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Strength Efficiency Factor for Nano Silica at Different Age

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Abstract: **Concrete is being widely used as a construction material, hence it is necessary to improve its properties. Thease days supplementary cementecious materials are used for enhancement of concrete properties. Use of Nano materials is gaining importance due to its vital characteristics, these materials help in developing high performance concrete[5]. This study aims at determining efficiency factor 'K' for Nano silica. Efficiency factor is the part of supplementary cementecious material in the Nano silica concrete which can be considered as equivalent to Portland cement [3]. The efficiency factor helps in economic mix design of Nano silica concrete. This paper presents the results of an experimental study to evaluate strength of hardened concrete and strength efficiency factor 'K' for Nano silica by replacing the cement by various percentages of Nano silica (0.25% to 2.5% by weight of cement) for M20, M40 concrete at 7 & 28 days of curing. Modified Bolomey equation[3] is used for determination of strength efficiency factor. From this study it can be concluded that the optimum replacement of Nano Silica is 2% and 1.5% respectively for M20&M40 concrete. The mode value of 'K' is 6.0, 6.64 for 7 & 28 days respectively of M20 concrete, similarly 5.83, 5.94 for 7 &28 days respectively of M40 concrete.**

Keywords: **Nano Silica, Strength efficiency factor, Nano Silica concrete, Supplimentery Cementecious Material (SCM).**

1. INTRODUCTION

In recent years variety of blending materials are more widely used to improve the performance of cement concrete [1]. The efficiency factor for Silica fume &Metakoline replaced concrete mixes shows increasing trend as the replacement level is increased up to 10%, where as fly ash replaced mixes shows decreasing trend [2].The Bolomey's emperical expression can be used to predict strength efficiency factor of GGBS & HVFA in concrete mixes at different percentage of replacement levels [3].Nano Silica is one of the blending materials used to improve the properties of concrete. Nano Silica concrete is stickier than normal concrete due to large surface area of Nano Silica, also it has better permeability resistance [4]. The pozzolanic activity of Nano Silica is much better than that of Silica fume [5]. Nano silica consumes calcium hydroxide crystals & improves the interfacial zone [6]. Fly ash has low initial activity but pozzolanic activity significantly increases after incorpating little Nano silica [7]. Compressive strength and strength of mortar with Nano silica particles were all higher than those of mortar containing Silica fume at 7 &28 days [8]. The flexural fatigue performance containing nano particles have excellent flexural fatigue performance compared with plain concrete, in particular at high stress level[9]. It is necessary to know strength efficiency factor for reduction of cement content results in economic mix designs. Hence it is necessary to know the effectiveness of SCM. towards the development of strength and their replacement. This paper discusses the efficiency factor of Nano silica at different percentages of replacement. The percentage replacement is from 0.25 to 2.5 for M20 & M40 concrete.

Research Significance: The aim of this investigation is to determine efficiency of Nano Silica to develop a mix design procedure. K factor describes the efficiency of SCM to act as a cementing material. When K>1, it indicates the SCM used is more efficient than cement, as hydration process is fast compared to OPC. In such a case saving of cement is possible resulting economic mix design of concrete. When K<1, it indicates the SCM used is less efficient than cement as hydration process is slow compared to OPC. In such a case more quantity of SCM should be used to achieve required target strength.

Bolomey's compressive strength equation is $S=A[C/W]+B$.

Where S= Compressive strength of concrete in Mpa
C= Cement content in kg/m^3
W= Water content in kg/m^3
A, B are constants.
For structural concrete the above equation is reduced to
$S=A[C/W-0.5]$
Strength efficiency factor 'K' can be computed using modified Bolomey's equation
$S=A[(C+K*f)/W-0.5]$
Where f is the SCM content replaced by percentage weight of cement .
K is efficiency factor, thus W/(c+K*f) is water to effective binder ratio.By knowing the amount of C, f, W& the strength

achieved for each dosages of SCM, K can be computed. The value of constant 'A' in Bolomey's equation can be found from 7, 28 days compressive strength of M20, M40 concrete in the investigation.

Materials and Properties :

1) Cement: Ordinary Portland cement 43 grade confirming to IS:8112-1989;
Specific gravity is 3.15.

2) Fine aggregate: Locally available natural sand confirming to zone III of IS :383.
Density: 1.6 gm /cc
Specific gravity: 2.7

3) Coarse aggregate: Locally available crushed angular coarse aggregate of maximum
Size 20mm. confirming to IS: 383 grade.
Density: 1.7 gm/cc
Specific gravity: 2.7

4) Water: Potable water confirming to IS:456-2000.

5) Nano Silica:
Purity: 99%
Crystallite size: 1nm
BET surface area : 110 m^2/gm
Density: 0.236 gm/cc
Specific gravity: 0.4

TABLE 1(a): Quantity of materials for 1 cum of concrete. Mix proportion of M20 concrete 1:2.2:4.2

Cement	Fine aggregate	Coarse aggregate	Water	W/C
306 kg	673.2 kg	1285.2 kg	168.3 kg	0.55

TABLE 1(b): Quantity of materials for 1 cum of concrete.

Mix proportion of M40 concrete 1:1.9:2.9

Cement	Fine aggregate	Coarse aggregate	Water	W/C
392 kg	744.8 kg	1136.8 kg	176.4 kg	0.45

Experimental Programme: Initially M20, M40 concrete is prepared as per the mix proportions . Thirty specimens for each mix are cast and tested for 7 and 28 days as per the IS guide lines [10]. From the test results, the constant 'A' in the Bolomey equation can be found for both 7 & 28 days. Similarly compressive strengths for different replacements of Nano Silica is found for both 7 and 28 days. From above test results, the strength efficiency factor 'K' is evaluated using modified Bolomey's equation.

Methodology: To prepare Nano Silica conrete, initially water reducing agent of suitable proportion is mixed in water thoroughly. Then the required quantity of Nano Silica is added to the mix and stirred for two minuites. Cement, sand & coarse aggregate are mixed in pan mixer for five minuites. The mixture of water, water reducing agent & Nano Silica is poured into the pan mixer and rotated for ten minuites to achieve homogeneity. Fresh concrete is tested for workability, then concrete is poured into the cube mould and vibrated, The specimens are kept for 24 hours at room temperature. After demoulding, specimens are immersed in the water tank for curing.

Test Results: Table 2 (a): Lab Test results of M20 concrete

Age (days)	Mean compressive strength (MPa)	Constant A
7	23.63	18.04
28	27.0	20.61

Table 2 (b): Lab Test results of M40 concrete

Age (days)	Mean compressive strength (MPa)	Constant A
7	44.29	25.75
28	48.74	28.33

Table 3: Lab Test results of Nano Silica concrete

Percentage of Nano-Silica	7- days Comp. strength (MPa)		28- days Comp. strength (MPa)	
	M20	M40	M20	M40
0.25	24.41	44.90	27.60	49.41
0.50	24.60	45.60	28.15	50.18
0.75	25.00	46.30	28.60	50.95
1.00	25.50	47.00	29.15	51.72
1.25	25.95	48.11	29.67	53.10
1.50	26.41	49.18	30.20	54.20
1.75	26.50	48.57	30.80	53.80
2.00	27.25	48.40	31.40	53.26
2.25	26.66	47.90	30.50	52.91
2.50	26.50	47.50	30.30	52.40

Table 4: Strength efficiency factor 'K' of Nano Silica

Percentage of Nano Silica	K value for 7-days		K value for 28-days	
	M20	M40	M20	M40
0.25	4.67	4.75	4.90	4.83
0.50	5.63	5.32	5.87	5.36
0.75	5.72	5.45	5.86	5.48
1.00	6.05	5.60	6.20	5.62
1.25	6.14	6.22	6.19	6.45
1.50	6.21	6.60	6.26	6.70
1.75	5.64	5.33	6.43	5.53
2.00	6.19	4.52	6.54	4.53
2.25	4.81	3.74	4.81	3.89
2.50	4.23	3.20	4.23	3.28

Table 5(a): Statistics of strength efficiency factor for M20 Concrete

Days	Mean	Median	Mode	SD
7	5.53	5.68	6.0	0.51
28	5.73	6.03	6.64	0.63

Table 5(b): Statistics of strength efficiency factor for M40 oncrete

Days	Mean	Median	Mode	SD
7	5.07	5.32	5.83	0.99
28	5.16	5.42	5.94	1.00

Discussion on Test Results : Based on the test results . the values of constant 'A' are 18.04 & 20.61 respectively for 7 and 28 days compressive strength of M20 concrete. 25.75, 28.33 respectively for 7 and 28 days compressive strength of M40 concrete. The maximum strength obtained is at 2% replacement of Nano Silica (7, 28 days) for M20 concrete, similarly for M40 concrete maximum strength obtained is at 1.5% replacement of Nano silica(7, 28days). The modified Bolomey equation is considered for evaluating strength efficiency factor 'K'. It is found that the values of 'K' are 6.21 and 6.54 at 1.5, 2.0 percentage of Nano Silica for 7 days and 28 days respectively of M20 concrete. Similarly for M40 concrete the K value is 6.60, 6.70 at 1.5 percentage of Nano silica for 7days &28 days respectively.The variation of strength & strength efficiency factor'K' with percentage of Nano silica is shown in Annexure I &Annexure II.

2. CONCLUSIONS

From this study it can be concluded that the optimum replacement of Nano Silica is 2% and 1.5% respectively for M20 & M40 concrete.

From the results, it can be concluded that the value of K can be considered as 6.0 to arrive economical mix design.

Addition of Nano particles makes concrete more sticky hence, suitable Superplastisizer can be used to achieve required workability.

Due to the addition of Nano Silica, The percentage increase in M20 concrete is 15.31, 16.3 respectively for 7days & 28days, where as in M40 concrete is 11.0, 11.20 respectively for 7days & 28days

ANNEXURE I

Variation of compressive Strength with percentage of Nano silica

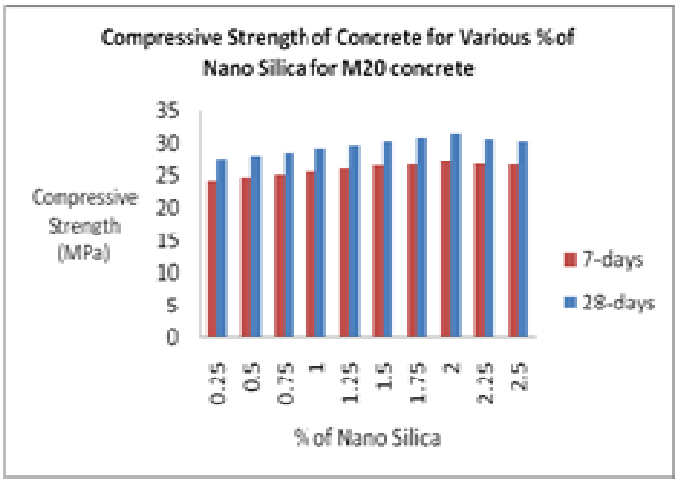

Fig 1(a)

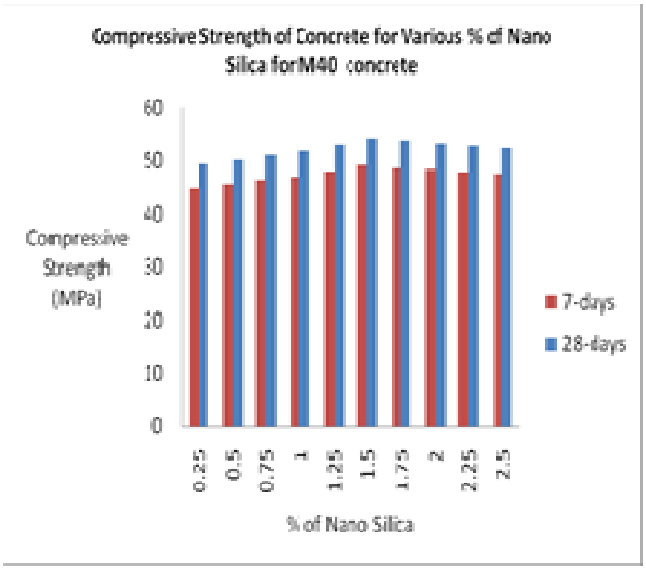

Fig 1(b)

Annexure II: Variation of Strength efficiency factor 'K' with percentage of Nano silica

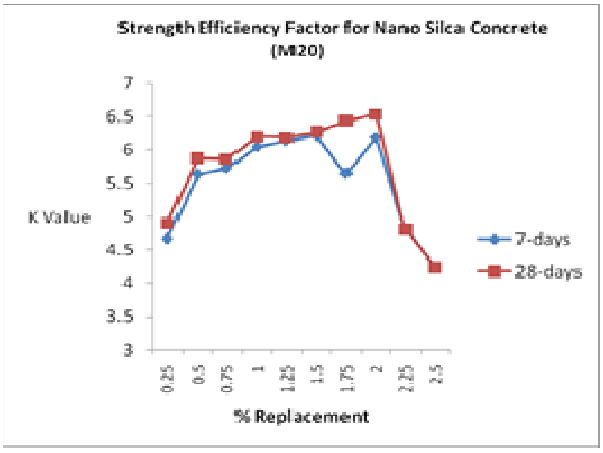

Fig 2(a)

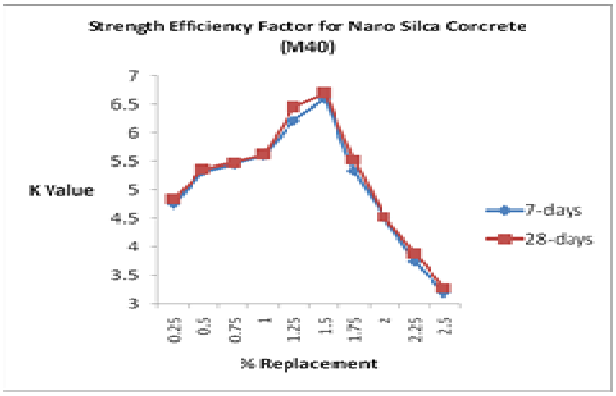

Fig 2(b)

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