The Combined Effect of Attapulgite High Reactive Mineral Admixture and Superplastisizer on Compressive Strength of Attapulgite Lightweight Aggregate Concrete

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ABSTRACT
The goal of this study , mainly is to investigate the combined effects of using both Attapulgite high reactive mineral admixture and superplastisizer on the compressive strength of Attapulgite lightweight aggregate concrete ALWAC and some properties of sconcrete . The used coarse lightweight aggregate was made from Attapulgite clays with maximum size of 19 mm , and the optimum percentages of addition for both mineral and chemical admixture was 6% partial replacement from cement for Attapulgite mineral admixture and 0.5 L/100 kg cement for the superplastisizer used .The gained percentages of enhancement for compressive strength was (12.2%,12.6% and 16.3%) for curing ages of 7, 28 and 56 respectively as compared with the referenced plane mix when only the Attapulgite mineral admixture to be added , while the combined effect of both admixtures was clear by the percentages of (19.3% , 15.5% and 25%) for curing ages 7,28 and 56 respectively as compared to the plane referenced mix . The obtained equilibrium density of ALWAC was 1818 kg/m^3 (ACI 213r-03 , less than 1840 kg/ m^3 for structural purposes)for the concrete mix containing the two admixtures . The water absorption of ALWAC was reduced by the addition of the Attapulgite mineral admixture by (4% , 4.85% and 4.9%) at 7,28 and 56 days of curing respectively but, using the superplastisizer cause an increase in water absorption and the percentages above get lowered to (2% , 3% and 2.6%) at the ages of 7,28 and 56 days respectively .
Keywords: Lightweight aggregate concrete, Attapulgite clays , High reactivity Attapulgite ,

INTRODUCTION
Lightweight concrete in time now plays a significant role in the field of constructions by it's important properties of the decreased density and higher insulation capacity specially in structural uses since that properties will offer a reduction in self weights of structural members thus may lead to a reduction in sectional dimensions of these members ,reduction in the total sizes and numbers of foundations needed like footings , rafts and piles that lead to cost reduction compared to the higher costs of (LWC) production means and sustainable benefits by saving the natural sources of the materials beside the environmental benefits , since some of lightweight aggregates (LWA) produced from industrial wastes or by-products [1]

Lightweight aggregate concrete (LWAC) have been used in the ancient period , 3000 years before the Christian Era and most of the aggregates used in concrete from origin of volcanic rocks .The demand for using LWAC widely increased and production technologies were developed to initiate production lines in factories and the materials used in production of lightweight aggregate are from nature as minerals like clays, slates, and shales , as well as industrial materials produced as by-products like fly ash, bed ash, blast furnace slag, etc. [3]

The structural lightweight aggregate concrete LWAC is attractive for designers in many fields of construction now, fields like multi-story buildings, high rise buildings , bridges , petroleum platforms , marine structures and architectural purposes because of the higher strengths and durable behaviour compared to other types of LWC that need sometimes to higher costs and complicated means during the production stages [2] .

Literature Review

Attapulgite as a local clay mineral , in Iraq , investigated by **Al-Ameedi** [4] 2012 **,** research started with the production of the mineral admixture from the raw materials that collected from Tar Al-Najaf region , then grinded by the means of storming and transforming to a power with high fineness . The next step was the determination of calcination temperature at which the material turns to an active pozzolanic material , 750˚C was the temperature needed for treating Attapulgite by heat with calcination time of 30 minutes . The optimum percent of replacement from the weight of cement was very important for the research specially when (HRWR) is to be used , so that Attapulgite added in percentages of (3% to 11%) to a mix with proportion of (1:1.45:1.75) by weight , and the results showed that (6%) of addition by weight of cement was the preferred since it was obtained the higher strength of 79.7 MPa . The results for the main mixes of the study indicated considerable increasing for compressive strength , density , splitting tensile strength and flexural strength , at 60 days the increasing percentages were (57.7% , 3.73% , 46.44% , 44.26%) respectively , and the absorption of water decreased with 36% . At the age of 90 days compressive strength showed an increase of 59 % .

At the year of 2014 **Al-Aride9**[5] **;** studied the ability of using a local clays , from the south-west of Iraq , as a coarse aggregate .The researcher divided the study into parts , part one for manufacturing of the coarse (LWA) and find out the suitable burning temperature , compatible with the **ASTM C330-03**, and the second part was for producing (LWAC) from the manufactured aggregate. The results of the Attapulgite lightweight aggregate (ALWA) were (808 km/m3) for the bulk density and the dry specific gravity was (1.45) at a treatment burning temperature of (1100 C) for a duration of (30 minutes) . The (LWAC) produced from the (ALWA) ,at the second part of the study experimental work , was investigated for some of its mechanical properties at curing ages of (7, 28 and 56) days , those properties were compressive strength , flexural strength , splitting strength , the static modulus of elasticity , water absorption and some non-destructive tests .

The results of concrete produced were within the requirements of **ACI 213R -03** , that results were (27.7 Mpa) for compressive strength for a density of 1824 Kg/m3 with w/c ratio of (0.4) and percentages of increase for splitting strength , flexure strength and modulus of elasticity (41%,28.3%,81%) respectively .

Experimental work

Materials

Cement

The Portland cement used from local source ,Al-Mass, and the properties of this cement are shown in tables (1)and(2) as a chemical analysis and physical properties respectively. Results demonstrated that the used cement is identified with the **Iraqi Specification No.5/1984**[5]

Sand

Fine aggregate with fineness modulus of 2.81 was used for all concrete mixes. Table (3) shows the sieve analysis and the grading curve for the sand used. The grading curve and the chemical and physical properties of natural sand are shown in Table (4) which indicates that the sand falls within zone two according to the requirement of the **Iraqi Specification No. 45/1984**[6].

Coarse Aggregate

The crushed graded Attapulgite clay particles burn by oven with a burning temperature of 1100ºC at the rate of temperature rising of 5˚C/min. for 1/2hour as soaking time at this burning temperature. Tables (5 and 6) show the grading and the properties of Attapulgite coarse lightweight aggregate .

Water

For all concrete , mixes tap water is used for mixing and curing of samples

Superplastisizer

Glinume 54 is used in this research as chemical admixture, and it complies with **ASTM C494-04** [10]Types A and F.

Attapulgite High Reactivity (AHR)

Attapulgite clays were used to produce high reactivity Attapulgite. The raw material of Attapulgite contains rocks so it needs to be grinded by storming to convert it to high fineness powder. The suitable calcinations temperature were investigated by and they concluded that the optimum firing temperature was 750 ˚C and the rate of temperature rising was (4˚C/ min), and the sample stills for 1/2 hour as a soaking time when the oven temperature reaches to the required degree . Table (7) shows chemical analysis of (HRA). Table (8) indicates that (HRA) conformed to the chemical requirements of the **ASTM C618–01**[11] Class N pozzolana. The strength activity indexes of (HRA) were 101.4 and 108.8 at 7 and 28 days respectively, and they conformed to requirements of **ASTM C311-02** [12] which is specified **S.A.I** for both 7 and 28 days to be not less than 75..

Trial Mixing

This stage is to determine the optimum dosage of the chemical admixture (superplastisizer) that compatible with the addition of the Attapulgite mineral admixture . Table (9) shows the results of the trial mixes and the optimum dosage of

Superplastisizer was 0.5 L/ 100 kg cement for 6 % partial replacement of cement with the Attapulgite mineral admixture .

Mix Proportion

For all mixes of this paper the w/c ratio was (0.4) and targeted slump was (100_+5 mm) for mix proportion of (1:1.12:0.84)[ ] , with cement content of 540 kg/m^3, the aggregate used was 454 Kg/m^3 ,dry weight, and 625 kg/m^3 for the coarse aggregate (ALWA) and fine aggregate (sand) respectively .

Mixing Method

The concrete mixing process has been done by using lab. mixer of 150 liters size . The mixer's pan and blades were wiped by a damp cloth to ensure no other material to be interfere the mixture . The concrete mix , dry constituents were placed in the mixer and started to be mixed for two minutes to ensure homogeneity and to split the agglomeration of cement particles. The mixing steps was as follows[5]: coarse aggregate (ALWA) , sand and 50% of the mixing water were loaded into the mixer and then mixed for 1 minute. Then the required quantity of the dry cement mixed with the required Attapulgite admixture in their dry condition and then mixed with 45% of the remaining water and added into the mixer and mixed for 2 minutes **.** The remained 5% of water used with the superplastisizer in a solution then added to the mixer for 2 minutes of continues mixing process .

Testing of Hardened Concrete

The hardened concrete test was achieved according to the ASTM procedures and specifications . The tests were oven dry density , compressive strength , Modulus of elasticity , drying shrinkage , water absorption and ultrasonic pulse velocity .

ALWAC Fresh properties

Fresh Density

The fresh density of (ALWAC) was carried out according to the ASTM C138-04[19] , cylindrical capacities of 0.003 m^3 was used for the sampling purpose and an average of three samples values was taken , as that shown in the table (11) .

Slump

The slump test was carried out according to the ASTM C143-03[20] and the results of the test , table (12) , varied from 85 mm to 110 mm , and the used (ALWA) was in the SSD condition , this variation coming from the addition of the admixtures and also the variety in the saturation degree of the aggregate that affects the water content by the amount of water that the aggregate will absorb from the fresh mixture of concrete .

Hardened Concrete Properties .

Oven Dry Density and Equilibrium Density

According to the ACI 213R – 03[2] , as shown in table (13) below , the results of the calculated equilibrium density conforms the requirements of structural (LWAC) .In other hand all mixes conform the classifications of RILEM[65] since all the density results less than 2000 kg/m^3 .

The calculated equilibrium density determined from the ASTM C 567-03 [13] by the equation below.

$$Ec = Oc + 50\ kg/m^3$$

Where :

Ec = Calculated Equilibrium Density

Oc = Oven Dry Density

Table (14) shows the results of (ALWAC) densities for each type of mixes .

Compressive Strength

The (ALWAC) compressive strength results is shown in table(15) and figure (1) .The tested specimens were cubic (100x100x100) mm and the results were converted to cylindrical to conform the ASTM requirements . The results indicated that the relation was nonlinear between the compressive strength with the ages of curing .The compressive strength results for (ALWAC) ,most of the mixes, essentially continued to gain strength increase between the ages of 28 days to 56 days and 56 days to 90 days .

From the table (15) of results and figure (1), it can be noticed that the mix B (6% Attapulgite high reactive mineral admixture) showed an increase for compressive strength values of (12.2% , 12.6% , 16.3%) compared to the reference mix A at7, 28 ,and 56 days of curing age respectively , in other hand there was other increase for compressive strength for the same mix between 28 days age with 56 days of about 7.7 % ,this results showed that the addition of the Attapulgite high reactive mineral admixture improved the strength property of (ALWAC) as that in Al-Admdi study for normal weight concrete .

The addition of the chemical admixture (superplastisizer) cause an increase for the compressive strength for mix C (6% Attapulgite mineral + 0.5 L/100 kg cement superplastisizer) about 6.25% , 2.5% , 7.6% and 7.1 at the ages of 7 , 28 , 56 and 90 days respectively , compared with mix B which is free of the superplastisizer .

The combined action of the two admixtures above that was indicated by the results of mix C , was clear by the percentages of increase compared to the reference mix A , 19.3% , 15.5% and 25% for ages 7 , 28 and 56 days respectively .

Static Modulus of Elasticity

The static modulus of elasticity was measured according to the ASTM C469-03[60] at the point of 40% of the ultimate load , with constant rate of loading within the range of (0.24$\pm$ 0.03 MPa/s) . The results of modulus of elasticity showed an increase with the age of curing for all mixes as that shown in table (16) and figure (3) below.

The combined action of both superplastisizer and the high active mineral admixture of Attapulgite gave an increase in modulus of elasticity at 7 and 28 days of 0.6% and 1.25% respectively , that can be related with the enhanced matrix properties of the (ALWAC) by adding the mineral admixture that caused less defects and cracks and higher compressive strength compared to the plain reference mix , figure (3) . The values of the modulus of elasticity showed an increase with the increase of the compressive strength values , that can be noticed from the figure (4) .

Drying Shrinkage

Due to the lost of free water from concrete , there is a change in dimensions occurs in concrete members and specimens , this change defined as the drying shrinkage of concrete, and this dimensional change effects the compressive strength of concrete at the long term ages and its durable performance . The test was conducted by using demic point method and the (ALWAC) specimens tested up to 90 days after a period of wet curing of 7 days then the specimens stored in room condition along the test needed time . Figure (5) shows the relationship between all mixes change length results at the certain testing dates.

As that shown in the figure (5) , the mixes had a lower length change compared to the reference mix A , that might be due to the action of the high reactive mineral admixture of Attapulgite . The use of superplastisizer led to an increase in the length change for mix C , that might be related to the increase in the water content that caused higher amount of voids left behind the free water evaporation .

ALWAC Water Absorption

According to the ASTM C642-97[62] the cylindrical specimens of (ALWAC) was tested in the curing ages of 7 , 28 and 56 days and the results shown in the figure (6) . The addition of Attapulgite high reactive mineral admixture reduced the water absorption of (ALWAC) , mix B , by 4% , 4.85 and 4.9% at curing ages of 7 , 28 and 56 respectively but when the superplastisizer was used in combination with the mineral admixture , mix C , this percentages of reduction lowered to 2% , 3% and 2.6% at the ages of 7 , 28 and 56 days respectively .

Ultrasonic Pulse Velocity (UPV)

The Ultrasonic pulse Velocity (UPV) method is one of the non-destructive concrete testing methods , depends mainly on measuring the time travelling of an ultrasonic pulse ,longitudinal ultrasonic waves, passing through the concrete .The measurement of travelling times between initial onset and reception of the ultrasonic pulse are electronically reported . The distance between transducers divided by the travelling time gives an average velocity for the wave propagation. The standard procedure of this test described in ASTM C 597-02[18] .

As that shown in figure (7) there was an increase in (UPV) with the increase in concrete compressive strength , this increase in concrete compressive strength and (UPV) probably due to the reduction in void content .

Conclusions

1- It is possible to use the Attapulgite high reactive mineral admixture with lightweight aggregate concrete to enhance the property of compressive strength and other related concrete properties .
2- The use of Attapulgite high reactive mineral admixture led to increase the compressive strength with the percentages of (12.2%,12.6%,and 16.3%) at curing ages of 7,28,and 56 days respectively .
3- The combined action of Attapulgite high reactive mineral admixture with the superplastisizer gave the ALWAC compressive strength enhancement of (19.3% , 15.5% and 25%) for curing ages of 7 , 28 and 56 days respectively .
4- The use of Attapulgite high reactive mineral admixture led to decrease the water absorption of ALWAC by percentages of (4% , 4.85 and 4.9%) at 7 , 28 and 56 dyas of curing .
5- The Ultrasonic pulse velocity test showed that the concrete matrix of ALWAC enhanced when Attapulgite high reactive mineral admixture as that clear in the higher values of pulse velocity that means less in defects and voids .

Table (1) Physical Requirements of cement

Physical properties		unit	Test Result	IQS 5/1984[6]
Initial setting time		hrs : min	1:50	≥45 min
Final setting time		hrs : min	2:30	≤10 hrs
Fineness(Blaine)		m^2/kg	319	>230 m^2/kg
Compressive strength(N/mm^2)	3days	MPa	18.0	≥15 MPa
	7days	MPa	25	≥23 MPa

Table (2) chemical Analysis of cement compounds

Oxide composition	Abbreviation	% by weight	Limits of IQS No.5/1984[6]
Lime	CaO	61.4	
Silica	SiO_2	21.43	
Alumina	Al_2O_3	4.71	
Iron oxide	Fe_2O_3	3.50	
Sulphate	SO_3	2.19	≤ 2.8%
Magnesia	MgO	2.94	≤ 5%
Potash	K_2O	0.35	
Soda	Na_2O	0.26	
Loss on Ignition	L.O.I.	2.20	≤ 4%
Lime Saturation Factor	L.S.F.	0.881	0.66-1.02
Insoluble Residue	I.R.	0.70	≤ 1.5
Main compounds (Bouge eq.)[7]		**% by weight of cement**	
Tricalcium Silicate (C_3S)		44.2	
Diacalcium Silicate (C_2S)		28.1	
Tricalcium Aluminate (C_3A)		6.56	
Tetracalcium Aaluminoferrite (C_4AF)		10.65	

Table (3) Sieve analysis of fine aggregate

Sieve Size (mm)	Passing%	IQS 45/1984 Zone (2)
4.75	100	90-100
2.36	97.8	75-100
1.18	63.8	55-90
0.60	47.2	35-55
0.30	9.4	8-30
0.15	0.41	0-10
0.075	0	0-3

Table (4) Chemical properties of fine aggregate

Physical properties	Test result	specification	Limits of Specificatio (I Q S)
R.D	2.6	ASTM C128-03[7]	_____
Sulphate content%	0.31	IQS 45/1984[6]	≤0.5
Absorption%	0.8	ASTM C128-03[7]	____
Dry Unit Weight (kg/m^3)	1580	ASTM C29-03[8]	____
Materials finer than75 μ m %	1.84	IQS 45/1984[6]	≤5
Fineness Modulus	3.81	IQS 45/1984[6]	____

Table (5) Sieve Analysis of Attapulgite coarse aggregate

Sieve No.	Sieve size	%passing ASTMC330-03	Selected %passing	%Retained
1	25	100	100	0
2	19	90-100	95	5
3	9.5	10-50	30	65
4	4.75	0-15	0	30

Table (6) physical properties of Attapulgite coarse LWA .

Aggregate	Bulk Density (loose-dry) Kg/m^3	Saturated Surface Dry Specific gravity	Oven-Dry Specific Gravity	Absorption %
Attapulgite	808	1.86	1.46	28
Requirments	Max. 880	-------	Max. 2.6	5-30

Table (7) Chemical and physical analysis of Attapulgite HR Admixture*

Oxide composition	`Oxide content %
SiO_2	60.48
Al_2O_3	13. 95
Fe_2O_3	6.07
CaO	8.46
MgO	5.92
Na_2O	1.2
SO_3	0.45
K_2O	2.47
L.O.I	0.1
Physical properties	
Specific Surface Area m^2/kg	2010
Spesific Gravity	2.2
Density kg/m^3	2193

Table (8) Chemical requirements of (HRA) according to ASTM C618-01

Oxide Composition	Attapulgite %	Pozzolan Class N
$SiO_2 + Al_2O_3 + Fe_2O_3$	80.5	70% Min.
SO_3	0.45	4 % Max.
Loss on Ignition	0.1	10% Max

Table(9) Strength Activity index results

Mixes	Water content ml	Cement content gm	w/c ratio	Attapulgite admixture gm	Satandard sand gm	28 days compressive strength MPa
Control mix	242	500	0.484	---	1375	27.2
20% replace	254	400	0.509	100	1375	29.6

Table (10) :The trial mixing results .

Attapulgit Mineral Admixture	W/C	Superplastisizer L/100kg cement	Slump mm	Dry density kg/m3	Compressive Strength 7 days MPa	Compressive strength 28 days MPa
6%	0.4	.75 %	201	1840	34.3	42.13
		.6%	180	1857	33.7	43.07
		.5%	110	1826	34.6	43.47
7%	0.4	.75%	flow	____	____	____
		.6%	210	1861	34	38.2
		.5%	160	1839	35.9	39.8
8%	0.4	.75%	flow	____	____	____
		.6%	flow	____	____	____
		.5%	210	1847	28.3	31.9

Table(11) results of Fresh Density

Mix Designation	A()	B	C
Fresh Density kg/m^3	2187	2165	2174

Table (12) Slump test results .

Mix Designation	A(5)	B	C
Slump mm	95	93	110

Table (13) ACI 213R -03 Requirements for Structural LWAC .

Calculated Equilibrium Density max, kg/m^3 (lb/ft^3)	Average 28-day Splitting Tensile Strength, min, MPa (psi)	Average 28-day Compressive Strength, min, MPa (psi)
	All Lightweight Aggregate	
1760 (110)	2.2 (320)	28 (4000)
1680 (105)	2.1 (300)	21 (3000)
1600 (100)	2.0 (290)	17 (2500)
	Sand/Lightweight Aggregate	
1840 (115)	2.3 (330)	28 (4000)
1760 (110)	2.1 (310)	21 (3000)
1680 (105)	2.1 (300)	17 (2500)

Table (14) Oven dry density and equilibrium density of (ALWAC) .

Mix Designation	A(5)	B	C
Oven dry density kg/m^3	**1775**	**1765**	**1768.5**
Equilibrium density kg/m^3	**1825**	**1815**	**1818.5**

Table (15) Compressive Strength results .

Mix Designation	Attapulgite Mineral Admixture %	Superplasti-sizer L/100cement	Steel fibers %	Compressive Strength MPa			
				7 days	28 day	56 day	90day
A(5)	---	---	---	22.8	27.7	28.9	---
B	6 %	---	---	25.6	31.2	33.6	35.2
C	6 %	0.5	---	27.2	32	36.2	37.7

Table (16) Modulus of Elasticity results

Mixes Designation	Attapulgite Admixture%	Superplastisizer L/100kg cement	Steel fiber%	Modulus of Elasticity Gpa	
				7 days	28 days
A	0	0	0	17.4	23.5
B	6	0	0	17.3	23.6
C	6	0.5	0	17.5	23.9

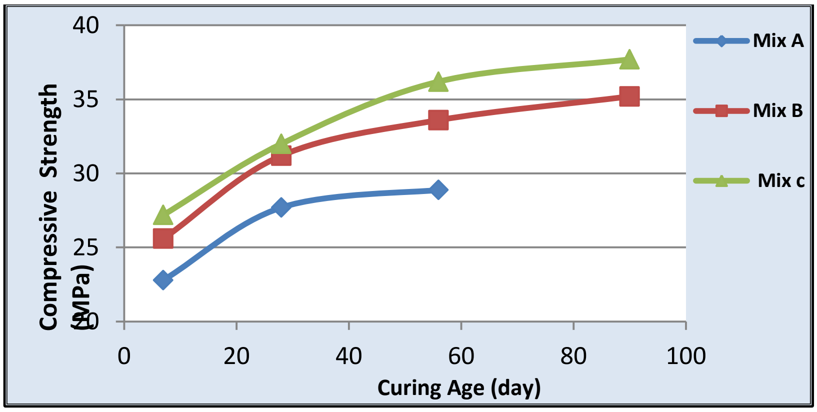
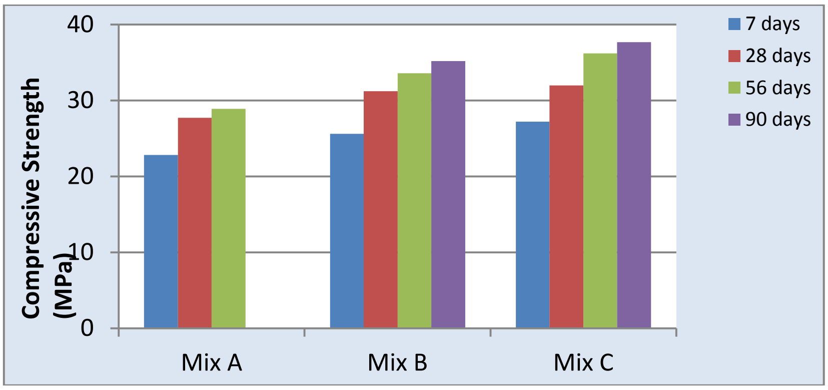


Figure (1) Relationship of compressive strength and curing age



Figure(2) change of compressive strength with the different types of mixes

Figure (3) Relationship between Modulus of elasticity and Curing Age

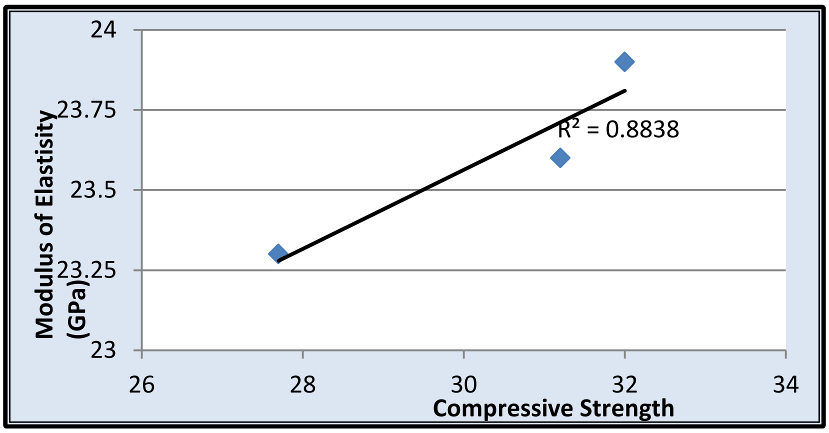


Figure (4)Relationship between Modulus of elasticity and 28 days compressive strength

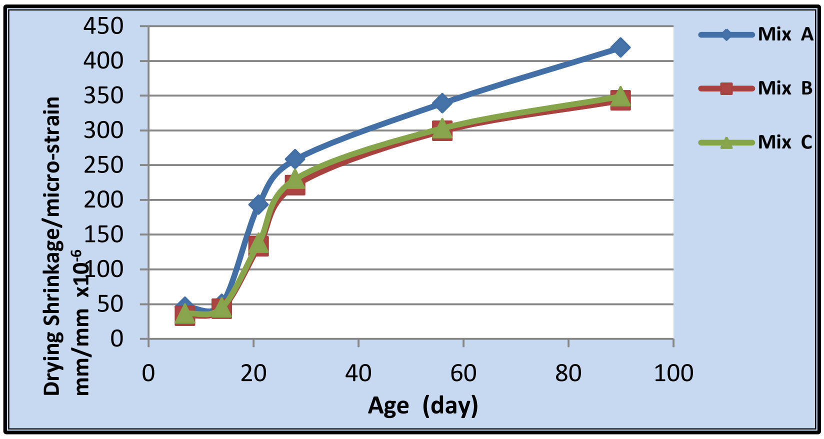


Figure (5) Relation between Drying Shrinkage and Age of ALWAC .

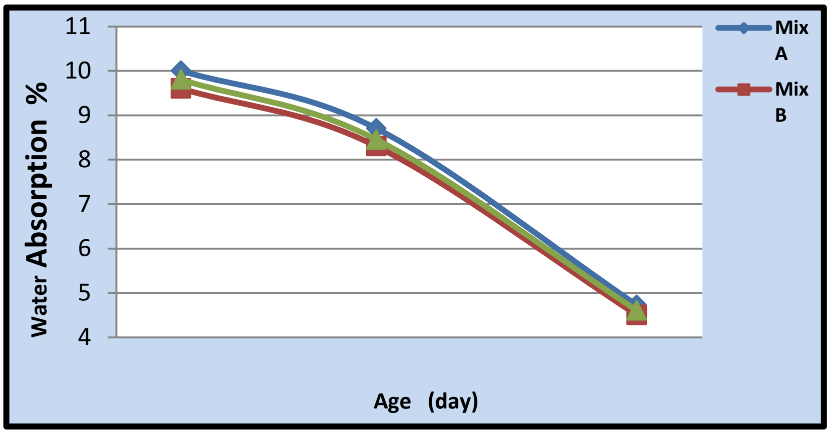


Figure (6) Relationship of ALWAC Absorption and the age

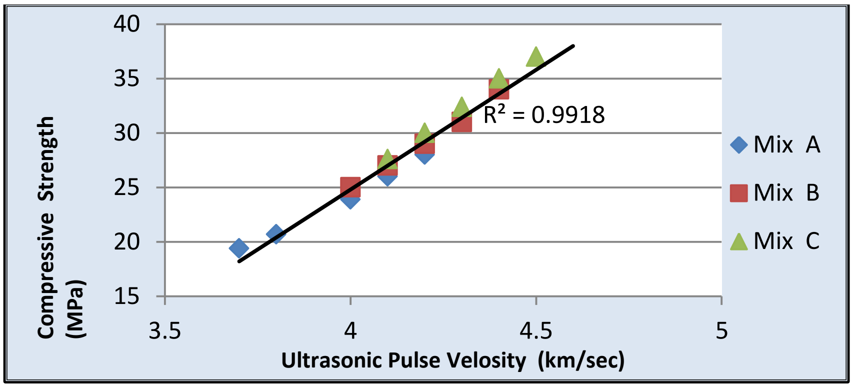


Figure (7) Relationship of UPV and the compressive strength

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