to predict the 7 and 28days compressive strength from respectively UPV values

Fcu: compressive strength of concrete(Mpa)

V: Ultrasonic plus velocity

Fcu = 1.269 e0.841V (7days)……………..(1)

Fcu= 0.888 e0.880V (28 days)…………..(2)

Moreover the actually measured compressive strength values are plotted versus the corresponding predicted ones for LWC in Fig. (10-c) and (10-d). the plotted results confirm the reliability of the proposed method for the estimation of the concrete compressive strength with different UPV.

Table (5): Compressive strength, rebound number and ultrasonic pulse velocity of NWC mixes

Coarse agg. content kg/m^3	Fibers content %	Compressive strength (MPa)		Rebound number		Ultrasonic pulse velocity (km/sec)	
		7	28	7	28	7	28
1000	0	32.7	44.5	35.6	42.0	4.524	4.716
1000	0.25	32.9	44.7	35.9	42.3	4.556	4.749
1000	0.5	34.2	46.2	37.2	43.8	4.609	4.800
1000	0.75	36.7	49.5	39.1	45.7	4.714	4.906
1050	0	33.9	45.6	36.3	42.7	4.546	4.732
1050	0.25	34.3	46.0	36.6	43.0	4.582	4.767
1050	0.5	36.5	48.9	38.3	45.3	4.651	4.835
1050	0.75	37.4	49.9	39.7	46.4	4.726	4.911
1100	0	35.1	46.7	36.9	43.2	4.568	4.746
1100	0.25	36.4	48.3	37.8	44.3	4.620	4.798
1100	0.5	37.6	49.9	39.1	45.8	4.669	4.848
1100	0.75	40.1	[illegible]	40.9	48.1	[illegible]	[illegible]

Table (6): Compressive strength, rebound number and ultrasonic pulse velocity of LWC mixes

Coarse agg. content (kg/m^3)	Fibers content %	Compressive strength (MPa)		Rebound number		Ultrasonic pulse velocity (km/sec)	
		7	28	7	28	7	28
348	0	21.7	29.1	18.4	22.1	3.340	3.925
348	0.25	22.5	30.6	18.9	23.0	3.378	3.995
348	0.5	23.3	31.5	19.6	23.8	3.434	4.036
348	0.75	24.8	33.0	21.6	26.1	3.507	4.100
365	0	21	28.2	18.0	21.6	3.322	3.898
365	0.25	21.2	28.4	18.3	21.9	3.345	3.952
365	0.5	22.2	29.7	19.1	22.9	3.407	4.002
365	0.75	23.1	30.6	20.7	24.9	3.467	4.018
381	0	20.3	27.0	17.7	21.0	3.304	3.871
381	0.25	20.4	27.1	17.9	21.3	3.324	3.924
381	0.5	21.2	28.1	18.6	22.1	3.382	3.969
381	0.75	22.7	30.1	[illegible]	[illegible]	[illegible]	[illegible]

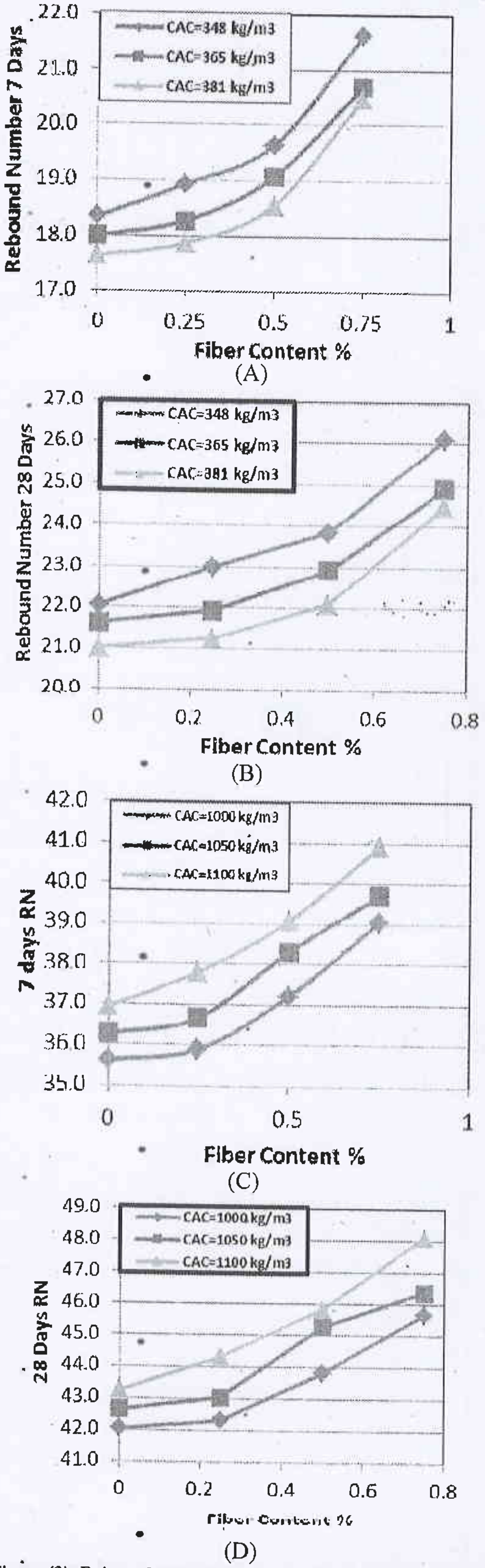
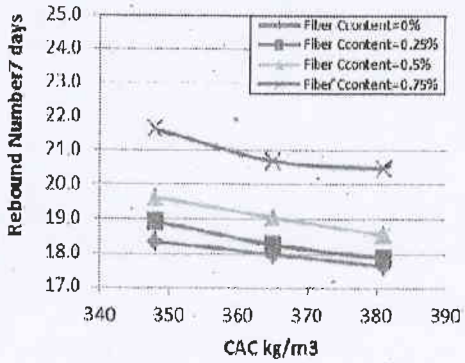
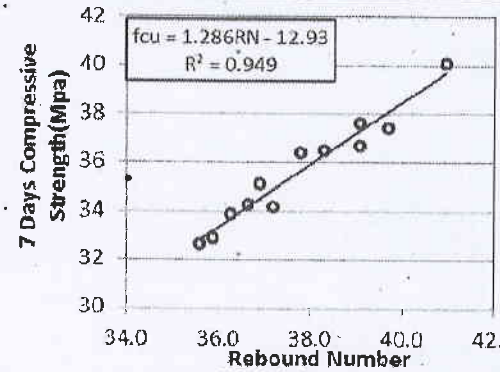


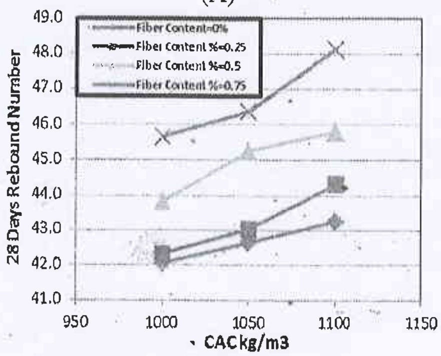
Figure (3): Rebound number Fiber content relationship for (a) NSC at 7 Days, (b) NSC at 28 Days, (c) LWC at 7 Days and (d) LWC at 28 Day.



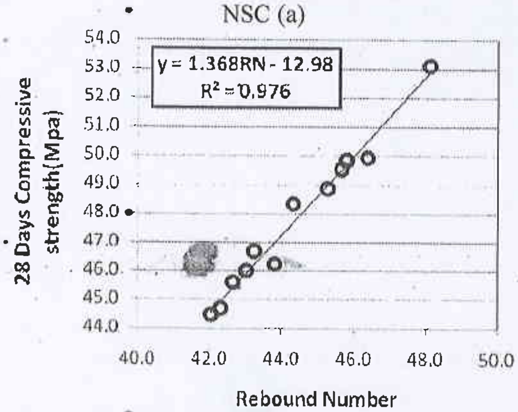
(A)



NSC (a)

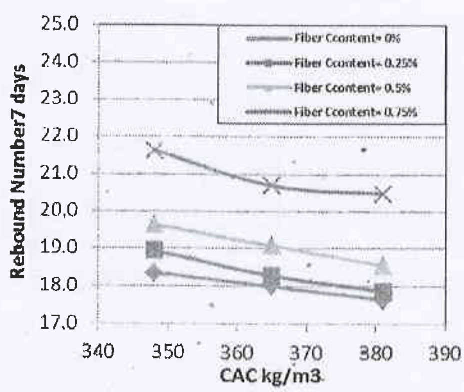


(B)

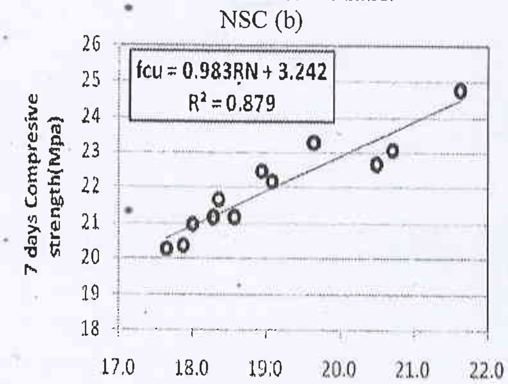


NSC (b)

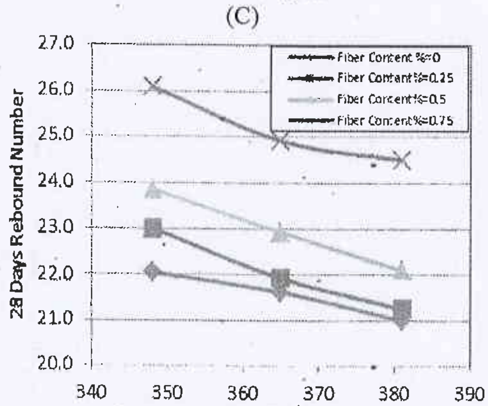
Figure (4): Rebound number - coarse aggregate content relationship for (a) NSC at 7 Days, (b) NSC at 28 Days



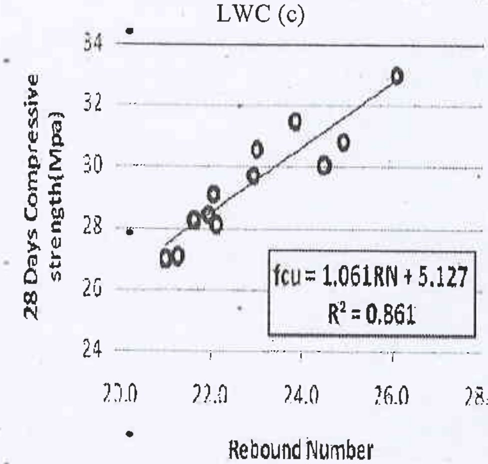
(C)



LWC (c)



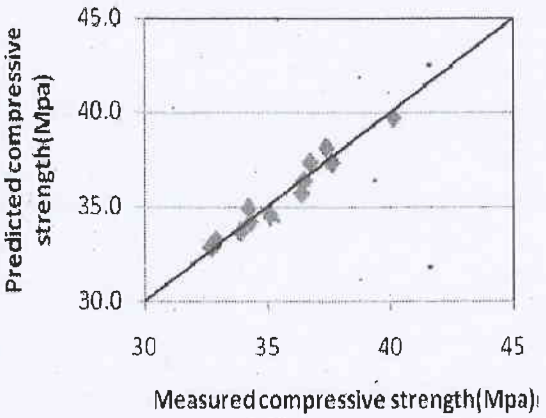
(D)



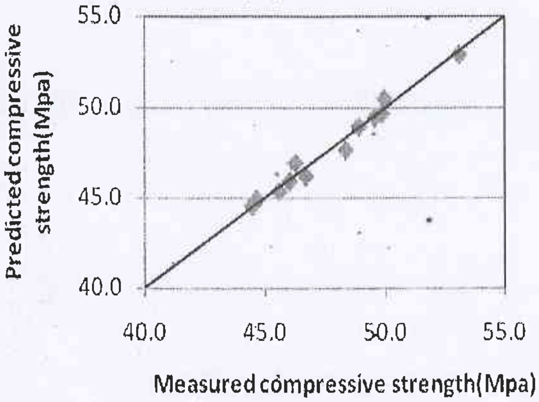
LWC (d)

Figure (4): Rebound number - coarse aggregate content relationship for (c) LWC at 7 Days and (d) LWC at 28 Day

Figure (5): Rebound number – compressive relationship for (a) NSC at 7 Days, (b) NSC at 28 Days, (c) LWC at 7 Days and (d) LWC at 28 Day



(A)



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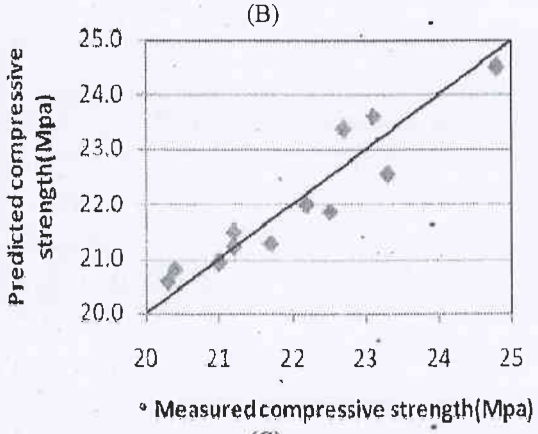
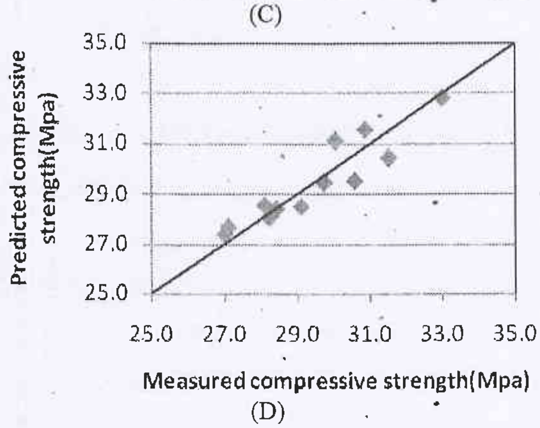
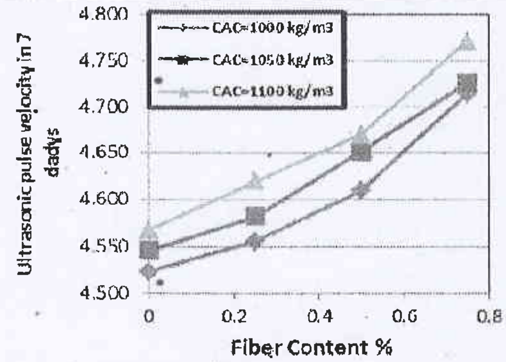


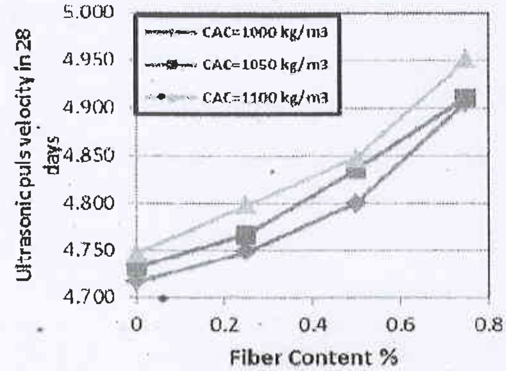
(C)



(D)

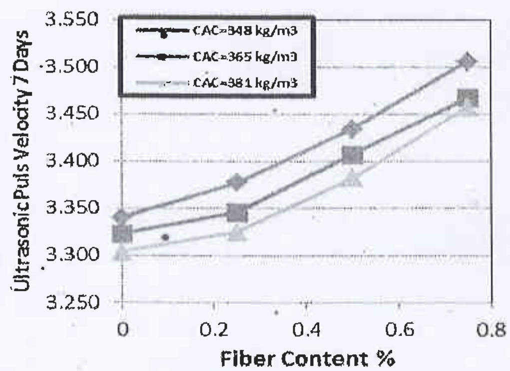


NSC (A)

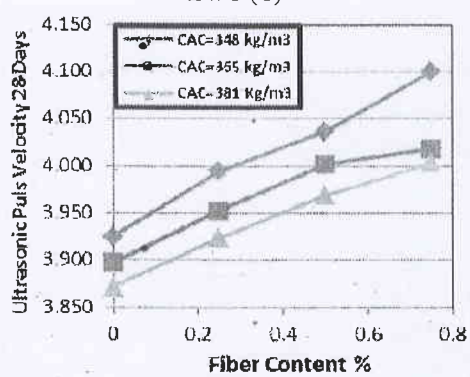


NSC (B)

Figure (7): Ultrasonic pulse velocity fiber content relationship for (a) NSC at 7 Days, (b) NSC at 28 Days

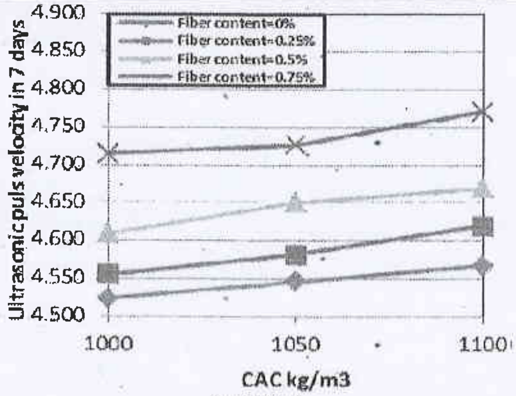


LWC (C)

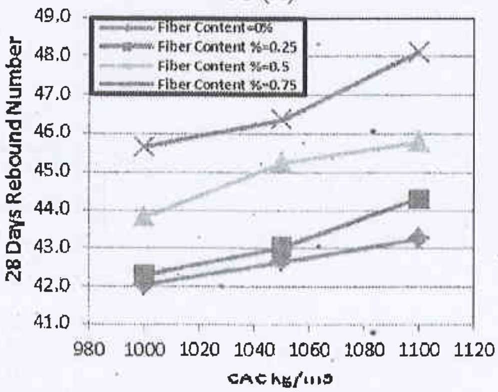


LWC (D)

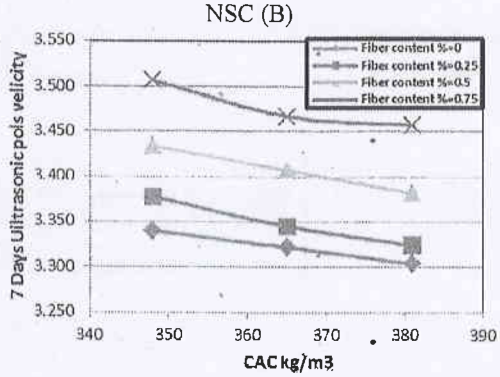
Figure (7): Ultrasonic pulse velocity fiber content relationship for (c) LWC at 7 Days and (d) LWC at 28 Day



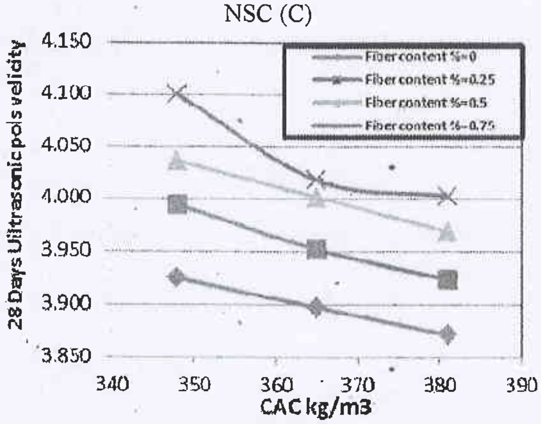
NSC (A)



NSC (B)

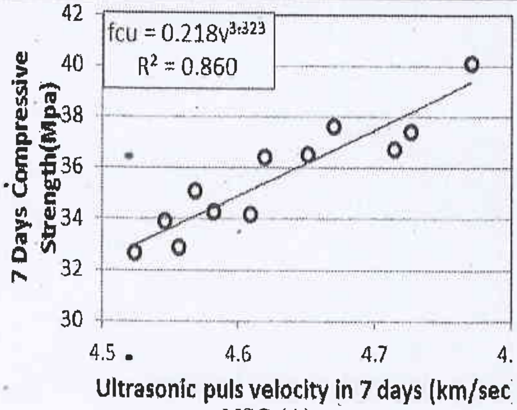


NSC (C)

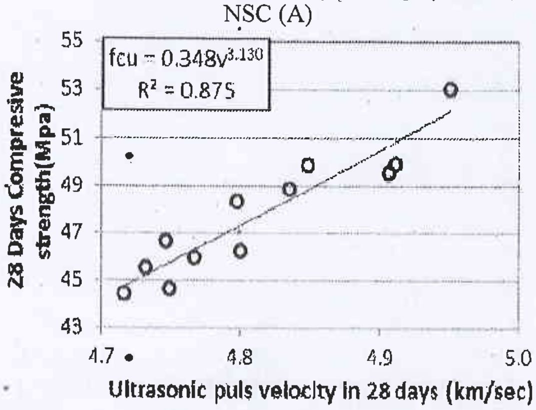


NSC (D)

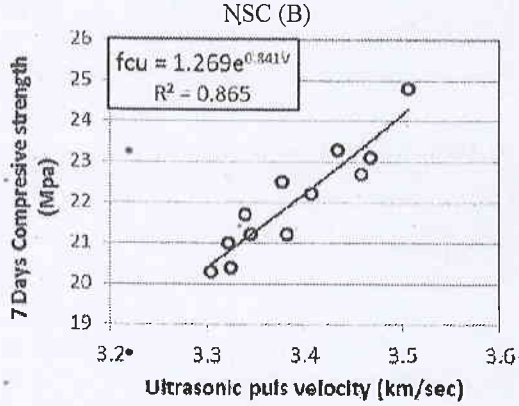
Figure (8): Ultrasonic pulse velocity- coarse aggregate content relationship for (a) NSC at 7 Days, (b) NSC at 28 Days, (c) LWC at 7 Days and (d) LWC at 28 Day



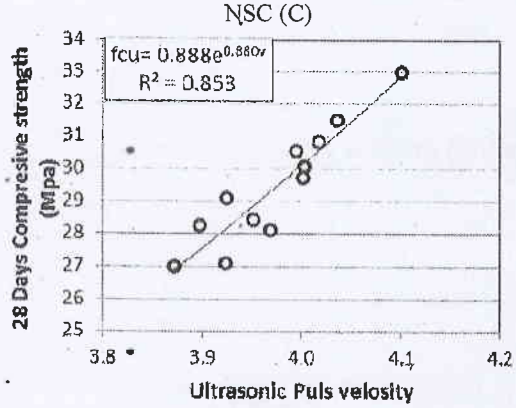
NSC (A)



NSC (B)

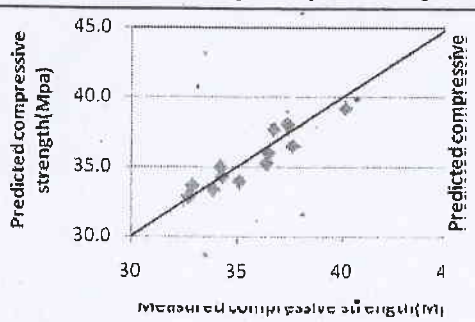


NSC (C)

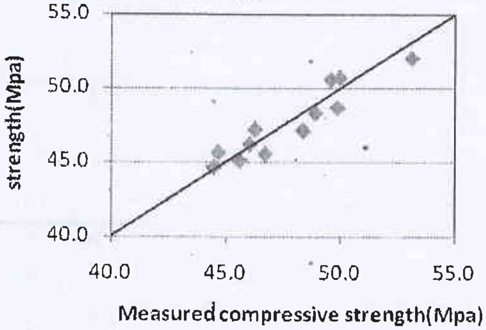


NSC (D)

Figure (9): ultrasonic pulse velocity compressive strength relationship for (a) NSC at 7 Days, (b) NSC at 28 Days (c) LWC at 7 Days and (d) LWC at 28 Day

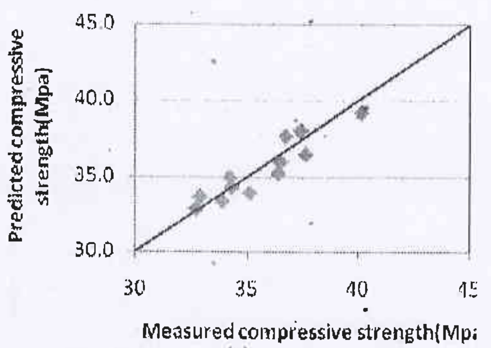


(a)

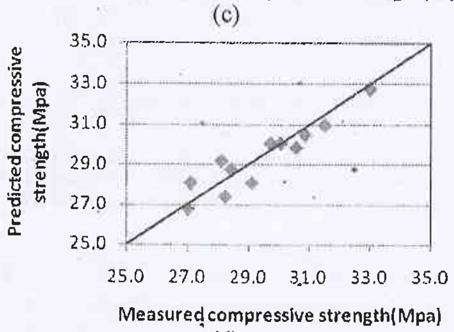


(b)

Figure (10): Actual compressive strength values predicted ones at different ages for different concrete mixes depending on UPV results :(a) NWC at 7 days (b) NWC at 28 days



(c)



(d)

Figure (10): Actual compressive strength values predicted ones at different ages for different concrete mixes depending on UPV results :(a) NWC at 7 days (b) NWC at 28 days(c) LWC at 7 days (d) LWC at 28 days

CONCLUSIONS

From the test results obtained in this study the following conclusions can be drawn:

1. The rebound number increases as coarse aggregate content increases for NSC but for LWC the rebound number decreases.
2. The rebound number increases as fiber content increases clearly in the lightweight concrete more than in normal weight concrete and this increase in the 28 days more than in the 7 days.
3. The increase in the fiber content causes an increase in the ultrasonic pulse velocity in the light concrete and normal strength concrete and this increase is same for the 28 days and the 7 days.
4. It can be observed that for all fiber contents in NWC, the ultrasonic pulse velocity increases as coarse aggregate content increases but for LWC the ultrasonic pulse velocity decreases.
5. The influence of type and amount of aggregate and steel fiber is very important and cannot be neglected for accurate prediction of compressive strength of concrete based on rebound number and ultrasonic pulse velocity.
6. The good relationships were obtained from curve fitting for the results; therefore the proposed equations can be used to estimate compressive strength of normal and lightweight concrete. The predicted compressive strength values are in a good agreement with those from the experimental tests.

REFERENCES

[1] British Standards Institution, BS 6089 "Guide to the assessment of concrete strength in existing structures",(BSI, London, 1981).
[2] Bungay, J.H., "The testing of concrete in structures" (Surrey University Press, London, 1982) p. 207.
[3] Tam, C.T., "Non-destructive testing of concrete – limitation and usefulness", 2nd Conference on Our World in Concrete and Structures, Singapore, August 1977, pp. 29-43.
[4] Sri Ravindrarajah, R., and Tam, C.T., "Combined pulse velocity and rebound hammer method for evaluation of concrete strength", Proc. of the Canadian Society of Civil Engineering Conference, Saskatoon, Canada, May 1985.
[5] ASTM C 33-03, "Standard specification for Concrete Aggregates", ASTM International, American Society of Testing Materials, USA. Vol. 4.2, 2003.
[6] ASTM C330-03, "Standard specification for structural light weight Aggregates", ASTM International, American Society of Testing Materials, USA. Vol. 4.2, 2003.
[7] ASTM C 494-04, "Standard specification for Chemical Admixtures for Concrete", ASTM International, American Society of Testing Materials, USA. Vol. 4.2, 2004.
[8] ASTM C 805-02, "Standard Test Method for Rebound Number of Hardened Concrete", ASTM International, American Society of Testing Materials, USA. Vol. 4.2, 2002.
[9] ASTM C 597-02, "Standard Test Method for Pulse Velocity through Concrete", ASTM International. American Society of Testing Materials, USA, Vol. 4.2, 2002.