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MODIFICATION OF LIGHT WEIGHT AGGREGATE CONCRETE BY AN OPTIMUM AMOUNT OF NANO-SILICA

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***Abstract:*.** Due to the use of LWA in concrete the weight of concrete member reduces by 30% which makes the load bearing member slender which leads to economical design of structure but the compressive strength also reduces by 45% so, on addition of NS on concrete by an optimum amount of around 3% it partially compensate the strength reduction by increasing the strength of LWAC by 14.2% & also due to addition of NS in cement it reduces the expansion behavior of cement because Nano-silica is highly pozzolanic material It react with free lime(cause expansion) present in cement which gives it cementitious properties and as a result gives strength to concrete by producing more C-S-H gel and make cement sound. Incorporating a small amount of nanoparticles in concrete can modify the nano-structure of cementitious materials and can enhance mechanical and durability properties of concrete. While use of light weight aggregate helps in reduction in self dead load of structure & the foamy nature of pumice stone makes this stone more durable to shock hence can be used in earthquake resisting structure.

keyword **- Pumice stone,nano-silica(NS),compressive strength**

I. INTRODUCTION

1.1General:

The study is done on the behavior of nano particle material and pumice stone as an alternative to normal aggregate in cement concrete. In these study nano-silica is consider as a nano-material whereas Pumice is a type of volcanic rock erupted from an active volcano from sudden cooling of magma leading to generation of micro-voids in these type of stone making it light, low dense of approximately equal to 850-1850kg/m3[**Selvaprasanth et al,2019**]. The nano particle preferred for the study is nano-silica which is a ultra fine particle at the other side the pumice stone as an aggregate has micro-voids both combinedly may alter the physical and micro-structural nature of concrete because of the use of pumice stone the weight of the concrete structure is reduced to some percent, where as nano-silica is added to some percentage as a admixture in concrete mixture. The ultra fine Nano-particle occupies the void space that exists on the upper surface of pumice stone may leading to the better bonding in concrete.

Hydration process of cement:

$$\text{Cement(opc)} + \text{water} \longrightarrow \text{C-S-H gel} + Ca(OH)_2 + \text{heat}\uparrow$$

This C-S-H gel is mainly responsible for the compressive strength and mechanical properties of the concrete and the byproduct formed is later on responsible for sulphate attack in presence of sulphate salt.

Sulphate attack on concrete:

$$Ca(OH)_2 + Na/Mg\text{-}SO_4 \longrightarrow CaSO_4 + Na/Mg(oH)_2$$

$$CaSO_4 + C_3A \longrightarrow \text{ettringite crystal}$$

The ettringite crystal has volume increasing tendency it expand to 2.5-3 times leading to generation of cracks in hardened concrete this phenomenon is called sulphate attack on concrete so if we properly utilized or controlled formation of $Ca(OH)_2$ the sulphate attack on concrete is prevented this can be possible by addition of pozzolanic material like NS because $Ca(OH)_2$ itself has no adhesive property but when it react with pozzolanic material it develop adhesive property and also concrete become more impermeable there is an another problem solved by addition of NS that is unsoundness problem of concrete which is due to the presence of free calcium hydroxide.In the recent past few decade use of Nano-material has gain a particular attention in various application to produce material with improved properties. It is used in various field in these modern world like in biomedical application, food industry and agriculture, textile industry, optical and electronic instrument and in so many fields. The introduction of nano-silica objective in concrete technology is to make concrete denser and due to high specific surface area to volume it enhance the workability of concrete. Due to the ultra fine Nano size particle occupy the voids present in the concrete at microscopic level leading to densification of concrete on another hand use of light weight aggregate make concrete light weight and the foamy nature of pumice stone makes this stone more durable to shock hence can be used in earthquake resisting structure. Together light weight aggregate along with Some % of Nano-silica has certain advantages over LWC like light weight and at the same time less air void making it strong durable, reduction in thermal coefficient and conductivity, resistance to fire. The use of light weight pumice stone generally reduce the strength of concrete by 40-50%, but due to use of this aggregate the weight of structure of also reduced by around 20-25%[**sultan et.al]** hence by using of 1-5% optimum amount of Nano-silica in light weight concrete partially compensate to some extent the strength reduction due to the use of light weight pumice stone as aggregate[**Montgomery et. Al**]

1.2 History:

From the ancient period we are using pumice stone as per Valmiki Ramayana lord Ram had constructed a bridge called ram setu (Adam's bridge) from Rameshwaram island Tamil nadu to Mannar island Srilanka which is about 48km long(geological survey of India) due to light weight nature of pumice stone it is used in construction of this bridge. There after pumice stone are used to make light weight concrete structure. The Roman Empire had constructed the port of Cosa, pantheon dome in Italy at early 273BC from light weight aggregate of varying density these structure are still use for spiritual purpose[AIC committee 213]. The use of Nano-silica as a replacement or admixture in concrete is new concept and is not practiced in past, but from past hundred year the use of micro silica called silica fumes or silica dust are used as a pozzolanic material in concrete as a replacement to cement.

1.3 problem identification:

The dry density of conventional concrete is 2400kg/m3[**Is 456:2000**] and due to use of pumice stone in concrete the density of concrete structure is reduced to 1600kg/m3 at 100% replacement of normal aggregate with LWA which is around 40% reduction in weight[**Meyyappan et al,2019**] but the strength of LWA is low thereby reduce the strength of concrete so there is a need of special kind of admixture(NS) that compensate the strength reduction due to use of LWA by increasing strength of concrete ,also there is a problem of unsoundness of cement and sulphate attack of cement due to presence of free calcium hydroxide.

1.4 Aims and objective:

To determine the optimum %dose of NS that increases maximum compressive strength of concrete. To make concrete light weight by the use of LWA and to improve the mechanical and physical properties of LWC by addition of optimum % dose of NS also to find out the effect on soundness property of cement due to addition of NS by performing soundness test.

2. MATERIAL:

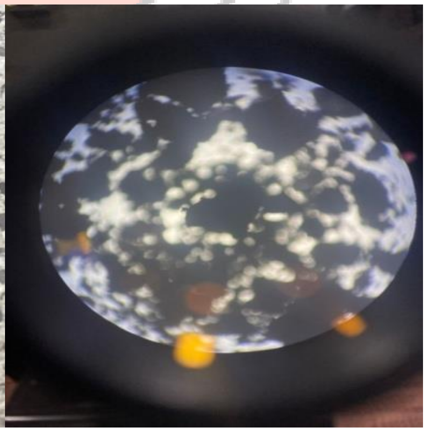
a. Pumice stone

Pumice is a type of volcanic rock or igneous rock erupted form an active volcano from sudden cooling of magma resulting in the formation of large number of micro-voids, hence making it light weight less dense. It density varies from 850 to1850kg/m^3[**Selvaprasanth et al,2019]** depending upon the condition of formation of stone. The porosity index of this stone varies from 58-64%%[**Lockwood et al,2010**]

Pumice aggregate

5X optical Zoom

50X optical Zoom



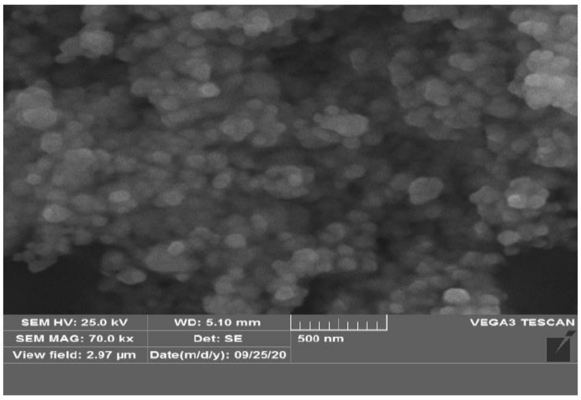
b. Nano-silica

Nanoparticle or ultrafine particle is usually defined as a particle of matter that is between 1 and 100 nanometre(nm) in diameter. It is easily available online in Indiamart site. Dealer or company name- adnano technologies pvt. Ltd. It is mainly composed of sio2 (silica di-oxide) present more than 99% of total Nano-silica and it is available with different purity percentage.

Technical specification of Nano-Silica:

Purity(SiO_2) = 99.9%, Bulk density = 0.25g/cm^3
Average particle size = 20-50µm, morphology = spherical

SEM IMAGES



c. OPC(ordinary Portland cement)

OPC 33 grade is used in various cement and concrete cube testing, the quality and properties of OPC 33 grade cement must conform to IS code 269:1989 and cement bags were conform to IS 269 mark.

d. fine aggregate(sand) and coarse aggregate

The type of sand used is natural river sand which is free from organic material, salinity and is used for both normal concrete and light weight Nano-silica added concrete test. Angular crushed aggregate of size range 40mm passing and 20mm retained on sieve is selected for various cube test.

Technical specification of coarse aggregate

Specific gravity =2.74 (by pycnometer test)
Aggregate impact value = 7.8% (by impact value test)
Water absorption = 0.6% (oven dry method)

e. Water :

Quality of water used in various test is as per IS 456:2000. The PH value of water shall not be less 6.Water should be free from organic matter.

3. METHODOLOGY:

Compressive strength test on cement mixed Nano-silica:

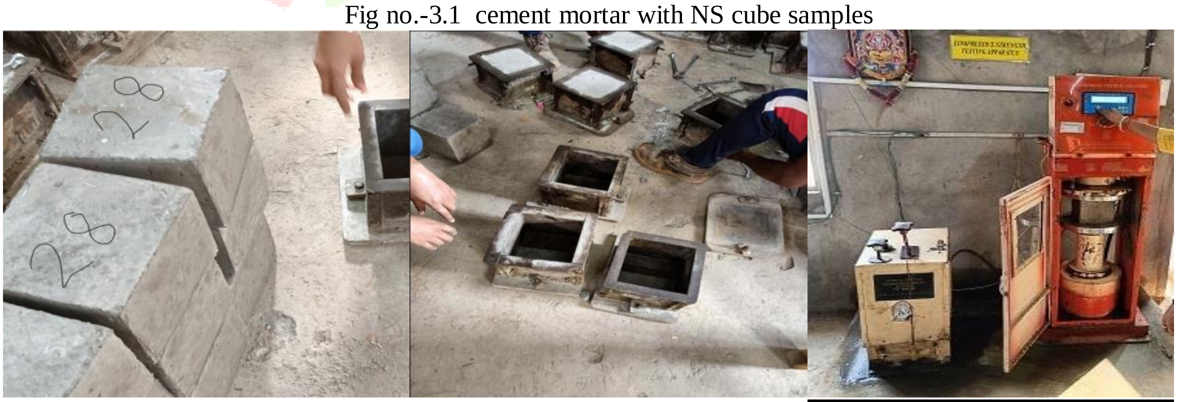
Objective-"To determine optimum Nano-silica percentage which gives maximum strength to cement concrete or mortar**"**

Standardization of CTM conforms to IS: 14858(2000)
Compaction of mortar cube and size of steel mould conforming to IS: 10080-1982.
The procedure and sample preparation adopted in this test is as per IS 4031(part 3)

Cube Sample preparation:

Mix the cement and sand (1:3) with initially **0**% of Nano-silica by weight of cement in one cube preparation and sequentially increasing Nano-silica percentage by **+1**% and prepare 6 different cube of dimension (70.6*70.6*70.6mm) with different Nano-silica percentage till 3days compressive strength test result on graph is start falling. The amount of water used in cube preparation is (P/4+3)%, where p is % of water required to produce standard consistency which is **30**%(obtained from consistency test of cement). Repeat the same procedure to prepare cube sample for 28days compression test.

Fig no.-3.1 cement mortar with NS cube samples



Test procedure :

Curing of prepared cube specimen is done for 3 days before testing by submerged in a tank filled with water test the cube After 3days in CTM machine by keeping the cube in bearing surface of test machine, the load applied is uniform at a rate of 35N/mm^2/min until the specimen develop cracks or failed in compression. Note down the reading from CTM machine where the specimen starts failing. Repeat the same test procedure for 28days compression strength test.

Formula:

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Load at which cube sample fails(N)}}{\text{Area of cube sample}(mm^2)}$$

Compressive strength test of concrete cube:

IS 516:1959, Method of test for compressive strength of concrete is followed The compressive strength of concrete at 3 days, 7days and 28days is determined from compression testing machine(CTM). The compressive strength at any day(3,7,28 day) is the average of 2 cube. A graph of compressive strength is plotted in between light weight aggregate concrete and light weight Nano-silica added concrete concrete to note down the difference in compressive strength due to combined effect of both NS and LWA

Sample preparation:

6 cube of Light weight aggregate concrete and 6 cube of Nano-silica added light weight concrete of nominal mix M20(1:1.5:3) is prepared and the size of cube specimen is 150mm*150mm*150mm. The amount of NS to be added is of optimum percentage(3%) determined from compressive strength test of cement mixed with Nano-silica. The w/c ratio(**0.45**) is used in mixing considering to IS456:2000. Amount of Compaction applied on both types of cube should be similar therefore fill each cube in 3 layer with 35 stroke per layer by taming rod.

Fig no 3.2- **concrete cube sample test**

Test Procedure

Cubes are removed from mould after 24hrs and kept submerged in container filled with water for curing of cube after 3days 2 cube of both types of cube is tested in CTM Apply the load gradually without shock and continuously at the rate of 1.4N/mm^2/min. till the specimen develop crack or fail Record the maximum load and note it. Repeat the same procedure for 7days and 28days compressive strength test and note it down

Formula:

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{Load at which cube sample fails (N)}}{\text{Area of cube sample (mm}^2\text{)}}$$

Soundness test:

Free lime cause expansion of concrete after it set leading to cracking of concrete. It is performed in Le-chaterlier apparatus. It value is generally less than 10mm for OPC.

Objective- To determine unreacted free lime present in normal cement and Nano-silica mixed cement and to compare the difference in soundness of normal cement and after addition of Nano-silica in cement. Higher is the presence of free lime higher is the expansion lower is the soundness.

Paste preparation:

Prepare two types of paste (cement paste & cement past+ 3% optimum NS) by adding 0.78*p% of water, where p is the amount of water required to produce standard consistency which is determined from standard consistency test(**30%**)[by following **IS 4031(part 4):1998**], therefore amount of water added is **23.4%** by weight of cement.

Test procedure:

Fill this paste in Le-chaterlier mould and cover the mould from top and bottom by glass plate submerged the mould assembly in water at room temperature(27+-2ºC) for 24hrs. after 24hr remove the mould assembly from water and measure the distance between the indicator rod (consider this distance A) after measuring distance again submerged the mould in water at room temperature then slowly increase the temperature of water to boiling point level and kept it for 3hrs at boiling temperature. Remove the assembly after 3hrs and kept it left to cool down to room temperature and measure the distance between the indicator rod(consider this distance as B)

Formula:

Expansion or soundness value = **A-B**

Weight test:

The weight of conventional concrete cube (150*150*150mm) is 7.8kg.
The weight of LWA concrete cube (150*150*150mm) is 5.4kg

$$\text{\% weight reduction due to100\% pumice as aggregate} = \frac{7.8\text{kg} - 5.42\text{kg}}{7.8\text{kg}} = \mathbf{30.7\%}$$

4. RESULT AND DISCUSSION:

Compressive strength test of cement(OPC 33) mixed with different % of nano-silica result:

Optimum Nano-silica percentage is to be determined **Table no. 4.1** and **fig no 4.1**
The data obtained from CTM is represented in table no. 4.1

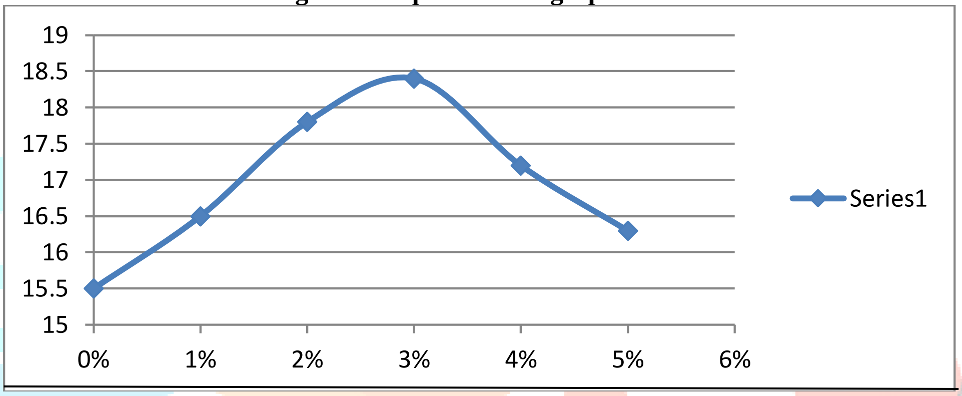
$$\text{Compressive strength of cube} = \frac{\text{Failure load}}{\text{Area of cube } (4984\ mm^2)}$$

Table no.-4.1

S.NO	Curing period	% Nano-silica added	Peak Strength observed(n/mm2) (MPa)
1.	**3 days**	**0%**	**15.5**
2.	**3 days**	**1%**	**16.5**
3.	**3 days**	**2%**	**17.8**
4.	**3 days**	**3%**	**18.4**
5.	**3 days**	**4%**	**17.2**
6.	**3 days**	**5%**	**16.3**

The graphical representation of table no.4.1 is shown in fig no.4.1

Fig no- 4.1 optimum NS graph



- The 3 days compressive strength of cement(opc 33)without Nano-silica silica is 15.5MPA
- From graph it is obtained that optimum percentage of Nano-silica is around **3%** by weight of cement that increases strength of cement on further increase in Nano-silica beyond 3% there is a decrease in compressive strength of cement.

Percentage increase in compressive strength at optimum Nano-silica replacement at 3 days $\frac{18.4-15.5}{15.5}$ = **18.7%**

- The increase in compressive strength of cement at 3% Nano-silica is around 18-20% for 3days.
- 3% optimum Nano-silica content is used in comparative study of Light weight aggregate concrete cube and light weight Nano-silica added concrete cube.

Compressive strength test result of cube sample:

Table 4.2

Compressive strength of 3% Nano-silica added concrete cube of x days with pumice stone(100%) used as aggregate using mix proportion same as M20(1:1.5:3)								
3 days strength (MPa)			7 days strength (MPa)			28 days strength (MPa)		
Cube 1	Cube 2	Average strength	Cube 1	Cube 2	Average strength	Cube 1	Cube 2	Average strength
7.5	7.7	7.6	11.6	12	11.8	15.6	16.4	16

Table 4.3

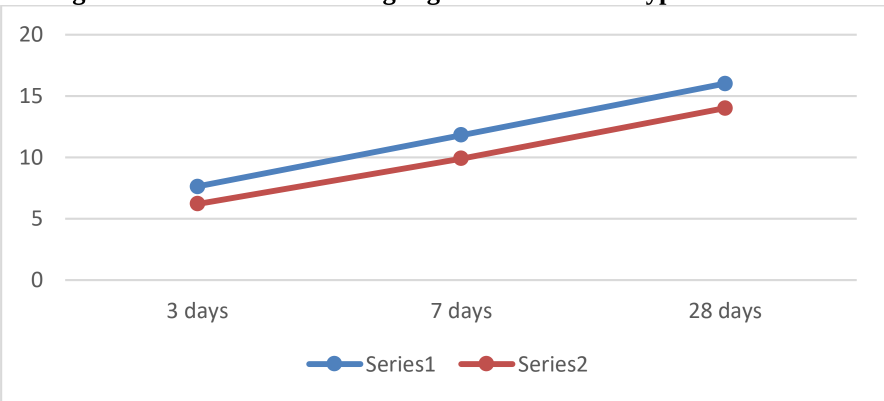
Compressive strength of light weight concrete cube of x days with 100% replacement of normal aggregate with pumice aggregate using mix proportion(1:1.5:3)								
3 days strength (MPa)			7 days strength (MPa)			28 days strength (MPa)		
Cube 1	Cube 2	Average strength	Cube 1	Cube 2	Average strength	Cube 1	Cube 2	Average strength
6.4	6	6.2	9.7	10.2	9.9	13.7	14.3	14

At 3days %increase in compressive strength of LWA+NS concrete compared to LWA concrete= (7.6-6.2)/6.2= 22.5%

At 7days %increase in compressive strength of LWA+NS concrete compared to LWA concrete = (11.8-9.9)/9.9 = 19%

At 28days %increase in compressive strength of LWA+NS concrete compared to LWA concrete = (16-14)/14 = 14.2%

Fig no 4.2-shows rate of strength gain of 2 different types of concrete



Series1- NS+LWA concrete; Series2-LWA concrete

Soundness test result:

Sample without NS

Distance between the indicator rod after 24hr of curing at 27± 2 °C (A) = 3mm
Distance between the indicator rod curing for 3hr at boiling temperature (B) =9
Expansion or soundness value = A-B
= 9-3= 6mm

Sample with 3% NS

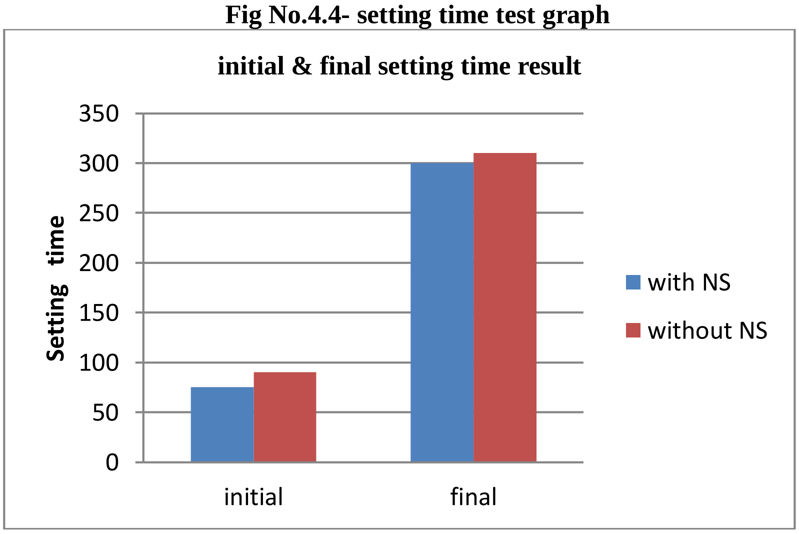
Distance between the indicator rod after 24hr of curing at 27± 2 °C (A) = 3mm
Distance between the indicator rod curing for 3hr at boiling temperature (B) =7mm
Expansion or soundness value = A-B
= 7-3= 4mm
Difference in expansion due to NS = 2mm
% difference in reduction of expansion due to NS =30%

initial and final setting time test result:

Table No- 4.5

TEST SAMPLE	Initial setting time test(min.)		Final setting time test(min.)	
	With NS (3%)	Without NS	With NS (3%)	Without NS
Sample	75	90	290	310

Fig No.4.4- setting time test graph



Initial setting time test:

The initial setting time of OPC 33 without NS = 90 minute.
The initial setting time of OPC 33 with optimum amount(3%) of NS = 75 minute.
The difference in setting time due to 3% NS = 15 minute.
% difference due to 3% NS = **16.6%**

Final setting time test:

The final setting time of OPC 33 without NS = 310 minute

The final setting time of OPC 33 with optimum amount(3%) of NS =290 minute

The difference in setting time due to 3% NS = 20 minute.

% difference due to 3% NS = **6.64%**

5. Conclusion:

- 3% Nano-silica is most optimum for increase in compressive strength of cement and beyond 3% increase in compressive strength start falling and the increase in compressive strength of cement mortar is **18.7%** for 3days at optimum percentage due to use of NS at 3% in LWAC it increases the compressive strength of LWAC by 22.5%, 19% and 14.2% for 3days, 7days and 28days.Considering 28days increase in compressive strength is 14.2% in LWAC Despite of being having less compressive strength LWAC is advantageous to use at place where the load is not heavy or the concrete member is non-load bearing because the weight of member reduces by 30%(depending upon mix ratio practically possible for standard grade of concrete) which led to economical design of load bearing member(column, footing.etc).
- Due to addition of NS the initial setting time shorten by 15min which is 16.6% shortening of initial setting time compare to normal OPC cement while final setting time shorten by 10min which is just 6.6% which can be neglected hence addition of NS majorly effect initial setting time of OPC.
- The expansion/unsoundness behavior of cement is reduced by 2mm(in le-chaterlier mould) which is around 30% reduction in expansion of cement mould due to addition of NS in cement as compare to cement mould without NS.

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