Investigate and Comparison effect add Amorphous and Crystalline - Nano SiO_2 on properties of Concrete

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Abstract

In this paper, the study included the comparison between amorphous silica and crystalline silica (quartz), and with nano scale size, two types of silica was added to concrete by ratios (5%, 10%, 15%, and 20%) as a replacement by the weight of cement. Destructive and non-destructive tests was conducted on the specimens, the results show in destructive test the compressive and tensile strength increase in 15% wt addition ratio in both types of silica, but in amorphous silica was high than in quartz. The results of non-destructive tests show in (Schmidt Hammer) the 15% ratio in both kinds of silica show high hardness than other ratios. Ultra sonic (pules velocity) test, noted the better quality was in 15% ratio in amorphous silica and also show fastest pules velocity.

Keywords: Concrete, Cement, Nano-SiO_2, Ultrasonic, Schmidt Hammer, Tensile strength, Compressive strength.

تحقيق ومقارنة تأثير أضافة السيليكا العشوائية والبلورية-بالحجم النانوي على خصائص الخرسانة

الخلاصة

في هذا البحث، شملت الدراسة مقارنة بين السيليكا العشوائية والسيليكا البلورية (الكوارتز)، بحجم النانو، تم إضافة نوعين من السيليكا بنسب (5٪، 10٪، 15٪، و 20٪) كبديل جزئي من وزن الأسمنت. وقد أجريت الاختبارات الأتلافية وغير أتلافية على العينات، تظهر النتائج في الاختبارات الأتلافية ان هناك زيادة قوة الضغط والشد في نسبة اضافة 15٪ في كلا النوعين من السيليكا، ولكن في السيليكا غير متبلورة كانت مرتفعة بالمقارنة مع المتبلورة (الكوارتز). النتائج في الاختبارات غير الأتلافية ظهرت في (مطرقة شميدت) ان نسبة اضافة 15٪ في كلا النوعين من السيليكا أظهرت صلابة عالية من النسب الأخرى. اختبار السرعة الصوتية لوحظ أن أفضل نوعية كانت في العينة في نسبة 15٪ من السيليكا غير المتبلورة، وكذلك اظهرت أسرع سرعة لانتقال للموجة.

الكلمات المرشدة: خرسانة, أسمنت، نانو سيليكا، موجات فوق صوتية، مطرقة شمدت، قوة الشد، قوة الضغط

INTRODUCTION

Concrete industry has seen in recent decades is a major development in the production of new types of them for the construction of reliable concrete installations in properties in terms of affordability inflicted by high pressure

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and durability [10]. In many instances, the serviceability of the deteriorated structures becomes an important issue and therefore the cost-effective solution is often to use patch repair [11]. Nano materials have attracted much scientific interest due to the potentially new performance of the particles in nanometer (10^{-9} meter) scale. The nano scale particles can result in dramatically improved or different properties from conventional grain-size materials of the same chemical composition. Hence industries can re-engineer many existing products and design novel products that function at unprecedented levels. Nano particles can make traditional building materials stronger and harder, giving them enhanced ductility and formability.

However, the present applications of these materials are mainly limited to produce antiaging, antiseptic, purified air composite paint or other ecological building materials using nano-TiO_2, nano-SiO_2 or nano-Fe_2O_3. There is little research on mixing nano-particles in cement-based materials [1]. In view of the above-mentioned, the aim of the study was to investigate the influences of nano-SiO_2 in cement mortars. Silica fume in micro scale and in powder form with SiO_2 ranging from 85% to 95% has been used either as a partial replacement for cement or as an additive when special properties are desired. Many investigating the use of silica fume as a partial replacement for cement in combination with superplasticizer have shown a significant increase in the strength of concrete.

The development of an ultra-high strength concrete was made possible by the application of DSP (Densified System containing homogeneously arranged ultrafine Particles) with superplasticizer and silica fume content. The amorphous or glassy silica, which is the major component of a pozzolan, reacts with calcium hydroxide formed from the hydration of the calcium silicates. The rate of pozzolanic reaction will be proportional to the amount of surface area available for reaction [2,3].

EXPERIMENTAL WORK

MATERIALS:-

Cement

Ordinary Portland cement manufactured by (tasluga factory \ Bazian) cement factory was used throughout this investigation. Table (1) and (2) show the physical and chemical properties.

Table (1) Chemical properties of the cement

Oxides composition	Content%	Limits of (Iraqi Standard) No.5/1984
CaO	52.21	-
SiO_2	20.18	-
Al_2O_3	5.00	-
Fe_2O_3	3.60	-
MgO	2.31	<5.00
SO_3	1.44	<2.80
L.O.I.	3.29	<4.00
Insoluble residue	1.11	<1.5
Lime Saturation Factor,L.S.F.	0.94	0.66-1.02
Main compounds (Bogue's equations)		
C_3S	57.04	-
C_2S	14.83	-
C_3A	8.60	-
C_4AF	10.95	-

Table (2) Physical Properties of the Cement

Physical Properties	Test results	Limits of (Iraqi Standard) No.5/1984
Specific surface area (Blaine method), m^2/kg	483	≥230
Setting time (Vicate apparatus), Initial setting, h:min Final setting, h:min	 2:50 4:30	 ≥00:45 ≤10:00
Soundness (Auto Clave) method, %	0.25	≤0.8

Fine aggregate:-

AL-Ekadir in Karbala region sand was used as fine aggregate**,** Table (3) show the sieve analysis of fine aggregate.

Table (3) Sieve analysis of fine aggregate

SieveSize(mm)	% Passing	% Passing according to limits of Iraqi Standard No. 45/1984
4.75	95	90-100
2.36	90	85-100
1.18	85	75-100
0.60	70	60-79
0.30	25	12-40
0.15	5	0-10
Fineness Modulus = 2.3		

Coarse Aggregate:-

The coarse aggregate that crushed to12.5 mm maximum size was used. It was obtained from AL - Nebai source, Table (4) show the sieve analysis.

Table (4) Sieve analysis of coarse aggregate

Sieve size (mm)	Selected % passing	% passing ASTM C330-87
12.5	95	90-100
9.5	70	40-80
4.75	15	0-20
2.36	5	0-10

Types of silica: -

Amorphous and Crystalline SiO_2 added as ratios (5%, 10%, 15% and 20%) by weight of cement and the physical properties show in table (5), and chemical properties show in table (6). And (fig1) show X.R.D of amorphous and crystalline (quartz) silica.

Table (5) Physical Properties

	Amorphous Silica	Crystalline silica(quartz)
Partical Size	20 to 200 nm	15 to 100 nm
Density	2220 Kg/m^3	2270 kg/m^3

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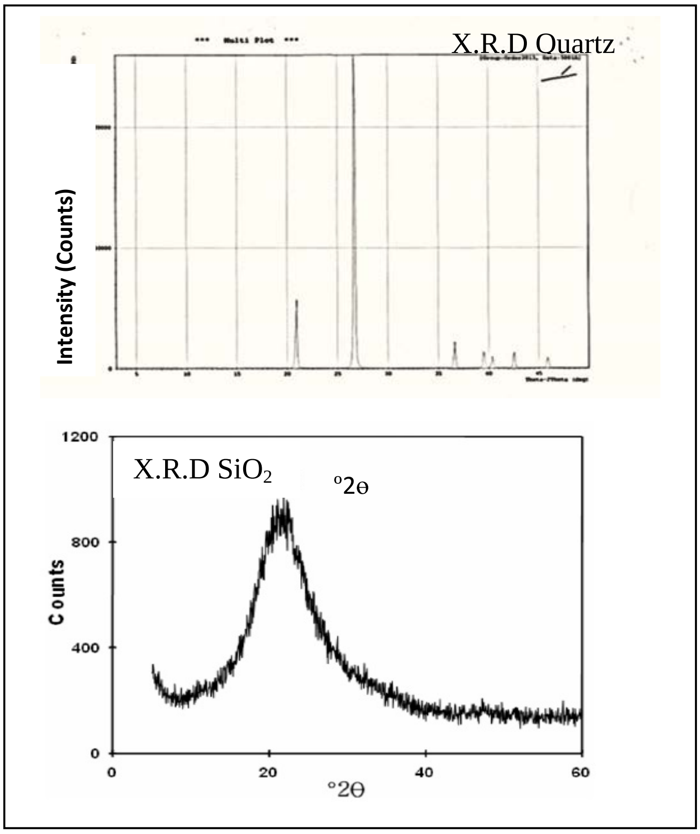


Figure(1). X.R.D of Quartz and SiO2 Amorphous

Table (6) Chemical Properties

Chemical Composition	Amorphous Silica %	Crystalline silica(quartz)%
SiO2	95.90	99.8
Fe2O3	1.30	0.03
CaO	0.41	0.11
MgO	0.38	0.01
Na2O	0.11	0.01
K2O	0.31	0.01
Loss of Ignition	1.58	0.03

Preparation of Concrete Specimens:-

Concrete Mixing:-

The details of mix proportions are presented in Table (7). All mixes was adding silica as a partial replacement by cement weight content, and cast a specimens as a cylinder mold (100×200) mm to compressive and tensile strength and cubic molds (150×150×150) mm to non-destructive tests.

Table (7) Details of the Mixes Used Throughout This Investigation

Mix designation	Mix Proportion	(W/C)*	Amorphous Silica	Crystalline silica(quartz)
1	1:2:3	0.5	0	0
2	1:2:3	0.5	5%	0
3	1:2:3	0.5	10%	0
4	1:2:3	0.5	15%	0
5	1:2:3	0.5	20%	0
6	1:2:3	0.5	0	5%
7	1:2:3	0.5	0	10%
8	1:2:3	0.5	0	15%
9	1:2:3	0.5	0	20%

*W/C : **water/Cement** ratio

Mixing Procedure:-

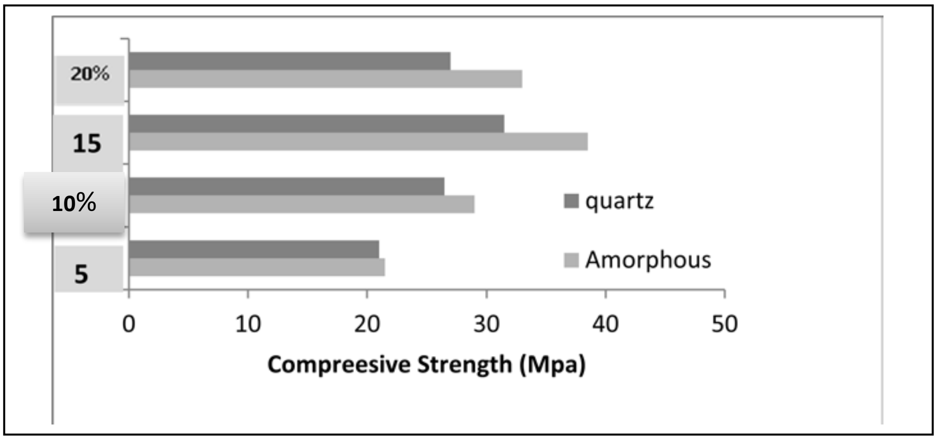
Adopted concrete mix 1:2:3 in the casting process from each mix. a total of 3 cylindrical concrete specimens 100 mm in diameter and 200 mm high[4] and 3 cubic specimens 150×150×150 mm[5]. The molds were oiled properly for easy out specimen and then fill the mold with three layers of the mixture and with each layer instills by tamping rod to ensure out the bubbles and distribution. After casting and finishing, the specimens were demolded after 24 hours of casting and then they were transferred to a curing tank placed at the laboratory temperature of 18 to 20ºC. The specimens were cured in the water tank for 28 days, and then dried in the air to be tested.

RESULTS AND DISCUSSION:-

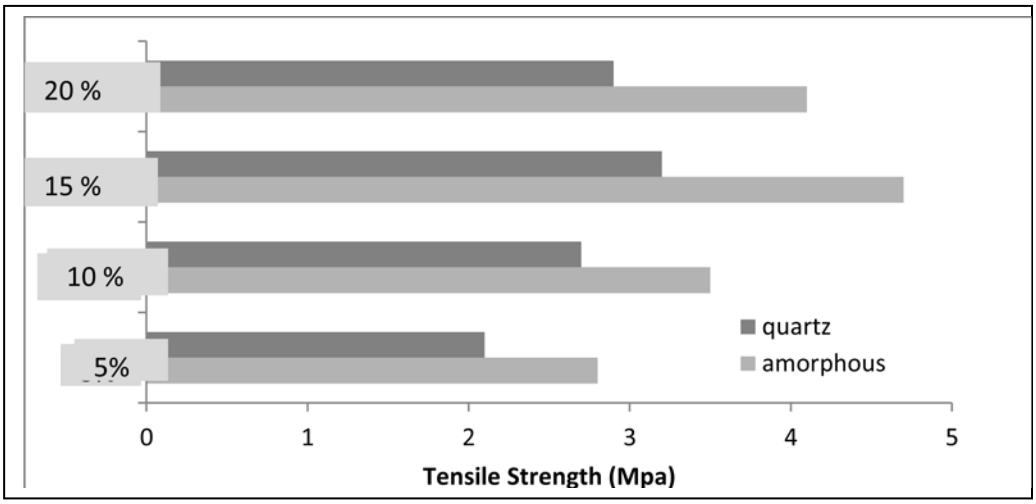
Destructive tests

Compressive and Splitting tensile Strength:-

Compressive and Splitting tensile Strength was calculated from examination of the dimensions of the cylinder (100×200 mm) Concrete containing Quartz and amorphous silica, and ratios (5%, 10%, 15% and 20%) and the results are shown in Figure (2,3). The test measured according to ASTM C39 for Compressive strength and ASTM C496 for splitting tensile strength [7 and 8].

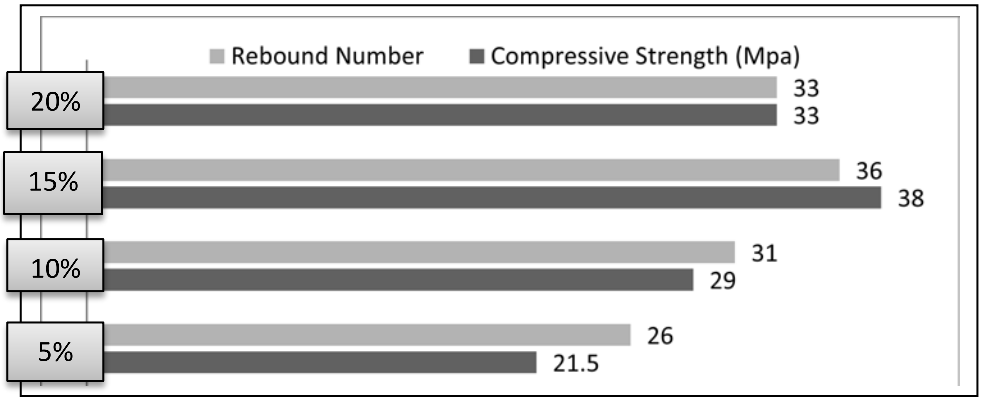


Figure(2). Relation between compressive strength and ratio of amorphous and quartz silica

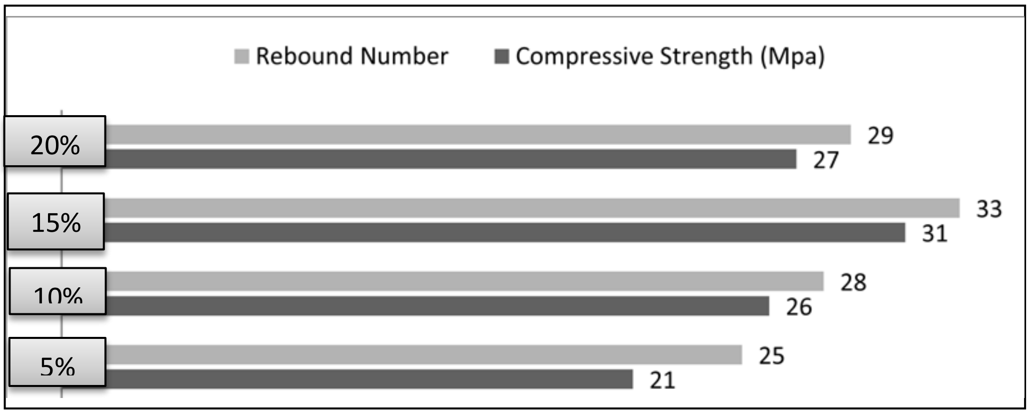


Figure(2). Relation between tensile strength and ratio of amorphous and quartz silica

The specimen tests non-destructive test by (Schmidt Hammer / **Proceq** Company). Where the specimen determine by rebound number (R) of hammer on the surfaces of cubic specimens, and the tested take different places from the same specimen and determine the average of rebound number, then knowing the compressive strength from the rebound number by the curve was gives with device. The rebound number of concrete specimen without additives record (24.5), and noted as show curve below in (Fig4), the rebound number of hammer was high in the ratio 15% compared with another ratios in amorphous silica, thus the compressive strength was high according to the curve of device, that it is mean the hardness of concrete is good. And also noted that the ratio 15% of crystalline silica (quartz) show (Fig 5) high rebound number of hammer compared with another ratio, so the 15% ratio have high compressive strength. And with compared amorphous silica with crystalline silica, noted the amorphous silica have higher rebound number and thus high compressive strength than the crystalline silica.



Figure(4) Relation between R with compressive strength of amorphous



Figure(5) Relation between Rebound number with compressive strength of quartz

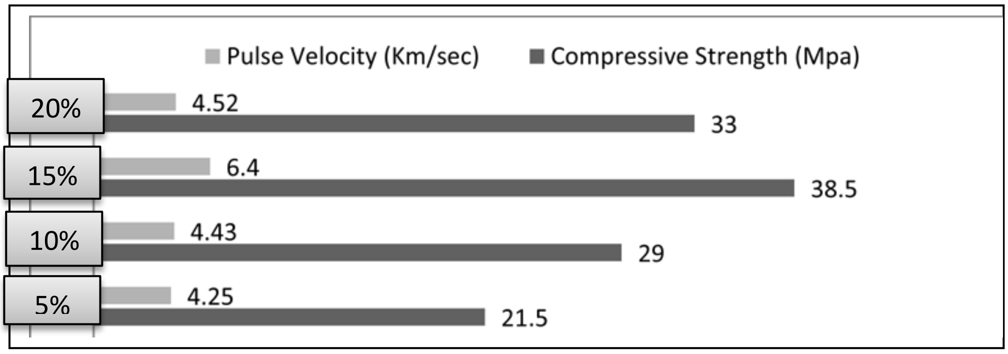
Ultra Sonic (Pulse Velocity):-

Specimens tested by Ultrasonic (pundit lab – **Proceq** Company) to determine the quality of concrete. The pulse velocity of concrete specimen without additives record

(4.24 Km/sec), and by determine the pulse velocity of concrete that contain amorphous silica show increase the pulse velocity by increase the additives, but noted that the high velocity was in 15% than the other ratio of amorphous silica as show in (Fig 6), also the pulse velocity of concrete have crystalline silica increase by increase the additives, and the high velocity was 15% than other additives (Fig 7). And the highest pulse velocity was in 15% amorphous additives. However, all the specimens was good but the specimen have 15% amorphous was excellent according to Neville, A.M. (Table 8)

Table (8) Classification of the quality of concrete on the basis of pulse velocity [6]

pulse velocity (km/s)	Quality of concrete
> 4.5	excellent
4.5-3.5	good
3.5-3.0	doubtful
3.0-2.0	poor
<2.0	very poor



Figure(6) Relation between pulse velocity and compressive strength of amorphous silica

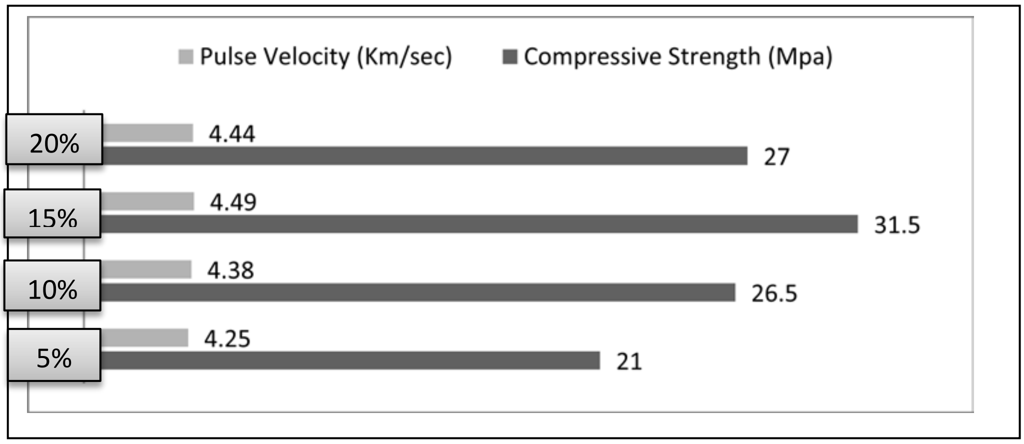


Figure (7) Relation between pulse velocity and compressive strength of quartz

Water Absorption%

The specimens contain quartz and amorphous nano-silica show decrease in absorption of water at 28 days comparison with reference specimen (7.780 absorption %), while the table 9 show all specimens. The test measure according to ASTM C642 [9].

Table(9) water Absorption %

RATIO OF ADDITIVES	5%	10%	15%	20%
NANOQUARTZ	5.8	5	3.7	4
Amorphous nano silica	6.1	5.3	3	3.8

CONCLUSIONS

Conclusion from this research, Nano-amorphous silica is active than Nano-crystalline silica in concrete mix, where amorphous silica show high mechanical properties and show high quality in non-distractive test than crystalline silica. Also conclusion is the better added ratio is 15% in both type of silica, but the percentage of ratio15 % in amorphous silica was higher than in crystalline silica.

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