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Study on strength properties of high performance concrete using Meta kaolin and Nano-silica as admixtures

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Abstract - *Concrete is the most used universal element or ingredients among all other building materials. Certain admixtures are used along with the cement to overcome the strength, durability, toughness, low permeability and resistance to chemical attack. The aim of this study is to compare the mechanical properties of (Meta kaolin, Nano-silica) combination with nominal concrete. The adding percentage of Nano-silica will be in the range of 1.5%, 3% and 4.5% partial replacement of cement by weight. The percentage of Meta kaolin will be in the range of 0%, 10%, 20% and 30% partial replacement of cement by weight. Different water binder ratio of 0.3, 0.35 and 0.4 and aggregate binder ratio of 2.5 are used. Optimum strength will be observed at 10% of Meta kaolin and 4.5% Nano-silica admixtures in (Meta kaolin, Nano-silica) combination will generate moderately better results compared to nominal conventional concrete. The fresh concrete properties are slump cone tests, and hardened concrete tests are compressive strength, split tensile strength, flexural strength are studied and evaluated at 7 days and 28 days respectively.*

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

1. INTRODUCTION

The concrete which consists of two or more admixtures possess high durability, high strength, high density, low permeability and resistance to chemical attack when compared to conventional concrete is termed as HPC. For the normal conventional concrete, water/cement ratio required is 0.30 to 0.50. Whereas high performance concrete requires 0.30 to 0.45 water/cement.

In the concrete, cement chemically reacts with water and produces binding gel that binds other component together and creates stone type of material. The reaction process is called 'hydration' in which water is absorbed by the cement. In this process apart from the binding gel, some amount of lime [Ca (OH)] is also liberated. The coarse and fine aggregates act as filler in the mass. Hydration process of cement is exothermic and large amount of heat is liberated. Higher will be the cement content greater will be the heat liberation leading in distress to concrete. The high-grade cements have been developed by changing the ratio of mineralogical constituents of the cement particularly by increasing the ratio of Tricalcium Silicate (C_3S) to Dicalcium Silicate (C_2S) and increasing the fineness of the cement. Actually, these changes have resulted in high early strength rather than high strength cement. The hydration products from C_3S and C_2S are similar but quantity of calcium hydroxide (lime) released is higher in C_3S as compared to C_2S, so The high-grade cement which has high C_3S, releases higher amount of surplus lime resulting in higher porosity in the concrete mass. To overcome the above problem minimum percentage of cement replaced by industrial waste and low cost mineral admixtures such as Fly ash, Meta kaolin, GGBS, Fibers, and Nano-silica.

2. LITERATURE REVIEW

Sayed ABD EL-BAKY, Sameh YEHIA, Ibrahim S. KHALIL in Nanocon (2013) explains that the addition of 1, 3, 5, 7 and 10% of Nano-silica size 19nm in cement by weight content increases the workability and strength property and percentage of 7% of Nano-silica is record as best percentage. Thus the improvement in strength property is calculated as 55.7% and 46.9% in that order, compare with the normal concrete, mainly at premature age.

Hongxia Yang results show that bending tensile strength and shrinkage increases when required quantity of nanomaterials (Nano-Silica) with size 9-19nm comes in contact with the ordinary Portland cement. The addition percentage of Nano-Silica will be in the range of 0.5%, 0.75%, and 1%. The bending tensile strength is evaluated at 28 days after curing. Observes that at 0.75% dosage of Nano-silica will gives optimum strength compare to other ns percentage mix.

Yogesh R. Suryawanshi, Amar G. Kadam, Sagar S. Ghogare, Ramrao G. Ingale, Priyanka L. Patil (2015) study investigates the effects of Meta kaolin & Super plasticizer on strength properties of M-35 grade concrete. The experimental program is designed to find the compressive strength of concrete by partially replacing the

cement in concrete production. The replacement levels of cement by Meta kaolin are selected as 4%, 8%, 12%, 16% and 20% for constant water/cement ratio of 0.43. For all mixes compressive strength is determined at 3, 7, 28 days for 150 X 150 X 150 mm size cubes. Current experimental study shows that 12% replacement of cement by Meta kaolin gives higher strength.

Dr.K.Srinivasu, M.L.N.Krishna Sai, Venkata Sairam Kumar.N (2014) this paper deals with the use of Meta kaolin which is having good pozzolanic activity and is a good material for the production of high strength concrete. This is getting popularity because of its positive effect on various properties of concrete. Due to its pozzolanic action increases strength and durability properties of concrete. In observation an analysis was done in utilization of Meta kaolin in concrete as a partial replacement material to cement say 10%, 15% which has given excellent results.

Dr. D. V. Prasad and S. Venkata Maruthi (2016) revealed in the paper that Meta kaolin 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.

H. R. Sobhani Kavkani, A. R. Mortezaei and R. Naghizadeh (2016) to obtain high performance concrete different mineral admixtures like Meta kaolin, silica fume and Nano-silica were used. Two different types of sand were used grain size of 0.015-4mm were mixed with Portland cement type II, super plasticizers used is polycarboxylate, mineral admixture with 650kg/m^3 cement content and 0.35 w/c ratio. The amount of cement content was replaced Meta kaolin or silica fume by (5-15wt %) or Nano-silica by (0.8wt %). The max compressive strength of 28 days samples were 76MPa, 79MPa and 75MPa for 15% replacement of cement with Meta kaolin, silica fume and 5% with Nano-silica. The compressive strength of these samples showed 28%, 33% and 26% increase in comparison with reference sample.

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). Meta kaolin: 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 0.30, 0.35 and 0.40 w/c ratio with 2.5 aggregate-binder ratio

Table- 1: Simple materials calculation of concrete for 0.3 water/cement ratio in percum

C* %	MK* %	NS* %	Water Ltrs	C* kgs	MK* kgs	NS* kgs	CA+FA* Khs
100	0	0	217.2	724.0	0	0	1448.1
98.5	0	1.5	217	712.5	0	10.8	1446.7
97	0	3	216.7	700.9	0	21.6	1445.3
95.5	0	4.5	215.7	695.6	0	32.3	1438.5
88.5	10	1.5	216.3	638.3	72.1	10.8	1442.5
87	10	3	216.1	626.9	72.1	21.6	1441.1
85.5	10	4.5	215.9	615.4	71.9	32.3	1439.7
78.5	20	1.5	215.7	564.5	143.2	10.7	1438.4
77	20	3	215.5	553.2	143.7	21.5	1437.0
75.5	20	4.5	215.3	541.9	143.5	32.3	1435.6
68.5	30	1.5	215.1	491.2	215.1	10.5	1434.2
67	30	3	214.9	480.0	214.9	21.4	1432.9
65.5	30	4.5	214.7	468.8	214.7	32.2	1431.5

Table-2: simple materials calculation of concrete for 0.35 w/c ratio in percum

C* %	MK* %	NS* %	Water Ltrs	C* kgs	MK* kgs	NS* kgs	CA+FA* Khs
100	0	0	216.9	619.13	0	0	1547.83
98.5	0	1.5	216.5	609.33	0	9.27	1546.53
97	0	3	216.3	599.55	0	18.54	1545.25
95.5	0	4.5	215.1	589.76	0	27.79	1543.96
88.5	10	1.5	215.9	546.13	61.71	9.25	1542.64
87	10	3	215.8	536.43	61.65	18.49	1541.45
85.5	10	4.5	215.6	526.47	61.60	27.72	1540.18
78.5	20	1.5	215.4	483.23	123.11	9.23	1538.95
77	20	3	215.0	473.60	123.01	18.45	1537.68
75.5	20	4.5	215.0	463.99	122.91	27.65	1536.41
68.5	30	1.5	21.4.9	420.64	184.22	9.21	1535.20
67	30	3	214.7	411.09	184.07	18.40	1533.93
65.5	30	4.5	214.57	401.55	183.92	27.58	1532.66

Table-3: Simple materials calculation of concrete for 0.4 w/c ratio in percum

C* %	MK* %	NS* %	Water ltrs	C* kgs	MK* kgs	NS* kgs	CA+FA* Khs
100	0	0	240.21	600.54	0	0	1500.54
98.5	0	1.5	240.02	591.05	0	9.00	1500.13
97	0	3	239.82	581.58	0	17.98	1498.92
95.5	0	4.5	239.65	572.12	0	26.95	1497.71
88.5	10	1.5	239.45	529.78	59.86	8.97	1496.07
87	10	3	239.25	520.38	59.18	17.94	1495.35
85.5	10	4.5	239.06	511.00	59.79	26.89	1494.15
78.5	20	1.5	238.88	468.80	119.44	8.95	1493.00
77	20	3	238.69	459.47	119.34	17.90	1491.80
75.5	20	4.5	238.49	450.16	119.24	26.83	1490.60
68.5	30	1.5	238.31	408.11	178.73	8.93	1489.47
67	30	3	238.18	398.85	178.59	17.85	1488.27
65.5	30	4.5	237.93	389.61	178.45	26.76	1487.08

5. METHODOLOGY

In this current study initially cement is replaced by Nano-Silica 1.5%, 3% and 4.5% by weight. Further investigation carried out by combined replacement of Meta kaolin at 10%, 20% and 30% with Nano-Silica at 1.5%, 3% and 4.5% by weight of cement. Aggregate binder ratio of 2.5 and water/cement ratio of 0.30, 0.35 and 0.40 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 300mm 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 plot the graph for same.

Fig 1: Types of mixing Nano-silica with super plasticizers water solution and with fine aggregates

6. ANALYSIS AND TEST RESULTS

Compressive strength: The compressive strength of concrete is one of the utmost important and valuable properties of concrete.

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

0% Admixture	7 days compressive strength in MPA			28 days compressive strength in MPA		
W/C	0.3	0.35	0.40	0.30	0.35	0.40
0% NS	47.11	45.55	43.66	58.33	56.16	53.77
1.5% NS	51.88	50.26	47.44	63.11	58.04	55.92
3% NS	54.22	51.33	49.35	65.77	62.78	58.01
4.5% NS	55.77	53.86	50.92	67.15	64.89	62.22
10% Admixture	7 days compressive strength in MPA			28 days compressive strength in MPA		
W/C	0.3	0.35	0.40	0.30	0.35	0.40
0% NS	53.77	51.33	50.22	65.55	62.66	60.46
1.5% NS	60.25	58.64	55.72	75.32	72.74	68.44
3% NS	62.66	59.11	57.33	77.63	75.33	72.64
4.5% NS	63.77	60.88	58.92	79.08	77.11	74.72
20% Admixture	7 days compressive strength in MPA			28 days compressive strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	44.45	42.33	41.06	54.11	51.11	50.27
1.5% NS	46.88	44.22	42.11	56.77	54.55	51.03
3% NS	49.07	46.66	44.06	59.11	56.36	54.11
4.5% NS	52.16	48.77	45.88	62.33	59.04	57.33
30% Admixture	7 days compressive strength in MPA			28 days compressive strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	40.88	39.33	37.06	53.77	52.88	50.33
1.5% NS	43.11	40.44	49.11	55.08	53.11	51.55
3% NS	45.77	42.66	41.44	56.88	54.92	52.77
4.5% NS	48.04	45.22	43.07	59.11	56.33	53.06

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

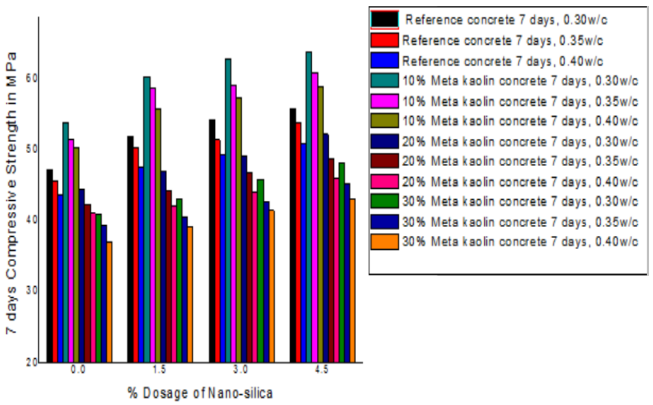
Table-5: Split flexural Strength of high performance concrete containing Meta kaolin of 0%, 10%, 20% and 30% With Nano-Silica of 0%, 1.5%, 3% and 4.5%

0% Admixture	7 days flexural strength in MPA			28 days flexural strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	6.84	6.42	6.11	12.28	11.84	11.42
1.5% NS	7.46	6.78	6.32	13.78	12.14	11.76
3% NS	7.92	7.32	6.67	14.12	13.68	12.02
4.5% NS	8.55	7.84	7.28	14.77	14.12	13.54
10% Admixture	7 days flexural strength in MPA			28 days flexural strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	7.56	7.12	6.78	13.46	12.32	12.04
1.5% NS	8.25	7.45	7.02	14.84	13.32	12.78
3% NS	8.56	8.13	7.32	15.36	14.77	13.26
4.5% NS	9.07	8.45	8.06	15.68	15.22	14.68
20% Admixture	7 days flexural strength in MPA			28 days flexural strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	6.72	6.33	6.02	11.44	11.07	10.88
1.5% NS	7.11	6.55	6.18	12.66	11.33	11.02
3% NS	7.54	6.92	6.42	13.55	12.24	11.26
4.5% NS	8.02	7.26	6.88	14.02	13.43	12.07
30% Admixture	7 days flexural strength in MPA			28 days flexural strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	6.12	5.76	5.92	11.12	10.77	10.12
1.5% NS	6.63	6.28	6.07	11.55	11.12	10.66
3% NS	7.07	6.54	6.22	12.04	11.46	11.04
4.5% NS	7.55	6.77	6.44	12.77	11.92	11.38

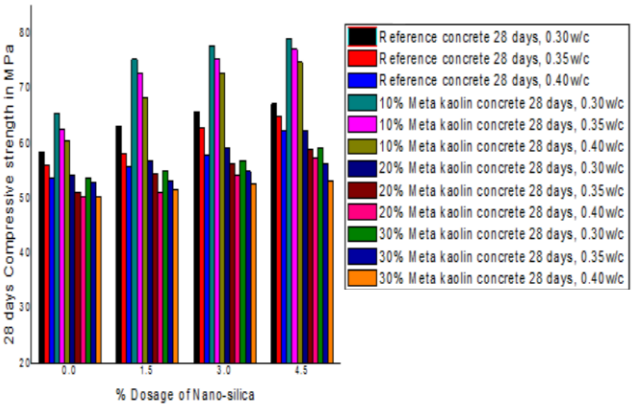
Tensile strength: The prism is normally tested to recognize the bending performance of the hardened concrete.

Table-6: 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%

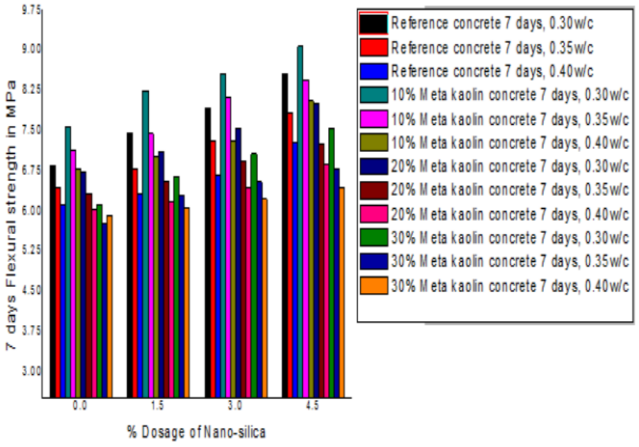
0% Admixture	7 days tensile strength in MPA			28 days tensile strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	4.02	3.82	3.64	5.12	4.78	4.21
1.5% NS	4.24	3.98	3.74	5.88	5.06	4.62
3% NS	4.52	4.16	3.92	6.36	5.72	4.94
4.5% NS	5.49	4.48	4.11	6.72	6.28	5.66
10% Admixture	7 days tensile strength in MPA			28 days tensile strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	4.64	4.17	3.92	5.42	4.88	4.32
1.5% NS	5.11	4.66	4.27	6.33	5.77	5.14
3% NS	5.57	5.02	4.55	6.86	6.11	5.68
4.5% NS	6.44	6.15	4.96	7.11	6.72	6.04
20% Admixture	7 days tensile strength in MPA			28 days tensile strength in MPA		
W/C	0.3 0	0.35	0.40	0.30	0.35	0.40
0% NS	3.98	3.72	3.34	4.88	4.26	3.92
1.5% NS	4.16	3.94	3.55	5.44	4.64	4.27
3% NS	4.42	4.02	3.77	5.82	5.32	4.62
4.5% NS	4.88	4.24	3.92	6.33	5.77	5.11
30% Admixture	7 days tensile strength in MPA			28 days tensile strength in MPA		
W/C	0.30	0.35	0.40	0.30	0.35	0.40
0% NS	3.66	3.44	3.06	4.38	3.92	3.46
1.5% NS	3.94	3.66	3.36	4.92	4.26	3.82
3% NS	4.22	3.77	3.54	5.44	4.76	4.22
4.5% NS	4.44	3.92	3.74	5.93	5.32	4.68



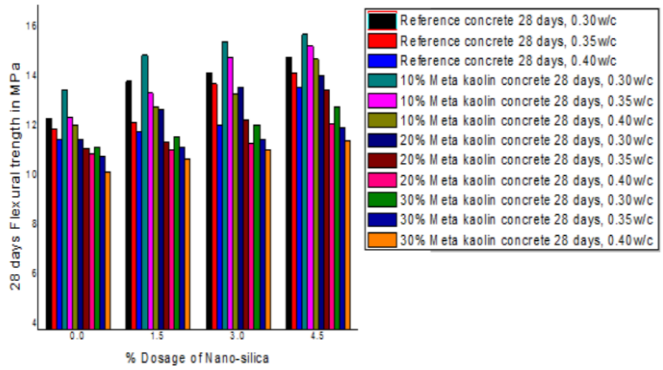
Graph-1: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 7 days Compressive strength with 0.3, 0.35 and 0.4 w/c ratio.



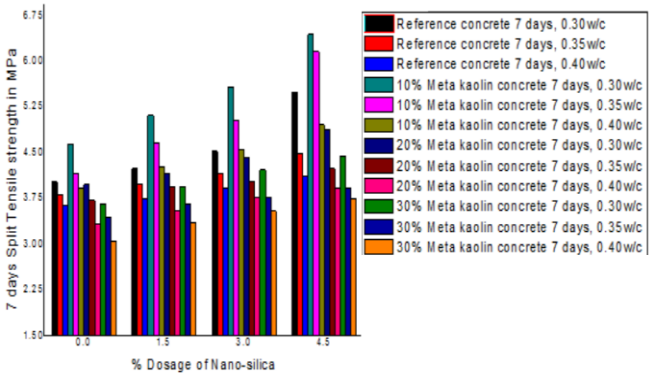
Graph-2: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 28 days Compressive strength with 0.3, 0.35 and 0.4 w/c ratio.



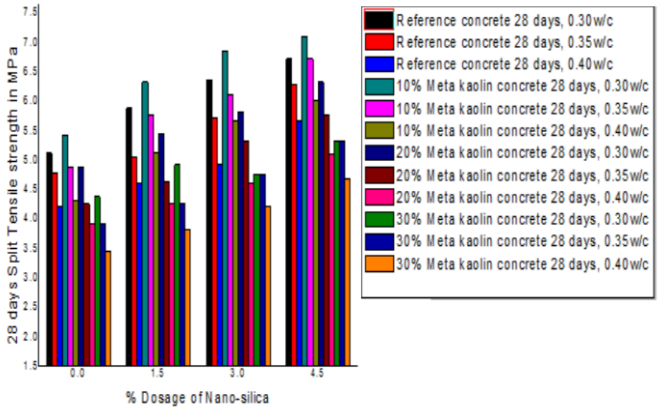
Graph-3: High performance concrete with 0%, 1.5%, 3%, 4.5% of Nano-silica and 0%, 10%, 20%, 30% Meta kaolin, 7 days flexural strength with 0.3, 0.35 and 0.4 w/c ratio.



Graph-4: 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 0.3, 0.35 and 0.4 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 split tensile strength with 0.3, 0.35 and 0.4 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 split tensile strength with 0.3, 0.35 and 0.4 w/c ratio.

7. CONCLUSION

1. The strength of HPC increases with addition of fly ash and Nano-silica.
2. The strength of HPC decreases with increases in w/c ratio.
3. The compressive strength of HPC increases with increase in percentage of Nano-silica. It is observed that at 7 days the increase in strength is 10.12%, 15.09% and 18.38% at 1.5%, 3% and 4.5% of Nano-silica. For 28 days the increase in strength is 8.19%, 12.75% and 15.12% at 1.5%, 3% and 4.5% of Nano-silica respectively.
4. The compressive strength of HPC increases with increase in percentage of Meta kaolin admixture up to 10% and further increase in Meta kaolin decreases the strength.
5. At 10% Meta kaolin the 28 days compressive strength observed is 79.08N/mm^2 at 4.5% of Nano-silica. At 20% addition the strength decreases and it is 63.33 N/mm^2.
6. The increase in percentage of compressive strength at 0%, 1.5%, 3% and 4.5% of Nano-silica with 10% Meta kaolin is 12.33%, 29.12%, 33.08% and 35.57% respectively.
7. The split tensile strength of HPC increases with increase in percentage of Nano-silica. It is observed that 7 days the increase in strength is 5.4%, 12.43% and 36.56% at 1.5%, 3% and 4.5% of Nano-silica. For 28 days the increase in strength is 14.84%, 24.21% and 31.25% at 1.5%, 3% and 4.5% of Nano-silica respectively.
8. The split tensile strength of HPC increases with increase in percentage of admixture Meta kaolin up to 10%. Further increase in Meta kaolin decreases the strength.
9. At 10% Meta kaolin the 28 days tensile strength observed is 7.11N/mm^2 at 4.5% of Nano-silica. At 20% addition the strength decreases and it is 6.33 N/mm^2.
10. The increase in split tensile strength of HPC at 0%, 1.5%, 3% and 4.5% of Nano-silica with 10% Meta kaolin is 5.8%, 23.8%, 33.9% and 38.8% respectively.
11. The flexural strength of HPC increases with increase in percentage of Nano-silica. It is witnessed that 7 days the increase in strength is 9.06%, 15.78% and 25.50% at 1.5%, 3% and 4.5% of Nano-silica. For 28 days the increase in strength is 12.21%, 14.98% and 20.27% at 1.5%, 3% and 4.5% of Nano-silica respectively.
12. The flexural strength of HPC increases with increase in percentage of admixture Meta kaolin up to 10%. Further increase in Meta kaolin decreases the strength.
13. At 10% Meta kaolin the 28 days flexural strength observed is 15.68N/mm^2 at 4.5% of Nano-silica. At 20% addition the strength decreases and it is 14.02 N/mm^2.
14. In overall the Meta kaolin admixture at 10% is observed high strength.
15. Plot the graph for test results 7 and 28 days respectively.

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