

INDUSTRIAL TRIAL AND TESTING OF NANO CEMENT TECHNOLOGY IN UAE

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In January 2016 under the agreement between OAO “Moscow IMET” and BINANI Cement Factory industrial trials of Nano Cement were conducted on one of the three production lines at BINANI cement plant in Dubai, United Arab Emirates. According to the Memorandum previously signed between the two parties, Nano Cement is to be produced with a ball mill with dimensions of 4.2 x 11m *without any changes to the line; feeding of modifier into the ball mill with a constant rate was arranged*. The plant proposed to produce about 1000 tons of Nano Cement 55 and a small amount of Nano Cement 35.

The production line number 3 has a two-chamber ball mill 4,2 x 11 m, feeding devices - conveyors, separator and hopper supplies: clinker - 600 tons; gypsum - 120 tons, mineral supplements - 120 tons. Grinding media load: in the first compartment - 90 m, in the second - 158 m; The line capacity is 75 tons per hour; Standard temperature in the mill - 105 °C. The vacuum at the outlet of the mill - 16 - 20 MPa.

As a mineral additive (sand) BINANI offered two sources - from Al Madam and from Ras Al Khaimah. Seven hundred tons of sand from Al Madam was delivered to the plant site. All other components - clinker, gypsum were the ones commonly used by the plant. The natural gypsum about 90% gypsum dihydrate. Table 1 shows the characteristics of the used Portland cement clinker. Table 2 shows properties of Portland cement.

Desert sand used in tests and delivered from Al Madam: sand chemical composition and mineralogy of the RSA method, performed after the trial showed the content,% wt. ∴ quartz - about 55%, calcium carbonate about 35% field spar about 10%.

Table 1

PLANT BINANI CEMENT FACTORY LLC, DUBAI
Analysis of Portland cement clinker

	Unit of measurement	Supplier's value	BINANI value	
free lime (free CaO)%	%	1.05	1.25	
Loss on ignition (LOI)%	%	0.23	0.22	
The insoluble residue (IR)	%	0.25	0.14	
SO ₃	%	0.48	0.38	
CaO	%	65.81	65.52	
SiO ₂	%	21.61	21.30	
Fe ₂ O ₃	%	3.81	3.89	
Al ₂ O ₃	%	5.31	5.60	
MgO	%	1.62	1.40	
Alkaline salt (Na ₂ O + 0.658 K ₂ O)	%	0.54	-	
LSF	-	0.95	0.95	
SM	-	2.37	2.24	
AM	-	1.39	2.44	
C ₃ S	%	58.28	60.52	
C ₂ S	%	17.99	15.15	
C ₃ A	%	7.62	8.27	
C ₄ AF	%	-	11.83	
Grinding Time	seconds	-	2400	
Expansion in autoclave	m ² Kg	-	346	
Le- Chatelier Expansion	%	-		
Autoclave extension	mm	-	2	
Setting Time	Initial	Minutes	-	125
	Final	Minutes	-	180
Compressive strength	2 days	MPa		25.3
	7 days	MPa		38.9
	28 days	MPa		50.0

Table 2

**Analysis of Portland cement M-500 (PC 500-D0-N)
(original cement for Nano Cement)**

Indicator	Standard	for ND Norm	actually received data
1	2	3	4
content (SO 3) %	GOST 5382-91	not less than 1.0 less than 3.5	1.98
Blaine, %	GOST 310.1-76	no less than 85 % passes through a sieve №008	98.9
Normal density of cement paste,%	GOST 310.3-76	no regulations.	31.5
Cone flow, mm	GOST 310.4-81	in the range 106-115 mm	115
setting time, initial/final	GOST 310.3-76	no earlier than 2 hours, no later than 10 hours	4h 45 min 6 h 00 min
soundness	GOST 310.4-81	No cracks	no cracks
compressive strength after steaming, MPa	GOST 310.4-81	Group effect for steaming: 1 > 32 2 28 - 32 3 at least 28	26.1
limit compressive strength, MPa, at the age of 3 days/ 7 days	GOST 310.4-81	not regulated not regulated	22.8 27.3
flexural strength, MPa after steaming, 3 day, 7 days	GOST 310.4-81	not standardized not standardized	4 81 5.76
flexural strength, MPa, aged 28 days	GOST 310.4-81	5.9	13/01/16
compressive strength, MPa, aged 28 days	GOST 310.4-81	49.0	13.1.16

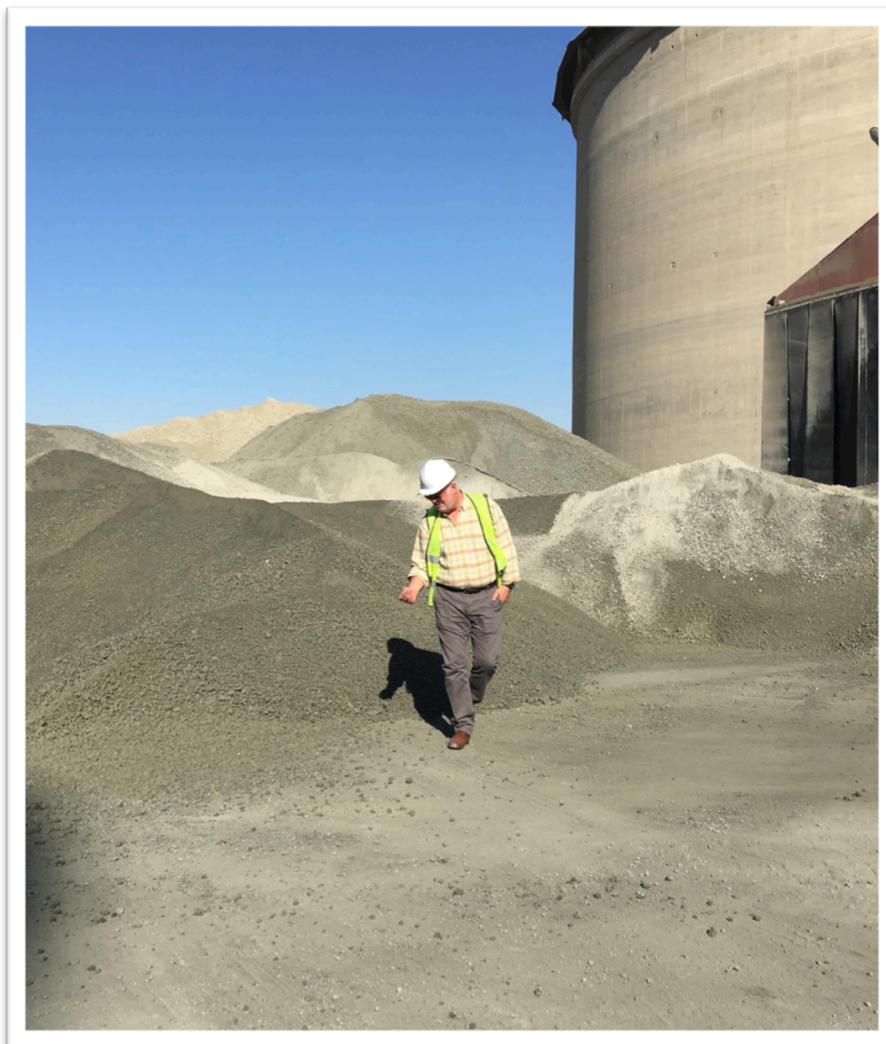


Figure 1. David Campbell examines the cement clinker BINANI

It was mutually agreed to use test construction and technical properties of Nano Cement by ASTM C1157 / C1157M-11 standards with the training of specific tests method by Russian specialists.

It was agreed to transfer Nano Cement samples 55 to evaluate the construction and the technical properties for the independent examination of the material, as well as the transfer of cement batch in the amount of 2 tons to Moscow IMET. In addition, it was suggested by BINANI to use Nano Cement 55 in concrete testing in their factory lab and give samples for the industrial production of concrete to plants in Dubai -. Potential Users



Figure 2 M.Ya.Bikbau checks sand from the Al Madam quarry site



Figure 3. Moscow IMET in the plant laboratory . From left to right: V.M.Nesvetaylo, laboratory technician Kayzar, Anil Paliwal, Director of the Laboratory, M.Ya.Bikbau, director of Moscow IMET

During the test the Russian modifier was used. It was delivered from Russia, packed in paper bags of 25 kg. Feeding of modifier was performed manually, directly to the main conveyor in front of the funnel of a ball mill in paper bags, which were opened with one hand. Modifier was added at rates of 1% and 0.8% by weight of the Nano Cement to the ball mill based on the type of Nano Cement to be produced.

Specialists at BINANI were concerned that the supply of significant volumes of sand would make the operation of the ball mill more difficult and cause an increase in specific energy consumption. In accordance with the agreement and the instructions of the Moscow IMET Nano Cement samples were taken every hour at the exit of the ball mill and brought to the laboratory. Industrial trial began at 8 : 20 am with feeding to the ball mill clinker, desert sand, gypsum and modifier ratio,% wt .: clinker - 55, sand - 40; gypsum -5; -1 modifier.

Table 3

Detailed performance of production line at BINANI plant

For the production of Nano Cement (from 8:50 to 14:50 January 20, 2016)

Clinker (%)	Sand (%)	Gypsum (%)	Modifier (%)	Feed (tons per hour)	The output (tones per hour)	temperature mill	Blaine (M ² /KG)	Balance (%)	Bunker storage
55.41	38.26	5.27	1.06	60 - 75	56 - 85	94 - 106	357 to 440	0.36 to 1.16 to 24.58	21

10.88N-35(15:00 to 15:30)

Clinker (%)	Sand (%)	Gypsum (%)	modifier (%)	Feed (tons per hour)	at the output (tones per hour)	temperature mill	Blaine (M ² Kg) /	Balance (%)	Bunker storage
35.71	58.20	5.29	0.80	75	100	105	525	0.46 to 16.20	dispenser

Total Nano Cement produced - **490,025 tones**

Energy costs -**43.31 kWh / ton**

clinker - 275 tons

sand - 190 tones @ 3% moisture

gypsum - 25 tons

modifier -**5.725 tones**

Table 4
Nano Cement Characteristics during sampling time - hours, minutes

sampling time	10	11	12	13	14	15	16	17
cement type	N-55	N-35						
Blaine (M ² / Kg)	357	440	394	440	428	384	421	525
Residue on sieve 90 microns (%)	0.36	0.46	0.32	0.90	1.16	0.62	1.54	0.46
residue on sieve of 45 microns (%)	11.10	13.20	10.88	18.22	17.14	13.84	24.58	16.20
setting time initial (minutes)	295	425	530	265	390	470	-	230
setting time final (minutes)	330	480	565	290	425	510	-	270
Water (g)	80	80	88	88	80	84	-	80

The data shows that the work of the ball mill on the basic parameters practically did not change compared to standard mode of operation of said BINANI line. The most important was the fact that the supply to the mill of desert sand containing 50 % quartz with the impact of the modifier was very positive (Table 3).

Instead, the basic factory mill capacity of 75 tons per hour during the period has increased with the production of Nano Cement from 75 up to 85 tons per hour, and with the production of Nano Cement 35 to 100 tones per hour (!) in this case, the Blaine Nano Cement 55 was more than 400 m²/ kg, and 35 Nano Cement increased to 525 m²/ kg (Table 4).



Figure 4. Control Room: left Sidiki K., Plant Director, Binani; M.Ya.Bikbau, director of Moscow IMET; D. Campbell, Director of Business Development, Moscow IMET International.

The industrial test results show promising ideas of M.Y. Bikbau.: a significant increase in the efficiency of grinding of Portland cement clinker in ball mills; when co-grinding with a modifier, quartz particles play a role of micro grinding bodies contributing to the prevention of the aggregation of small particles of cement, as well as cleaning the grinding bodies, providing a high specific surface area for Nano Cement and a significant reduction of specific energy consumption.

Chemical analysis of Nano Cement made by BINANI caused a lot of questions, answers to which were obtained after the tests in Moscow, at the Institute NII CEMENT. First of all, the content and the ratio of the main oxides SiO_2 : CaO was interesting.

Chemical analysis, confirmed by X-ray structural phase study showed that too low silica content number was due to not taking into account the insoluble residue. Quartz grains in conventional methods of cement chemical analysis, end up as a part of insoluble residue.

Table 5

**BINANI CEMENT FACTORY LLC, DUBAI
TESTING REPORT OF NANO CEMENT**

Production Date: - 20.01.2016

Qty: - 490 MTNano cement N-55 & N-35

	Unit	Specification as per BSEN 197-1:2011	Specification as per ASTM C- 150 Type-I	N-55	N-35	
Loss on Ignition (LOI)	%	5.00 Max	3.0 Max	7.61	10.94	
Insoluble Residue (IR)	%	5.00 Max	0.75 Max	22.36	30.78	
SO ₃	%	3.50 Max	3.50 Max	4.12	2.30	
CaO	%			42.93	37.00	
SiO ₂	%			32.58	37.44	
Fe ₂ O ₃	%			2.58	2.40	
Al ₂ O ₃	%			4.96	4.40	
MgO	%		6.0 Max	2.32	2.52	
Coefficient of lime saturation	-			0.41	0.32	
SM	-			4.32	5.52	
AM	-			1.92	1.83	
C ₃ S	%			-121.65	-173.51	
C ₂ S	%			185.23	238.20	
C ₃ A	%			8.78	7.60	
C ₄ AF	%			7.84	7.30	
Blaine	m ² /Kg			433	525	
Residue	90 microns	%		0.60	0.46	
	45 microns	%		15.66	16.20	
Auto Clave Expansion	%			0.10	0.10	
Le- Chatliere expansion	mm			2 mm	2 mm	
Setting Time	Initial	Minutes	60 Min	45 Min	395	230
	Final	Minutes		375 Max	430	270

Considering mentioned above, it would be correct to count the insoluble residue as silica. Therefore, actual content of SiO_2 in Nano Cement 55 is: $32.58 + 22.36 = 54.94\%$, and in Nano cement 35 actual content of SiO_2 is $37.44 + 30.78 = 68.28\%$.

That is why calcium silicates figures in Table 5 “Mineralogical composition of Nano Cement”, which includes silicate C_3S and C_2S attract attention, and also high LOI. The explanation of latter could be due to the presence of calcite in the Al Madam sand in an amount of about 35% by weight. Chemical and structural X-ray qualitative analysis of Ras Al Kkamaih sand has shown it has 45% of calcite, quartz - 45% feldspar - 10%.

The average Blaine of Nano Cement 55 was $433 \text{ m}^2 / \text{kg}$, whereas Nano Cement 35 (with increased amount of sand) has reached $525 \text{ M}^2 / \text{kg}$. All other oxides in chemical composition of Nano Cement require retesting and recalculating due to the presence of significant amounts of calcite; this contributes to the high loss on ignition number and to quartz (silica) hidden in the form of insoluble residue.

Construction and technical properties of Nano Cement 55 BINANI industrial production plant

Building - Technical properties of Nano Cement 55 (industrial production) were analyzed by independent laboratory of UNION CEMENT COMPANY, UAE (Table 6).

Table 6

Construction and technical properties of Nano Cement

Description & Particulars		Results	
		N-55	N-90
SiO ₂ (%)		31.70	37.82
Al ₂ O ₃ (%)		4.45	3.64
Fe ₂ O ₃ (%)		3.35	4.14
CaO (%)		54.08	50.61
MgO (%)		2.68	1.20
SO ₃ (%)		1.98	0.98
K ₂ O (%)		0.73	0.51
Na ₂ O (%)		0.11	0.11
TiO ₂ (%)		0.25	0.22



شركة أسمنت الإمارات (ش.م.ع.)
UNION CEMENT COMPANY (P.S.C.)

Dated: 23-03-16

NANO CEMENT ANALYSIS REPORT

Cement samples (02) provided by Mr. David on dated 17-02-2016. Samples analyzed as per the instruction of the concerned. Two samples were prepared along with following proportions.

1. Approximately sample quantity is 25 Kg. Code of this sample is **N-55** and the **composition proportion** are as follows;

⚖ Clinker used= 55% & Gypsum used= 5.0%

⚖ Sand(Dune) used =39% & Polymer used= 1.0%

2. Approximately sample quantity is 10 Kg. Code of this sample is **N-90** and the **composition proportion** are as follows;

⚖ Clinker used= 90% & Gypsum used= 4.0%

⚖ Sand(Dune) used =5.0% & Polymer used= 1.0%

Analysis carried out in UCC laboratory as per provided the procedure (EN 196-1; PNST 19-2014) for physical analysis. Chemical and physical analysis results are as under;

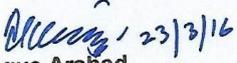
CHEMICAL ANALYSIS

Table 6 (continued)

P2O5(%)	0.11	0.21
Loss on Ignition (%)	8.24	2.88
Limestone (%)	15	1.0
Insoluble Residue(%)	21.30	23.72
PHYSICAL ANALYSIS		
Fineness, Blaine Test(M2/Kg)	461	769
Sieve Residue on 45 micron (%)	8.24	1.20
Consistency (%)	22.0	21.2
Initial Setting(Minutes)	115	10
Final Setting(Minutes)	260	20
Flexural Strength(MPa)	Water used for cubes 125ml	Water used for cubes 125ml
01 Days	1.29	2.72
03 Days	2.06	5.29
07 Days	2.14	5.55
28 Days	2.92	6.09
Compressive Strength (MPa)		
01 Days	13.48	33.56
03 Days	23.90	65.21
07 Days	35.26	72.95
28 Days	41.66	81.51

It is for your information please.

Regards,

 23/3/16
Rafique Arshad

Chief Quality Control

The strength parameters of Nano Cement 55 did not satisfy OAO «Moscow IMET». We expected higher performance indicators, at least a one class higher. Impressive are test results of the special highly penetrating Nano 90 used to strengthen ground and foundations of buildings and structures by pressure injection.

The strength parameters of Nano 55 correspond to 70% of the expected values. This could be explained firstly by the fact, that in compliance with the request of BINANI representatives' technological optimization of the ball mill operation was eliminated. The line was working only for 6 hours going straight into production of the brand new material. Also composition of Al Madam sand was a contributing factor to low quality of the cement (Nano 55 standard values call for 52.5-62.5 MPa at 28 days). Chemical and mineralogical analysis of Al Madam sand by the method of X-ray structural quantitative analysis demonstrated that the sand contains a significant amount of calcium carbonate in the form of calcite, very negatively affecting the efficiency of modification Portland cement into Nano Cement.

Table 7. Testing of concrete on the basis of 55 Nano Cement Industrial production plant BINANI

Test construction and technical properties of concrete mixtures on Nano Cement 55 (N 55) was conducted in the laboratory BINANI plant (Table 7). The mixtures were prepared in the presence of M.Ya.Bikbau and VM Nesvetailo. The composition of concrete has been set by M.Ya.Bikbau.

Mix design	Test A	Test B
20 mm (Kg)	7.0	14.0
10 mm	5.5	11.0
0 -5 mm	4.2	8.4
Sand (Kg)	2.7	2.8
Nano 55 (Kg)	5.5	14.0
Water (Kg)	2.0	3.8
Additives	0	0
slump (retention of concrete mix)		
The original	no slump	200 mm
30 min	230 mm	-
60 minutes	220 mM	-
90 minutes	210 mM	-
120 minutes	190 mM	-
compression strength (MPa)		
1 day	24.84	31.55
2 days	40.37	44.15
3 days	50.76	53.28
7 days	58.83	61.21
28 days	67.91	71.58

Tests have shown excellent workability of concrete mixtures on the basis of Nano Cement 55 (containing only 55% Portland cement) without the use of chemical additives, quick-high-strength concrete class B 55 were obtained.

Testing concrete at other enterprises in Dubai

An industrial batch of Nano Cement 55 was sent in the amount of several hundred tons to various ready mix companies in Dubai with a purpose to test it in different concrete products.



Figure 5. Representatives of Moscow IMET and DUCAN company (production of pavement blocks). From left to right: from DUCAN- B.Ogunmola, R&D Department, Dr. Mohammed Al-Farhan, Managing Director, from Moscow IMET - M.YA Bikbau, Director General, E.Campbell, Director of Communications, IA Lisakov, Engineer.

Nano Cement was used for the production of vibro-compressed building blocks at the Ducon Block Factory.

Testing concrete at Safe Mix, Dubai

Nano Cement 55 was tested at Safe Mix, Dubai. Two concrete mixtures with non-metallic fillers (design proposed by Safe mix) were prepared. Mobility of the mixture and concrete strength at standard periods of hardening were determined (Table 8)

Table 8

Design and properties of concrete mixtures; concrete strength on the basis of industrial production of Nano Cement 55 BINANI.

Ref No-	SMJ/ALT/01/13	Trial Mix Form						
Issue Dat:	02.05.2013							
Rev:-	1							
Date:	21/1/2016					Time	10:30 AM	
Lab Trial No ()		Plant Trial No ()		Location			
Contractor : M/s.	NANO CEMENT TRIAL							
Contractor : M/s.	0							
Project :	0							
Mix Class :	C40/50	Cement Type :	OPC (NANO)	W/C	0.28			
Specific Slump :	200 ± 30	mm		Max Limits :	3.00%			
Add1(kg)/M ³ :		Add2(kg)/M ³ :		Add. 1 Type :				
Add2(kg)/M ³ :		Add1(kg)/.03M ³ :						
			0.035	0.035	0.035	0.035		

	Cement(Shj)	M.S.	GGBS(Shj)	Water(L)	3/4' (Kg)	3/8' (Kg)	3/16' (Kg)	D.S(Kg)
Source					R.A.K	R.A.K	R.A.K	Al Dhaid
Dry/1m ³	380			114	624	457	561	437
Dry/.03m ³				3.99	21.84	15.995	19.635	15.295
Moist. %								
Absorp. %								
Correction								
Correct.Q.	11.4			3.272	18.645	13.655	16.694	13.253

Ambient Temperature:

D.O.No :

Slump & Temperature Test

Slump No	Duration(min)	Cube No:- 116	Cube No:- 117
1	0.00	215	220
2	30.00	215	210
3	60.00	210	210
4	90.00	200	190
5	120.00	190	190

Cube Test Requirement

Serial No	No Of Specimen	Test Description	Age Requirement	CUBE NO 116	CUBE NO 117
1	1-2	Strength	3 days	29.7, 30.2	28.4, 29.0
2	2-3	Strength	7 days	47.0, 47.9	46.9, 47.5
3	3-4	Strength	28 days	56.5, 57.2	56.4, 58.1

Remarks:

Cube 116, 117 - Nano Cement 55, No ad mixtures 0.28 w/c

NANO CEMENT TRIAL



Testing concrete at Dubai Ready Mix Company, Dubai

Dubai Ready Mix, is one of main players of Dubai concrete market. They have supplied concrete for such projects as Burj Kalifa - the tallest building in the world and the main attraction of Dubai and the UAE.

Dubai Ready Mix as well as other ready mix companies use expensive chemical additives and silica fume. OAO Moscow IMET suggested to obtain high-strength concrete with non-metallic fillers without chemical additives on the basis of Nano Cement 55. About 200 tons of Nano Cement 55 produced at BINANI was delivered to the ready mix plant for testing.

The composition of concrete mix based on Nano Cement 55 and non-metallic fillers was proposed by M.Ya.Bikbau and is presented in Table 9. As seen from the figures the concrete mix has good mobility and its persistence over time, which is very important for the conditions of transporting concrete in the United Arab Emirates - a country with a very hot climate.

No chemical additives were used in concrete mixtures. High early strength was achieved: 3 day compressive strength of concrete specimens was 45.7 MPa, and in 28 days of normal hardening, compressive strength reached - 72.3 MPa, that is concrete of class B 60 on Nano Cement 55 (actual content of Portland cement is 55% by weight that is a total of 209 kg). In this case, the concrete mix does not contain expensive silica fume, which is normally added at 10-15% by weight for this class of concrete, let alone expensive chemical additives.

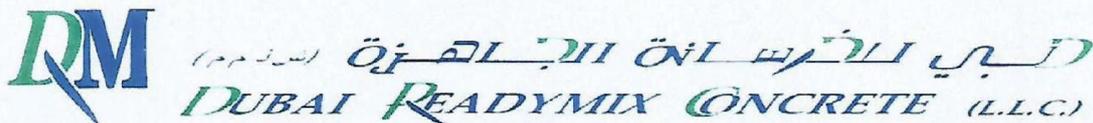
KEY FINDINGS:

1. Industrial testing of Nano Cement technology on the existing production line at BINANI showed the fundamental possibility of implementing a new technology on existing lines of Portland cement grinding, achieving significant reduction in specific energy consumption, CO₂ emissions, production cost savings.

2. Testing Nano Cements at various ready mix plants confirmed the high technical properties of Nano Cements and concrete on their basis.

Table 9

Composition and properties of the concrete mix and concrete on the basis of industrial production of Nano Cement 55 BINANI.



TRIAL MIX REPORT

BS EN 206-1, BS EN 12350-2,6,7, BS EN 12390-2,3,7,8, BS EN 1881 -122,208, ASTM C403/C 403M ASTM 1202

Descriptonal Detail:

Date : 25-01-2016 Time:
 Reference No:
 Client/Contractor: Binani Cements
 Mix Details: Internal testing of ~~the~~ Nano Cement

Mix Proportions:

Cement	15.0
GGBS/FA	—
MS	—
Water	4.2
20 mm	11.0
10 mm	12.0
0-5 mm	9.0
Dune Sand	3.0
Sp432	—
RP 264	—

Fresh Properties:

Density(EN 12350 -6):	—
Air Content(BS EN 12350 -7) :	—
Bleeding :	nil.
Intial Slump	220
30Min	220
60Min	190
90 Min	—
120min	—

Hardened Concrete :

AGE Days	Density (Kg/m3)	Strength (N/mm2)
03	2510	45.7
07	2460	56.7
28	2490	72.3

Durability Test:

RCP	—
Water Absorption	—
Water penetration	—
ISAT	—

Remarks:

04 Cubes Cast for testig
Lab Trial

Conducted By:

Rep: from Russia.

(Name, Sig, Date)

Approved By:

[Signature]

(Name, Sig, Date)