Use Of Nanotechnology For Modern Construction

Abhijit Mangaraj
Department of Civil Engineering
GIFT Autonomous
Gangapada, Bhubaneswar

Subhasmita Pradhan
Department of Civil Engineering
GIFT Autonomous
Gangapada, Bhubaneswar

Rajesh Kumar Mantry
Department of Civil Engineering
GIFT Autonomous
Gangapada, Bhubaneswar

Amiyajyoti Nayak
Department of Civil Engineering
GIFT Autonomous
Gangapada, Bhubaneswar

Abstract: *A broad range of challenges faced by the construction industry, ranging from the performance of the materials to environmental and safety issues, relate to materials and their properties. Recent developments in various areas of nanotechnology show significant promise in addressing many of these challenges. Research and developments have demonstrated that the application of nanotechnology can improve the performance of traditional construction materials, such as concrete and steel. Noteworthy improvements in concrete strength, durability and sustainability are being achieved with considered use of metal/metal oxide nanoparticles and engineered nanoparticles (carbon nanotubes and carbon nanofibres), and environment-responsive anticorrosion coatings formed using nanoencapsulation techniques are showing promise in laboratory settings. Developments in nanotechnology are also improving the accuracy and commercial viability of sensor-based structural health monitoring; a task rapidly gaining importance as the structures that comprise many countries' most expensive investments near the end of their design life. As energy usage worldwide continues to grow, a focus on the potential for nanotechnology developments to reduce energy consumption has become evident. Research demonstrates that nanotechnology can contribute to novel cooling systems, and improve the functionality of solar cells and insulation. A range of nano materials are also being used to add new functionalities, such as self-cleaning properties, to traditional construction industry products, for example paint and cement. First generation products are available on the market and further advances are evident in the academic literature.*

Keywords*: Nano Fibre, Nano materials, Self-cleaning property*

Introduction: Nano technology is most widely used in all the fields such as nano science, construction field, electrical, biomedical, and medical field. Nowadays, the nano technology is gradually augmentation in the Civil Engineering Construction field, for (ex) nano coatings, nano-polymer has been used for corrosion resistance of steel rebar and also nano sensor has been used for the corrosion deduction and protection of steel bar. The nano-powder based materials used for enhanced strength and good durability performance in concrete. Concrete structures, transportation structures are problem to cracking that leads to weakening corrosion, deteriorating due to chloride attack, carbonization, sulfates and damage from alkali-silica reactivity. These troubles shorten the service life of concrete structures such as bridges, dams, pavements and tunnels and decreased their level of performance. The main objective of this research is to attain the development of strength and corrosion analysis in concrete element /structures and resistance to cracking (that leads to corrosion weakening due to chloride attack, deterioration and damage from alkali-silica reactivity) in structural elements, crack-free pavements at transportation structures by using nano composite materials and measure the corrosion in steel

Here nano composite materials incorporated with cement, in various percentages replaced and different combinations, such as binary and ternary combination. The behavior of nano material in concrete elements, the binary combination mix has given good mechanical properties and durability. When the nano materials gradually increased in cement, the compressive strength, tensile strength and flexural strength gradually decreased. The nanomaterials have more specific area and produce a high amount of heat hydration. It is responsible for producing the tri-calcium silicate and early strength achieved. The 2% binary combination B-1, B-2 mix has given the best mechanical properties compared to the other mixes.

1.2 SCOPE OF THE WORK

*Based on review of literature, a successful attempt has been made through nano composite materials to enhance the strength, durability and corrosion properties of nano composite concrete specimens. Around 42 nano composite concrete specimens are prepared for the research work. To improve overall quality of concrete for various applications, nano-composite specimens are selected to incorporate into it. Finally the noteworthy improvement has been observed in the strength, durability and corrosion of the nano composite concrete specimens. The 28 days compressive and flexural strength have been improved for the binary combination mix B-1 (2% nano-SiO_2 + 2 % nano- $CaCO_3$), of nano composite materials replaced with cement showed increased compressive strength about 22.86% and 40.74%.*1.3**.**

1.3 OBJECTIVES

Main objectives of the present doctoral research work are to study effect of nano composite materials on the strength, durability and corrosion analysis of concrete.

1. To design mix ratio for M40 Grade of ratio using the nano composite materials

2. Fabrication and characterization of embeddable zirconium oxide potential sensor for identification of corrosion and prevention of steel bar.

3. To analyze and confirm the workability performance of the nano composite concrete mix studies.

4. The SEM and X-ray analysis to be done to study internal characterization.

5. To study the compressive strength of the binary nano composite concrete specimens and ternary nano composite specimens and the durability aspects of the binary nano composite concrete specimens and ternary nano composite specimens.

6. To study the corrosion of steel bar aspects of the binary nano composite concrete specimens and ternary nano composite specimens with respect to zirconium oxide potential sensor.

Literature Review

Application and uses of Nano Technology in Construction Field

Nanotechnology is being used in all fields of science and technology. The application of nanotechnology may include various fields such as construction (strength of materials), medical (drug delivery to treat various diseases), electronics industry (nano rods and wires), mechanical (automation), food science and materials processing in industries. Concrete is the most widely used nano-material in construction industry which is prepared using nano silica (particle size ranges from few nanometres to 100 micrometres). Various alterations in mix proportioning and composition (addition of admixtures) are made in preparing concrete to achieve desired results such as high strength, high performance and high ultra-strength. Recent advancements in concrete technology demonstrated the possibility of improving its quality by altering its composition with additional nano-particles. The higher pozzolanic nature and quick pore-filling in these concrete have considerably reduced the initial and final setting time when compared with the conventional concrete materials. Similarly, the durability of concrete is achieved by improving the impermeability with reduced bleeding and segregation.

The different percentages of Nano-SiO_2 replaced with cement such as 0%, 0.2%, 0.5%, 0.8% 1%, 2% and 3% to enhance the strength of the materials. The 0 to 1% of nano-SiO_2 replaced with cement gives better compressive, tensile, flexural strength and durability of concrete when compared than the conventional concrete. Increased percentage of nano- particles replaced with cement gradually decreases the mechanical and durability performance is reported by YoukunCheng et al. (2019). When the cement reacts with nano-SiO_2 then the early strength is achieved due to the size of the particles is smaller (40nm) and pozzolaanic response becomes weaker (ChenglongZhuang et al.2019, Dayana Gulevich et al. 2019, Zhidan Rong et al. 2020). Nano-$CaCO_3$ when replaced with cement, to increase the Di-calcium silicate (C_2S) and reduce the Tri-calcium silicate (C_3S) it is observed from the X–ray diffraction (XRD). Various percentage of Nano-$CaCO_3$ added with cement such as (1%, 2% and 3%). The Nano-$CaCO_3$ (1%) replaced with cement gives better flexural strength and toughness compared with conventional concrete is reported earlier (Hakamy 2020). The widely used nano-particles in the construction field are nano-TiO_2, Al_2O_3, $CaCO_3$, SiO_2 and nano-clay particles. When nano particles add or partially replaced with cement, the permeability of concrete becomes less due to the nano particles density and the microstructure of the matrix (Yousef Askari Dolatabad et al.2019). Various percentage of added colloidal nano-silica with cement, it is increased the compressive strength, tensile strength and non-destructive test (rebound hammer ultrasonic plus velocity), performance if good compared with the without colloidal nano-silica specimen and also increased the modulus of elasticity of concrete compared than the conventional concrete due to formation of silanol (Si –OH) and higher surface area by Bibhuti Bhusan Mukharjee et al. (2019).

MATERIAL AND METHODS

3.1 INTRODUCTION

A detailed materials and experimental procedure adopted in this investigation is presented in this chapter.

3.1.1 Water

Potable water used for all mixes of concrete.

3.1.2 Cement

Ordinary Portland cement is used for this research with and specific gravity of cement 3.15. The physical properties of cement, fine aggregate and coarse aggregate are given in Table 3.1.

Table 3.1 The physical Properties of cement, fine aggregate and coarse aggregate

Description	Specific gravity	Density in kg /m^3	Fineness modulus m^2/kg	Standard consistency	Soundness, Le Chatelier, mm
Cement	3.15	3150	314	26.4	1.0
Fine aggregate	2.65	1620	3.01	-	-
Course aggregate	2.81	1120	2.72	-	-

3.1.3 Fine Aggregate

River sand conforming to zone III of IS, 383-1970. The specific gravity of fine aggregate and density is 2.65 and 1762 kg /m3.

3.1.4 Coarse Aggregate

The coarse aggregate of 20 mm is used and it has bulk density of 1710 kg/m3 and the specific gravity 2.81and fineness modulus of 2.72 is used.

3.1.5 Nano Composite Materials

Nano-SiO2 and CaCO3 used for partially replacing the cement and are procured from Elkem Metallurgy (P) Ltd. Delhi The physical and chemical properties of nano composite materials are given in Table 3.2and as shown in Figure 3.1.

Table 3.2 Physical and Chemical composition of OPC, Nano –SiO2, Nano-CaCO3

Item	OPC %	Nano-SiO2 %	Nano-CaCO3 %
CaO	63.81	0.27	96
SiO2	21.45	95.3	0.3
Al2O3	4.45	0.65	0.3
Fe2O3	3.07	0.28	0.3
Mgo	2.42	0.41	0.8
Alkalies (Na2O+ K2O)	1.3	1.03	0.4
SO3	2.46	-	0.7
TiO2	0.22		-

Nano-CaCO3

Nano-SiO2

Fig 3.2. Nano material and mixture with water

3.3 MIX PROPORTIONS

In order to study the variations in combinations of nano-composites on the strength and corrosive properties of concrete, several specimens were casted with varying weight fractions of nano-composites as replacement to the cement. The control specimens are denoted as A-0 mix for each of the combinations. The binary mixture B-1 mix represents 2% nano-SiO2+ 2% nano-CaCO3 as replacement of cement while B-2 mix represents 5% nano- SiO2+5 % nano-CaCO3.

3.4 CASTING AND TESTING OF SPECIMENS

The mix is prepared for M40 grade of concrete and mix ratio 1:1.38:

2.41 for both conventional concrete and nano composite concrete. The mix proportion and quantity of materials used per cube of concrete is shown in Table 3.3. All experimental works are done using a water-cement ratio of 0.40. Size of (150 × 150 × 150 mm) cube is used for determining the compressive strength. The height of cylinder is 300 mm and the diameter is 150 mm is prepared for split tensile strength of concrete. The specimens are tested in 3 days, 7 days, 14 days and 28 days with each proportions of nano composite of binary and ternary concrete mix. A prism of size (500 × 100 × 100 mm) has been cast for determining the flexural strength of concrete.

Table 3.3 The mix proportion and quantity of materials used per cube.

Mix designation	Cement (kg)	Nano SiO2 (kg)	Nano CaCO3 (kg)	Water (mL)	W/C	Fine aggregate (kg)	Coarse aggregate (kg)
A -0	1.900	-	-	760	0.4	2.622	4.579
B -1	1.824	0.038	0.038	760	0.4	2.622	4.579
B -2	1.710	0.095	0.095	760	0.4	2.622	4.579

Results and Discussions:

4.1 FRESH CONCRETE

4.1.1 Slump Test

Slump cones are used to measure the “workability” or “consistency” of fresh concrete mix. The slump value for nano-composite specimens and conventional concrete specimens are shown in Figure 4. 1. When the slump value is increased then the workability of concrete also increased because the slump values are directly proportional to workability. On the other hand, when the slump value is decreased, the workability of concrete is very stiff. From Table 4.1. The conventional concrete specimen gives higher slump value and good workability when compared with the nano-composite concrete specimens. Subsequently, the mix B-1, B-2 gives higher value. The workability of concrete is decreased in order to increase demand of water, due to the addition of nano materials, further decreased the slump value and shortened the initial and final setting time by increased colloidal nano-silica. Nano particles have higher surface area so that higher insist of water during the hydration time was suggested by Chithra et al. (2016) and Senff et al. (2009). Nano-SiO2 when replaced with cement, to reduce the slump value due to nano particles have large surface area and absorb the more water molecules was studied by Mukharjee & Barai (2020), Zhuang & Chen (2019).

Table 4.1 Slump value in conventional and nano composite concrete mixes

S.No.	Mix designation	Slump value in mm
1.	A -0	80
2.	B -1	75
3.	B -2	85

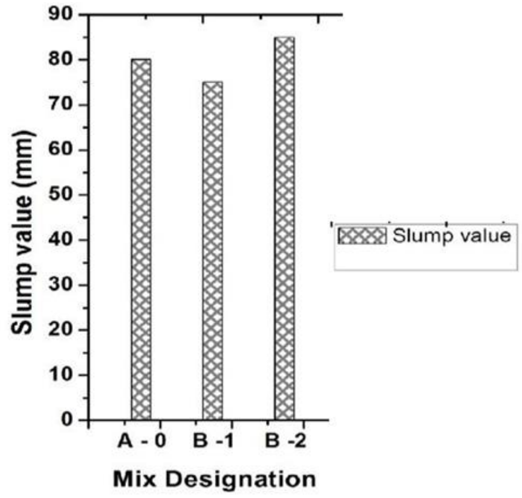

Figure 4.1 Variation of Slump values of control specimen and nano composite specimens.

4.2.1.1 Compressive strength of binary combination mix

The compressive strength values of B-1 and B-2 mix results are shown in Figure 4.12. The 28 days compressive strength of mixes B-1 and B- 2 (2% nano-SiO2 + 2% nano-CaCO3 and 5% nano-SiO2 + 5% nano-CaCO3 particles) are increased by 22.86% and 18.06% respectively with reference to the conventional concrete mix A-0. The enhancement of 3, 7 & 14 days compressive strength of mixes B-1 and B-2 are found to be about 6.72%, 9.20% and 12.34% for mixes B-1 and 17.87%, 25.41% and 23.61% for mixes B-2 respectively with reference to the conventional concrete mix A-0. Pores of concrete are decreased by nano-materials and thus the compressive strength is increased (Mohseni et al. 2015).

Average strength(μ) = Average crushing value / No of samples

Table 4.2 Mix identifications and compressive strength of control and Nano composite Concrete Specimen at Different Curing ages.

Mix ID	Percentage of Cement	Nano materials (%)		Compressive Strength inN/mm^2			
		Nano SiO2	Nano CaCO3	3 Days	7 Days	14 Days	28 Days
A -0	100			16.23	24.12	32.56	44.18
B -1	96	2	2	17.32	26.34	36.58	54.28
B -2	90	5	5	19.13	30.25	40.25	52.16

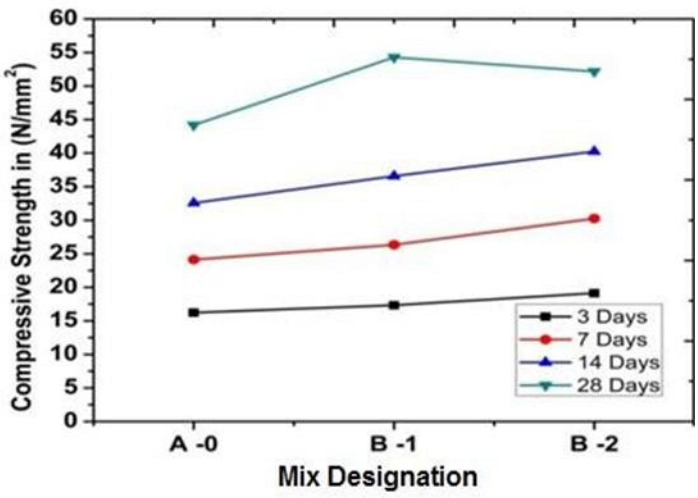

Figure 4.12 Variation of binary combination of compressive strength of control and Nano Composite Concrete Specimen B-1 and B-2 mix.

Table 4.2 Mix identifications and 90 days compressive strength of Nano composite Concrete Specimen

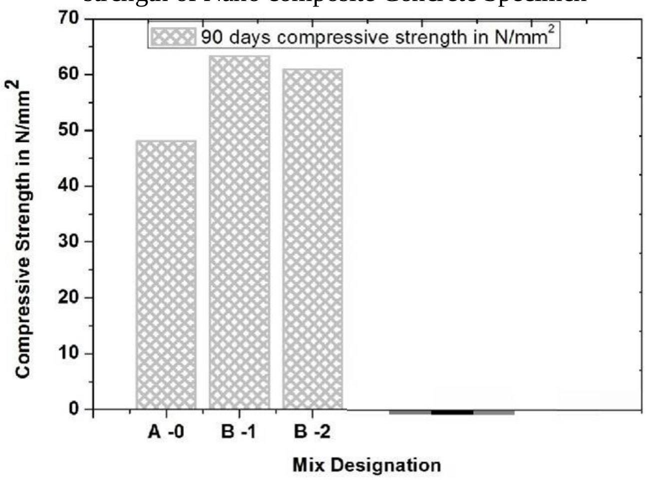

Figure 4.14 90 Days compressive strength of nano composite concrete specimen.

4.1.1 Split Tensile Strength

The tensile strength of concrete is the concrete capability to withstand pulls forces without breaking and is called as the tensile strength of concrete. The cylindrical specimens have been cast for identifying split tensile strength at 3, 7, 14 and 28 days. Figures 4.15, 4.16 and 4.17 and Table 4.3Shows the split tensile strength of binary and ternary combinations of different nano concrete composite mixes which has improved tensile strength due to the addition of nano-SiO2, nano-CaCO3, with grade of concrete. All nano composite specimens have given better tensile strength when compared with conventional concrete specimens.

Table 4.3 Mix identifications and tensile strength of control and Nano composite Concrete Specimen at Different Curing ages

Mix ID	Tensile Strength inN/mm^2				Percentage Change in tensilestrength with respect to A -0			
	3 Days	7 Days	14 Days	28 Days	3 Days	7 Days	14 Days	28 Days
A -0	1.9	2.3	2.5	2.7	-	-	-	-
B -1	2.3	2.8	3.1	3.4	21.053	21.739	24.000	25.926

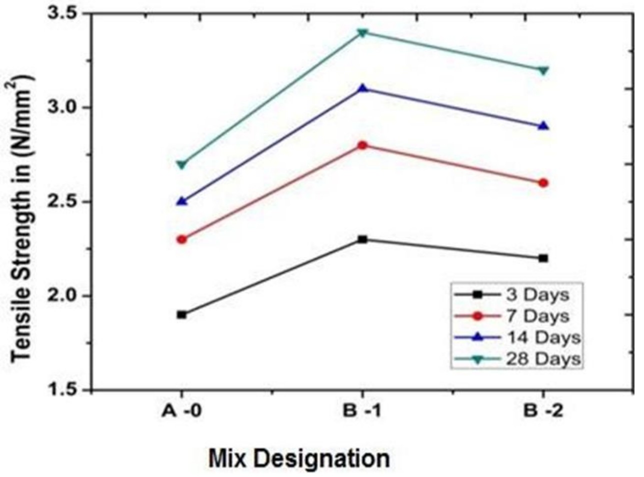

Figure 4.15 Variation of binary combination of tensile strength of control and Nano Composite Concrete Specimen B-1 and B-2 mix.

Conclusion:

- The 28 days compressive, tensile and flexural strength results indicated that the binary combination mix B-1 (2% nano-SiO2 + 2 % nano- CaCO3), B-2 (5% nano-SiO2 + 5% nano-CaCO3) of nano composite materials replaced with cement showed increased compressive strength about 22.86%, 18.06% . tensile strength about 25.929%, 18.595% and flexural strength 40.74%, 12.50% when compared with the conventional concrete.
- In general the strength of concrete specimen was increased when the nano materials are added up to 2% and then it is reduced.

REFRENCE

[1] 1. Feynman, R., “There's Plenty of Room at the Bottom” (reprint from speech given at annual meeting of the West Coast section of the American Physical Society), Engineering and Science, 23, 1960, pp. 22-36.

2. Drexler, K. E., Peterson, C., and Pergamit, G., Unbounding the Future, William Morrow, New York, 1991.

3. Bhushan, B. (Ed.), Handbook of Nanotechnology, Springer, 2004

4. Gann D., A Review of Nanotechnology and its Potential Applications for Construction, SPRU, University of Sussex, 2002.

5. Whatmore, R.W., and Corbett, J., “Nanotechnology in the Marketplace”, Computing and Control Journal, June, 1995, pp. 105-107.

6. Atkinson, W.I., Nanocosm - Nanotechnology and the Big Changes Coming From the Inconceivably Small, AMACOM, p.36-39.

7. Poole, C.P., and Owens, F.J., Introduction to Nanotechnology, John Wiley and Sons, 2003.

8. Smitherman Jr., D.V. (Ed), Space Elevators: an Advanced Earth-Space Infrastructure for the New Millennium, NASA/CP-2000-210429, 2000.

9. Roco, M.C., Williams, R.S., Alivisatos, P. (Eds.), Vision for Nanotechnology R&D in the Next Decade, IWGN Report on Nanotechnology Research Directions, National Science and Technology Council, Committee on Technology, 1999.

10. Klabunde, K.J. (Ed.), Nanoscale Materials in Chemestry , John Wiley and Sons, 2001.

11. Zhang, W.-X.; Wang, C.-B.; Lien, H.-L., Catal. Today, 40, 1998, pp.387-395.

12. Chan, W.C.W., Maxwell, D.J., Gao, X., Bailey, R.E., Han, M., Nie, S., Curr. Opin. Biotechnol., 13, 2002, pp.40-46.

13. Watanabe, T., Kojima, E., Norimoto, K., Kimura, T., Machida, M., Hayakawa, M., Kitamura, A., Chikuni, M., Saeki, Y., Kuga, T., Nakashima, Y., “Multi-functional material with photocatalytic functions and method of manufacturing same”, US patent US6294247, 2001.

14. Super-Hydrophilic Photocatalyst and Its Applications, http://www.toto.co.jp/hydro_e/index.htm

15. Pilkington Activ™ - Self-cleaning Glass, http://www.pilkington.com/international+products/activ/usa/english/default.htm.

16. Zhang, Q., Wang, J., Cheng, S., “Study on the CPE/Nano SiO2 blends”, J. Funct. Polym., 15 (3), 2002, pp. 271-275.

17. Bauer, B.J., Liu, D. Jackson, C.L. et al., “Epoxy/SiO2 interpenetrating polymer networks”, Polym. Adv. Technol., 7, 1996, pp. 333-339.

18. Somekawa, H., Tanaka, T., Sasaki, H., Kita, K., Inoue, A., and Higashi, K., “Diffusion bonding in ultra fine-grained Al–Fe alloy indicating high-strain-rate superplasticity”, Acta Materialia, V.52, No.4, 2004, pp.1051-1059.

19. Wilson,M., Smith, K.K.G., Simmons, M. and Raguse, B., Nanotechnology - Basic

Science and Emerging Technologies, Chapman & Hall/CRC, 2000. [13] Y. Li, J. Li, Y. Wan, and Z. Xu, “Experimental study of light transmitting cement-based material (LTCM),” Constr. Build. Mater., vol. 96, pp. 319–325, 2015.

A. A. Momin, R. B. Kadiranaikar, V. Jagirdar, and A. Inamdar, “Study on light transmittance of concrete using optical fibers and glass rods,” IOSR J. Mech. Civ. Eng., vol. 2, no. 2, pp. 67–72, 2014.

[14] Y. Li, J. Li, and H. Guo, "Preparation and study of light transmitting properties of sulfoaluminate cement-based materials," Mater. Des., vol. 83, pp. 185–192, 2015.

[15] Z. Zhou, G. Ou, Y. Hang, G. Chen, and J. Ou, "Research and development of plastic optical fiber based smart transparent concrete," Proc. SPIE, vol. 7293, pp. 1–6, 2009.

[16] A. Altlomate, F. Alatshan, F. Mashiri, and M. Jadan, "Experimental study of light-transmitting concrete," Int. J. Sustain. Build. Technol. Urban Dev., vol. 7, no. 3–4, pp. 1–7, 2016.

[17] H. Okamura and K. Ozawa, "Mix design of self compacting concrete," Concr. Libr. JSCE, vol. 24, no. 25, pp. 107–120, 1995.

[18] EFNARC, Specification and guidelines for selfcompacting concrete. European Federation for Specialist Construction Chemicals and Concrete Systems. Norfolk, UK, 2002.

[19] S. Paul and A. Dutta, "Translucent concrete," Int. J. Sci. Res. Publ., vol. 3, no. 10, pp. 1–10, 2013.

[20] N. K, U. Farook, S. Ahmed, J. MK, R. Saleem, and S. Omar, "Experimental analysis of translucent concrete by using optical fibers," SSRG Int. J. Civ. Eng., vol. 3, no. 3, pp. 76–81, 2016.