International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 11 | Nov -2017 www.irjet.net p-ISSN: 2395-0072

Experimental Study on Various Strength of High Performance Concrete by Using Metakaolin and Nano-Silica

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Abstract - *Concrete is a widely used construction material, consumes natural resources like lime, aggregates, water. In this present investigation there is replacement of composite concrete material with industrial wastes in the present investigation, a study has been made for the development of high performance concrete using mineral admixture such as Metakaolin and Nano-silica as feasibility made to know the strength on Concrete. The mix proportion is arrived from 0%, 10%.20% and 30% of cement is replaced with Metakaolin. Different water binder ratio of 0.275,0.325 and 0.375 and aggregate binder ratio of 2.0 is used, In this connection series of concrete cubes of size 100x100x100 ,cylinders of 200x100 and beams of 100x100x500 size were cast with various mix proportions and were cured for 7 and 28 days .The cured specimens are tested for getting strength characteristics of concrete.*

Key Words: Nano-silica, Metakaolin, super plasticizers, strength property.

1. INTRODUCTION

Cement is one of the important components of concrete. The production of Portland cement is not only costly and energy intensive, but it also produces large amount of carbon emission. Hence to reduce consumption of cement, the application of Pozzolana materials is increasing day-by-day in the form of partial replacement for concrete preparation. It is considered most efficient by using this Pozzolana's for making concrete, thus improve the strength and durability properties of the concrete. Cement is one of the main constituents of concrete and its main product of hydration is C-S-H is of Nano structure.Metakaolin is used as partial replacement substance for cement in concrete, it reacts with Ca(OH)2 one of the by-products of hydration reaction and results in additional C-S-H gel leading to increase in strength properties of concrete. By partial replacements of Metakaolin to concrete not only reduces CO2 emission into atmosphere during production of cement but also increase the service life of the buildings.

Nano-Silica, a new pozzolanic material produced. Impermeability and strength characteristics of concrete can be improved by using Nano-silica.

In this paper, our attempt has been made to study the effect of combined application of Metakaolin and Nano-Silica on various strength properties of concrete with different W/C ratio for concrete mix.

1.1 2. Objective

The present experimental investigation is to obtain the influence of application of Metakoalin and Nano-Silica on various strength properties of High Performance concrete. Combination of 0%, 10%, 20% and 30% of Metakoalin and 1.5%, 3%, and 4.5% of Nano-Silica compressive strength, tensile strength and flexural strength tests were performed on concrete specimens and results were compared with normal concrete.

2. LITERATURE REVIEW

Xia Oquian and Zongjinli (2001)56 studied the stress–strain relationships of concrete containing 0% to 15% of Metakaolin at an incremental rate of 5%. They concluded that incorporation of Metakaolin up to 15% has increased the tensile and compressive strength.

Badogiannis.E et al (2004) evaluated the effect of Metakaolin on concrete. Eight mix proportions were used to produce HPC, where Metakaolin replaced either cement or sand of 10% or 20% by weight of the control cement content. The strength development of MK concrete was evaluated using the efficiency factor (k value). The replacement with cement gave better results than that of sand. When Metakaolin replaced cement,its positive effect on concrete strength generally started after 2 days where as in case of sand it started only after 90 days. Both Metakaolin exhibited very high k-values (close to 3.0 at 28 days) .

Nabil M. Al-Akhras (2005) replacing cement with Metakaolin to find out the durability of concrete against sulphate attack. 5,10 and 15% replacements of cement with Metakaolin with water cement ratio of 0.5 and 0.6. After the specified days, the samples were immersed in 5% sodium sulphate solution for 18 months. The effect of Metakaolin addition proved to be beneficial in improving the resistance of concrete to sulphate attack. Metakaolin with water cement

ratio of 0.5 exhibited better results in sulphate resistance than 0.6.

Murali.G and Sruthee P(2012) experimentally studied the use of Metakaolin as a partial replacement substance for cement in concrete. The optimum level of replacement was reported as 7.5%. The result showed that 7.5% of Metakaolin increased the compressive strength of concrete by 14.2%, the split tensile strength by 7.9% and flexural strength by 9.3%.

Dr. D. V. Prasad and S. Venkata Maruthi (2016) revealed in the paper that Metakaolin and Nano-Silica are used as fractional substitute for cement for the preparation of concrete. In this current study initially cement is replaced by Meta kaolin 5%, 10% by weight. Further investigation carried out by combined replacement of Meta kaolin at 5% and 10% with Nano-Silica at 1%, 2% and 3% by weight of cement. According to the hardened properties like compression, split tensile and flexural strength, it can be observed that concrete prepared with a combination of 5% MK and 2% NS indicated increased strength compared to the conventional concrete. The improve in the strength properties of concrete is suitable to the accessibility of additional binder in the presence of MK and NS.

3. MATERIALS

1. **Cement (OPC):** Ultratech 43 grade cement with specific gravity 3.09.
2. **Coarse aggregates:** crushed stones from local quarry with size 20mm and 10mm which retained on 12.5mm sieve. The weight of the coarse aggregate was 60% of the total aggregate and specific gravity of coarse aggregate was 2.65.
3. **Fine aggregates:** sand from Local River which passing through 4.75 mm and its specific gravity was 2.60.
4. **Nano-silica:** The Nanomaterials used in our project was amorphous in nature obtained from ASTHRA CHEMICALS, Chennai. Its size 17 nm and specific gravity varies from 2.3 to 2.4.
5. **Metakaolin:** the kaolin material used in our project was purchased from SHRI RAM MINERALS, Ahmadabad. Its specific gravity was 2.60.
6. **Super plasticizers:** to improve the workability and the consistency of mix, water reducing chemical admixtures CONPLAST SP 430 DIS (sulphonated naphthalene formaldehyde) is used.
7. **Water:** locally available water, whose specific gravity is assumed to be 1.0.

4. DESIGN MIX

In our study the mix design is based on the absolute volume method, following are the 0.275,0.325 and 0.375 w/c ratio with 2.0 aggregate-binder ratio

Table 1: Simple materials calculation of concrete for 0.275 water/cement ratio in per cum

C* %	MK * %	NS * %	Water Ltrs	C* kgs	MK* kgs	NS* kgs	CA+FA * Kgs
100	0	0	205.9	748.7	0	0	1497.4
98.5	0	1.5	206.6	740.2	0	10.8	1502.8
97	0	3	207.4	731.6	0	21.6	1508
95.5	0	4.5	208.2	722.9	0	32.3	1513
90	0	0	204.97	671	74.5	0	1490.6
88.5	10	1.5	205.7	662.0	74.80	3.08	1496
87	10	3	206.5	653.2	75.08	6.2	1501.5
85.5	10	4.5	207.22	644.28	75.35	9.32	1507
80	20	0	204.1	593.62	148.4	0	1484
78.5	20	1.5	204.79	584.6	149.9	3.07	1489
77	20	3	205.54	575.52	149.48	6.2	1494
75.5	20	4.5	206.29	566	150	9.3	1500
70	30	0	203.15	517.12	221.6	0	1477
68.5	30	1.5	203.88	507.86	222.42	3	1483
67	30	3	204.67	498.54	223.23	6.13	1488
65.5	30	4.5	205.3	489.15	224	9.24	1493

Table 2- : Simple materials calculation of concrete for 0.325 water/cement ratio in percum

C* %	MK * %	NS * %	Water Ltrs	C* kgs	MK* kgs	NS* kgs	CA+FA* Kgs
100	0	0	234.54	721.67	0	0	1443.35
98.5	0	1.5	235.37	713.35	0	3.53	1448.44
97	0	3	236.205	704.98	0	7.08	1453.56

95.5	0	4.5	237.044	696.54	0	10.66	1458.72
90	0	0	233.53	646.710	71.85	0	1437.12
88.5	10	1.5	234.35	638.16	72.10	3.515	1442.17
87	10	3	235.18	629.56	72.36	7.05	1447.25
85.5	10	4.5	236.01	620.89	72.619	10.62	1452.3
80	20	0	232.34	572.38	1423.09	0	1430.96
78.5	20	1.5	233.34	563.62	143.59	3.5	1435.97
77	20	3	234.16	550.79	144.10	7.02	1441
75.5	20	4.5	234.98	545.89	144.60	10.57	1446.1
70	30	0	231.54	498.701	213.72	0	1424.86
68.5	30	1.5	232.34	489.71	214.473	3.48	1429.8
67	30	3	233.158	480.66	215.223	6.995	1434.82
65.5	30	4.5	233.975	471.55	215.97	10.529	1439.83

5. METHODOLOGY

From this experiment, initially cement is replaced by Nano-Silica 1.5%, 3% and 4.5% by weight. Further investigation carried out by combined replacement of Metakaolin at 10%, 20% and 30% with Nano-Silica at 1.5%, 3% and 4.5% by weight of cement. Aggregate binder ratio of 2 and water/cement ratio of 0.275, 0.325 and 0.375 with different dosage of super plasticizers by keeping the slump constant (true slump) are used in this research. Meta kaolin is mixed in dry condition, whereas mixing of Nano-silica are in two forms. Firstly half Nano-Silica is mixed with super plasticizer water solution; the other half can be mixed with fine aggregates because of small sized particles. Mix design is calculated from absolute volume method and same data are used to make mix in the field. To test the workability and consistency of concrete,

Slump test are conducted in the field before mould is filled. compression test for cubes 100mm×100mm×100mm, flexural test for cylinders 200mm height 150mm diameter and tensile test for prisms 100mm×100mm×500mm as per IS standards. Strength tests are evaluated for testing after 7 and 28 days curing respectively, Corresponding readings are noted down and compared with the normal conventional concrete and for same values graph is plotted.

Fig1: Portion mixing of Nano-Silica with super plasticizer, water and fine aggregate.

6. ANALYSIS AND TEST RESULTS

Compressive strength: It is one of the important and valuable properties of concrete.

Table-3: Compressive Strength of high performance concrete containing Metakaolin of 0% ,10%, 20% and 30% With Nano-Silica of 0%,1.5%, 3% and 4.5%

0%Admixture	7 days Compressive strength in MPA			28 days Compressive strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	49.97	48.11	46.22	61.33	59.33	56.73
1.5% NS	55.33	52.84	50.32	66.67	61.22	59.06
3% NS	57.42	54.22	52.74	69.56	66.08	61.16
4.5% NS	59.77	56.44	54.07	70.14	68.45	65.82
10% Adm	7 days Compressive strength in MPA			28 days Compressive strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375

0% NS	58.33	55.76	54.92	71.44	68.33	66.08
1.5% NS	65.55	63.66	61.02	81.82	78.12	74.32
3% NS	67.88	64.08	63.55	84.12	82.77	78.77
4.5% NS	69.11	66.11	65.18	86.27	84.33	81.05
20% Adm	7 days Compressive strength in MPA			28 days Compressive strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	48.82	46.77	45.08	59.08	56.22	55.08
1.5% NS	52.11	48.55	46.22	62.11	59.85	56.32
3% NS	54.02	51.07	48.77	65.55	61.77	59.13
4.5% NS	57.77	53.77	50.48	68.06	64.52	62.82
30%Adm	7 days Compressive strength in MPA			28 days Compressive strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	44.08	42.52	39.82	57.92	56.55	54.52
1.5% NS	46.77	43.44	42.77	59.08	57.77	55.44
3% NS	49.33	45.72	44.66	61.08	59.11	56.83
4.5% NS	52.08	48.81	46.33	63.55	60.63	57.04

Tensile strength: The prism is normally tested to recognize the bending performance of the hardened concrete.

Table-4: Split Tensile Strength of high performance concrete containing Meta kaolin of 0%, 10%, 20% and 30% With Nano-Silica of 0%, 1.5%, 3% and 4.5%.

0% Admixture	7 days Tensile strength in MPA			28 days Tensile strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	4.36	4.13	3.95	5.66	5.22	4.66
1.5% NS	4.62	4.32	4.11	6.44	5.55	5.07
3% NS	4.94	4.52	4.33	6.93	6.3	5.44
4.5% NS	5.92	4.93	4.55	7.33	6.92	6.22
10% Adm	7 days Tensile strength in MPA			28 days Tensile strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	5.33	4.63	4.44	6.13	5.48	4.83
1.5% NS	5.77	5.11	4.72	7.05	6.44	5.84
3% NS	6.11	5.55	5.08	7.62	6.88	6.22
4.5% NS	7.22	6.83	5.62	7.84	7.42	6.66
20% Adm	7 days Tensile strength in MPA			28 days Tensile strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	4.33	4.08	3.72	5.33	4.72	4.44
1.5% NS	4.55	4.32	3.94	5.92	5.11	4.72
3% NS	4.82	4.46	4.11	6.36	5.92	5.04
4.5% NS	5.31	4.62	4.33	6.92	6.43	5.62
30% Adm	7 days Tensile strength in MPA			28 days Tensile strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	3.92	3.65	3.33	4.82	4.38	3.77
1.5% NS	4.28	3.93	3.62	5.33	4.62	4.12
3% NS	4.55	4.11	3.84	5.92	5.13	4.64
4.5% NS	4.82	4.33	4.04	6.44	5.75	5.11

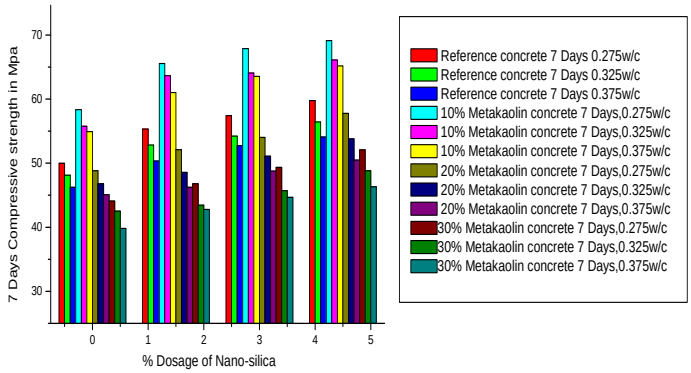
Flexural strength : Tensile strength is one of the simple and significant properties of concrete.

Table-5: Split flexural Strength of high performance concrete containing Meta kaolin of 0%, 10%, 20% and 30% With Nano-Silica of 0%, 1.5%, 3% and 4.5%.

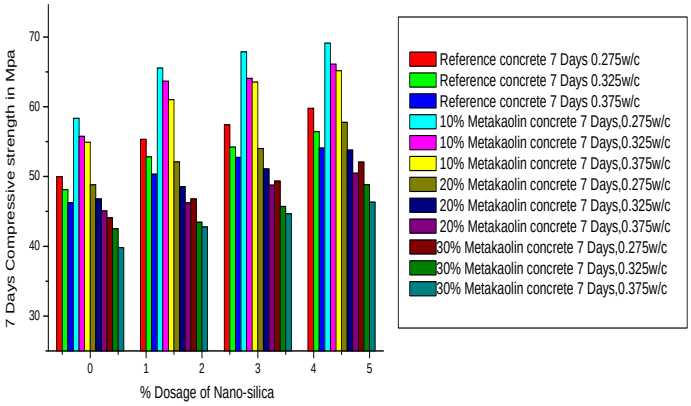
0% Admixture	7 days Flexural strength in MPA			28 days flexural strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	7.46	6.92	6.72	13.44	12.92	12.62
1.5% NS	8.22	7.42	6.94	15.33	14.44	12.84
3% NS	8.84	8.04	7.44	15.33	15.02	13.06
4.5% NS	9.26	8.66	8.06	16.27	15.44	14.66
10%Adm	7 days Flexural strength in MPA			28 days flexural strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	8.22	7.86	7.55	14.84	13.56	13.22
1.5% NS	9.14	8.22	7.76	16.36	14.66	14.06
3% NS	9.52	9.04	8.08	16.88	15.88	14.62
4.5% NS	9.98	9.33	8.92	17.33	16.78	16.22
20%Adm	7 days flexural strength in MPA			28 days flexural strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	7.26	6.88	6.52	12.36	11.98	11.88

1.5% NS	7.77	7.16	6.77	13.77	12.33	11.96
3% NS	8.22	7.55	6.98	14.66	13.44	12.22
4.5% NS	8.64	7.88	7.55	15.22	14.52	13.04
30%Adm	7 days flexural strength in MPA			28 days flexural strength in MPA		
W/C	0.275	0.325	0.375	0.275	0.325	0.375
0% NS	6.72	6.33	6.46	12.22	11.77	11.06
1.5% NS	7.68	6.92	6.72	12.66	12.22	11.77
3% NS	6.82	7.22	6.88	13.14	12.55	12.06
4.5% NS	8.11	7.42	7.06	13.96	13.04	12.55

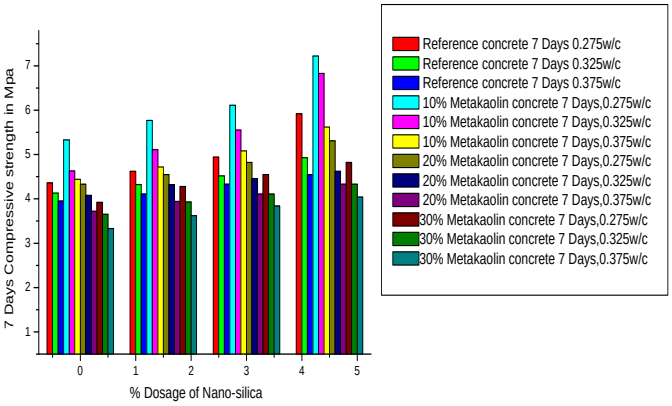
Graph-1: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 7 days Compressive strength with 0.275.0.325 and 0.375 w/c ratio



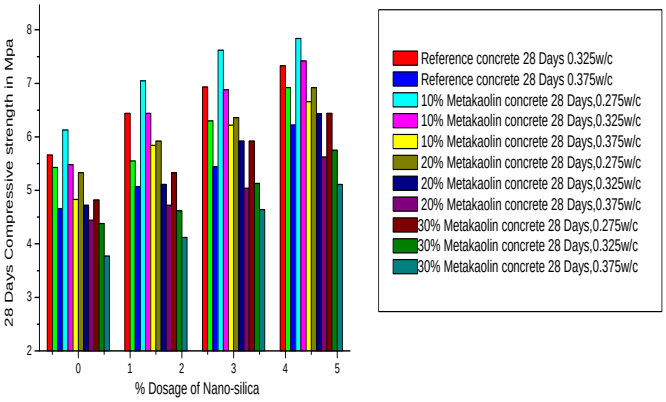
Graph-2: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 28 days Compressive strength with 0.275, 0.325 and 0.375 w/c ratio.



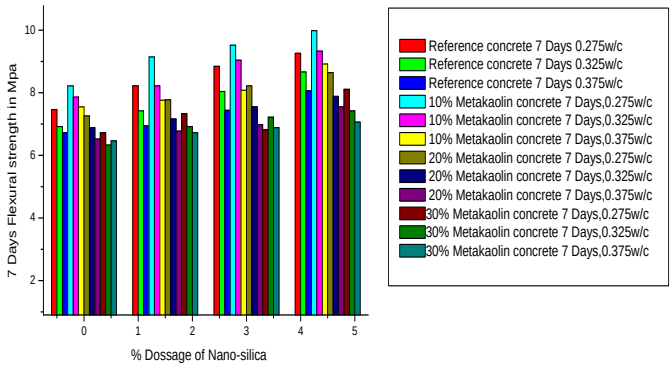
Graph-3: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 7 days Split tensile strength with 0.275, 0.325 and 0.375 w/c



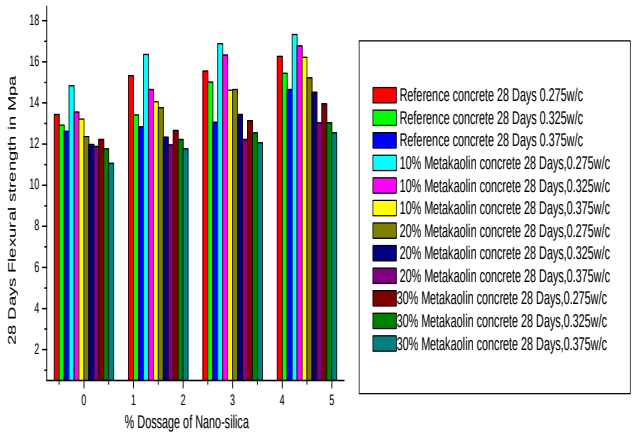
Graph-4: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 28 days Split tensile strength with 0.275, 0.325 and 0.375 w/c ratio.



Graph-5: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 7 days flexural strength with 0.275, 0.325 and 0.375 w/c ratio.



Graph-6: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 28 days flexural strength with 0.275, 0.325 and 0.375 w/c ratio.



3. CONCLUSIONS

Based on the current experimental investigation the following conclusions can be observed

1. The strength of the HPC is observed to be increased in appended with Metakaolin and Nano-silica.

2. The strength of HPC decreases with increases in water cement ratio.

3. The compressive strength of HPC increases with increases in percentage of Nano- silica .It is observed that at 7 days the increase in strength is 10.72%,14.90% and 19.61% at 1.5%,3% and 4.5% of Nano-silica. For 28 days the increase in strength is 8.7%, 13.42% and 14.36% at 1.5%,3% and 4.5% of Nano-silica respectively.

4. The compressive strength of HPC increases with increases in percentages of Metakaolin admixture upto 10% and further increased in Metakaolin decreases the strength.

5. At 10% Metakaolin the 28 days compressive strength observed is 86.27N/mm2 at 4.5% of Nano-silica .At 20% of Metakaolin the strength decreases to 68.06N/mm2.

6. The increase in percentages of Compressive strength at 0%, 1.5%.3% and 4.5% of Nano-silica with 10% Metakaolin is 16.48%, 33.41%, 37.15% and 40.66% respectively.

7. The Split tensile strength of HPC increases with increases in percentages of Nano-silica. It is observed that 7 days the increases in strength is 5.96%, 13.3% and 35.77% at 1.5%,3%.4.5% of Nano-silica. For 28 days the increases in strength is 13.78%, 22.45% and 29.50% at 1.5%,3% and 4.5% of Nano-silica respectively

8. The Split tensile strength of HPC increases with increases in percentage of admixture Metakaolin upto 10% .Further increases in Metakaolin decreases the strength.

9. At 10% Metakaolin the 28 days strength observed is 7.84 N/mm2 at 4.5% of Nano- silica .At 20% of Metakaolin the strength decreases and it is 6.92 N/mm2..

10. The increase in Split tensile strength of HPC at 0%, 1.5%, 3% and 4.5% of Nano-silica With 10% Metakaolin is 8.30%, 24.55%, 34.62 % and 38.51% respectively.

11. The Flexural strength of HPC increases with increase in percentages of Nano-silica. It is witnessed that 7 days the increases in strength is 10.18%,18.49% and 24.13% at 1.5%,3% and 4,5% of Nano-silica .For 28 days the increases in strength is 14.06%,15.69% and 21.05% at 1.5%,3% and 4.5% of Nano-silica respectively.

12. The Flexural strength of HPC increases with increase in percentages of admixture Metakaolin upto 10%.Further increase in Metakaolin decrease the strength.

13. At 10% Metakaolin the 28 days strength observed is 17.33N/mm2 at 4.5% of Nano-silica. At 20% addition the strength decrease and it is 15.22% N/mm2.

14. In overall the Metakaolin admixture at 10% is observed High strength'

ACKNOWLEDGEMENT

I am thankful to my guide, Dr. H. M. Somasekharaiah, Professor, Department Civil Engineering and Mrs. Pushpalatha R Gadag, Assistant Professor, Department Civil Engineering for their guidance and constant encouragement. Also I thank my parents, friends for their continuous support in making this work complete.

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[15] Effect of Nano-silica on the compressive strength of concrete by satyajit parida NIT Rourkel

BIOGRAPHIES

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