An Investigation into the Role of Nano-Silica with Light Weight Concrete for Better Replacement of Coarse Aggregate.

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Abstract

A lot of Investigation has been done on the Nano-silica show its impact on improving both strength and durability of concrete. The lightweight materials could decrease the dead load, weight of beams, columns, and foundation. Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay or slate materials that have been fired in a rotary kiln to develop a porous structure. Other products such as air-cooled blast furnace slag are also used. This types of concrete is variously knows as aerated, cellular, foamed or gas concrete. The objective of this research is to investigate the performance of lightweight concrete with Nano-silica. Different concrete mixes with 350 kg/m3 cement content and 0.4 as a constant water-cement ratio were produced with different dosage of Nano-silica Different mixes were produced using LECA with different dosage of Nano- silica (0.75%, 1.5%, and 2%). Strength and durability of all mixtures were studied, also the microstructure of concrete mixes was observed. Adding Nano-silica produced more homogeneity and fewer voids in the concrete microstructure. Comparing the results of this research by the results of previous research.

Keywords—*Nano-silica, lightweight concrete, Light expanded clay aggregate (LECA), Hardened properties, Durability, Microstructure visualization, lightweight concrete beam, flexure test.*

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1 INTRODUCTION

1.1 Lightweight Expended Clay Aggregate (LECA)

Lightweight expanded clay aggregate (LECA) is a lightweight aggregate made by heating clay to around 1,200 °C (2,190 °F) in a rotary kiln. The yielding gases expand the clay by thousands of small bubbles forming during heating producing a honeycomb structure. LECA has an approximately round or potato shape due to circular movement in the kiln and is available in different sizes and densities. LECA is used to make lightweight concrete products and other uses.

Figure 1. Lightweight expanded clay aggregate (LECA)

1.2 LWC (Light weight concrete)

Lightweight concrete mixture is made with a lightweight coarse aggregate and sometimes a portion or entire fine aggregates may be lightweight instead of normal aggregates. Structural lightweight concrete has an in-place density (unit weight) on the order of 90 to 115 lb / ft³ (1440 to 1840 kg/m³).

1.2.1 Types of Lightweight Concrete
1. Lightweight Aggregate Concrete
1.2.3 Types of Lightweight Concrete Based on Density and Strength
LWC can be classified as:-

- Low density concrete
- Moderate strength concrete
- Structural concrete

1. Low Density Concrete
2. Moderate Density Concrete
3. Structural Concrete

1.3 Coarse Aggregate

Coarse aggregates are irregular broken stone or naturally-occurring rounded gravel used for making concrete. Materials which are large to be retained on 4.7 mm sieve size are called coarse aggregates, and its maximum size can be up to 63 mm.

1.3.1 Maximum Size of Aggregate for Various Works

- For Non-reinforced work, maximum size should be from 40 to 75 mm (1.5 to 3 inch).
- For R.C. Foundation work, maximum size should be from 40 mm (1.5 inches).
- For R.C. work (beams, columns, slabs in buildings), maximum size should be from 20 mm (3/4 inch).

For Shell roof and thin members, maximum size should be from 10 mm (3/8 inch).

1.4 Nano-silica

Silicon dioxide nanoparticles, also known as silica nanoparticles or Nano-silica, are the basis for a great deal of biomedical research due to their stability, low toxicity and ability to be functionalized with a range of molecules and polymers.

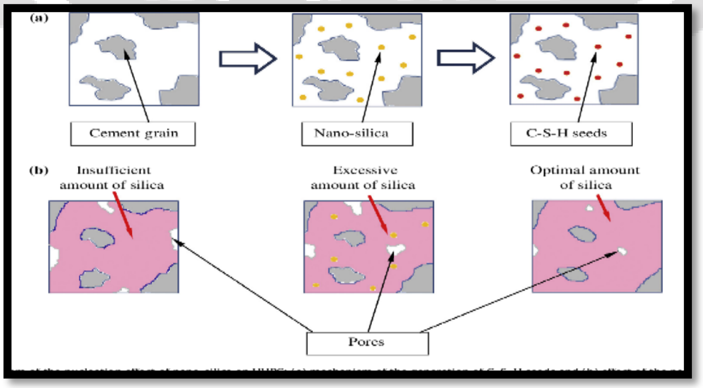

Figure 4. Effect of Nano-silica on the hydration and microstructure development of Ultra-High Performance Concrete.

1.5 Applications:

The central uses of silica nanoparticles are as an added substance for the production of elastic and plastics; as a fortifying filler for concrete and other development composites; and as a stable, non-poisonous stage for biomedical applications, for example, medicate conveyance and the agnostic.

1.6 Objective:

The objective of this research is to investigate the performance of lightweight concrete with Nano-silica. Different concrete mixes with 350 kg/m3 cement content and 0.4 as a constant water-cement ratio were produced with different dosage of Nano-silica Different mixes were produced using LECA with different dosage of Nano- silica (0.75%, 1.5%, and 2%). Strength and durability of all mixtures were studied, also the microstructure of concrete mixes was observed. The test results confirmed that using Nano-silica developed the compressive and tensile strength. At the compressive strength, it is considered that the percent 0.75% of Nano- silica is the ideal percentage at ages 7, 28 and 90 days. Adding Nano-silica produced more homogeneity and fewer voids in the concrete microstructure.

LITERATURE REVIEW

[1]. Yoon, Jin Young et. al. This study examined the structural behavior of Lightweight concrete (LWAC) using lightweight aggregates (Light expanded clay aggregates LECA) and normal weight aggregates, aims to investigate on concrete mix M25 by the effect of partially and fully replacement of the coarse aggregate by Leica with various percentage such as 20%, 40%, 60%, 80% and 100% and fly ash percentage such as 15%, 20%, 25% used as partial replacement for cement in concrete. Analysis of this concrete was done in fresh state as well in hardened state to evaluate physical and mechanical properties of concrete. This paper concentrated on performance parameters such as compressive strength, splitting tensile strength of the light weight concrete using LECA. The Lightweight concrete density varies from 40% - 100% replacement of LECA such as 1996kg/m3 -1597kg/m3. It reduces the weight of concrete and cost of concrete by reducing the aggregate cost and produces economical system. In strength performance of 15% replacement of fly ash content with 40% replacement of coarse aggregates concrete for better results to ensure its optimal proportions.

[2]. Thomas Tamu et. al. The type of lightweight aggregate and its volume fraction in a mix determine the density of lightweight concrete. Minimizing the density obviously requires a higher volume fraction, but this usually causes aggregates segregation in a conventional mixing process. This paper proposes a two-stage casting process to produce a lightweight concrete. This process involves placing lightweight aggregates in a frame and then filling in the remaining interstitial voids with cementations grout. The casting process results in the lowest density of lightweight concrete, which consequently has low compressive strength. The irregularly shaped aggregates compensate for the weak point in terms of strength while the round-shape aggregates provide a strength of 20 MPa. Therefore, the proposed casting process can be applied for manufacturing non-structural elements and structural composites requiring a very low density and a strength of at most 20 MPa.

[3]. Sachin Paul et. al. The guide summarizes the present state of technology. It presents and interprets the data on fine grained-aggregate concrete from many laboratory studies, accumulated experience resulting from successful use, and the performance of structural fine grained-aggregate concrete in service. This guide includes a definition of fine grained-aggregate concrete for structural purposes, and discusses, in condensed fashion, the production methods for and inherent properties of structural fine-grained aggregates. Other chapters follow on current practices for proportioning, mixing, transporting, and placing; properties of hardened concrete; and the design of structural concrete with reference to ACI 318.

[4]. Jihad Hamad Mohammed et. al. Concrete is the most common used material for construction and their design consumes almost the total cement production in the world. The use of large quantities of cement produces increasing CO_2 emissions, and as a consequence the greenhouse effect. A method to reduce the cement content in concrete mixes is the use of silica fines. One of the silica fines with high potential as cement replacement and as concrete additive is Nano-silica (NS). However, the commercial NS is synthesized in a rather complex way, resulting in high purity and complex processes that make them non-feasible for the construction industry. Furthermore, the application of NS and its effect in concrete is not fully understood yet. In a recent research project, a new Nano-silica [1-4] is produced from olivine. This NS, as well as commercially available NS, will be applied and tested. In addition, a mix design tool used for self-compacting concrete (SCC) [5] [6] will be modified to take into account particles in the size range of 10 to 50 nm. This paper aims to present the state of the art of NS application in concrete, focusing on the NS properties to render it suitable to be applicable in concrete. It includes the NS production process, their addition effect and their application in concrete. Also, an overview of the experimental setup and further research is presented.

METHDOLOGY TEST PROGRAM

3.1 Phase (1):

3.1.1 The goal of this stage is picking the reasonable lightweight aggregate that gets higher compressive quality at the necessary thickness extend (1400:1500) kg/m3 and w/c proportion =0.4. The accompanying table show utilized materials as LWC and their concrete ID.

Table (4): Concrete ID for each lightweight aggregate type:

Concrete ID	A	B	C	D	E	F	G
Lightweight Aggregate	Broken burnt bricks	crushed clay bricks	polystyrene	adibor 55	Kiment Block	Delta Block	LECA

Expansion of limited quantities of NS (i.e., 0.25%) caused 10% in-wrinkle in compressive quality at 28 days. [21] Demonstrated the impact of NS expansion on the penetrability of eco-concrete. It was appeared with a mercury porosity test that the relative porousness and pores sizes diminished with the option of 1 and [26] Used various measurements of Nano-silica (1, 2, 3, 4, and 5% of concrete weight) added to elite cement. The compressive quality of cement had demonstrated an expanding pattern with the expansion in the amount of Nano-silica yet the augmentation was halted when the Nano-silica was past 2%. The quality of cement has definitely diminished by half when the Nano-silica is at 4%. In view of the abovementioned and as a result of barely any national assets, broken earth block, squashed red block, broken a light structure block and polystyrene encompassed with concrete will be utilized as lightweight total for an at-entice notwithstanding light extended dirt total to get auxiliary lightweight concrete at the medium densities.

3.2 Phase (2):

In the wake of picking the reasonable lightweight aggregates, the impact of including Nano silica by the various measurements (0%, 0.75%, 1.5%, and 2%) will be concentrated on the appropriate lightweight solid blend by testing the solidified and strength legitimate ties and saw by the microstructure test.

3.2.1 Test of hardened properties:

- **Compressive strength test:**

Compressive qualities were tried by three examples for each age on 7, 28 and 90 days on Ø100 x 200 mm barrel shaped by [3].

3.3 Splitting tensile strength test:

Splitting tensile strength was tested by three specimens for one age at 28 days of curing on Ø100 x 200 mm cylindrical according to [4].

3.3.1 Durability tests:

3.3.1.1 Density, Absorption, and Voids in Hardened Concrete:

In this test to determine density, absorption and voids volume, the test specimens that no less than 350 cm^3 as a volume, pass several stages according to [5].

3.3.1.2 Water absorptivity:

As per [6], in this investigation the pace of ingestion of water by concrete is controlled by estimating the expansion in mass of an example because of assimilation of water as a component of time when just one surface is presented to water on the Ø100 x 50 mm examples. The underlying assimilation (mm) from 1 min to the initial 6 h and the auxiliary ingestion (mm) from 1 day to 8 days were prevent mined by estimating the mass of the solid examples normally.

3.3.1.3 Abrasion resistance:

The groundwork for this test tests is placed in the broiler at a temperature 110 °C for 24 hours. The test example is a solid shape with measurements 70mm*70mm* 70mm that cut in the wake of embellishment in the 3D square (100*100*100) mm, at that point utilizing [12] which made 16 cycles including 22 revolutions of each face for every example to decide the thickness misfortune rate reason for scraped area opposition.

3.4 Phase (3):

Improve the selected mixture at these possible materials and density range to get high compressive strength making the high strength structural element like a reinforced beam. Then, the beam has to be tested, recorded all results to compare adding Nano silica effect to the structural elements.

Table (5): Properties of Nano-Silica particles:

Diameter (nm)	Purity (%)	Surface area(m^2/g)	Density(g/cm^3)	Molecular	Molecular weight
42965	98	240	0.5	SiO_2	60.08

About materials, there are a great deal of kinds of lightweight total which some of them were utilized in this investigation as lightweight extended earth total (LECA) material that has thickness 950 kg/m3, smashed dirt of blocks, broken consumed blocks that both have thickness 1700 kg/m3 and polystyrene has thickness 21kg/m3. Adibor 55 is exchange name of polystyrene encompassed with concrete at CMB Company in Egypt which has thickness 150 kg/m3. It's containing a fortified material like concrete and different materials. In this examination, it was isolated before utilizing at a gathering of preliminaries. Concrete squares which comprise of a mortar, polystyrene, and added substances pouring at conventional blocks molds creating likewise by CMB Company in Egypt, have thickness is 700 kg\m3. Delta Block comprises of white shoe blocks as fig (1) which is delivered by Belena Egypt Company with thickness 650 kg/m3 and its properties were introduced at the table (6). Delta square, concrete square, and red consumed blocks were broken to measure 4.75 and 10 mm to use as L.W.A.

3.5 Materials:

Light weight aggregate solid contrasts from ordinary cement as far as the synthesis of the kind of totals, added substances. In this investigation, as per the concrete is created by [14] and [32] was utilized position (CIM I/52.5N) to get the most quality opposition. The substance and physical properties of it will be appeared in the table (2) and (3) separately. Likewise, the degree of utilized sand will be appeared at the table (4). The principle factor was added to solidify in this examination is Nano silica which the concoction properties will be appeared in the table (5). At long last, the super plasticizer (SP) was added to all solid blends as indicated by [7] to encourage the functionality as a consistent level of concrete weight that rises to 2% and a thickness approach 1080 kg/m3.

Table (6): Chemical composition of cement:

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K2O	Na_2O	SO_3	CL^-	In. Residue	L.O.I
Chemical analysis (%)	24.6	3.68	3.11	62.1	1.66	0.52	0.31	0.08	0.12	2.1	1.63

Table (7): Physical and mechanical properties of cement:

Physical property	Specific gravity	Soundness (mm)	Initial setting time (min.)	Compressive strength (Mpa) (2days)	Compressive strength (Mpa) (28days)
Cement	3.15	5	88	25.63	57.79

Table (8): Particle size distribution and physical properties of fine particles (sand):

Particle size(mm)	10	4.75	2.36	1.18	0.6	0.3	0.15	filler	Bulk density (kg/m3)
sieve no		4	8	16	3	5	1	-	1650
passing %	100	97.6	93.4	83.1	48.2	15.5	3	0	

Table (9): Properties of lightweight sandal bricks (Delta block):

Conc. ID	Cement	Water	Sand	Gravel	lime stone	L.W.A	S.P.	Density	slump	w/c	Fr 7d	Fc 28d
	kg/m³								cm	-	Mpa	
A	350	262.5	-	-	375	615	7	2010	-	0.75	16.4	19.1
B	350	281.25	250	-	-	750	7	2065	-	0.8	10.8	12.24
C	350	140	518	478	-	8	7	1580	0.5	0.4	4.08	5.52
D	350	140	503	250	-	250	7	1670	1	0.4	10.32	12
E	350	140	200	153	-	650	7	1770	2.5	0.4	7.2	8.4
E1	350	140	153	100	-	750	7	1470	3	0.4	1.68	2.4
F	350	255	330	-	333	340	7	1750	1	0.73	13.8	15.48
F1	350	140	602	-	-	330	7	1670	1.5	0.4	6	9
G	350	140	433	-	-	570	7	1420	0.3	0.4	10.8	12
G1	350	147	503	-	-	500	7	1560	0.8	0.42	17.8	22.9

MIXING PRODUCER AND PREPARATION AND CURING OF THE SPECIMENS:

At first, the concrete, light weight (sand) and Nano silica powder were blended in dry structure for 2 minutes. The water was blended in with the super plasticizer in the outside pot. At that point, the blend powder is blended in with water and super plasticizer for 5 minutes to get extraordinary homogeneity. At last, the lightweight total (LECA) was added to this blend and was blended for 10 minutes to get totally blending. Tests of cement were poured by layers to introduce the solid everywhere throughout the blender at that point were compacted for (1~2) minutes by the automat-ed vibrator kept in steel shape for 24 hours. From that point onward, they were expelled from the molds and restored in water at 23 ± 2˚C until the age for each test as indicated by [2].

RESULTS

4.1 Phase (1):

The decision phase of the perfect lightweight concrete (LWC) relies upon the compressive quality and thickness. The accompanying table presents a few preliminaries of every material. About mixture (A), Limestone was utilized in this mixture as a fine aggregate instating of sand. This technique gets a decent compressive quality. One of the hindrances of broken consumed blocks is its unquenched ability of water as a result of its substance materials type. It has a high thickness so it can't be utilized as L.W.A.

4.2 Phase (2):

The perfect mixture plan in with the appropriate lightweight aggregate (LECA). In this stage, Nano silica will be included by the various measurements 0%, 0.75%, 1.5%, and 2% as a substitution level of concrete weight. Each test outcome will be talked about with looking at by the reasonable mixture plan of LECA with and with-out Nano-silica to examine the impact of Nano-silica.

4.2 MICRO-STRUCTURAL ANALYSIS:

Examining Electron Microscope (SEM) was utilized for the investigation of solid examples delivered in this exploration and that are steady with the solid mixture and fluctuate in Nano-silica re-arrangement proportion for every mixture and two proportions 0%, 0.75%, 1.5%, 2%, and this test is recognized as follows: First to uncover a little void inside the solid that filled Nano-silica in light of their little particles size. Second, exposure of the degree of the combination of material solid blend in with them and that help Nano-silica in their joining through the pozzolanic response property that professional dices more C-S-H gel that would fill a huge voids in the solid, which assists with expanding the opposition of solid, which is delivered when blending Nano-silica particles with calcium oxide (Ca (OH) 2) brought about by blending concrete in with blending water. The accompanying pictures appear under a magnifying lens for the solid examples at paces of 0% and 0.75% and 1.5% and 2% to outline the impact of the utilization of Nano-silica concrete with those of various proportions.

4.3 PHASE (3):

The picked mixture was a perfect blend at all above accessible materials regarding quality and another test. Along these lines, in this phase of research, the picked blend will be improved to contemplate the impact of including Nano-silica in wording at quality when it utilizes for making the basic component as the pillar.

CONCLUSIONS

This research is to investigate the performance of lightweight concrete with Nano-silica. Different concrete mixes with 350 kg/m3 cement content and 0.4 as a constant water-cement ratio were produced with different dosage of Nano-silica Different mixes were produced using LECA with different dosage of Nano- silica (0.75%, 1.5%, and 2%). Strength and durability of all mixtures were studied.

Nano silica will be included by the various measurements 0%, 0.75%, 1.5%, and 2% as a substitution level of concrete weight. Each test outcome will be talked about with looking at by the reasonable mixture plan of LECA with and with-out Nano-silica to examine the impact of Nano-silica.

REFERENCES

1. Experimental Investigation on Mechanical Properties of Lightweight Concrete Using Leca" 5, no. 11 (2016): 1511–14.
2. Yoon, Jin Young, Jae Hong Kim, Yoon Yi Hwang, and Dong Kyu Shin. "Fine grained Concrete Produced Using a Two-Stage Casting Process." Materials 8 (2015): 1384–97. Doi: 10.3390/ma8041384.
3. Thomas Tamu et al., Partial Replacement of Coarse Aggregates by Expanded Polystyrene Beads in Concrete. Construction and Building Materials, Vol-3, 2014.
4. Sachin Paul1 Ganesh Babu2, Mechanical Properties of Light Weight Aggregate Geopolymer Concrete Using Light Weight Expanded Clay Aggregate. Transactions on Engineering and Sciences, Vol.2, Issue 10, October 2014
5. Jihad Hamad Mohammed, Ali Jihad Hamad, 2014, A Classification Of Lightweight Concrete: Materials, Properties And Application Review, International Journal of Advanced Engineering Applications, Vol.7, Iss.1, 2014, 52-57.
6. Nkansah, M. A., Christy, A. A., Barth, T., and Francis, G. W., The Use of Lightweight Expanded Clay Aggregate (LECA) as Sorbent for PAHs Removal from Water, Journal of Hazardous Materials, Vol. 217, p. 360-365, 2012.