Theoretical Modelling Of Ultra High Strength Nano Concrete

Patil R N[1], Pol C B[2]

[1]PG Student, Dept. of Civil Engineering, Walchand College of Engineering, Sangli, Maharashtra, India, 416415
[2]Professor, Walchand College of Engineering, Sangli, Maharashtra, India, 416415

---***---

Abstract - *This paper consists of an investigation carried out in the field of Nano-Technology more specifically Nano-Materials. This investigation involves the smart use of Nano Materials particularly in conventional concrete forms new nano-concrete which is defined as Ultra High Strength Nano-Concrete. Basic ingredients for this nano-concrete are Graphene, Nano silica, cement, sand, aggregates, and water. Nano technology is an enabling technology that opens new possibilities in construction sustainability. A concrete Produced by replacing a certain percentage of cement with nano material is called the nano concrete. This paper deals with the study of mechanical properties like compressive strength, tensile strength and bond strength of the nano concrete in comparison with conventional concrete.* This study summarizes the influence of nano-silica on strength and durability of different grades of concrete with the used of nano-silica as a replacement of cement

***Key Words*: Nano concrete, Conventional concrete, Nano silica, Compressive strength, flexural strength.**

1. INTRODUCTION

Nano technology is a new emerging area in field of engineering. Development of nanotechnology in the field of material science and evolution of advanced instrumentation have paved way for application of nanotechnology in the construction field. Incorporation of nano sized particles in cement composites makes a significant change in structural and nonstructural properties of cement paste, mortar and concrete. Nano particles have more specific surface area and this increase in surface area leads to changes in morphology, increase in chemical reactivity, structural modification of cement hydrates and enhancement of the properties of concrete. The use of nano materials in concrete, results in stronger and more durable concrete with desired stress-strain behaviour.

Concrete is the most common material used in the construction. It is composing material composed of coarse aggregate, finely powdered cement, fine aggregate and water with inherent physical, chemical, and mechanical properties. The use of nano-silica will create a new concrete mixture that will result in long lasting concrete structure in the future. Only a small percentage of cement can be replaced to achieve the desired results. These nanomaterials improve the strength and permeability of concrete by filling up the minute voids and pores in the microstructure. The use of nano-silica in concrete mix has shown results of increase in the compressive, tensile and flexural strength of concrete. 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.

2. OBJECTIVES

1. Parametric study of limit state design philosophy for conventional concrete.
2. Modelling various parameters of Ultra High Strength Nano Concrete in accordance with the laid conventional design philosophy.
3. Design of Ultra High Strength Nano Concrete structural components by developed methodology.
4. Comparison of the designs of conventional and ultra high strength nano concrete structural components.

3. STRUCTURAL MODELS CONSIDERED

According to this invention, there is provided a Ultra-High-Strength Nano-Concrete Material for enhancing Compressive Strength, Tensile Strength and Young's Modulus, the said material comprises:

Carbon is brittle material with high modulus of elasticity, so using carbon-parent material -Graphen in concrete mix design improves the Tensile Strength of Concrete and overall modulus of elasticity. Also the silicate in the form of Nano-silica gives the improved chemical reaction between cementetious materials and enhances the compressive strength of concrete mix proportion.

A. CEMENT

Ordinary Portland Cement of any desired grades conforming to IS: 12269-1987 is used for preparing concrete specimens. The properties of cement used are given in the Table 1.

Table-1: Properties of cement

Sr. No.	Characteristics	Value
1	Specific gravity	3.15
2	Normal Consistency	30%
3	Setting Time a. Initial Setting Time b. Final Setting Time	 35 min 180 n

B. Fine Aggregate

The fine aggregate was used in the experimentation was confirming to IS: 383-1970 specifications fine aggregate is the main component grading zone- II of IS: 383-1978 was used.

Table-2: Properties of fine aggregate

Sr. No.	Characteristics	value
1	Fineness modulus	3.88
2	Specific gravity	2.75
3	Water absorption	1%

C. Coarse Aggregate

The coarse aggregate used in concrete is 12 mm size aggregate and tested as per IS: 383-1970 specification

Table-3: Properties of Coarse aggregate

Sr. No.	Characteristics	value
1	Fineness modulus	8.21
2	Specific gravity	2.82
3	Water absorption	0.8%

D. Nano-SiO2 has been found to improve concrete workability and strength, to increase resistance to water penetration, and to help control the leaching of calcium, which is closely associated with various types of concrete degradation.

Table-4: Properties of Nano-silica

Sr. No.	Characteristics	Value
1	Physical state	Powder
2	Particle size	5
3	Specific gravity	1.3-1.32

E. Water

The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc. Locally available potable tap water is used for curing.

4. EXPERIMENTAL WORK

Experimental work was done to compare compressive strength, tensile strength and modulus of elasticity of concrete of different grades and with replacement of ordinary Portland cement with optimum nano-silica concrete. The comparative study of mechanical properties of conventional and nano-concrete were studied with optimum nano-silica concrete.

a) Compressive strength

The compressive strength of concrete is determined after curing of 3, 7 and 28 days cubes and test results were obtained for different grades of conventional concrete and nano-silica.

Table-6: Grades vs Strength

Grades	Conventional	Ultra High strength Nano concrete
10	14.2	18.46
20	28.41	37.39
30	32.7	42.51
40	47.2	60.03
45	55.38	74.5
60	69.58	88.15
70	76.3	94.83

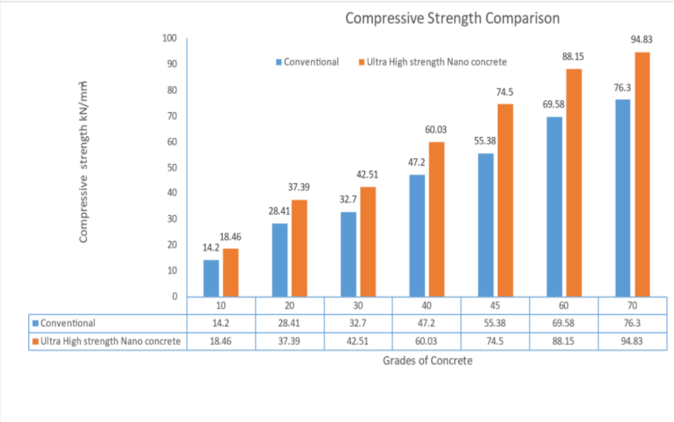

Fig-1: Compressive Strength Comparison

b) Tensile strength

Determination of tensile strength of concrete is necessary to determine the load at which the concrete member may crack. Tests are conducted on casted cylinder at the age of 3, 7 & 28 days.

Table-7: Tensile Strength

Grades	Conventional	Ultra High Strength Nano Concrete
10	1.2	1.836
20	2.35	3.59
30	3.65	5.58
40	4.81	6.94
45	5.45	8.1
60	7.23	11.06
70	8.4	12.852

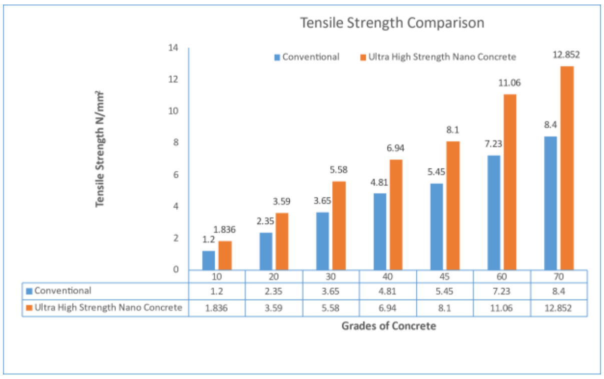

Fig-2: Tensile Strength Comparison

c) Young's modulus

Young modulus, or modulus of elasticity in tension or compression, is a mechanical property that measures the tensile or compressive stiffness of a solid material when force is applied lengthwise.

Table-8: Young's Modulus Comparison

Grades	Conventional	Ultra High Strength Nano Concrete
10	15.8	17.69
20	22.3	24.97
30	27.38	30.66
40	31.62	35.41
45	36.69	41.09
60	38.72	43.36
70	41.83	46.84

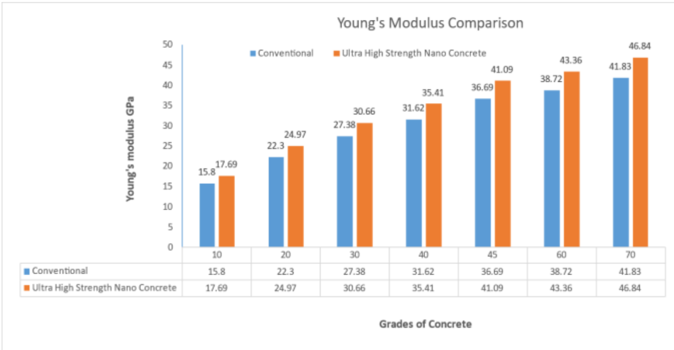

Fig-3: Young's Modulus Comparison

5. CONCLUSIONS

Use of Ultra High Strength Nano-concrete for construction will

i. Attains highest tensile strength (50% more as compared with conventional concrete).

ii. Attains highest compressive strength (30% more as compared with conventional concrete).

iii. Attains highest young's modulus and hence ductility (20% more as compared with conventional concrete).

iv. Attains highest bonding capacity between intermolecular arrangements changed by the nano-silica.

v. Attains highest water tightness.

vi. Attains highest corrosion resistance.

vii. Attains highest durability.

viii. Attains highest toughness.

ix. Attains highest ductility.

x. Attains highest workability.

6. REFERENCES

[1] Zou, Z. H., Wu, J., Wang, Z., Wang, Z. (2016). "Relationship Between Half-Cell Potential and Corrosion Level of Rebar in Concrete, Corrosion Engineering." Science and Technology, Vol. 51, Issue 8, pp. 588-595.

[2] Hassan, A. A. A., Hossain, K. M. A., Lachemi, M. (2009). "Corrosion Resistance of Self-Consolidating Concrete in Full-Scale Reinforced Beams." Cement and Concrete Composites, Vol. 31, Issue 1, pp. 29-38.

[3] Aveldaño, R. R., Ortega, N. F. (2011). "Characterization of concrete cracking due to corrosion of reinforcements in different environments." Construction and Building Materials, Vol. 25, Issue 2, pp. 630-637.

[4] Malumbela, G. (2010). "Measurable Parameters for Performance of Corroded and Repaired RC Beams Under Load." PHD thesis, Department of Civil Engineering, University of Cape Town, South Africa.

[5] Supit, S., Shaikh, F. U. A. (2015). "Durability Properties of High Volume Fly Ash Concrete Containing Nano Silica." Materials and Structures, Vol. 48, Issue 8, pp. 2431-2445.

[6] Shaikh, F. U. A., Supit, S. W. M. (2015). "Chloride Induced Corrosion Durability of High Volume Fly Ash Concretes Containing Nano Particles." Construction and Building Materials, Vol. 99, pp. 208-225.

[7] Ranjbar, M. M., Madandoust, R., Mousavi, S. Y., Yosefi, S. (2013). "Effects of Natural Zeolite on the Fresh and Hardened Properties of Self-Compacted Concrete." Construction and Building Materials, Vol. 47, pp. 806-813.

[8] Torkaman, J., Ashori, A., Sadr Momtazi, A. (2014). "Using Wood Fiber Waste, Rice Husk Ash, and Limestone Powder Waste as Cement Replacement Materials for Lightweight Concrete Blocks." Construction and Building Materials, Vol. 50, pp. 432-436.

[9] Kalla, P., Misra, A., Gupta, R. C., Csetenyi, L., Gahlot, V. (2013). "Mechanical and Durability Studies on Concrete Containing Wollastonite–Fly ash Combination." Construction and Building Materials, Vol. 40, pp. 1142-1150.

[10] Sujjavanich, S., Suwanvitaya, P., Chaysuwan, D., Heness, G. (2017). "Synergistic Effect of Metakaolin and Fly ash on Properties of Concrete." Construction and Building Materials, Vol. 155, pp. 830–837.

[11] Al Menhosh, A., Wang, Y., Wang, Y., Augusthus-Nelson, L. (2018). "Long Term Durability Properties of Concrete Modified with Metakaolin and Polymer Admixture." Construction and Building Materials, Vol. 172, pp. 41–51

[12] Miri, M., Beheshti Nezhad, H., Jafari, M. (2014). "Experimental Investigation on Mechanical Properties of Concrete Containing Nano Wollastonite and Modelling with GMDH- Type Neural Networks." (in Persian), Amirkabir Journal of Science & Research (Civil & Environmental Engineering), Vol. 46, Issue 2, pp. 49- 51.

[13] Ni, T., Zhang, L., Yuan, B. (2011). "Influence of Wollastonite or Plant Fiber on Performance of Autoclaved Cement Concrete." Applied Mechanics and Materials, Vol. 99-100, pp. 692-695.

[14] Kalla, P., Rana, A., Chad, Y. B., Misra, A., Csetenyi, L. (2015). "Durability Studies on Concrete Containing Wollastonite." Journal of Cleaner Production, Vol. 87, pp. 726-734.

[15] Soliman, A. M., Nehdi, M. L. (2014). "Effects of Shrinkage Reducing Admixture and Wollastonite Microfiber on Early-Age Behavior of Ultra-High Performance Concrete." Cement and Concrete Composites, Vol. 46, pp. 81-89.

[16] Zhang, L. C. (2013). "Durability of Concrete Containing Wollastonite and Fly Ash." Advanced Materials Research, Vol. 800, pp. 361-364.

[17] Wu, F., Gong, J. h., Zhang, Z. (2014). "Calculation of Corrosion Rate for Reinforced Concrete Beams Based on Corrosive Crack Width." Journal of Zhejiang University SCIENCE A, Vol. 15, Issue 3, pp. 197-207.

[18] Cao, Ch., Cheung, M.M.S., Chan, B.Y.B. (2013). "Modelling of Interaction Between Corrosion-Induced Concrete Cover Crack and Steel Corrosion Rate." Corrosion Science, Vol. 69, pp. 97–109

[19] Rodriguez, J., Ortega, L.M., Casal, J., Diez, J.M. (1996). "Corrosion of Reinforcement and Service Life of Concrete Structures." Durability of Building Materials and Components, Vol. 7, Issue 1, pp. 117–126.

[20] Vidal, T., Castel, A., François, R. (2004). "Analyzing Crack Width to Predict Corrosion in Reinforced Concrete." Cement and Concrete Research, Vol. 34, pp. 165–174.

[21] Zhang, R., Castel, A., François, R. (2010). "Concrete Cover Cracking with Reinforcement Corrosion of RC beam During Chloride-Induced Corrosion Process." Cement and Concrete Research, Vol. 40, pp. 415–425.

[22] Khan, I., François, R., Castel, A. (2014). "Prediction of Reinforcement Corrosion Using Corrosion Induced Cracks Width in Corroded Reinforced Concrete Beams." Cement and Concrete Research, Vol. 56, pp. 84–96

[23] Li, H., Li, B., Jin, R., Li, Sh., Yu, J-G. (2018). “Effects of Sustained Loading and Corrosion on the Performance of Reinforced Concrete Beams.” Construction and Building Materials, Vol. 169, pp. 179–187.

[24] Ye, H., Fu, Ch., Jin, N., Jin, X. (2018). “Performance of Reinforced Concrete Beams Corroded under Sustained Service Loads: A Comparative Study of Two Accelerated Corrosion Techniques.” Construction and Building Materials, Vol. 162, pp. 286–297.

[25] Malumbela, G., Moyo, P., Alexander, M. (2012). “Longitudinal Strains and Stiffness of RC Beams under Load as Measures of Corrosion Levels.” Engineering Structures, Vol. 35, pp. 215-227.

[26] Kim, Y. Y., Kim, J. M., Bang, J.-W., Kwon, S.-J. (2014). “Effect of Cover Depth, W/C Ratio, and Crack Width on Half Cell Potential in Cracked Concrete Exposed to Salt Sprayed Condition.” Construction and Building Materials, Vol. 54, pp. 636-645.

[27] ASTM C 876. (2015). “Standard Test Method for Half Cell Potential of Reinforcing Steel in Concrete.” West Conshohocken, PA: ASTM International.

[28] Nygaard, P. V. (2008). “Non-Destructive Electrochemical Monitoring of Reinforcement Corrosion.” Phd thesis, Department of Civil Engineering, Technical University of Denmark.

[29] Madandoust, R., Bungey, J. H., Ghavidel, R. (2012). “Prediction of the Concrete Compressive Strength by Means of Core Testing Using GMDH-Type Neural Network and ANFIS Models.” Computational Materials Science, Vol. 51, pp. 261–272.

[30] Du, Y., Cullen, M., Li, C. (2013). “Structural Performance of RC Beams under Simultaneous Loading and Reinforcement Corrosion.” Construction and Building Materials, Vol. 38, pp. 472–481.

[31] El Maaddawy, T., Soudki, Kh., Topper, T. (2005). “Long-Term Performance of Corrosion-Damaged Reinforced Concrete Beams.” ACI Structural Journal, Vol. 102, Issue 5, pp. 649-656.

[32] ASTM C150. (2009). “Standard Specification for Portland Cement.” West Conshohocken, PA: ASTM International.

[33] Balaguru, P., Chong, K. (2008). “Nanotechnology and Concrete: Research Opportunities.” In Nanotechnology of concrete: Recent Developments and Future Perspectives (ACI SP-254), Detroit, MI: American Concrete Institute.

[34] Sanchez, F., Sobolev, K. (2010). “Nanotechnology in Concrete – a Review.” Construction and Building Materials, Vol. 24, pp. 2060–2071.

[35] ASTM C 618. (2015). “Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.” West Conshohocken, PA: ASTM International.

[36] ASTM C33. (2016). “Standard Specification for Concrete Aggregates.” West Conshohocken, PA: ASTM International.

[37] ASTM C494/C494M-10. (2010). “Standard Specification for Chemical Admixtures for Concrete.” West Conshohocken, PA: ASTM International.

[38] ASTM C 143. (2001). “Standard Test Method for Slump of Hydraulic-Cement Concrete.” West Conshohocken, PA: ASTM International.

[39] BS 1881: Part 116. (1983). “Testing Concrete: Method for Determination of Compressive Strength of Concrete Cubes.” British Standard Institution (BSI).

[40] El Maaddawy, T., Soudki, Kh. (2003). “Effectiveness of Impressed Current Technique to Simulate Corrosion of Steel Reinforcement in Concrete.” Journal of Material in Civil Engineering, Vol. 15, Issue 1, pp. 41-47.

[41] Malumbela, G., Moyo, P., Alexander, M. (2012). “A Step Towards Standardising Accelerated Corrosion Tests on Laboratory Reinforced Concrete Specimens.” Journal of the South African institution of civil engineering, Vol. 54, Issue 2, pp. 78–85.

[42] Rinaldi, Z., Imperatore, S., Valente, C. (2010). “Experimental Evaluation of the Flexural Behavior of Corroded P/C Beams.” Construction and Building Materials, Vol. 24, pp. 2267–2278.

[43] ASTM G1. (2003). “Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.” West Conshohocken, PA: ASTM International.

[44] DuraCrete-Final Technical Report. (2000). “The European Union-Brite EuRam III Research Project: Probabilistic Performance Based Durability Design of Concrete Structures.” Document BE95-1347/R17, CUR, Gauda.

[45] Zhang, R., Castel, A., Francois, R. (2009). “Serviceability Limit State Criteria Based on Steel–Concrete Bond Loss for Corroded Reinforced Concrete in Chloride Environment.” Materials and Structures, Vol. 42, pp. 1407–1421.