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Strength of Nano Concrete using Nano Silica

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INTRODUCTION:-

Concrete is the material of present as well as future. The wide use of it in structures, from buildings to factories, from bridges to airports, makes it one of the most investigated material of the 21st century. Due to the rapid population explosion and the technology boom to cater to these needs, there is an urgent need to improve the strength and durability of concrete. Out of the various materials used in the production of concrete, cement plays a major role due its size and adhesive property. So, to produce concrete with improved properties, the mechanism of cement hydration has to be studied properly and better substitutes to it have to be suggested. Different materials known as supplementary cementitious materials or SCMs are added to concrete improve its properties. Some of these are fly ash, blast furnace slag, rice husk, silica fumes and even bacteria. Of the various technologies in use, Nanotechnology looks to be a promising approach in improving the properties of concrete. Thus the basic concept behind Nano modification of materials is that of bottom-up engineering, starting with engineered modifications to the molecular structure with an aim to affect the bulk properties of the material. Conceptually, this is simply an imitation of nature. In practice, the introduction of nanotechnology represents a revolution that is allowing for the development of high-performance and long-lasting products and processes within an ideal context of sustainable development.

Nanomaterials are very small sized materials with particle size in nanometres. These materials are very effective in changing the properties of concrete at the ultrafine level by the virtue of their very small size. The small size of the particles also means a greater surface area. Since the rate of a pozzolanic reaction is proportional to the surface area available, a faster reaction can be achieved . Only a small percentage of cement can be replaced to achieve the desired results. These nanomaterials improve the strength, durability and permeability of concrete by filling up the minute voids and pores in the microstructure.

Nano-concrete also results in a lower rate of corrosion of the steel reinforcements due to the pore filling nature of the nano silica particles in the concrete. If Portland cement can be manufactured using the nano sized particles, it will open up a large number of opportunities for further research and development of concrete used in construction industry. The nano particles also make the cement more environmentally friendly and reduce the impact of the construction industry on the environment, hence leading to a more sustainable future. The cement manufactured using this method will not only be more economical than ordinary cement polymers, but will also have a fire resistance. Hence the structure built using nano particles will be stronger and more durable than conventional concrete, which in turn increases the service life of the building

The use of nanosilica in concrete mix has shown results of increase in the compressive, tensile and flexural strength of concrete. It sets early and hence generally requires admixtures during mix design. Nano-silica mixed cement can generate nano-crystals of C-S-H gel after hydration. These nano-crystals accommodate in the micro pores of the cement concrete, hence improving the permeability and strength of concrete.

This research will try to fulfill its goal through a set of objectives; it will first start by defining Nanoconcrete in brief and its common additives by comparing last literatures. Next, the research will discuss the main difference of Nano-concrete mixes compared to ordinary mixes of concrete. Following that, the research will discuss the application of Nano-concrete in buildings and its effect on contemporary architecture. Finally, the research will list the final key points in the conclusion.

LITERATURE REVIEW:-

1. **Li et.al(2004)** incorporated Nano silica into ordinary traditional concrete and reported 3days compressive strength increase and also at later stages same trend was observed with 4% nano-Silica in high volume fly ash concrete. Same results were obtained for Split tensile and flexural strength test. An increase of about 23-38 % and 7-14% at 7days and 28days respectively. Investigations on Nano-silica in concrete resultd in reduction in water absorption, coefficient of water absorption and permeability than Normal concrete.

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2. **M.Saravanan et.al (2016)** replaced the Nano-silica in various proportion such as 5%, 10%, 15%, 20% to the weigth of cement. When concrete is reduced to Nano level its properties are strongly influenced so that it increases strength and durability. The mechanical properties of concrete such as compressive strength, tensile strength and flexural strength of respective specimen were tested after 7days and 28 days curing.

Specimen %		5	10	15	20	Traditional
Compressive Strength (N/mm^2)	7 days	3.39	3.5	2.8	2.76	1.62
	28 days	4.95	5.16	4.46	4.42	2.93
Tensile Strength (N/mm^2)	7 days	31.12	34.97	33.57	33.72	18.95
	28 days	37.78	40.97	39.22	39.22	27.36

It is evident that addition of 10% of Nano-silica with the concrete cubes, the compressive strength and tensile strength after 7days and 28 days is more when compared to other mix percentages. [1]

3. **Billa et.al (2017)** deals with Partial replacement of Waste Plastics and waste rubber as partial replacement in concrete at an increment of 5% each time. They observed an increase in compressive strength on addition of a certain minimum quantity of Nano silica. Also there is a substantial increase in the early-age strength of concrete compared to 28 days strength of concrete. Test results shows that the quality of concrete gets slightly affected on addition of Nano silica but overall quality of concrete is preserved.[2]

4. **P.Vasanthi et.al (2017)** studied the properties and durability of Nano Concrete and determined the compressive strength of cubes with 2% of nano silica on M40 grade that has been immersed in HCL (acid test), NaOH (alkaline test) and Na2SO4 (sulphate test). Materials used for the project Portland Pozzolana Cement (53 Grade) conforming and Gravel of 12mm and below size is used as the Coarse Aggregate. Nano Silica is the first product that replaced the micro silica. Nano silica produces high compressive strength concrete. Polycarboxylates are chemical admixtures that can be added to concrete mixture to improve workability. Test results shown that the M40 grade concrete mixed with 2% of Nano Silica shows a 15% increase in Compressive Strength immersed in HCl, 20% increase in samples immersed in Na2SO4 and NaOH. Also they observed an increased in Durability when compared to the ordinary mix concrete. [3]

5. **Wijdan D et.al (2017)** made a conclusion that Nano concrete is not only important as an enhanced construction material but also in the context of energy and effort conservation effort. Thus enabling the construction of more creative forms which was impossible to construct the use of ordinary concrete mix. Self-compacting concrete (S.C.C) which is produced through the addition small amount of Nano silica results in concrete with high strength and Durability. Hence, it could be used to construct complex shapes and improved concrete's mechanical strength. Self-cleaning concrete could be made by adding nano titanium dioxide (Nano TiO2). This results in self cleaning concrete with special photo catalytic property to convert air pollutents into harmless substance with sunlight help. It also caused cement for rapidly Hydrate. [4]

OBJECTIVES:-

1. Properties of cement such as Normal consistency, initial and final setting time can be improved.
2. To study the effect of Nano-silica on compressive and tensile strength.
3. To study the workability and durability of concrete.

PROPERTIES OF MATERIALS:-

Properties of concrete:-

Durability:- Ability of hardened concrete to resist deterioration caused by weathering, chemicals, and abrasion.

Workability:- Ease of placing, handling, and finishing.

Weather Resistance:-Resistance to deterioration caused by freezing and thawing, wetting and drying, and heating and cooling.

Erosion Resistance:- Resistance to deterioration caused by water flow, traffic, and wind blasting.

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Chemical Resistance:- Resistance to deterioration caused by salt water and sulphate salts.

Water Tightness: Resistance to water infiltration.

Strength:- Should posses High Compressive, Flexure and Tensile strength.

Economy:- Cost effective, low maintainance.

Characteristics of Aggregates:

Resistance to Freeze &Thaw:- (Important in structures subjected to weathering)
The freeze-thaw resistance of an aggregate is related to its porosity, absorption, and pore structure. Specifications require that resistance to weathering be demonstrated by the magnesium sulfate test.

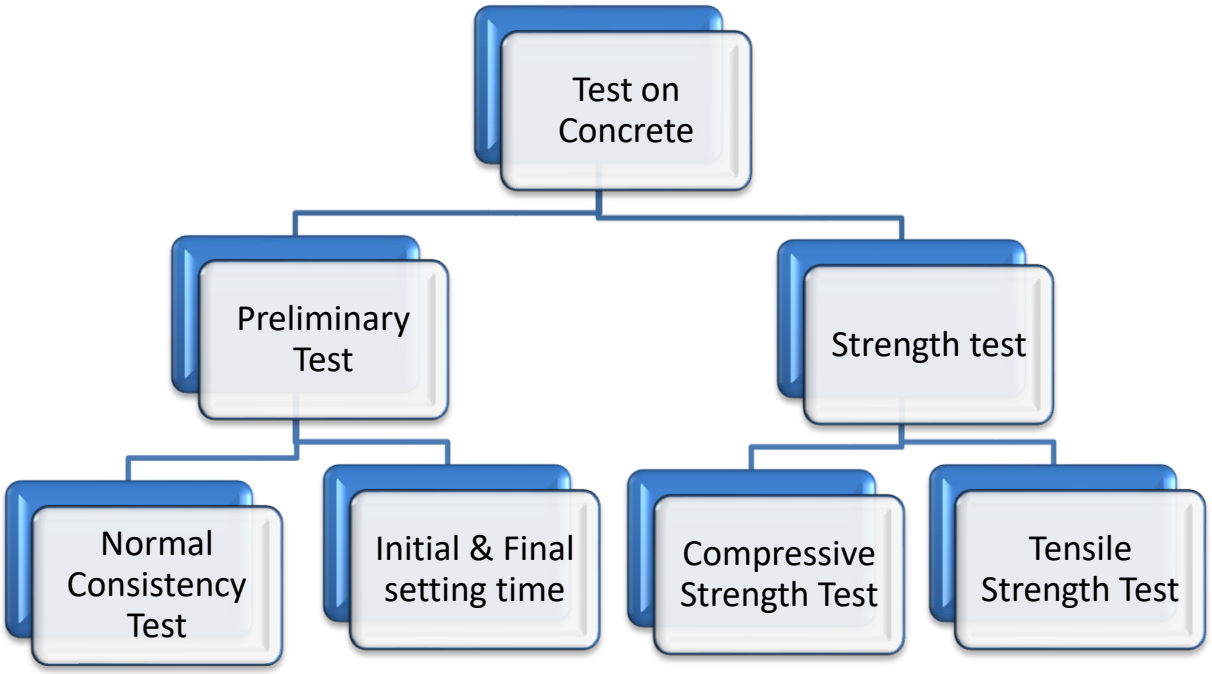
Abrasion Resistance:- (Important in pavements, loading plat-forms, floors, etc.)
Abrasion resistance is the ability to withstand loads without excessive wear or deterioration of the aggregate.

Chemical Stability:- (Important to strength and durability of all types of structures)
Aggregates must not be reactive with cement alkalies. This reaction may cause abnormal expansion and map-cracking of concrete.

Particle Shape and Surface Texture:- (Important to the workability of fresh concrete)
Rough textured or flat and elongated particles, due to their high surface area, require more water to produce workable concrete than do rounded or cubical aggregates.

Grading:- (Important to the workability of fresh concrete)
The grading or particle size distribution of an aggregate is determined by sieve analysis.

METHODOLOGY:-



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Procedure for preparation of Nano-Concrete:-

1. Samples are to be prepare by adopting 1%, 2%,, 3% and 3.5% adding of Nano silica by weight of cement.
2. Cube samples of size 150mm x 150mm x 150mm are to be prepare for testing of Compressive strength of concrete for 7days , 14 days and 28 days.
3. Cylinder samples of 300mm length and 150mm diameter are prepared for testing of Tensile Strength of concrete for 7days, 14days, 28days.
4. Workability of different cement concretes are to be determine and compare with Normal/ traditional concrete by various methods.
5. Durability of cement is measured by finding the % weight losses on each testing days and noted.
6. All the materials used to be prepare the samples are as per IS specifications.
7. All the tests performed are as per IS specification.

Samples of Nano concrete block

Preparation sample of nano concrete blocks

TESTS TO BE CONDUCTED:-

Preliminary Tests:

1. *Normal Consistency Test:*
   The aim of conducting this test is to determine the amount of water to be added to the cement paste to obtain the Normal Consistency. This test serve as a preliminary test in cement because the water content to be used for other tests on cement depends on it. The water content for various tests on cement which depends on Normal Consistency are initial and final setting time, soundness and compressive strength test. The normal consistency depends upon the factors such as temperature and fineness of cement. Higher the temperature higher will be the fineness of cement, normal consistency is higher and vice-versa.

PROCEDURE:

- Weigh about 300gm of cement free from lumps and place it in the clean tray.
- To start with add about 25% of clean water and mix thoroughly by means of hand. Care should be taken to see that the time of gauging is not less than 3min and should be not more than 5mins. The gauge time shall be counted from the time of addition of water to dry cement until filling the mould with the paste.
- Fill the Vicat's mould with this paste, the mould is resting on non-porous plate. After completely filling the mould smooth off the surface of the paste by single movement of trowel making it level. The mould may be slightly shaken to expel the air.
- Place this mould along with non-porous plate under the Vicat's apparatus attached with plunger. Lower the plunger gently to touch the surface of the test mould.
- Prepare trial pastes with varying percentage of water initially 26%,28%,30%,32% etc. This percentage of water to be taken depends on depth of penetration. As the depth of penetration approaches the desired depth of penetration(5-7mm) decrease the interval of percentage of water to be added i.e.,1% and 0.5%.
- Determine the depth of penetration for different percentage of water as mentioned in above step. The percentage of water which indicates the depth of penetration between 5mm to 7mm is taken as the Normal consistency of cement.

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Vicat's Apparatus

2. *Initial Setting Time :*
Setting is the change in state from fluid to rigid state. The initial set is the stage in the process of hardening after which any cracks that may appear will not be re-unite. Concrete operations like mixing, transportation, spacing, compaction and finishing requires time. All these operations must be completed within the initial setting time of cement. If we continue the concreting operation below the initial setting time development of strength of concrete will be disturbed. Therefore it is necessary to know the initial setting time of cement, so that all these concrete operations can be completed within the time.

PROCEDURE:

- Take 300gms of fresh cement free from lumps.
- Take water quantity equal to 0.85P, where P stands for normal consistency
- Mix water and cement, and prepare a paste, statrt the stopwatch the moment water is added to cement.
- Fill the Vicat mould and smooth off the surface of the paste making it level with the top of the mould. The gauging time(3-5 min) is again maintained. The mould may be slightly shaken to expel the air.
- Place this mould together with the non-porous plate under the vicat's apparatus attached with needle (1mm diameter), lower the needle gently to touch the surface of test block and release it. The needle makes an ipmresssion thereon, while attachment fails to do so.
- Repeat the procedure until there is no impression made by circular attachment.
- The time the moment water is added to cement till the circular attachment fails to make impression on the test block is the final setting time.

Needle used for finding
Initial setting time of cement

Needle with annular
attachment used in
Final setting time of cement

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Final Setting Time Of Cement:

The final set is a stage in the process of hardening, when paste has attained certain strength and hardness .At final test paste concrete can withstand little s disturbance. Therefore once the concrete is placed it should remain undisturbed till final setting time. Hardening should be rapid so that structure can made use of as early as possible.

PROCEDURE:

- Take 300gms of fresh cement free from lumps.
- Take water quantity equal to 0.85P, where P stands for normal consistency
- Mix water and cement, and prepare a paste, statrt the stopwatch the moment water is added to cement.
- Fill the Vicat mould and smooth off the surface of the paste making it level with the top of the mould. The gauging time(3-5 min) is again maintained. The mould may be slightly shaken to expel the air.
- Place this mould together with the non-porous plate under the vicat's apparatus attached with needle(circular attachment), lower the needle gently to touch the surface of test block and release it. The needle makes an ipmresssion thereon, while attachment fails to do so.
- Repeat the procedure until there is no impression made by circular attachment.
- The time the moment water is added to cement till the circular attachment fails to make impression on the test block is the final setting time.

STRENGTH TEST:_

Compressive Strength Test: Compressive strength of concrete is important property of concrete. The other properties of concrete has definite relationship with the compressive strength. If the compressive strength of concrete is improved there is an improvement in other properties of concrete also, therefore compressive strength is an essential test.

Compressive strength of concrete also depends on size of specimen, the height of test specimen is releated to its lateral dimensions has great influence on strength test. The more slender the specimen lower will be the crushing strength value. Therefore two types of standard test specimens that is cubes and cylinders are used in this study.

$$\text{Compressive strength} = \frac{\text{Load}}{\text{Area}}$$

Apparatus: Compression testing machine,
Preparation of cubes of dimensions: 15cm x15cm x15cm.

PROCEDURE:

- Concrete mix is design for M30 grade as per IS standards and the proportions are indicated in the observation.
- Calculate the material required for 3cubes and 3 cylinders using the concrete of proportion 1:1.5:3 by mass and water to cement ratio 0.5
- Take Coarse Aggregate, Fine aggregate, cement ,water and Nano silica in required quantity and mix it thoroughly.
- Apply oil uniformly to the inside of the mould on all the surfaces.
- Mix them thoroughly in the mechanical mixer until uniform colour of concrete is obtained.
- If mixing is by hand the cement and the gine aggregate shall be mixed dry to the uniform colour and then the coarse aggregate is to be added, mix until the coarse aggregate is uniformly distributed. Now water shall be added and whole mix is mixed until the resulting concrete is uniform.
- Fill concrete in cube moulds in four layers each of approximately 75mm and ramming each layer with 25 blows evenly distributed over the surface.
- Stike off the excess concrete with a straight metal edge flash with top of the moulds.
- Immediately after being made, the mould should be kept in humidity chamber with 90% of humidity or covered with wet gunny bags.

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Compression Testing Machine | 15 cm Cube Mould | Concrete Cube

Curing:

- After 24hrs of casting cylindrical specimens are capped by neat cement paste of 35% water content on the capping apparatus. After another 24hrs specimens are immersed in water for final curing.
- Specimens are removed from the mould after 24hrs and cured in water for 7days and 28 days.
- Temperature of curing must be maintained 27'C and water should be periodically changed.

Testing:

- Compressive strength of cube specimens are made as soon as practicable after removing from the curing pit.
- Size of the test specimen is determined by averaging perpendicular dimensions atleast at two places.
- Determine the mass of each specimen.
- Place the specimen centrally on the compressive testing machine and load is applied continusly and uniformly.
- The rate of loading is controlled through central value by hand two 14N/mm^2 /min.
- The load is increased until the specimen fails and record the maximum load.

Tensile strength test:

The tensile strength is one of the basic and important property of concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. In the design of structure concrete is exploited so as not to relay on its tensile strength which is low.

PROCEDURE:

- Concrete mix is design for M30 grade as per IS standards and the proportions are indicated in the observation.
- Calculate the material required for 3cubes and 3 cylinders using the concrete of proportion 1:1.5:3 by mass and water to cement ratio 0.5
- Take Coarse Aggregate, Fine aggregate, cement ,water and Nano silica in required quantity and mix it thoroughly.
- Caste minimum three cylindrical specimen for each ages(7days,28days)
- Place the cylindrical concrete specimen for curing.
- After 7 days and 28 days place the cylinders between the platens of testing machine keeping two plywoods strips at top and bottom.
- Apply the load gradually at the rate of 1.4 N/mm^2 per minute until the failure.
- Note down the maximum load applied as tensile strength. [5]

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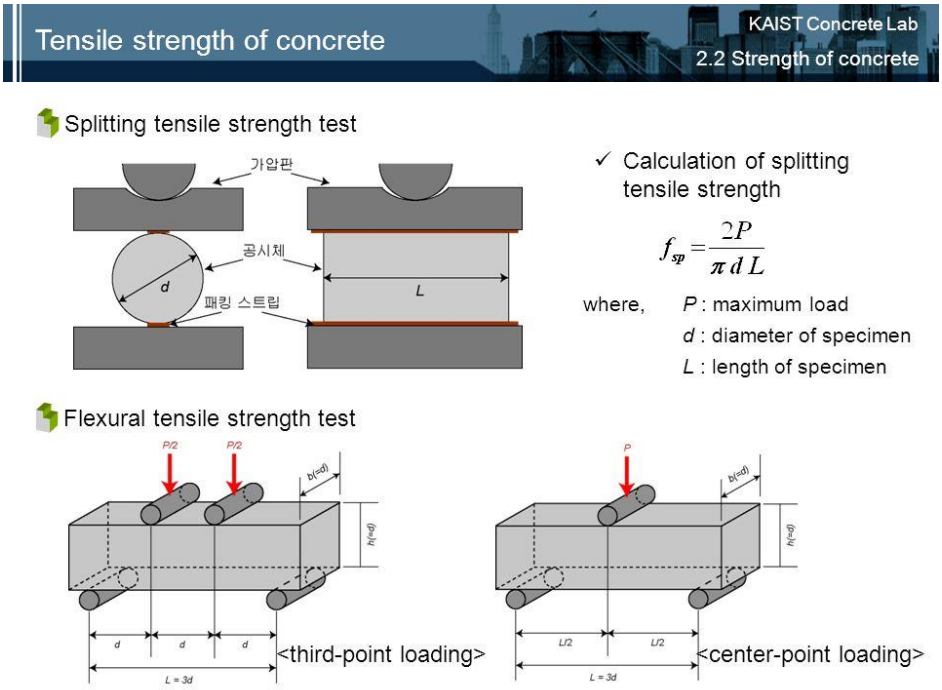

Apparatus for Tensile strength Test

EXPERIMENTAL WORK

The preliminary tests were conducted on cement, fine aggregate, coarse aggregate and the test results were obtained. Based on the results obtained the mix proportion for M 30 concrete is done.

The properties of materials tested are as follows,

Aggregates

Aggregates generally occupy 65- 80% of a concrete's volume. Aggregates are inert fillers floating in the cement paste matrix for concretes of low strength. The strength of aggregates do not contribute to the strength of concrete for low strength concrete. The characteristics of aggregates impact performance of fresh and hardened concrete.

Aggregate Classification

- Size:- Coarse Aggregates & Fine Aggregates.
- Specific Gravity:- Light Weight, Normal Weight and Heavy Weight Aggregates.
- Availability:- Natural Gravel and Crushed Aggregates.
- Shape:- Round, Cubical, Angular, Elongated and Flaky Aggregates.

Fine Aggregate

- Sand and/or crushed stone.
- Size < 4.75 mm.
- Fine Aggregate content usually 35% to 45% by mass or volume of total aggregate.

Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources.

Table 1: Properties of fine aggregate:

Properties	Result
Specific gravity	2.7
Bulk density (compacted condition)	1914 Kg/m^3
Fineness modulus	2.8 %

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Table 2:Sieve analysis of fine aggregate

Sieve size	Mass retained in gms	% of mass retained	Cumulative mass retained in gms	%finer
4.75mm	48.52	4.852	4.852	95.148
2.36mm	34.56	3.456	8.308	91.708
1.18mm	165.54	16.55	24.858	75.142
600micron	170.56	17.04	41.898	58.1
300micron	505.52	49.05	90.978	9.02
150micron	70.56	7.56	98.51	1.48

Coarse Aggregate

Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. They can either be from Primary, Secondary or Recycled sources. Aggregates are either Land- or Marine-Won. Gravel is a coarse marine-won aggregate; land- won coarse aggregates include gravel and crushed rock. Gravels constitute the majority of coarse aggregate used in concrete.

Secondary aggregates are materials which are the by-products of extractive operations and are derived from a very wide range of materials. Recycled concrete is a viable source of aggregate and has been satisfactorily used in granular sub bases, soil-cement, and in new concrete.

Table 3:Properties of Coarse aggregate

Specific gravity of C.A	2.87
Fineness modulus	3.98 %
Bulk density	1615 kg/m^3

Cement

Cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used solely, but is used to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete.

Portland cement is by far the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with other materials (such as clay) to 1450 °C in a kiln, in a process known as calcination. Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Portland cement may be grey or white.

Table 4:Physical Properties of cement

Sl.No	Properties	Results
1	Specific gravity	3.08
2	Normal consistency	34%
3	Initial setting time	35 mins
4	Final setting time	450 mins

Test Specimens

The compressive stress, split tensile strength and flexural strength of concrete are determined by casting cubes of size 150x150x150 mm, cylinders of size 300x150 mm and prisms of size 500mmx100mmx100mm and allowed for 7 and 28 days curing and the test results were obtained for various percentage of Nano silica.

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Table 5 compressive stress of controlled concrete cubes and Nano silica cube

% of Nano Silica	Compressive stress in 7 days (N/mm^2)	Compressive stress in 14 days (N/mm^2)	Compressive stress in 28 days (N/mm^2)
0	23.99	27.31	32.60
1	28.16	30.37	33.43
2	30.95	32.7	34.15
3	32.75	35.6	39.80
3.5	31.66	34.2	37.50

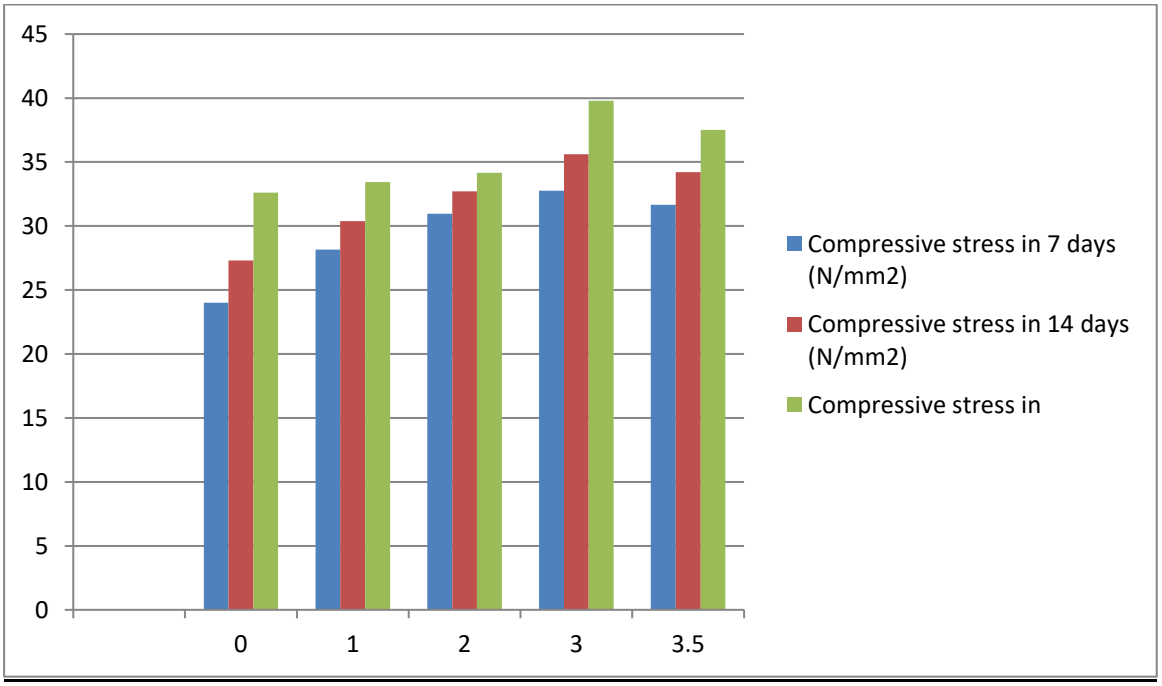

Chart-1 Graph Showing Results of Compressive Strength Test

Table 6 Split Tensile Strength Of controlled concrete Cylinders and Nano silica concrete cylinders

% of Nano Silica	Split tensile strength in 7 days (N/mm^2)	Split tensile strength in 14 days (N/mm^2)	Split tensile strength in 28 days (N/mm^2)
0	2.87	3.51	
1	3.06	3.79	
2	3.26	3.98	
3	3.82	4.64	
3.5	3.45	4.31	

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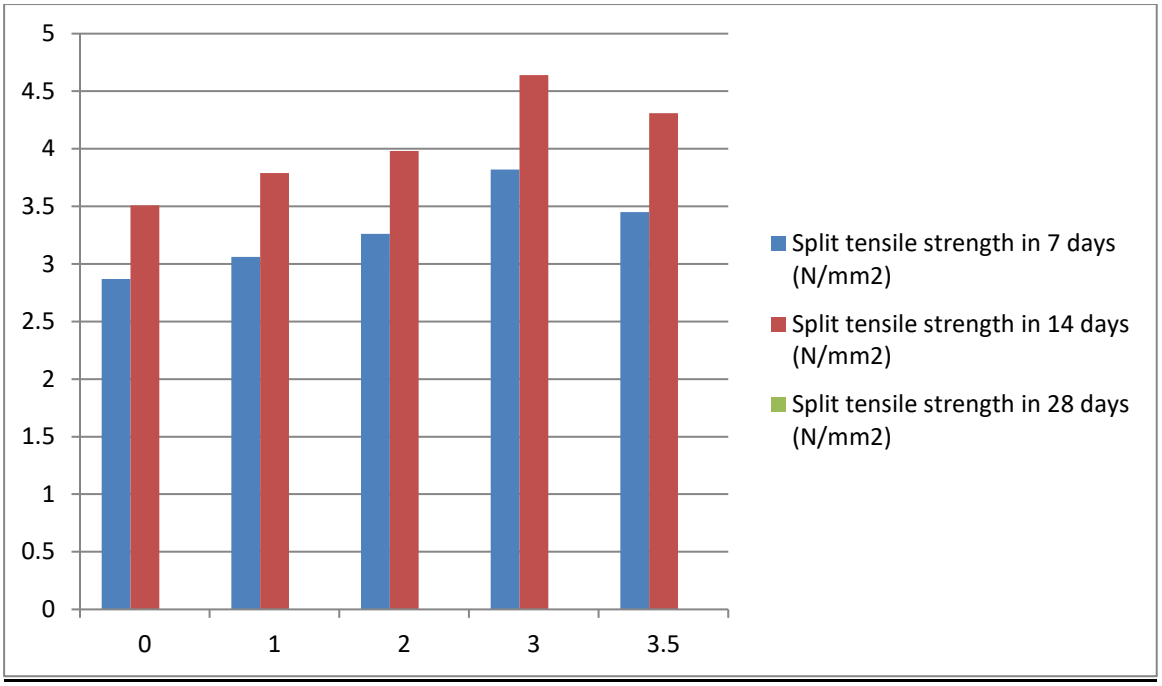

Chart-2 Graph showing Results of Tensile Strength

CONCLUSION:-

The compressive strength of concrete initially increased up to 3% of Nano-Silica and with further increase in the Nano-Silica content the compressive strength of concrete decreases. Concrete containing lower percentages (3%) of Nano-Silica possess higher values of compressive strength than that of controlled concrete.A considerable increase split tensile strength of Nano-Silica concrete was observed compared to controlled concrete.

Based on the experimental results, use of Nano-Silica in small quantities is advantageous on the performance of concrete. Nano- Silica added in small quantities can improve the strength. It can also be concluded that the permeability of concrete decreases with the increase in the percentage of Nano-Silica up to 3% due to the effect of Nano-Silica filling the voids in concrete.

The initial and final setting times of cement mortar containing Nano-silica was found to decrease with increase by percentage of Nano Silica. Use of Nano – silica in the concrete reduces the co_2 emission.

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