Comparison of mechanical properties of nano concrete with conventional high strength concrete

V. Sai Kiran, V. Sandeep Chowdary and P. Veerabhadra Rao

This paper deals with the study of mechanical properties of a new type of concrete called Nano Concrete [1] in which the coarse and fine aggregates are completely avoided and fly ash [2, 3] is added which acts both as complementary cementitious material and as a Micro aggregate. Mechanical properties like Compressive strength, Split tensile strength and Bond strength of this concrete are compared with those of the conventional concrete of high strength (control concrete). This paper also serves as an extension to the previous literature available on this newly invented concrete in which its mechanical properties are compared with those of the control concrete with same cement content [4, 5]. All the experimental work carried out for finding the aforementioned properties is in accordance with the corresponding Indian standard codes. Results reveal that the Compression and Split tensile strength values of nano concrete are higher than the corresponding values of control concrete whereas the bond strength value of this concrete is slightly lower than that of control concrete.

INTRODUCTION

Nano concrete (NAC) is the newly invented concrete in which coarse and fine aggregates are completely avoided and fly ash plays the role of aggregate, in addition to its main role as complementary cementitious material (CCM).

Invention of nano concrete

In the process of research for up-gradation of FaL-G technology (Fly Ash, Lime, Gypsum) using fourth generation admixtures by Dr. Bhanumathidas and Mr. Kalidas (Founder Directors of INSWAREB - Institute of Solid Waste Research and Ecological Balance) at INSWAREB Labs, Visakhapatnam, it was aimed to address the issues of conventional concrete i.e., transition zone, durability enhancement and conserving the environment etc. This mix was initially named as No-Aggregate Concrete (NAC) and a comparative study of its mechanical properties with those of conventional concrete of same cement content was carried out. After further research this new type of concrete has been renamed as Nano Concrete (NAC) due to the following reasons:

1. In NAC, aggregate is avoided, wherein fly ash, consisting of sub-micron particles, plays the role of micro aggregate.
2. When compared with micro pores of conventional concrete having coarse and fine aggregate, NAC is liable to have Nano pores for having micro aggregate. This is evident from the results of Rapid Chloride Permeability Test (RCPT) which has registered 27-300 coulombs for NAC as against 3000-5700 coulombs for conventional concrete [6].

Composition

In Figure 1, 'w/cm' refers to water to cementitious material ratio. Cementitious materials include OPC, fly ash and anhydrite gypsum, since fly ash is treated as CCM.

Table 1. Properties of aggregate

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.76	2.835
Fineness modulus	2.79	N.A
Water absorption	N.A.	2%
Surface texture	Smooth	Rough
Particle shape	N.A.	Angular
Type	Medium sand	N.A.
Zone	II	N.A

This Concrete has following benefits when compared to conventional concrete:

1. The density of NAC is 1700 to 1900 kg/m^3 as against 2500 kg/m^3 of control concrete, whereby dead load of the structure built with NAC will be lesser thus facilitating to rationalise super structure, resulting in cost reduction.
2. NAC is prepared with special admixture facilitating high compaction and workability: it does not require vibrator for compaction. As shown in Figure 2, in fresh state this behaves both like a self-compacting and self-levelling concrete.

This experimental study mainly focused on finding the mechanical properties such as compressive strength, split tensile strength and bond strength of NAC and control concrete and then comparing them to spell upon applicational scope of the former.

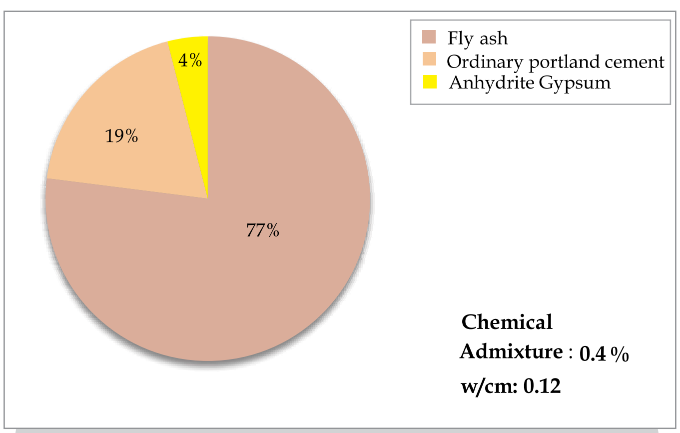

Figure 1. Composition of nano concrete

This research work was carried out at INSWAREB labs, Visakhapatnam and Gayatri Vidya Parishad College of Engineering (Autonomous), Visakhapatnam during December 2012 to May 2013.

MATERIALS AND METHODS

The raw materials used for this experimental work are as follows:

Aggregate

Locally available natural sand with 4.75 mm maximum size in dried condition was used as fine aggregate and angular shaped coarse aggregate with a maximum size of 20 mm was used in control concrete. Table 1 reveals the various test results of aggregates, conducted as per IS 2386:1963 (Part 3) (Reaffirmed 1997) [7].

Fly ash

Fly ash used in the making of NAC is obtained from the Simhadri NTPC Power Plant, Parawada at Visakhapatnam. This fly ash is used in NAC only, where the aggregates are completely avoided. The percentage retention on IS 45 micron sieve upon wet sieving is 26.3% as against the maximum of 34% vide IS 3812 (1981) [8].

Figure 2. Casting of NAC specimen

Table 2. Properties of cement

Test conducted	Description	Test result
Specific gravity	Obtained using specific gravity bottle	2.88
Initial setting time	Obtained using Vicat apparatus as per IS 4031(Part5):1988 [10]	54 minutes
Fineness	Found in terms of percentage passing through IS Sieve No.9(90 μm)as per IS 4031(Part1):1988 [11]	99.56%
Sound-ness	Expansion found out using Le- Chatelier Apparatus as per IS: 4031(Part 3):1988 [12]	1 mm

Cement

In this experimental study, 53 Grade Ordinary Portland Cement (OPC) conforming to IS 12269:1987 [9] was used. The properties of the cement used are shown in Table 2.

Chemical admixture

The admixture which was used only in NAC to provide necessary workability was a fourth generation super plasticizer.

Water

Fresh potable water, which is free from acid and organic substances, was used in making and curing of both the concretes.

Mix proportioning

Table 3 shows the various trial mixes which are cast to arrive at a design mix (control concrete) of high compressive strength grade, comparable to that of NAC.

Table 3. Trial design mixes of control concrete

Trial mix no.	Trial mix-1		Trial mix-2		Trial mix-3	
Material	Kg/m^3	P	Kg/m^3	P	Kg/m^3	P
OPC	393	1	420	1	400	1
Sand	630	1.60	700	1.67	616	1.54
10-12 mm	570	1.45	406	0.97	574	1.44
20 mm	676	1.72	737	1.75	702	1.76
Water	174	-	168	-	160	-
Total	2443	-	2431	-	2452	-
w/c ratio	0.44	-	0.40	-	0.40	-

"P" denotes mix proportions in weight

Table 4. Mix proportion of NAC

Materials	Quantity (kg/m^3)	Proportion
Fly ash	1400	20
OPC	350	5
Anhydrite gypsum	70	1
Water	210	*
Chemical admixture	1.4	0.4% ~
*W/cm: 0.12 , ~In terms of O.P.C		

Cubes of 10 cm size of all the above mentioned trial mixes are cast and subjected to accelerated curing. Based on the compressive strength values obtained after testing, the Trial Mix-3 is chosen as Design mix for control concrete, for which the other mechanical properties are found out and compared with the corresponding values of NAC.

Mix design for NAC

Fly ash, Ordinary Portland Cement of 53 Grade and Anhydrite Gypsum are mixed together with water and chemical admixture in proportions given in Table 4.

Experimental methods

The mixing, casting, de-moulding, curing, and testing of control concrete were carried out as per IS 516:1959 [13] whereas, the mixing of NAC has been carried out by using a special roller mixer specified for the production of NAC which is generally used in the production of FaL-G bricks as shown in Figure 3.

Figure 3. Roller mixer used for mixing NAC

All the specimens of control concrete are demoulded after 24 hours of casting and these specimens are cured by wet covering under controlled conditions. The specimens which are taken out of curing are immediately tested, after taking out surplus water, at various ages as per the requirements of each test. In contrast, the specimens of NAC required a minimum of 48 hours for de-moulding. The curing and testing procedures are same as that of control concrete. The cubes of 10 cm size are tested for compressive strength as per IS 516:1959 [13]. For split tensile strength testing, the cylinders of 10 cm diameter and 20 cm height are tested as per IS 5816:1999 [14]. The bond strength testing is carried out on 15 cm cube with 16 mm diameter ribbed bars and the test is conducted in accordance with IS 2770 (Part 1):1967 [15]. All the tests have been conducted on minimum three specimens.

RESULTS AND DISCUSSIONS

Compressive strength

As observed in Figure 4, 28-Day Strengths of Control concrete and Nano concrete are obtained as 64.17 MPa and 78.08 MPa respectively. Hence, both these concretes fall in the range of high strength grade i.e., M60-M80 [16]. It can also be noted that the early strengths of NAC at 3 & 7 Days i.e., 18.83 MPa & 46.67 MPa are lower than those of the Control Concrete i.e., 31.67 MPa & 50.87 MPa. But, the strengths at 14, 28 & 180 days are higher for NAC, as compared in Figure 4. This is due to the pozzolanic reaction in NAC, which is slow at early ages and gains momentum at later stages. The other reason for higher compressive strength of NAC is the absence of Transition zone [1].

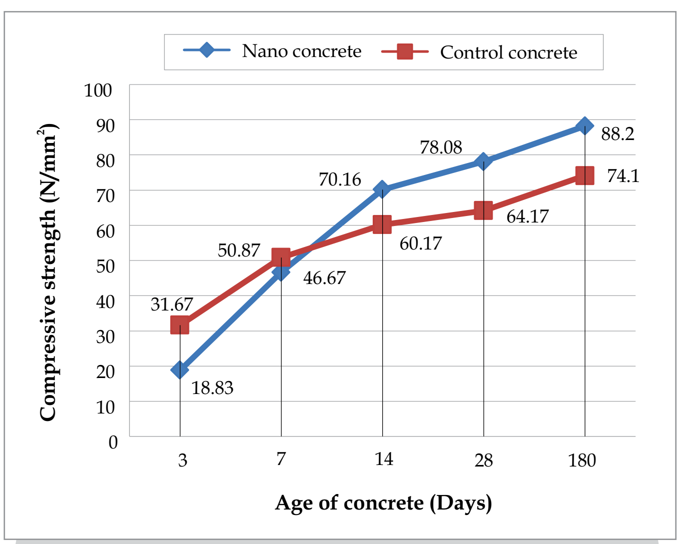

Figure 4. Comparison of compressive strength at various ages

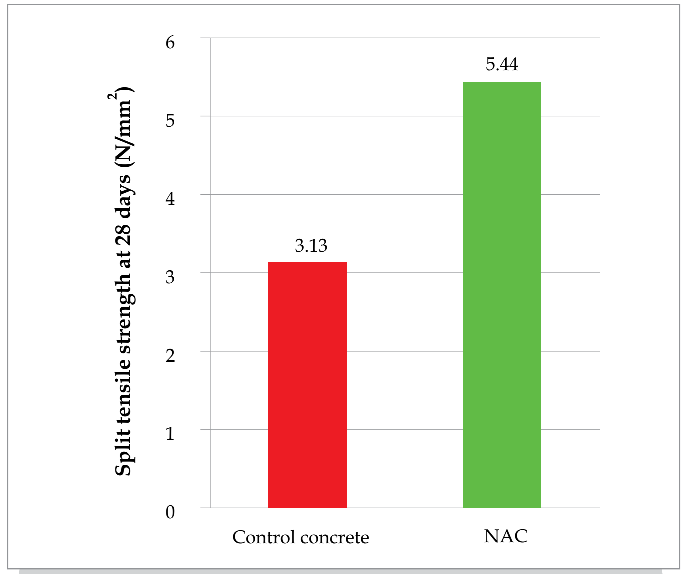

Figure 5. Comparison of split tensile strength

Split tensile strength test

In accordance with the comparative performance of both the concretes with respect to Split Tensile Strength, as shown in Figure 5, the value for NAC-5.44 MPa, is found to be higher than that of conventional concrete-3.13 MPa, which shows that the tensile strength of NAC is relatively higher. This may be attributed to the higher compressive strength of NAC. It should be noted that the split tensile strength test is an indirect way of finding the tensile strength of a concrete specimen subjected to compressive loading as shown in Figure 6.

Figure 6. Split tensile testing of a NAC cylinder

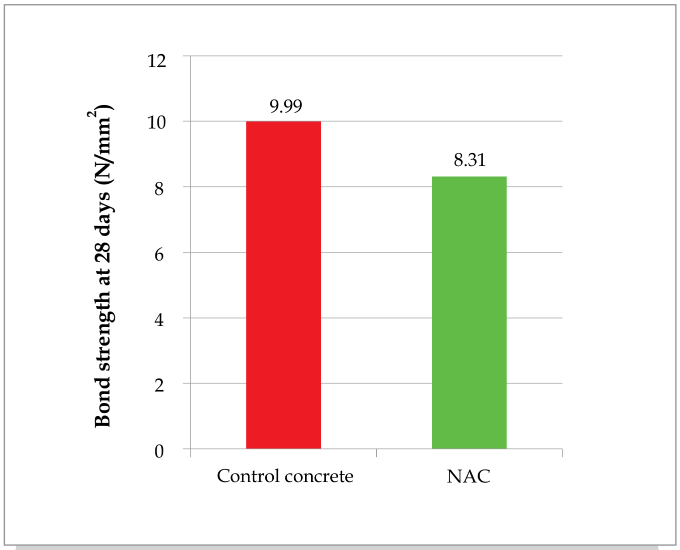

Figure 7. Comparison of bond strength

Figure 8. Bond strength testing of a 15 cm cube of control concrete

Bond strength test

The pull-out test results given in Figure 7 reveal that the bond strength of NAC-8.31 MPa is lower than that of the control concrete-9.99 MPa. The lower bond strength of NAC with the reinforcing bar can be attributed to the matrix of NAC which contains only fine materials of smooth surface, thereby minimising the development of required frictional forces, whereas in control concrete the bond strength is higher due to good friction developed with the presence of coarse and fine aggregates. Figure 8 shows a specimen of 15 cm Cube of Control Concrete with embedded reinforcing bar, being tested with Universal Testing Machine under controlled lab conditions.

CONCLUSIONS

This is a typical research work serving the agenda of sustainable development and this is the concrete for future generations who may get stuck to meet their needs for coarse and fine aggregate due to the depletion of natural resources by present generations. The following conclusion can be drawn from the comparative studies made on the mechanical properties of control concrete and NAC of high strength grades.

1. The performance of NAC in compression test is better than that of the control concrete
2. The spilt tensile strength of NAC is higher than that of control concrete
3. The bond strength of NAC is found to be slightly lower than that of control concrete

Acknowledgement

The authors thankfully acknowledge the guidance and technical knowledge imparted by Dr. Bhanumathidas and Mr.Kalidas, the innovators and Patentees of NAC, in successfully accomplishing this research work.

The authors would heart fully thank Ms. B. Laalithya Swetha, Ms. A. Reshma and other students, esteemed faculty members and non-teaching staff of Civil Engineering Dept., of G.V.P.C.E., Visakhapatnam, Andhra Pradesh for extending their kind support throughout the research work.

References

1. Dr.N.Bhanumathidas & N.Kalidas, "Irrational Concrete with Rational Performance": Press Note published by INSWAREB, Visakhapatnam on 18th January, 2010

2. N.Bhanumathidas & N.Kalidas, "Fly ash: The resource for Construction Industry", published by the Indian Concrete Journal, April 2013

3. N.Bhanumathidas & N.Kalidas, "Fly ash characterisation for use as a Pozzolanic Material", presented at II International Symposium on Concrete Technology for Sustainable Development held at Hyderabad (Feb 27-Mar 03, 2005)

4. Kalidas.N & Dr.Bhanumathidas.N, "No Aggregate concrete (NAC): The Future Concrete", published by The Master Builder, March 2010: Volume 12, No.3

5. Dr. Mrs. Bhanumathidas & N.Kalidas, "Concrete in India-Need for Rapid Transition", published by The Master Builder, July 2014: Volume 16, No. 7

6. Press Release by INSWAREB, Visakhapatnam on 24th March, 2012: "Joint Research with GVP College of Engineering on No-Aggregate Concrete"

7. ______ *Method of test for aggregate for concrete*, IS 2386:1963 (Part 3) (Reaffirmed 1997), Bureau Of Indian Standards, New Delhi.

8. ______ *Specification for Fly ash for use as pozzolana and admixture (First revision)*, IS 3812:1981, Bureau Of Indian Standards, New Delhi.

9. ______ *Specification for 53 Grade for Ordinary Portland Cement*, IS 12269:1987, (Reaffirmed 1999) Bureau Of Indian Standards, New Delhi.

10. ______*Methods of Physical tests for Hydraulic Cements : Determination of initial and final setting times (First revision)*, IS 4031(Part 5):1988 (Reaffirmed 2000), Edition 2.1 (1993-03) Bureau Of Indian Standards, New Delhi.

11. ______ *Methods of Physical tests for Hydraulic Cements: Determination of fineness by Dry sieving (Second revision)*, IS 4031(Part 1)-1996, Bureau Of Indian Standards, New Delhi.

12. ______*Methods of Physical tests for Hydraulic Cements : Determination of Soundness (First revision)*, IS 4031(Part 3):1988 (Reaffirmed 2000), Edition 2.1(1993-03) Bureau Of Indian Standards, New Delhi.

13. ______*Method of Test for Strength of Concrete,* IS 516:1959 (Reaffirmed 1999), Edition 1.2(1991-07) - Bureau Of Indian Standards, New Delhi.

14. ______*Method of test for splitting tensile strength of Concrete*, IS 5816:1999, Bureau Of Indian Standards, New Delhi.

15. ______*Method of testing Bond in reinforced concrete by Pull-out test*, IS 2770:1967 (Part 1), Bureau Of Indian Standards, New Delhi.

16. ______ *Plain & Reinforced Concrete- Code of Practice*, IS 456:2000, Bureau Of Indian Standards, New Delhi.

Mr. V. Sai Kiran holds a B.Tech. from G.V.P.C.E (A), Visakhapatnam, Andhra Pradesh, in Civil Engineering. He is a Senior Engineer, Quality Assurance & Quality Control, in Larsen & Toubro Ltd., Construction Division, at one of the company's projects - Sunteck City, Sector-1 located at Goregaon (W), Mumbai. His areas of interest include design, research & development of sustainable concrete mixes for high rise & industrial buildings.

Mr. V. Sandeep Chowdary holds a B.Tech. from G.V.P.C.E (A), Visakhapatnam, Andhra Pradesh in Civil Engineering. He is a Senior Engineer, Planning, in Larsen & Toubro Ltd., Construction Division at one of the company's projects - Statue of Unity (World's tallest Statue, once built) located near Sardar Sarovar dam, Narmada District, Gujarat. His areas of interest include research on concrete useful for industrial application; precast technology for rapid construction & exploring efficient project management techniques.

Prof. P. Veerabhadra Rao, M.E, is a Professor in Civil Engineering Department and Dean of Infrastructure, Planning and Development at G.V.P.C.E, Visakhapatnam, Andhra Pradesh. His areas of interest include application of precast technology in mass housing; research in new concrete for industrial application and design of concrete & steel structures