Institute for Solid Waste Research & Ecological Balance (INSWAREB)

(The Unique Techno-Scientific Organisation in NGO Segment)

Research on No-Aggregate Concrete/ Nano Concrete (NAC)

The aggregates (sand and stone) in concrete are indispensable inputs for three reasons:

- Without aggregates a cement cast element is liable to get shrinkage, leading to cracks.
- Strength of neat cement is around 70-90 MPa against popularly used concrete with strength of 20-25 MPa. Thus aggregates help to moderate strength of concrete to required grade.
- Cost of aggregates is certainly lesser than that of cement, thus bringing down the cost of concrete.

If there is a cementitious paste which can overcome shrinkage and cost-issues, despite avoiding aggregate, why not accept such concrete? Moreover, if such concrete is lighter in weight and higher in strength, increasing the factors of safety, is it not more desirable? Over and above, if such concrete is made of industrial byproducts using lesser cement it is all the more a welcome development.

This is exactly what the founder directors of this institute, Dr N Bhanumathidas and N Kalidas have invented and patented in 2010. This wonder product is called No-Aggregate Concrete (NAC), which means ***a concrete without sand and stone***.

Background to the Invention:

Urge to use complementary cement materials out of industrial wastes and thrust to conserve natural materials have given rise to NAC. As popularly known in building material research, the inventors have developed FaL-G technology in 1989 introducing FaL-G as the cementitious material by using all the inputs, fly ash, lime and gypsum out of industrial byproducts.

FaL-G Mansion 1991-slab with FaL-G concrete in lime route without using even a gram of cement

Tie beams in FaL-G concrete slab

To prove its efficacy they did cast 2000 sft of slab way back in 1991 for their house that consists of 15-18 ft long beams, where a couple of them are tie beams too. This has helped

to demonstrate the potential of FaL-G as structural cement and inspiring confidence to its use for bricks and blocks.

In their further studies for optimising FaL-G they developed various mixes using 4th generation admixtures in result of which they encountered with a mix showing up absolute workability, compaction and cohesiveness, all at 0.15 WCF (factor of Water/cementatious material) with grade strengths of 55 MPa to 65 MPa. When they have looked at the broken specimens the matrix was resembling somewhat close to that of ceramic with absolute pore-refinement. This has caught up their imagination that, using such material as structural media would address the issues of durability in a single go in a holistic manner.

The inventors emphasize FaL-G as the 'Ayurveda' of cement-concrete formulation. More the attrition greater is the potency. The edge runner serves this basic principle by tapping the holistic performance of fly ash. There upon the special admixture does the wonder. The role of anhydrite too cannot be ignored. All this collectively account for the high workability at the least WCF in FaL-G as NAC.

Immediately they conducted some basic engineering studies applicable to concrete, patented and declared the invention as No-Aggregate Concrete (NAC). In convention to their practice of taking the lab work to field without delay, they did cast the dome of 10.5 ft dia with NAC over the 2nd floor of FaL-G Mansion, which was due for face-lift at that time, in addition to other applications such as cantilever beam and shear wall. It is interesting to note that the 2-year specimen has shown up a compressive strength of 110 MPa, almost double the strength over its 28-day strength.

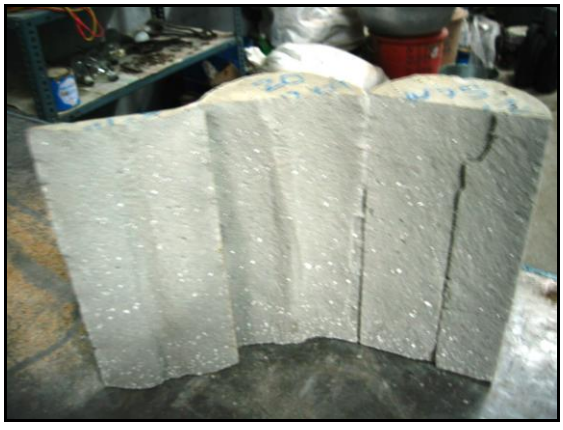
They have also christened their product as ***Nano Concrete***. In a given material and matrix, smaller the particles higher the bond, so much so the energy required to snap such bond. Nano science works on this premise, and Nano Concrete performs very much within this frame. Micron and sub-micron particles of fly ash that develop adhesive bond at early ages do attain cohesive bond with progress of age due to reaction of lime and other mineralogical hydrates on surface of particles. This is manifested in Nano Concrete developing over 100 MPa strength over an year as against 55 MPa at 28-day. Such quantum jump in strength is uncommon in cement concrete, whatever be the technique of preparation.

Issues with Transition Zone:

Transition zone is the interface between coarse aggregate and cement paste. Generally concrete do fail at transition zone, when subjected to stress, because of adverse effects caused by differential thermal stresses and weak crystallography at this zone. When OPC is used, belching out high surplus lime at early ages, such surplus lime gets dissolved in water tending to settle at transition zone. In high performance concretes aggregate size is rationalised in order to minimise differential stresses at transition zone, upon which the strengths are attributable to the strength of cement matrix associated with sand.

In NAC, first of all, there is no scope for transition zone for having avoided coarse aggregate. Even the inert fly ash particles do develop cohesive bond with cement matrix making the ultimate NAC-matrix close to monolithic. This is manifested in NAC by high strength (55-70 MPa) and lowest permeability at 27 coulombs.

Specimens after MOR: L to R: Control & NAC



NAC cylinder after Split tensile strength

Fly ash works as pozzolan to the extent of reactive portion and micro-aggregate to the extent of inert portion. Basic engineering data has been developed at INSWAREB as recorded in the table below:

Strength in MPa

Age of testing :	**3-day**		**7-day**		**28-day**	
Engineering data:	**Cement Concrete**	**NAC**	**Cement Concrete**	**NAC**	**Cement Concrete**	**NAC**
Compressive strength	15.6	10.6	25.0	20.2	39.3	56.2
Split tensile strength	--	--	--	--	3.47	3.69
Flexural Strength-MOR	--	--	--	--	4.40	5.20
Bond Strength	--	--	--	--	14.6	12.7
Chloride Permeability: Coulombs	**Control**		**NAC**			
At accelerate curing-24 hrs. At 90-day-Normal curing.	5701 4346		27 405			
Note: The two-year strength conducted on NAC specimen cast during the execution of dome, has shown up the strength of 110 MPa.						

Studies on Shrinkage:

As innovative material, NAC has to address all facets of concrete behaviour with data back up and further work is in progress. Shrinkage studies are one among them. But it is opined that because of 0.15 to 0.18 WCF NAC has hardly any scope for shrinkage. For example, when studied for drying shrinkage, NAC has shown up 0.05% as against permissible limit of 0.15% vide IS 4031 (Part 10)-1988 and IS 1727-1967.

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Beams tested for flexural strength: control Vs NAC concrete

NAC beam positioned for flexural strength (MOR)

The table below gives mix ratios and cost comparison of NAC with cement (OPC) concrete:

Input	Rate/kg Rs.	M-50 OPC Concrete		M-25 OPC Concrete		M-50 NAC	
	Rate/kg	Qty - kg	Cost Rs.	Qty - kg	Cost Rs.	Qty - kg	Cost Rs.
OPC	6.00	480	2880	360	2160	306	1836
Fly ash	0.60	-	-	-	-	1147	688
Sand	0.60	585	351	725	435	-	-
Aggregate: 10mm	0.60	498	299	484	290	-	-
20 mm	0.75	680	510	660	495	-	-
Water	0.05	173	9	170	8	270	30
w/cem.material	-	0.36	-	0.47	-	0.18	-
Chem.admixture	200	3	600	-	-	7.6	1520
Mineral admixture	3	-	-	-	-	77	231
Concrete prep. Cost Rs.	-	-	400	-	400	-	400
Grand total Rs.			**5049**		**3788**		**4705**

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Dome, cast on the upper floor of FaL-G Mansion, Visakhapatnam, in Jan 2010

But, in order to authenticate the invention for structural applications, considerable structural engineering research is necessary for which GVP College of Engineering has come forward. In addition to the advanced research, students of the college would be exposed to various facets of the research studies through dissertation, project works and doctoral studies.

Taking advantage of outcome of the Structural Research, live structures would be executed such as water bodies, private and public utility buildings.

Because of light weight, NAC is expected to revolutionise precast component industry. Hence research would stretch in studying the applicability in various precast elements.

Eco Carbon Pvt. Ltd., the associate of INSWAREB, has committed to invest for the research and deliver the fruits to the welfare of mankind and mother Earth. In the background of this agenda, Eco Carbon Pvt. Ltd., and GVP College of Engineering have signed a collaborative research program on NAC on 24th March 2012.

Precast roofing panels (5 x 2 mtr) cast at GVP Medical College Project, Visakhapatnam, India, being lift on 7th day with 50 MPa strength.

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There are a good number of constraints to use NAC in commercial way:

Firstly, the WCF to admixture dose is very critical. During some portion of the studies, top 10-15 mm layer of cast elements were observed to be incohesive and soft for violating the discipline on WCF. It took almost six months to identify the flash point to avoid such mishap. Secondly, mixing regime is crucial with respect to specific duration to tap the workability. If one is in hurry and keeps adding water, the mix attains more fluidity causing plastic shrinkage with visible cracks on the surface of cast element leading to dilution of strength.

Third dimension is brittleness due to ultra high strengths. A well prepared NAC has the ability to attain 35 MPa strength at 3-day; 52 MPa at 7-day and over 80 MPa by 28-day. Though brittleness is not uncommon to high strength concretes, NAC with its ceramic-like matrix appear to behave distinctly different against cement concrete, more so as RCC member. This aspect gives thrust for structural engineering research to identify the limitations or benefits of this wonder-product, keeping in view its application for high rise buildings, bridges and high profile structures.

NAC makes good sense for precast elements because:

- Accuracy of inputs is possible due to dosing mechanisms governed by instrumentation techniques.
- Butter-like mix of NAC facilitates casting with absolute finish associated with detailing of mould profiles, if any, making it amenable for ornamental concrete too.
- Density of NAC is around 1800-1900 kg/cu.m; almost 20-25% reduction over that of control concrete.
- High early strengths of NAC, which can also be augmented within 36 hours through accelerated curing, prove conducive for handling precast elements for immediate despatch to market bringing down the inventory costs.
- As the construction market is gearing up to produce and use precast elements, we believe that NAC is the timely boon to precast industry.

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Visakhapatnam

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