THE EFFECT OF COARSE AGGREGATE RATIO ON THE PROPERTIES OF NO FINE LIGHT WEIGHT CONCRETE

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ABSTRACT

The main object of this work is to study the effect of coarse aggregate/cement ratio (A/C) on the property of no fine concrete. In this work, three ratio of A/C were used (6, 9 and 12 by weight).The cement content is maintained constant (125kg/m^3) while the w/c ratio ranges from (0.39 to 0.55 by weight). Tests are carried out on hardened concrete to investigate the effect of coarse aggregate/cement ratio on the compressive strength, absorption%, density, porosity%, ultrasonic pulse velocity, acoustic impedance of mixes.

The results showed that increasing the percentage of A/C ratio by weight from 6 to 12 for the used mixes reduces the compressive strength, ultrasonic pulse velocity and acoustic impedance, on the other hand the porosity and the absorption percentage, increase with increasing ratio of A/C for all studied mixes.

At 28 days the compressive strength , ultrasonic pulse velocity and acoustic impedance tests with A/C ratio of (12) are (2.8.MPa), (2km/sec) and (3×10^6 Kg/(sec.m^2)) respectively while decreasing the ratio to (6) improves these properties to (9.3MPa), (3km/sec) and (5.7×10^6 Kg/(sec.m^2)) respectively On the other hand the porosity and the absorption % decrease with decreasing the ratio of A/C for all studied mixes . At 28 days the porosity and the absorption % with A/C ratio of (12) are (40%) and (2.7%) respectively with decreasing the ratio to 6 decrease these properties to (19%) and (1%) respectively.

The densities of the mixes were tested. At 28 days the density with A/C ratio of (12) are (1512 kg/m^3)with decreasing the ratio to 6 increase the density to(1907 kg/m^3)

Based on the analysis of experimental results, several graphs and tables have been prepared to study the properties of no fine concrete.

تا ثير نسبة الركام الخشن على خواص الخرسانة الخالية من الركام الناعم

الخلاصة

الهدف الأساسي لهذا العمل هو دراسة تاثيرنسبة الركام الخشن/ السمنت (A/C) على خواص الخرسانة الخالية من الركام الناعم . تم استخدام ثلاثة نسب وزنية من (A/C) ، (6 ، 9 و 12) . محتوى السمنت ثابتاً(125 كغم/م^3) بينما نسبة الماء / السمنت تتراوح بين (0.39 الى 0.55) اختير اجراءالفحوصات على الخرسانة المتصلبة لدراسة تاثيرنسبة الركام الخشن/ السمنت على مقاومة الانضغاط ، نسبة الامتصاص ، الكثافة ، المسامية ، فحص الموجات الصوتية و فحص المعاوقة الصوتية .

النتائج اظهرت ان زيادة نسبة (A/C) من 6 الى 12وزنيا" ادى الى نقصان في مقاومة الانضغاط ، فحص الموجات الصوتية و فحص المعاوقة الصوتية من الناحية الاخرى المسامية و نسبة الامتصاص قد ازدادت عند زيادة نسبة (A/C) للخلطات الخرسانية.

في عمر 28 يوم مقاومة الانضغاط ، فحص الموجات الصوتية و فحص المعاوقة الصوتية عند نسبة (A/C) (12) كانت (2.8 ميكاباسكال)،(2كم\ثا) و(3×10^6 كغم\(ثا . م^2)) على التوالي بينما نقصان النسبة الى(6) ادى الى تحسين الخواص السابقة (9.3 ميكاباسكال)، (3 كم\ثا) و(5.7×10^6 كغم\(ثا . م^2)) على التوالي و من الجانب الاخر المسامية و نسبة الامتصاص قلت مع تقليل نسبة (A/C) للخلطات الخرسانية.

في عمر 28 يوم المسامية و نسبة الامتصاص عند نسبة (A/C) (12) كانت (40%) و (2.7%)على التوالي بينما نقصان النسبة الى(6) ادى الى تقليل تلك الخواص الى (19%) و(1%).

تم فحص الكثافة للخلطات الخرسانية في عمر 28 يوم عند نسبة (A/C) (12) وكانت (1512كغم\م^3) بينما نقصان النسبة الى(6) ادى الى زيادة في الكثافة الى (1907كغم\م^3)،

اعتمادا على تحليل النتائج مختبريا ، بضع رسومات و جداول اعدت لدراسة خواص الخرسانة الخالية من الركام الناعم.

KEYWORDS

No fine concrete , coarse aggregate/cement ratio (A/C), compressive strength, absorption% ,density, porosity % , ultrasonic pulse velocity and acoustic impedance.

INTRODUCTION

No-Fines concrete is a mixture of cement, water and a single sized coarse aggregate combined to produce a porous structural material. It has a high volume of voids, which is the factor responsible for the lower strength and its lightweight nature . No-fines concrete has many different names including zero-fines concrete , pervious concrete and porous concrete[1].

Neville[2] defined No-fine concrete as a form of lightweight concrete obtained when fine aggregate is omitted i.e. consisting of cement, water and coarse aggregate only. No- fines concrete is thus an agglomeration of coarse aggregate particles , each surrounded by a coating of cement paste up to about 1.3 mm thick.

The ACI 213R - 87 [3] uses densities to categorize concrete according to its application :-

- Low density concrete has a density between 300 and 800 kg/m^3
- Structural concrete has a density between 1350 and 1900 kg/m^3 and has a minimum strength of 17 MPa .
- Moderate strength concrete its compressive strength is between 7and17 MPa

Meininger [4] reported that , in no fine concrete the water – cement ratio in the range of 0.35 to 0.45 does a better job of coating the coarse aggregate without causing too much balling in the mixer or , at the opposite extreme, being so wet that paste tends to run off the aggregate . He also reported that the properties of no –

fines concrete depend not only on its proportion but also on its compaction , too much compaction can reduce the air voids and plug the flow channels , too little compaction will leave the structure with very high air voids resulting in low strength and a raveling surface.

Abadjieva et al [5] determined that the compressive strength of on – fine concrete increases with age at a similar rate to conventional concrete. The no –fines concrete specimens tested had aggregate-cement ratios varying from 6:1 to 10:1. The 28 day compressive strength obtained by these mixes ranged from 1.1 and 8.2 MPa , with the aggregate-cement ratio of 6:1 being the strongest . He concluded that the most plausible explanation for the reduced strength was caused by the increased porosity of the concrete.

Harber[1] reported that , the density of no-fine concrete is dependent upon the void content in the concrete. Due to the high air content it is a lightweight concrete with a density of about two third of conventional concrete. The density of no-fine concrete normally ranges between 1600 and 1900 kg/m^3. This is dependent upon the shape, size and density of aggregate, the aggregate-cement-water ratio and the compaction exerted on the concrete.

AL-Rubayie [6] reported that , the aggregate-cement ratios effect the property of No-fines concrete , he concluded that decreasing the ratio from 1:10 to1:6 lead to increasing the density and the compressive strength and decrease the absorption percentage.

Research Significance

In this study, an experimental work has been carried out to achieve the following:-

- Producing No Fine concrete according to the requirement for the mechanical properties of no fine light weight concrete with density ranges between 1600 and 1900 kg/m^3 by using different coarse aggregate-cement ratio (6:1, 9:1 and 12:1) .
- Evaluating the effect of aggregate-cement ratio on the mechanical properties of the concrete in its hardened state properties.

Materials

- Cement

Ordinary Portland cement (type I) is used in this study. The cement is (*Al-Qassim*) from Saudi Arabia origin was used in all mixes throughout this study. Its chemical and physical properties are given in Tables (1 and 2). Test results indicated that the adopted cement conformed to the Iraqi specification No.5 /1984 [7].

Table 1: Chemical composition properties of cement *

Oxides	%	IOS 5:1984 requirements
CaO	62.20	-
SiO_2	22.10	-
Al_2O_3	4.55	-
Fe_2O_3	3.34	-
MgO	2.32	≤5.0%
SO_3	1.85	≤2.8%
Na_2O	0.31	-

K_2O	0.43	-
L. O. I.	1.54	≤4.0%
Main compounds (Bogue's equation)		
C3S	44.64	-
C2S	29.68	-
C3A	6.41	-
C4AF	10.16	-

Table 2: Physical composition and properties of cement *

Properties	**Cement**	**IOS 5:1984 requirements**
Fineness Blaine method (m^2 /kg)	310	≥ 225
Vicat set times(hr:min) Initial Final	 2:10 3:40	 ≥45 min ≤10 hours
Compressive Strength (N/mm^2) at 3 days 7 days	 18.6 27.5	 >15 >23
Soundness: autoclave %	0.24	<0.8

* Chemical and Physical tests were made by the National Center Laboratories for Construction and Research (NCCLR)

- Coarse Aggregate

The aggregate generally used in no-fines concrete application usually ranges from 10 mm to 20mm.Five percent oversized and ten percent undersized materials are acceptable for use but there should be no particles smaller than 5 mm (Neville) [2]. If there are too many small particles it will tend to fill the voids , affecting the porosity of the concrete and associated properties.

Crushed gravel obtained from AL-Nebai area was used. The maximum coarse aggregate size was chosen to be 10mm. Table (3) shows the grading of coarse aggregate which conforms to the Iraqi specification No. 45/1984[8]. Table (4) illustrates the specific gravity, sulfate content and absorption of coarse aggregate.

Table 3: Grading of coarse aggregate of maximum size 10 mm

Sieve Size (mm)	**Passing%**	**Limits of Iraqi specification No.45/1984**
14	100	100
10	93.3	85-100
5	12.5	0-25
2.36	0	0-5

Table 4: properties of coarse aggregate*

Physical Properties	Test Results	Limit of the Iraqi Specification No.45/1984
Specific gravity	2.61	-
Sulfate content %	0.06	≤ 0.1 %
Absorption%	0.59	-
S.S.D	1650	-

* Physical tests were made by the National Center Laboratories for Construction and Research (NCCLR)

-Mixing Water

Ordinary tap water was used for mixing and curing for all concrete mixes of this study

Mix Proportions

The mix proportions for no – fines concrete depends predominantly on the final application. In building applications, the aggregate-cement ratio used is leaner, usually ranging from 6:1 to 10:1. This leaner mix ensures that the void ratio is high and prevents capillary transport of water. However, in pavement applications the concrete strength is more critical and aggregate-cement mixes as low as 4:1 is used. This lower ratio ensures an adequate amount of bonding between the aggregate and cement to withstand the higher loads. [1].In this search three aggregate –cement ratio by weight are used (6, 9 and 12) to study the effect of coarse aggregate ratio on the properties of no fine concrete.

Concrete Mixes

The weight method were carried out in design the concrete mixes . Three concrete mixes are used . These concrete mixes differed by water/cement ratio and the amount of coarse aggregate. After many trials, the details of the mixes used throughout this investigation are given in Table (5).

Table 5: Concrete mixes

Mix	Cement Kg/m^3	Water Kg/m^3	Aggregate Kg/m^3	w/c by weight	Aggregate-cement Ratio by weight
M_1	125	48.8	750	0.39	6
M_2	125	56.3	1125	0.45	9
M_3	125	68.8	1500	0.55	12

OPERATIONAL PROCEDURE

The following operating procedure was undertaken when using the pan mixer: [1] [2]

- The inside surface of the mixer was moistened.
- The aggregate should be dampened before mixing in order to facilitate uniform coating by the cement paste.
- The aggregate and the half of the required water was added.
- The mixing was started and the cement and remaining water was added slowly.
- The mixing continued until the aggregate was sufficiently covered with cement paste.
- The mix was discharged into the wheelbarrow by fully opening the trap.
- The motor was turned off.
- The power at wall was isolated.
- The inside of the pan mixer was cleaned with water.

No- fines concrete must be placed very rapidly because the thin layer of cement paste can dry out ; this would result in a reduced strength.

HARDENED CONCRETE PROPERTIES

Five tests were carried out on no fine concrete mixes compressive strength, density, absorption , porosity , ultrasonic pulse velocity, and acoustic impedance tests .

RESULTS AND DISCUSSION

- Compressive strength of hardened concrete

The compressive strength test was determined according to BS1881: part 116:1989 [9]. This test was measured on 150 mm cubes using an electrical testing machine with a capacity of 2000 kN, at loading rate of 15 MPa per minute.

According to BS 1881 :part 113 :1983 [10] the specimens for the compression test have been compacted . The average of three cubes was adopted for each test. The test was conducted at ages of 7, 28, and 90 days { tests made in Laboratories of Baghdad University}.The compressive strength results of the different studied concrete mixes are shown in Table (6) . These results indicate that: the compressive strength decreases with increases percentage of coarse aggregate/cement ratio .The recorded compressive strength results range from (9.3 - 2.8) MPa for all mixes at 28 days age.

Table 6: Compressive strength results of concrete mixes

Mix	Aggregate-cement ratio	w/c	Compressive Strength test MPa for ages		
			7 day	28 day	90 day
M1	6	0.39	5.0	9.3	11.4
M2	9	0.45	4.4	7.3	9
M3	12	0.55	1.8	2.8	3.4

Fig. (1) shows the increase in compressive strength with time, with decrease in the ratio of coarse aggregate, this can be related to the development of the interface bonds between the bulk hydrated cement paste and the aggregate, this agrees with many study [5] [6] .

Effect of water-cement ratio on compressive strength

The w/c ratio as such is not the main controlling factor and , in fact , there is a narrow optimum w/c ratio for any given aggregate. A w/c ratio higher than the optimum would make the cement paste drain away from the aggregate particles whereas , with too low w/c ratio , the cement could not be achieved[2]

Fig. (2) shows the increase in compressive strength with decrease in w/c ratio, this agrees with many study [5] [6] .

Fig. 1: Relation between compressive strength and age

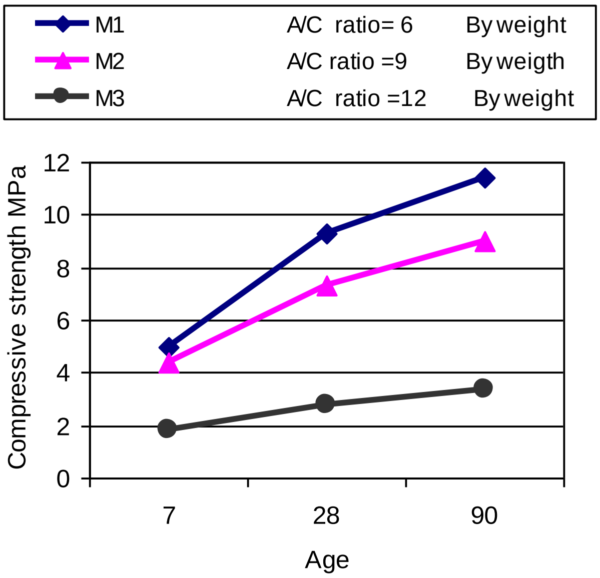
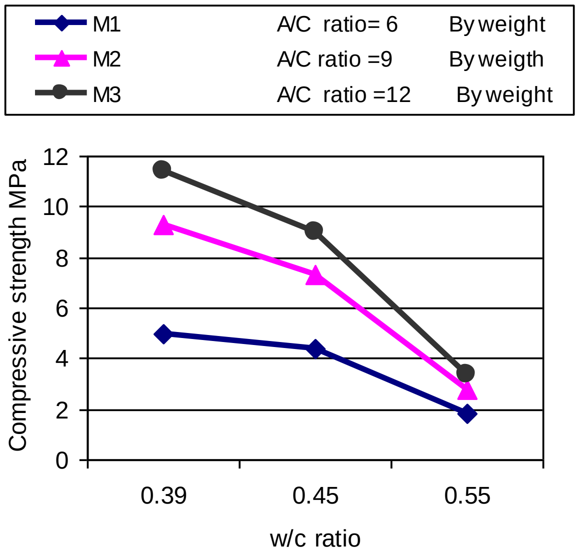


Fig. 2: Relation between compressive and w/c ratio



- Density and Absorption of Hardened Concrete

The absorption test was performed according to ASTM C642-82 [11] . This test was carried out on (150) mm cube specimens. At each test age the specimens weighted and dried in oven at temperature of (100-110) °C for 24 hours { tests made in Laboratories of Baghdad University, civil eng. Department}. After removing each specimen from the oven, it allowed to cool in dry air to temperature of 20-25 °C, then weighted. The specimens returned to oven for additional 20 hours drying period, and the procedure repeated until the difference between any respectively two successive weights is less than 0.5%, then the last weight considered to be the oven dry weight. After this, the specimens immersed in water at approximately 21 °C for not less than 48 hours and until two successive weights of the surface dried sample at intervals of 24 hours showed an increase in weight of less than 0.5% of the heavier weight. The specimen surface dried by removing surface moisture with a towel, and then weight. The heavier weight is considered saturated surface dry weight. The density and absorption results of the different studied concrete mixes are shown in Table (7) .The test conducted at age 28days. The average of three specimens adopted at each test. According to the ACI 213R - 87 [1] test result indicate that the concrete mixes with A/C ratio (9 and 12) were conform to moderate concrete .

Table 7: Density and Absorption results of the different studied concrete mixes

Mix	Aggregate-cement Ratio by weight	w/c	Density kg/m^3	Absorption %
			28 day	28 day
M1	6	0.39	1907	1
M2	9	0.45	1555	1.5
M3	12	0.55	1512	2.7

Figs. (3) and (4) show the effect of coarse aggregate ratio on both absorption and densities of all mixes respectively, decreasing the ratio of aggregate and the w/c ratio leads to decrease the absorption percentage and increase the densities of the mixes. This behavior may be ascribed to significant w/c reduction which improves the uniformity of the microstructure and reduces the capillary porosity leading to better packing and increase in the density and reduces the absorption percentage. This agree with study [6] [12] . Fig. (5) shows relationship between density and absorption percentage ,

Fig. (3) Relation between absorption % with A/C ratio

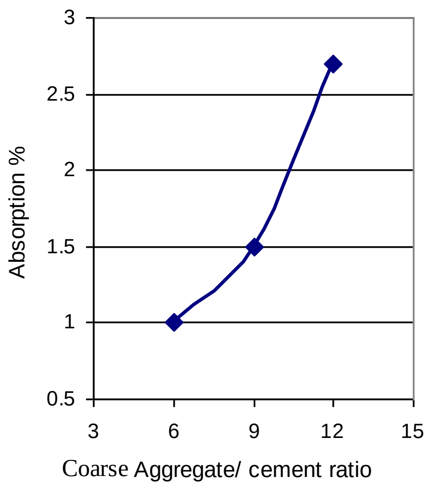


Fig. (4) Relationship between densities with A/C ratio

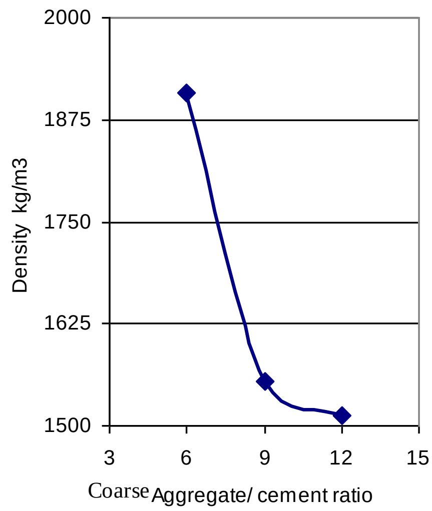
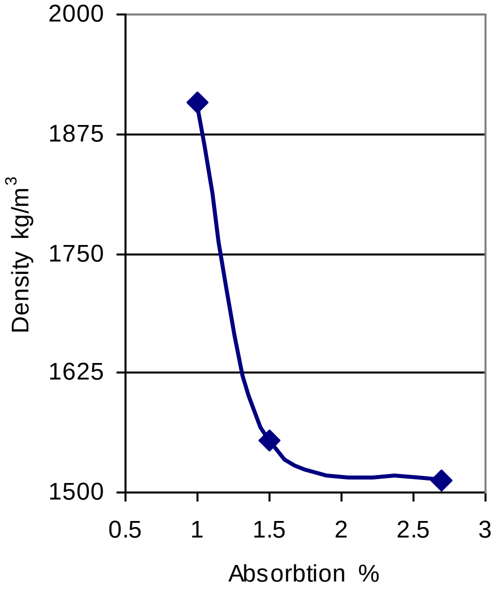


Fig.(5) Relation between absorption % and densities



- Porosity of concrete mixes

Neville[2] defined porosity as the total volume of the overall volume of pores larger than gel pores , expressed as a percentage of the overall volume of the hydrated cement paste , is a primary factor influencing the strength of the cement paste .

The porosity test was carried out at 28 days by using standard cubes measuring (150 ×150 × 150) mm .The average value of three cubes was calculated by the following equation [12]

Porosity= Density ×Absorption

Table (8) showed the average result of this test

Table 8: Porosity results of concrete mixes

Mix	Aggregate-cement Ratio by weight	w/c	Density kg/m^3	Absorption %	Porosity %
			28 day	28 day	28 day
M1	6	0.39	1907	1	19
M2	9	0.45	1555	1.5	23
M3	12	0.55	1512	2.7	40

Fig. (6) Shows the effect of coarse aggregate ratio on porosity of all mixes respectively, decreasing the ratio of aggregate and the w/c ratio leads to decrease the porosity, percentage. Figs. (7) And (8) show relationship between porosity with both of compressive strength and density respectively. It was clear that increasing % porosity lead to an decreasing in both of compressive strength and density This behavior may be ascribed to significant increasing the porosity lead to increase the voids witch lead to decreasing compressive strength and density this agrees with study done by AL - Zangy [12] .

Fig. (6) Relation between porosity percent With A/C ratio

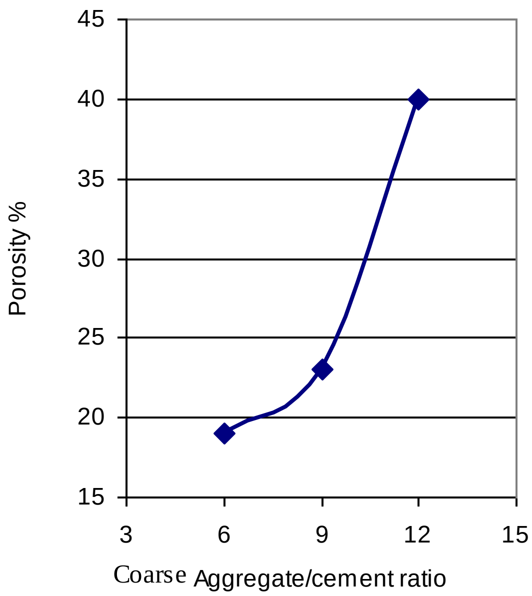


Fig. (7) Relationship between porosity and density

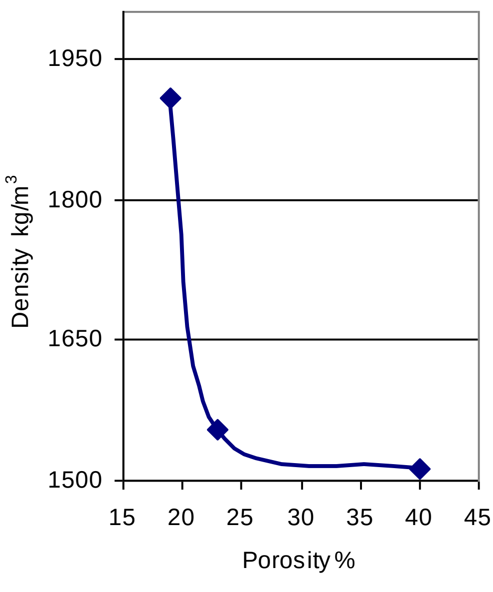
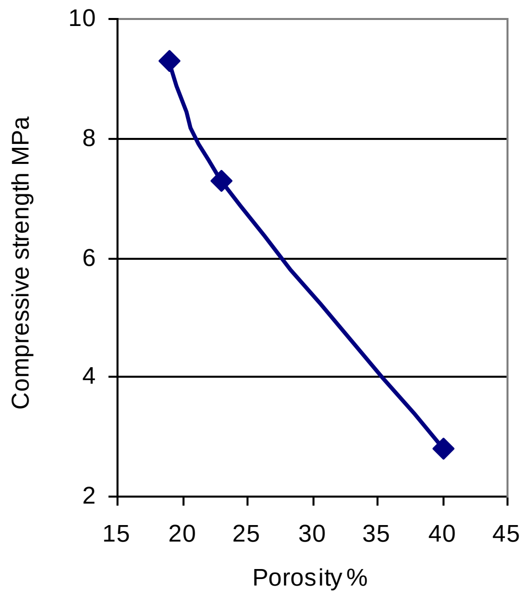


Fig. (8) Relationship between porosity and compressive strength



*** Ultrasonic Pulse Velocity Test (UPV)**

The ultrasonic test is a useful tool for assessing the uniformity of concrete and detecting cracks and voids. It gives useful information about size of micro-cracks zone, crack growth and the interior structure of the concrete element. [13]

According to ASTM C597-02 [14], the Portable Ultrasonic Non – Destructive Digital Indicating Tester (PUNDIT) is used. Standard cubes measuring (100 ×100) mm were demoulded one day after casting. { tests were made in Laboratories of Baghdad}

The time of travel between initial onset and the reception of the pulse was measured electronically . The path length between transducers, divided by the time of travel, gives the velocity of wave propagation:

V = L / T ……………………………………… (2)

where

V = Ultrasonic Pulse Velocity, km/sec

L = path length, mm

T = transit time, μ sec

Results of the ultrasonic pulse velocity test for all mixes, cured in tap water at 28, day, are listed in Table (9) .

Table 9: Ultrasonic Pulse Velocity results of concrete mixes

Mix	Aggregate-cement Ratio by wieght	w/c	Ultra-pulse velocity Km/sec
			28 day
M1	6	0.39	3
M2	9	0.45	2.9
M3	12	0.55	2

Fig.(9) shows the effect of coarse aggregate/cement ratio on ultrasonic pulse velocity of all mixes, decrease in this ratio and the w/c ratio leads to increase the ultrasonic pulse velocity .Figs. (10) and (11) show relationship between ultrasonic pulse velocity test with both of compressive strength and density respectively

It appears from these figures that as the compressive strength and density increase the ultrasonic pulse velocity increase at a different rate. This behavior may be ascribed to significant increasing the density lead to decrease the voids witch lead to decrease the spend time of velocity of the waves throw concrete, This agrees with many studies [13] [15].

**Fig. (9) Relation between Ultrasonic Pulse Velocity
With A/C ratio**

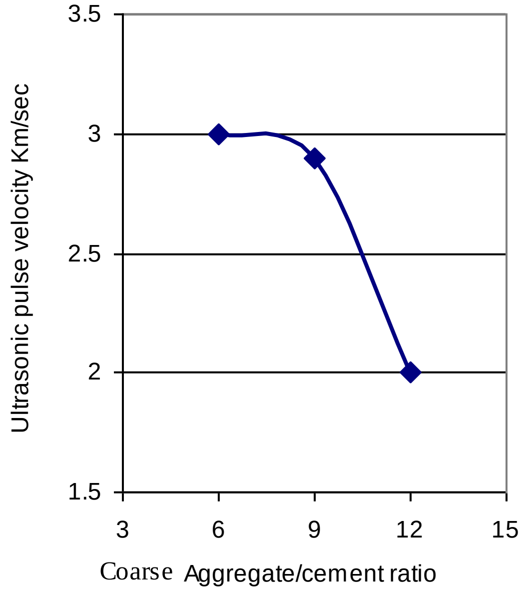
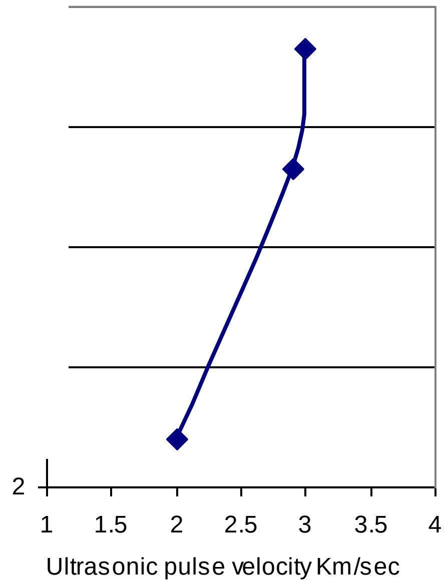


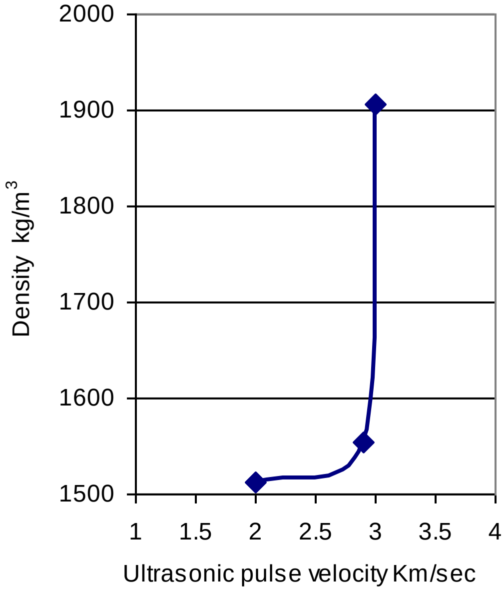
**Fig.(10)
Relationship**



**between ultrasonic
density**

Fig.(11) Relation between ultrasonic pulse velocity and compressive strength

pulse velocity and



- Acoustic Impedance test

The acoustic impedance is a characteristic which use to make comparison between Loudness in different environment such like Loudness in air and concrete.[16] Table (10) showed The acoustic impedance for various materials

Table (10) The acoustic impedance for various materials[16]

Name of material	Density (kg/m^3)	Ultrasonic Pulse Velocity m/sec	Acoustic Impedance Rayls × 10^6 Kg/($sec.m^2$)
Normal concrete	2300 — 2500	4000 — 4500	9.2 — 11.3
Light weight concrete with Light weight aggregate	1200 —1600	3000 — 3500	3.6 — 5.6
Iron	7700 — 7800	5900 — 6000	45 — 47
Aluminum	2700	6300	17
Copper	8900	4760	42
Water	1000	1480	1.48
Air	1.21	343	415×10^{-6}

The acoustic impedance was determined in this study using the pulse velocity method, in compliance with ASTM C 597-02[14] . In the present work, standard cube measuring (150 ×150) mm were demoulded one day after casting testing were cured in water and tested at 28 days .The Acoustic Impedance is calculated, as follows [16]

Acoustic Impedance = ρ V

V = ultrasonic Pulse Velocity, km/sec

ρ = concrete density (kg/m^3)

Table (11) showed the average result of this test

Table 11: Acoustic Impedance results of concrete mixes

Mix	Aggregate-cement Ratio by weight	w/c	ultrasonic Pulse Velocity km/sec	concrete density (kg/m^3)	Acoustic Impedance Rayls × 10^6 Kg/($sec.m^2$) 28 day
M1	6	0.39	3	1907	5.7
M2	9	0.45	2.7	1555	4.1
M3	12	0.55	2	1512	3

Fig. (12) shows the effect of coarse aggregate/cement ratio on the acoustic impedance of all mixes, increasing the ratio of coarse aggregate/cement ratio and the w/c ratio leads to decrease acoustic impedance. This agrees with studies done by AL-Jeelawi[6]

Figs. (13) (14) and (15) show relationship between acoustic impedance test with compressive strength , porosity % and density respectively

Fig. (12) Relationship between Acoustic Impedance and coarse aggregate/cement

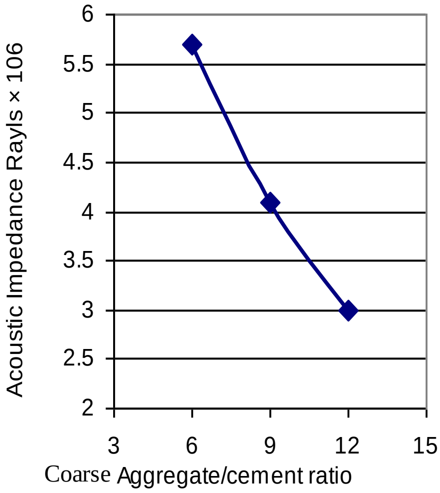


Fig. (13) Relationship between Acoustic Impedance and Compressive strength

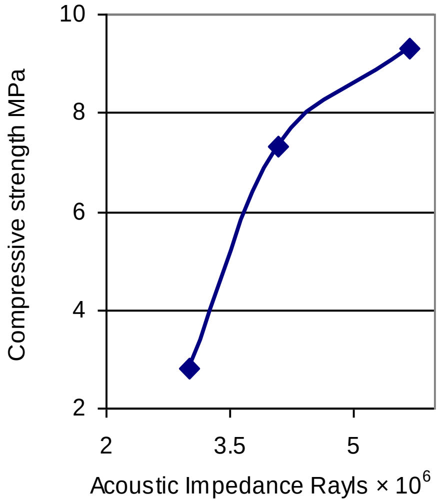


Fig. (14) Relationship between Acoustic Impedance and porosity

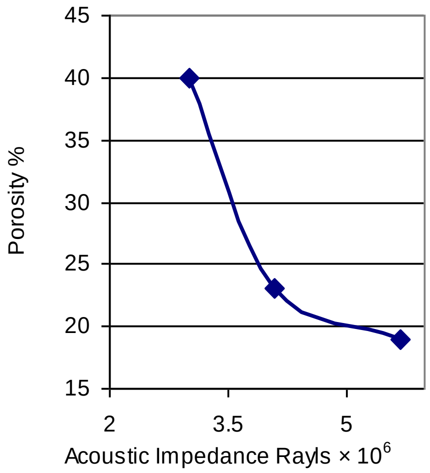
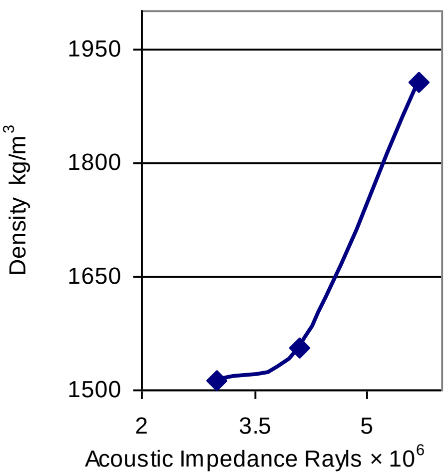


Fig. (15) Relationship between Acoustic Impedance and density



It appears from these figures that as the porosity increases, the acoustic impedance is decreases On the other hand the acoustic impedance increase with increasing the compressive strength and density at a different rate. This behavior may be ascribed to significant increasing the compressive strength lead to decrease the voids witch lead to increase in density and Acoustic Impedance and decrease in porosity This agrees with many studies [12] [16].

CONCLUSIONS

- These results indicate that, the compressive strength increases with time .The recorded compressive strength results range from about (9.3 to 2.9) MPa for all mixes at 28 days age.
- The aggregate-cement ratios effect the property of No-fines concrete , decreasing the ratio from 12 to 6 lead to increasing the density , ultrasonic pulse velocity , compressive strength and the acoustic impedance tests and decrease the absorption percentage and the porosity %.
- The analysis of results detected that there is an inverse relation between compressive strength, density ultrasonic pulse velocity and acoustic impedance with the A/C ratio. On the other hand the absorption % and porosity % is related directly with A/C ratio.
- It was clear that the compressive strength and density increases by decreasing the porosity %.
- The UPV increases directly with compressive strength and density.
- The tests clarified that the acoustic impedance increases directly with compressive strength and density on the other hand there is an inverse relation between Acoustic Impedance and the porosity %.

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