

EXPERIMENTAL INVESTIGATION ON STRENGTH & DURABILITY BEHAVIOUR OF CONCRETE BY REPLACING CEMENT WITH NANO SILICA AND ADDITION OF CRIMPED STEEL FIBRE

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Abstract: Concrete has a significant impact on the environment as the cement, whose production involves a large amount of CO₂, is its main ingredient. Enhancing the durability limitations of the concrete structures can reduce their impact on the environment. Incorporating a small amount of Nanoparticles in concrete can modify the Nano-structure of cementitious materials, and thus procure high durability. Nano Silica on the strength properties, durability limitations, and microstructural individuals of the concrete. The replacement level was varied from 2% to 5% in PPC. Cement is replaced by 2%, 3%, 4%, 5% of Nano Silica and 2% of Nano Silica is increased in Compressive Strength of concrete 40%. Crimped Steel Fibre are considered by high tensile and flexural strengths and high ductility, as well as by a high compressive strength and a very good workability. Durability and strength of concrete can be better-quality at lower fibre contents, where fibres are used in combination rather than reinforcement with a single type of fibre. Crimped Steel Fibre has been used with replacement of cement by 1.5% and 1.5% of Crimped Steel Fibre is improved in Compressive Strength of concrete 48%.

Keywords: Nano Silica, Crimped Steel Fibre, Compressive Strength Test, Tensile strength Test, Sorptivity.

I. INTRODUCTION

By using Nano Silica in concrete could reduce the emission of CO₂ in atmosphere concrete instead of cement concrete. Workability of cement concrete decreased by increasing the amount of Nano Silica. Nano concrete is produced by Incorporating nano material into cement during mixing has recognized itself as a capable method. Passed out in ductile structural composites along with its improved properties, low repairs coatings, better properties of cement material, decrease of thermal transfer rate of fire. To progress the durability and sustainability of concrete and have understood important accumulation in mechanical properties of cement materials by incorporating nano silica. Crimped Steel Fibres are low carbon, cold drawn steel fibres designed to provide concrete with temperature and shrinkage crack control, improved flexural reinforcement, improved shear strength and increase the crack resistance of concrete. Prevent the expansion of cracks in concrete. Increases impact, break and cut resistance of concrete. Reduces segregation, and contraction cracking of concrete. Delivers three-dimensional reinforcement against macro-cracking.

II. LITERATURE REVIEW

Aakanksha Patil et.al (2019) Addition of 1% of crimped steel fibres results in higher compressive strength and use of more than 1% steel fibres will bring down the compressive strength. Addition of 1% of crimped steel fibres result in higher tensile strength and use of more than 1% steel fibres will bring down the tensile strength.

Karthika P (2016) The compressive strength of concrete is increased by almost 40% by adding 2% nano silica in concrete. The split tensile strength of concrete is increased by almost 15% by adding 2% nano silica in concrete. The flexural

strength of concrete is increased by 35% by adding 2% nano silica in concrete. The durability of concrete containing 2% nano silica exhibits better resistance against sulphate attack, chloride attack and acid attack. The concrete containing nano silica 2% reduces the corrosion when compared to the conventional concrete.

Syed Shah Maqdoom Hussaini et.al (2019) 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. 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.

Shashank Shubham, et. al (2020) It is found that the adding of steel fibre in concrete increases the strength and toughness as compared to plain concrete. Steel fibre reinforced concrete give results for improve abrasion, flexural strength, impact resistance, high flexural and fatigue flexural with durability. Steel fibre reinforced concrete is very economical design alternative in this time. By addition of steel fibres in concrete increases the ductility.

Jagani Parin S (2019) Strong and rigid is steel fibre (high modulus fibres), from the above-mentioned literature review of improving concrete strength, have the ability to enhance the clear polypropylene fibres (low elastic modulus fibre), the brittle cementitious material, improved in the crack part after while more flexible maintaining the heat, deformability for an extended period of time through to toughness and has a property to delay the premature cracking. Oxidizing radiation

resistance, fracture energy, high wear resistance, basalt fibre bending strength increases lead.

III. MATERIAL USED

The various materials used in the preparation of concrete are as follows.

1. Cement.
2. Coarse Aggregate.
3. Fine Aggregate.
4. Crimped Steel Fibre.
5. Nano Silica.
6. Water.

IV. EXPERIMENTAL PROGRAMME

♦ Mix Design

To investigate the strength and durability of nano-silica and crimped steel fibre on the properties of conventional concrete the mix design is done according to 10262-2019. Strength properties of M25 grade concrete were studied.

♦ Casting of test specimen

In present study the specimen of standard cubes of size 150 X 150 X 150mm and 150mm x 300mm , 100mm x 50mm cylinders were used casted. The specimens were tested after 28 days of curing.

1) Mixing

Measured quantities of coarse aggregate and fine aggregate were spread over an impervious concrete floor. The dry PPC were spread out on the aggregate and mixed thoroughly in dry state turning the mixture over and over until the uniformity of color was achieved. Water was measured exactly and it was thoroughly mixed to obtain homogenous concrete. The mixing shall be done for 10 to 15 minutes.

2) Placing and Compacting

The cube moulds are cleaned and all care is taken to avoid irregular dimensions. The mix was placed in 3 layers and the layer was contacted using table vibrator to obtain dense concrete.

3) Curing

The test specimens were stored in a place free from vibration in moist air at 90% relative humidity and at temperature of 27+/- for 24 ½ hours from the time of addition of water to dry ingredients. After 24 hours the specimens are demolded and immediately immersed in clean, fresh water tank for 28 days.

4) Testing

All the tests performed are as per IS specification. After 28 days the specimens are taken for the test. Sorpivity of the modified concrete for the Durability of the concrete. compressive Strength of the modified concrete for the strength of the concrete.

V. PROCEDURE FOR PREPARATION OF CONCRETE

1. Samples are to be prepare by adopting 2%, 3%,4% and 5% adding of Nano silica and crimped steel fibre1.5%.
2. Cube samples of size 150mm x 150mm x 150mm are to be prepare for testing of Compressive strength of concrete for 28 days.

3. Durability of cement is measured by finding the % weight losses on each testing days and noted.

4. All the materials used to be prepared the samples are as per IS specifications.

5. All the tests performed are as per IS specification.



Concrete Cubes

VI. EXPERIMENTAL ANALYSIS

1. Compressive Strength Test: Compressive strength of concrete is important property of concrete. The other properties of concrete have 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 related to its lateral dimensions has great influence on strength test. The slenderer 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.

$$\text{Compressive strength} = \frac{\text{Load}}{\text{Area}} \text{ N/mm}^2$$

Apparatus: Compression testing machine,

Preparation of cubes of dimensions: 15cm x 15cm x 15cm.

Procedure:

- ❖ Concrete mix is design for M25 grade as per IS standards and the proportions are indicated in the observation.
- ❖ Calculate the material required for cubes using the concrete of proportion 1.1:1.6:2.57 by mass and water to cement ratio 0.5
- ❖ Take Coarse Aggregate, Fine aggregate, cement, water, crimped steel fibre and Nano silica in required quantity and mix it thoroughly.
- ❖ Apply oil uniformly to the inside of the moulds on all the surfaces.
- ❖ If mixing is by hand the cement and the fine 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 3 layers each of approximately 75mm and ramming each layer with 25 blows evenly distributed over the surface.
- ❖ Strike off the excess concrete with a straight metal edge flash with top of the moulds.

Curing:

After 24hrs of casting 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 28 days. Temperature of curing must be maintained 27°C and water should be periodically changed.

Testing:

- Compressive strength of cube specimens is made as soon as practicable after removing from the curing pit.
- Size of the test specimen is determined by averaging perpendicular dimensions at least at two places.
- Determine the mass of each specimen.
- Place the specimen centrally on the compressive testing machine and load is applied continuously and uniformly.
- The rate of loading is controlled through central value by hand two 14 N/mm² /min.
- The load is increased until the specimen fails and record the maximum load.



Compressive Strength Test

2. 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 rely on its tensile strength which is low. Split tensile strength for split tensile strength of concrete, 150mm x 300mm cylinders were used. The split tensile strength on cylinder were conducted on a computerized 22 compressive testing machine of capacity 3000KN. The method covers the determination of the splitting tensile strength of cylindrical concrete specimens. This method consists of applying a diametral compressive force along the length of a cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength.

Procedure:

- ❖ Concrete mix is design for M₂₅ grade as per IS standards and the proportions are indicated in the observation.
- ❖ Calculate the material required for cylinders using the concrete of proportion 1.1:1.6:2.57 by mass and water to cement ratio 0.5.
- ❖ Take Coarse Aggregate, Fine aggregate, cement, water, crimped steel fibre and Nano silica in required quantity and mix it thoroughly.
- ❖ Cast minimum three cylindrical specimen for each age (28days).
- ❖ Place the cylindrical concrete specimen for curing.

Curing:

After 24hrs of casting 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 28 days. Temperature of curing must be maintained 27°C and water should be periodically changed. After that the concrete cubes were immersed in containers containing acidic solutions for 28 days.

Testing:

- ❖ After 28 days of curing place the cylinders platens on testing machine
- ❖ Apply the load gradually at the rate of 1.4 N/mm² per minute until the failure.
- ❖ Note down the maximum load applied as tensile strength.
Split Tensile Strength of Cylinder = $\frac{2p}{\pi DL}$ N/mm²



Tensile Strength Test

3. Sorptivity Test: Sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The cylinders after casting were immersed in water for 28days curing. The specimen size 100mm x 50 mm after drying in oven at temperature of 100 ± 10 °C were drowned as shown in figure 4 with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting up to 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time.

Procedure:

- ❖ Concrete mix is design for M₂₅ grade as per IS standards and the proportions are indicated in the observation.
- ❖ Take good quality hard broken stones are used for coarse aggregate. The aggregates comply with IS383-1970 requirements, Fine aggregate, cement, water, crimped steel fibre and Nano silica in required quantity and mix it thoroughly.

- ❖ Calculate the volume of 100mm x 50mm batching of materials corresponding to the addition of Nano Silica and Crimped Steel Fibre.
- ❖ Clean the mould and gave a layer of crude oil, dry mix the batched material and take potable water according to water-cement ratio.
- ❖ Add the water gradually to the dry mix and mix it well.
- ❖ Cast the wet mix on the mould.
- ❖ Cast minimum three cylindrical specimen for each age (28days).
- ❖ Place the cylindrical concrete specimen for curing.

Curing:

After 24hrs of casting 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 28 days. Temperature of curing must be maintained 27°C and water should be periodically changed. After that the concrete cubes were immersed in containers containing acidic solutions for 28 days.

Testing:

The specimen was oven dried and the weight of the specimen was taken. The measurement of the capillary rise of the saturated calcium hydroxide solution on the concrete cylinder was found. The specimen is sealed by epoxy coating on the sides and immersed in solution with height of 5mm from bottom immersed in water. Two non-conducting sticks are kept at bottom of tray to hold the specimen. Care was taken to ensure the penetration of water is only by capillary rise. The quantity of solution absorbed by the specimen for every 30 minutes was measured by weighing it accurately to 0.1mg and the weighing procedure was completed within 30seconds. Sorptivity is the property by which water has been absorbed and transmitted by capillary action. Sorptivity (S) is calculated by $S = (W_c - W_d) / (A \times \delta \times t^{0.5})$

W_d = dry weight of the cylinder in grams

W_c = weight of the cylinder after capillary suction in grams

A = surface area of the cylinder exposed to water penetration by capillary action in mm²

δ = density of water

t = time in minutes

After conducting sorptivity test the specimens were completely immersed in saturated calcium hydroxide solution for 24 hours. Then the specimens are broken and the carbonation test was conducted on the broken surface of the specimen.



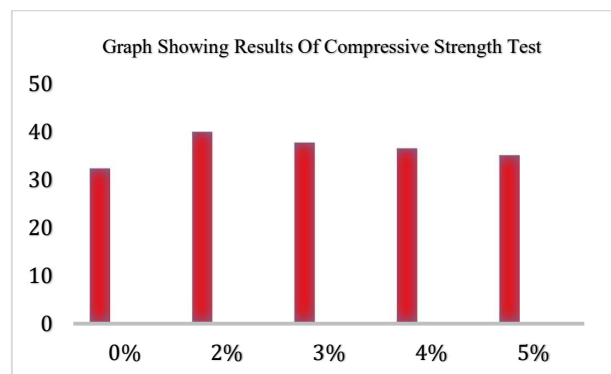
Sorptivity Test



VII. RESULT AND CONCLUSION

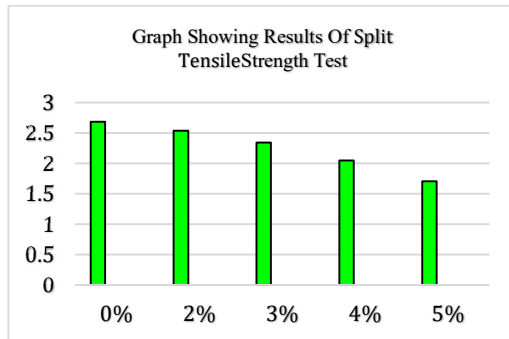
1. Compressive Stress Concrete Cubes and Nano Silica and Crimped Steel Fibre Cubes.

S.NO	%Of fibre	Curing days	Compressive strength Of Concrete (N/mm ²)
1.	0%	28	32.39
2.	2%	28	40
3.	3%	28	37.77
4.	4%	28	36.57
5.	5%	28	35.11



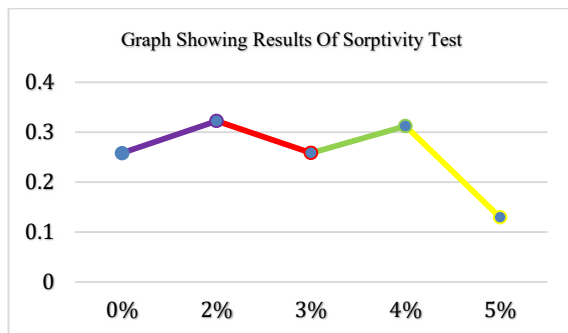
2. Split Tensile Strength Concrete Cylinders and Nano Silica and Crimped Steel Fibre Cylinders

S.NO	%Of fibre	Curing days	Split Tensile strength Of Concrete (N/mm ²)
1.	0%	28	2.54
2.	2%	28	2.68
3.	3%	28	2.05
4.	4%	28	1.90
5.	5%	28	1.71



3. Sorptivity Test on concrete cylinders and Nano silica and crimped steel fibre cylinders.

S.NO	%Of fibre	Sorptivity (mm/min ^(1/2))
1.	0%	0.258
2.	2%	0.322
3.	3%	0.258
4.	4%	0.312
5.	5%	0.129



VIII.CONCLUSION

The compressive strength of concrete primarily improved up to 2% of Nano-Silica and crimped steel fibre 1.5% with additional increase in the Nano-Silica and crimped steel fibre content the compressive strength of concrete decreases. Concrete containing inferior percentages (2%) of Nano-Silica and crimped steel fibre possess higher values of compressive strength than that of controlled concrete. A considerable increase split tensile strength of Nano-Silica and crimped steel fibre concrete was observed associated to precise concrete. Based on the experimental grades, usage of Nano-Silica and crimped steel fibre in small measures is beneficial on the presentation of concrete. Nano- Silica and crimped steel fibre added in small amounts can expand the strength. It can also be decided that the permeability of concrete decreases with the

increase in the percentage of Nano-Silica up to 2% due to the effect of Nano-Silica filling and crimped steel fibre the vacuums in concrete.

Strong and rigid is crimped steel fibre improving concrete, have the ability to enhance the brittle cementitious material, improved in the crack part after while more flexible continuing the heat, deformability for an extended period of time through to toughness and has a property to postponement the early cracking. Oxidizing radiation resistance, fracture energy, high wear resistance. It can hold increased compressive strength, splitting tensile strength, with the toughness properties of the three since the concrete exhibit excellent mechanical properties including the flexural strength initial the cracks in the bridge stage, it can improve the resonant capacity of the structure and structural stiffness, impact, can improve the fatigue strength and wear. The high-volume fraction in order to improve the mechanical properties of the composite fibres, that is proportional to, but larger than 2%, suggests that may affect the workability of the concrete.

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