Experimental study on behaviour of nano material concrete columns

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Abstract. Concrete is the most significant building material, without a close alternative, due to this there have been major advancement in concrete technology and the need to reinforcing has been made essential. It has been observed that cement-based material, on the addition of nano particles; develop distinctive properties at the molecular and nano level; in an experimental investigation made on square RC columns and nano concrete columns under axial loads. A total of 12 columns in which 6 numbers of RCC and 6 nos of nano concrete columns with 750mm height with square cross section (150mmx150mm) were tested. The loads are applied as concentric compressive loading up to failure. In this research, the behavior of nano concrete column is compared with conventional column. The parameters selected are stiffness, failure force and energy absorption, interpretation strength at ultimate state and service load conditions. Further the deflection and ductility behavior were also determined. The experimental studies showed a great improvement on the strength and energy ductility for nano concrete columns when compared with conventional concrete columns. This experimental study presents that nano concrete columns are capable of bearing increased axial load by 25% when compared to conventional concrete columns.

1. Introduction
Over the last decade, great deal of research work has been carried on in the replacement of standard materials with alternative chemical components introduce to achieve better workability of fresh concrete and durability in hardened concrete. Another critical factor that affects the strength of the structure is the corrosion of steel, and researchers have been investigating methods to control corrosion of steel in reinforced concrete structures [1,2]. Minimizing the utilization of Portland cement with minimal reduction in the strength of concrete is vital to the success of big projects in fiscal and environmental perspectives. To achieve this, it is imperative to explore the use of alternative building materials and naturally occurring compounds. It is estimated that the production of each tonne of cement results in a proportional amount of greenhouse gas emissions from clinker producing plants. This is bound to have an adverse effect on an already precarious environment [3,4]. The addition of nanoparticles along with cement-based materials to concrete has been observed to modify the properties at the molecular level and has been shown to produce better results in terms of the compressive strength and durability, while simultaneously decreasing the cost.
and environmental impact, as compared to conventional concrete mixes. Additionally, the incorporation of nanoparticles to the concrete mix has also positively impacted the corrosion resistance of steel, owing to its ability to alter properties at the nano level. [5-7]. Nano concrete deal with the application of nano technology in the concrete specimen. In the present investigation, schedule nano material in concrete columns of dimension 150X150X750mm are used for testing. This nano column is compared and interpretation of behavior with the typical standard conventional RC columns, are presented in this study. H. Li et. al. (2004) conducted investigation study through experimental to find out the strength of nanosilica (NS) concrete by analyzing the mechanical properties of Nano- Fe2O3 and nano SiO2 mortars. The micro structure analysis shows the reduced amount of Ca (OH)2 due to pozzolanic reaction. Tao conducted experimental study on the efficiency of NanoSiO2 on the water permeability and showed that the NanoSiO2 can improve the water resistance of concrete. H. Li et al. conducted study to identify the abrasion resistance by addition of nano particles. B.-W Jo et al. conducted a characteristic study to prove that nanoSiO2 carries on a filler to improve microstructure, addition as an activator due to pozzolanic response. M.Nill et al. observed through experimental study the highest electrical resistivity of concrete due to the addition of nano SiO2[9-15].

2. Present work
The strength behavior of nano columns in ultimate state and service load state were determined. The theoretical strength values were calculated in accordance with Indian standard code of practice. The axial compressive load, axial strain capacity and failure modes of nano concrete conventional columns are determined by comparing the experimental results with theoretical design values.

3. Nano silica
Extensive research is carried out is using the nano materials in the construction industry for improving the durability and sustainability. The physical properties of nano SiO2(nano-silica) are presented in table 1.

| Sl No. | Test Item                        | Standard Requirements | Test Results |
|-------|----------------------------------|-----------------------|--------------|
| 1     | Specific Surface Area (m2/g)     | 200 ± 20              | 202          |
| 2     | Ph Value                         | 3.7 – 4.5             | 4.12         |
| 3     | Loss on Drying @ 105 Deg.C (5)   | ≤ 1.5                 | 0.47         |
| 4     | Loss on Ignition @1000 Deg.C(%)  | ≤ 2.0                 | 0.66         |
| 5     | Sieve Residue (5)                | ≤ 0.04                | 0.02         |
| 6     | Tamped Density g/l               | 40 – 60               | 44           |
| 7     | SiO2 Content (%)                 | ≥99.8                 | 99.88        |
| 8     | Carbon Content (％)              | ≤ 0.15                | 0.06         |
| 9     | Chloride Content (%)             | ≤ 0.0202              | 0.009        |
| 10    | Al2O3                            | ≤ 0.03                | 0.005        |
| 11    | TiO2                             | ≤ 0.02                | 0.004        |
| 12    | Fe2O3                            | ≤ 0.003               | 0.001        |
4. Experimental study
Concrete was designed for the grade according to the Indian standard code of practice. An experimental investigation was carried out taking a total of twelve specimens in which 6 numbers of RCC and 6 numbers of nano concrete columns having a 750mm height with square cross section (150mmx150mm). The concrete used for casting a characteristic compressive strength is 34.5 and 45.8 N/mm². Four numbers of 12mm diameter steel rods of Fe 500 were used for the reinforcement of the columns with 8mm diameter steel rods as ties maintained at 200mm c/c. The theoretical results of columns at the ultimate stage are presented in table 2.

Table 2. Theoretical load, Experimental load for M20&M30 conventional reinforced concrete.

| S.No | Concrete Grade | Ultimate load (kN) control column (Theoretical) | Ultimate load (kN) Nano concrete column (Experimental) |
|------|----------------|-----------------------------------------------|-----------------------------------------------------|
| 1    | M20            | 264.84                                        | 380                                                 |
| 2    | M30            | 420.13                                        | 580                                                 |

Table 1. shows that the axial ultimate load of M20, M30 conventional concrete are 264 KN and 420KN and for nano concrete is 380KN and 580KN, the experimental load of the nano concrete columns has arrived against the conventional column resulting in 26.32% and 27.62%.

5. Mix design
As per IS 10262-2009, to carry out the experiments and the same has been presented in Table 3 and 4 for M20 & M30 consecutively.

Table 3. Recommended mix proportion.

| S.No | Grade of Concrete | Water/m³ | Cement kg/m³ | F.A kg/m³ | C.A kg/m³ |
|------|-------------------|----------|--------------|-----------|-----------|
| 1    | M20               | 191.6    | 383          | 546       | 1187      |
| 2    | M30               | 160      | 405          | 711       | 1283      |

6. Mechanical properties

6.1. Improvement of Mechanical Properties Using as Nano Silica
By adding nano silica to concrete, the columns gain strength as nano silica ranging from 5 to 200nm used in concrete proves to be more adhesive. Therefore, it improves the mechanical properties such as flexural strength, elastic modulus, and work for rupture. The adhesions of nano silica to concrete substantially reduce polymerization shrinkage and enhance fracture stiffness, flexural strength and compressive strength and this experimental study proves the potential benefit of using nano silica. Due to its micro size, nano silica accelerates the hydration process at early stage and refines the pore structure. This leads to enhanced durability.

6.2. Compressive strength of concrete cubes
Concrete cubes designed for M20 and M30 grade were casted and tested. The average compressive stress is found to be 34.45 N/ mm² and 45.80N/ mm² respectively. The observations are presented in table 4.
Table 4. Compression strength of cubes with nano silica at 28 days for M20 grade.

| S.No | SPECIMEN CODE | DATE OF CASTING | CURING PERIOD | DATE OF TESTING | COMPRESSION LOAD | AVERAGE COMPRESSIVE STRESS (N/mm²) |
|------|---------------|-----------------|---------------|-----------------|------------------|------------------------------------|
| 1    | C-1           | 5/2/2018        | 28 days       | 3/3/2018        | 758              | 758000                             |
| 2    | C-2           | 5/2/2018        | 28 days       | 3/3/2018        | 780              | 780000                             |
| 3    | C-3           | 5/2/2018        | 28 days       | 3/3/2018        | 788              | 788000                             |
|      |               |                 |               |                 | **AVERAGE**      | 34.45                              |

Table 4 shows the maximized compression strength was attained by using 2% of nano silica. Further addition of nano silica resulted in degradation of strength in concrete. The result shows that optimal percentage of nano silica is 2%.

Table 5. Compression strength of cubes with nano-silica at 28 days for M30 grade.

| S.No | SPECIMEN CODE | DATE OF CASTING | CURING PERIOD | DATE OF TESTING | COMPRESSION LOAD | AVERAGE COMPRESSIVE STRESS (N/mm²) |
|------|---------------|-----------------|---------------|-----------------|------------------|------------------------------------|
| 1    | C-1           | 5/2/2018        | 28 days       | 3/3/2018        | 1112             | 111200                             |
| 2    | C-2           | 5/2/2018        | 28 days       | 3/3/2018        | 1000             | 100000                             |
| 3    | C-3           | 5/2/2018        | 28 days       | 3/3/2018        | 980              | 980000                             |
|      |               |                 |               |                 | **AVERAGE**      | 45.8                               |

Table 5 shows the maximized compression strength was attained by using 2% of nano-SiO₂ (nano-silica). Further addition of nano-SiO₂ (nano-silica) resulted in degradation of strength in concrete. The result shows that optimal percentage of nano silica is 2%.

7. TESTING OF COLUMNS

7.1. Reinforcement details of square column

A total number of 12 column specimens are tested. Out of 12 columns two served as control specimens. The design and detailing of the RCC columns are shown in Table 6. Table 5 shows that the design and detailing of the conventional reinforced concrete columns.

Table 6. RC Column Detailing Specifications.

| Concrete grade | M20, M30 |
|----------------|----------|
| Column height  | 750mm    |
Table 7. Specimen label.

| S.NO | CONCRETE MIX            | COLUMNS |
|------|-------------------------|---------|
| 1    | Reinforced concrete     | RC1     |
|      | columns                 | RC2     |
|      |                         | RC3     |
|      |                         | RC4     |
|      |                         | RC5     |
|      |                         | RC6     |
| 2    | Nano concrete columns   | NC1     |
|      |                         | NC2     |
|      |                         | NC3     |
|      |                         | NC4     |
|      |                         | NC5     |
|      |                         | NC6     |

Figure 1. Specimen dimensions and reinforcement details.

Table 7 shows the column specimens are divided into 2 categories. First categories labeled (RC1 to RC6) reinforcement concrete columns and the second one group labeled nano concrete column (NC1 to NC6) and served as control column. The column of each group was tested under an axial compressive load.

7.2. Experimental Testing Procedure

Twelve columns are tested under axial ultimate compression in a hydraulic serve activated column testing frame of 100 Tones capacity in the post-graduate laboratory of the advanced structural engineering department. The resultant strain developed in the concrete and reinforcement due to the axial loading is determined using 120 Ω strain gauges, placed in the center concrete surface respectively, whose ends are connected to the strain indicator. Another two deflectometer is located at the middle height of the column along with the adjacent faces of the column to measure the buckling in two mutually perpendicular directions. Hinged supports were provided at both support of the column. The axial loads are applied gradually, using a manually operated servo-hydraulic pump, for regular intervals of each load increment. The corresponding axial shortening, lateral displacement in two mutually perpendicular directions at the middle height of the column, and the crack patterns were noted. The strain values are observed using an electrical strain indicator. The loads are applied up to the ultimate stage of the columns. The ultimate stage of the Nano concrete columns is found with compared by that of the control column. The crack patterns are observed. These columns are loaded up to their ultimate stage levels along with the corresponding experimental test results are presented.
Figure 2 and 3. Casting of concrete cubes and actual test setup compression strength on concrete cubes in the laboratory. Figure 4 and 5 shows the fabrication of steel reinforcement and reinforcement placed in the mould. Fig 6 and 7 shows that the casting of conventional and nano concrete columns.

Figure 2. Cubes and cylinders.

Figure 3. Compression testing of cubes.

Figure 4. Fabrication of reinforcements.

Figure 5. Reinforcement placed in the mould.
Figure 6. Casting of Reinforced Concrete columns.

Figure 7. Concrete columns after demoulding.

Figure 8. Column Testing Frame.

Figure 9. Column test setup.

Figure 8 and 9 shows that the testing of the specimen was carried out a loading frame 1000KN, by applying monotonically increasing compressive load at an increment of 10KN. The specimen on the loading frame, with dial gauges touching the top and bottom plates of the cap for recording an axial deformation is shown in figure 9.
8. Discussion of results
Failure mode stage of all columns under the axial Compressive behavior of the concrete column and Nano concrete columns specimens were mostly similar in each series in terms of load versus axial shortening and failure modes of the columns. The results relating to the axial load, axial stress, and axial deflection of the columns are presented in fig 8 and fig 9. Severe cracking is observed on the column surface this leads to significant expansion on the column. Further crack patterns are seen in the compression zone of the columns and small slight cracks in the tension zone of the specimen. The final result at the failure mode stage of all columns proves that the failure mode stage of the nano concrete column has better strength than that of the conventional concrete column.

9. Crack pattern
During the test, the crack patterns in the column were measured using a crack detecting microscope and the crack pattern is closely analyzed. With further loading, cracks develop. The crack patterns are presented in the columns as shown in figure 10 and 11. Figure 10 & 11 shows that the failure stage of the test specimens. Both conventional columns and nano concrete columns are severely crushed.

**Figure 10.** Control Column before Failure.

**Figure 11.** Control Column after Failure.
10. Load vs axial shortening
The axial shortening of columns Conventional column (RCC), nano control column (NCC), is observed by using a deflectometer. The load- axial shortening of the Nano concrete columns are compared with that of the control column. The relationship between the load versus axial shortening in presented in given below figure 12.

![Figure 12. Load vs axial shortening response of the specimens for M20 conventional concrete & nano conventional concrete columns.](image1)

![Figure 13. Load vs. axial shortening response of the specimens for M30 conventional concrete & nano conventional concrete columns.](image2)

The figure 12 shows he deflection at the ultimate load was found to be 3.09mm for conventional concrete, whereas the deflection at the ultimate load for 2% nano silica added to concrete was found to be 2.66mm. The ultimate load was found to be more for nano concrete when compared with conventional concrete, whereas the deflection at the mid span was found to be less for nano concrete.

The figure 13 The deflection at the ultimate load was found to be 3.52mm for conventional concrete, whereas the deflection at the ultimate load for 2% nano silica added to concrete was found to be 2.79mm. The ultimate load was found to be more for nano concrete when compared with conventional concrete, whereas the deflection at the mid span was found to be less for nano concrete.

11. Conclusions
The experimental results were tabulated and the following inference has been made based on output,

- Ultimate load of the conventional column for M20 grade is 264KN and the maximum axial shortening is 3.09mm.
- Ultimate load of the conventional column for M30 grade is 420KN and the maximum axial shortening is 3.52mm.
- Ultimate load of the nano concrete of M20 grade is 380 KN and the maximum axial shortening is 2.66mm.
- Ultimate load of the nano concrete of M30 grade is 580 KN and the maximum axial shortening is 2.79mm.
- Experimental load of nano conventional columns of M20 grade is 380KN against and for column (control) whose value is 264KN ,resulting in 26.32% higher load carrying capacity for nano concrete column.
- Experimental load of Nano concrete columns of M30 grade 580KN and for conventional column (control) whose value is 420KN, resulting in 27.62% higher load carrying capacity for nano concrete column.
The strength of Nano concrete columns is found to be good, compared to control column. The experimental load is more than theoretical load which shows that code estimate the strength of the column in lower side for all the type of columns.

12. References
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