EFFECT OF ELEVATED TEMPERATURE ON HIGH PERFORMANCE CONCRETE

Omkar.A.Salunkhe[1], Abhijeet A. Galatage[2,] Dr.Sumant K.Kulkarni[3,]

[1]*P. G. Student, Civil Engineering, Flora Institute of Technology, Pune, Maharashtra, India*
[2]*Assistant Professor, Civil Engineering, Flora Institute of Technology, Pune, Maharashtra, India*
[3] *Professor, Civil Engineering, Flora Institute of Technology, Pune, Maharashtra, India*

ABSTRACT

Concrete is used all over in construction industries. Generally conventional concrete is produced by using natural sand. As sources of natural sand are decreasing, there is need to find out the alternative for natural sand. Now days crushed sand is used as alternative for natural sand. Although concrete gets exposed to various temperature condition e.g. aircraft runway, base foundation of furnace, chimney etc. In such case when temperature is about 100ºC-1000ºC, strength and other properties of concrete gets affected. Generally, strength of concrete decreases when it gets exposed to elevated temperature. As artificial sand is used as alternative for natural sand there is need to study the difference between behavior of concrete manufactured by using natural sand and artificial sand when it is subjected to elevated temperature. In this paper, attempt is made for mix deign of M-40, M-50 concrete using natural sand and crushed sand in which Fly ash as well as Silica fume is used as partial replacement of cement and chemical admixture superplasticizer is also used. Further these grades of concrete are exposed to temperature ranging between 100ºC, 200ºC, 500ºC, 800ºC, 1000ºC for a specific time interval of 60min in electric furnace. Result shows that compressive strength of concrete made by using natural sand after effect of elevated temperature is less affected as that of concrete made by using artificial sand.

Keyword:- *M-40, M-50, Natural sand, Artificial sand, Fly ash, Silica fume, Superplasticizer, Elevated temperature,compressive strength.etc.*

1. INTRODUCTION-1

As we know that Concrete has compressive strength, durability and plasticity therefore it is a widely used construction material in all the modern structures. Concrete is used in high rise building and in special purpose in which concrete is subjected to various environmental conditions such as exposed to high temperature, when concrete is exposed unexpected fire, the properties of concrete changes hence it is necessary to understand the change in the concrete properties such as Mechanical, Physical etc. Generally concrete is exposed to elevated temperature in the following cases containment vessel, chimneys, nuclear reactor, pressure vessels, storage tank of crude oil, hot water, foundation of blast furnace and coke industry, furnace wall, air craft runway etc. This will affect on mechanical properties of concrete including compressive strength, loss of weight along with change in color spalling of concrete.

In this paper, an attempt is made to study the effect of elevated temperature on concrete which is made from both natural sand as well as artificial sand of various grades M-40, M-50, and to find out which type of concrete is more suitable for high temperature exposure. In this work, compressive strength of concrete is taken into account.

2. LITERATURE REVIEW-2

C. B. K. Rao.et al. [1] Evaluated principle effect due to elevated temperature. They observed loss in compressive strength along with loss in mass, spalling of concrete, change in colour. In their study, it is clearly mentioned that experimental results of normal concrete and high strength concrete subjected elevated temperatures at are different. Temperature they had taken for experiments were 200°C, 400°C, 600°C, and 800°C. Concrete used in this study is made up by using natural sand. Gyu-Yong KIM. et al. [2] Studied high temperature effect on compressive strength

of high strength concrete along with elastic modulus. They observed temperature effect for high strength concrete of 40, 60 and 80 MPa grade with temperature range of 20ºC- 700ºC. The results showed that the relative values of compressive strength and elastic modulus decrease with increasing compressive strength grade of specimen. Concrete used in this study is made up by using sea sand i.e. natural sand. Ali Ergun.et al. [3]Examined The effect of cement dosage on mechanical properties of concrete exposed to high temperatures. That time they found that when concrete non-combustible material is exposed to high temperature then physical, chemical, mechanical properties of concrete drastically change. They assessed the effect of elevated temperatures and cement dosages on the mechanical properties of concrete. Concrete used in this study made by using natural sand. temperature range taken for above experimental study is 100ºC-800ºC. S.V.V.K. Babu.et.al. [4]Examined the study on strength properties such as compressive strength, split tensile strength and flexural strength of M40 grade of HPC mixes with different replacement levels such as 25%,30%,35% & 40% of cement by fly ash and 60%,65%,70%,75% &100% of stone dust with sand by adopting water-binder ratio of 0.35. Super plasticizer (BASF) is used for better workability for high performance concrete. The result of these investigations demonstrates the strength characteristics of stone dust and the properties of fly ash based concrete mixes. Based on the results obtained, the replacement of 100% stone dust and 25% fly ash with 1.2% of super plasticizer which superior characteristics was arrived. M.Richard Ford .et.al.[5] experimental investigation is carried out to study the effects of elevated temperatures on the compressive strength of normal concrete and on concrete by partial replacement of cement with (0%to 25%) percentages of fly ash.are subjected to temperatures (400ºC to 600ºC)for specific time then they observed compressive strength of fly ash (0%to 10%) concrete is more than the normal concrete at room temperatures and elevated temperatures and also compared to compressive strength of fly ash (15%to 25%) concrete.

2.1 Objectives-1

1. To develop various grades of High Performance Concrete (M40-M50) using natural sand and cement will be replaced by Fly ash as well as Silica fume experimentally.
2. To develop various grades of High Performance Concrete (M40-M50) using artificial sand and cement will be replaced by Fly ash as well as Silica fume experimentally.
3. To investigate the behavior of High Performance Concrete subjected to temperature ranging from 30°C-1000°C.
4. To compare the behavior of High Performance Concrete manufactured by using natural sand and artificial sand.

3. METHODOLOGY-3

3.1 Material and its properties -1

1.Cement: cement used is ordinary Portland cement of grade 53 confirming to IS 8112 -1989. The physical properties of cement are given in the table

Table 1: Properties of Cement

Properties	**Average values for OPC**	**Standard values as per IS : (12269 -1987)**
Specific gravity	3.15	-
Consistency (%)	32 %	-
Initial setting time (min)	160	> 30
Final setting time (min)	230	< 600
Soundness (mm)	1.0	< 10
Compressive strength (MPa) 28 – days	69	> 33

2. Fine aggregate: In this paper concrete of various grades is manufactured by using crushed as well as natural. Following are the properties of fine aggregate

Crushed sand: As crushed sand is total replacement to natural sand as fine aggregate. It was collected from JYOTI stone crusher kanhwadi, Bhor. Having specific gravity and water absorption 2.09 and 1.6%. Sieve analysis giving fineness modulus 3.11.

Natural sand: The natural sand is collected from the Shirwal. The specific gravity of natural sand is 2.78. Sieve analysis giving fineness modulus3.13 fine aggregate conforming to zone I of IS 383 -1970

3.Coarse aggregate: coarse aggregate used has angular shape having maximum size 20mm. specific gravity and water absorption was found to be 2.79 and 1.77%. Sieve analysis of aggregate is presented in table. Coarse aggregate has fineness modulus 6.33.

Table 2 : Sieve analysis of Coarse aggregate

IS Sieve	Weight retained(kg)	% weight retained	Cumulative % retained	% passing
20mm	0.030	1.5	1.5	98.5
16mm	0.910	45.5	47	53
12.5mm	0.790	39.5	86.5	13.5
10mm	0.245	12.25	98.75	1.25
4.75mm	0.025	1.25	100.00	0.00
150mic	0.00	0.00	100.00	0.00
75mic	0.00	0.00	100.00	0.00
Pan	0.00	0.00	100.00	0.00

4. Fly ash: Fly ash (F class) is partially replaced with cement. In this study proportion used is 20% of cementitious material. Specific gravity of Fly ash is 2.2

5. Silica fume giving specific gravity2.21 is partially replaced with cement. In this study proportion used is 20% of cementitious material. Silica fume reacts with water forms finer paste as compare to cement paste. For better results, i.e. compressive strength silica fume should use at appropriate proportion.

6. Chemical admixture: Super plasticizer: In order to improve the strength of concrete a chemical admixture Masterpolyheed 8355 (BASF) superplasticizer is used which is water repelant having specific gravity 1.10.

7 Water: Fresh portable water, which is free from acid and organic substance, was used for mixing the concrete

4. EXPERIMENTAL WORK -4

4.1 Following testing conducted on Concrete-1

A) Compressive Strength
Mix design parameters: Mix design for M 40 and M 50 grade concrete.

Mix proportion and Mix details: Concrete mix proportion is designed as per IS 10262:2009 “CONCRETE MIX PROPORTIONING- GUIDELINES”. Amount of Fly ash replaced is 20% of cementitious material and superplasticizer used is 0.8% of cementitious material. Following table shows the mix proportion of M40 and M50grade concrete.

Table 3: Mix Prportion of concrete grades using Natural sand(fly ash)

Ingredients / Grades	Cement	Water	Sand	Coarse aggregate
M-40	385 kg/m^3	140 lit.	765.89 kg/m^3	1254.10 kg/m^3
M-50	456.5 kg/m^3	157.6 lit.	712.88 kg/m^3	1187.33 kg/m^3

Table 4: Mix Prportion of concrete grades using Artificial sand(fly ash)

Ingredients / Grades	Cement	Water	Sand	Coarse aggregate
M-40	385 kg/m^3	140 lit.	575.79 kg/m^3	1254.10 kg/m^3
M-50	456.5 kg/m^3	157.6 lit.	535.94 kg/m^3	1187.33 kg/m^3

Table 5: Mix Prportion of concrete grades using Natural sand (Silica fume**)**

Ingredients / Grades	Cement	Water	Sand	Coarse aggregate
M-40	350 kg/m^3	140 lit.	779.51 kg/m^3	1276.41 kg/m^3
M-50	415 kg/m^3	157.6 lit.	727.51 kg/m^3	1211.70 kg/m^3

Table 6: Mix Prportion of concrete grades using Artificial sand(Silica fume)

Ingredients / Grades	Cement	Water	Sand	Coarse aggregate
M-40	456.5 kg/m^3	157.6 lit.	575.79kg/m^3	1187.33 kg/m^3
M-50	415 kg/m^3	157.6 lit.	1276.41 kg/m^3	1211.70 kg/m^3

5. RESULTS

Purpose of this study is to compare the concrete by artificial sand to concrete by natural sand under the effect of elevated temperature. There are 2 grades of concrete i.e. M-40, M-50, are undertaken into study, therefore comparison of 14 and 28 days results of each grade of concrete of artificial sand with respect to another concrete of natural sand is required.

Table 7: Comparison of 14 days results of M-40 concrete (fly ash)

	M-40 Natural sand		**M-40 Artificial sand**	
Tempera-ture	**Avg. strength**	**% loss**	**Avg. strength**	**% loss**
27ºC	42.14 N/mm^2		39.74 N/mm^2	
100ºC	40.64 N/mm^2	3.55%	38.11 N/mm^2	4.10%
200ºC	40.07 N/mm^2	4.91%	37.47 N/mm^2	5.70%
500ºC	38.47 N/mm^2	8.70%	35.91 N/mm^2	9.63%
800ºC	33.91 N/mm^2	19.51%	31.36 N/mm^2	21.06%
1000ºC	20.13 N/mm^2	52.21%	17.45 N/mm^2	56.08%

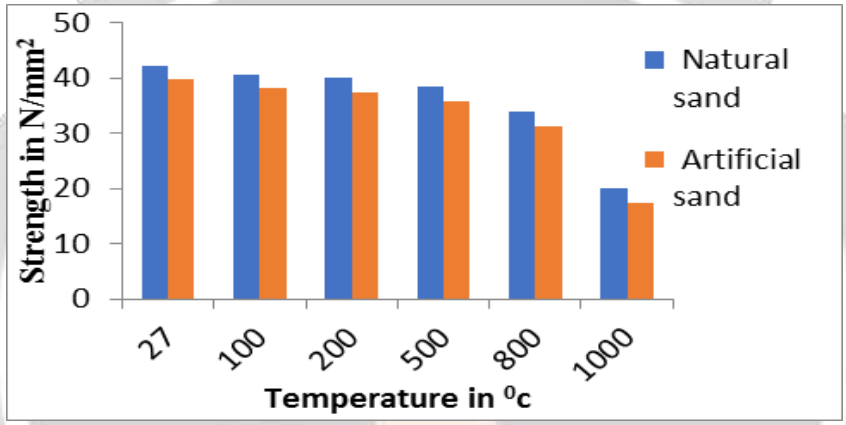

Chart -1: Comparison between M-40 concretes

Chart -1: shows that strength loss by concrete formed from natural sand is less than strength loss by concrete formed from artificial sand. For 100ºC and 200ºC difference is about 0.55-0.8%, for 500ºC and 800ºC it is about 0.93-1.56%. Beyond that graph shows that for 1000ºC the difference is 3.87%.

Table 8: Comparison of 14 days results of M-50 concrete(fly ash)

	M-50 Natural sand		**M-50 Artificial sand**	
Temperature	**Avg. strength**	**% loss**	**Avg. strength**	**% loss**
27ºC	51.48 N/mm^2	0%	49.02 N/mm^2	0%
100ºC	49.59 N/mm^2	3.68%	47.12 N/mm^2	3.87%
200ºC	48.99 N/mm^2	4.83%	46.24 N/mm^2	5.66%
500ºC	46.99 N/mm^2	8.72%	44.17N/mm^2	9.88%
800ºC	41.15 N/mm^2	20.06%	38.11N/mm^2	22.26%
1000ºC	25.18 N/mm^2	51.07%	22.25N/mm^2	54.60%

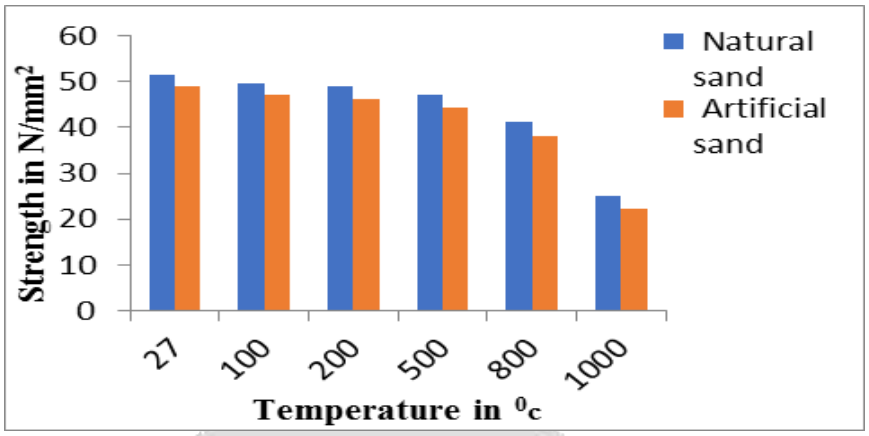

Chart -2: Comparison between M-50 concretes

Chart - 2 shows that strength loss by concrete formed from natural sand is less than strength loss by concrete formed from artificial sand. For 100ºC and 200ºC difference is about 0.19-0.83%, for 500ºC and 800ºC it is about 1.16 - 2.2%. Beyond that graph shows that for 1000ºC the difference is 3.53%.

Table 9: Comparison of 28 days results of M-40 concrete (fly ash)

	M-40 Natural sand		**M-40 Artificial sand**	
Temperature	**Avg. strength**	**% loss**	**Avg. strength**	**% loss**
27ºC	50.43 N/mm^2		49.64 N/mm^2	
100ºC	48.38 N/mm^2	4.06%	47.50 N/mm^2	4.37%
200ºC	47.22 N/mm^2	6.36%	46.39 N/mm^2	6.54%
500ºC	45.50 N/mm^2	9.77%	44.64 N/mm^2	10.07%
800ºC	40.48 N/mm^2	19.33%	39.65 N/mm^2	20.12%
1000ºC	29.86 N/mm^2	40.78%	27.65 N/mm^2	44.29%

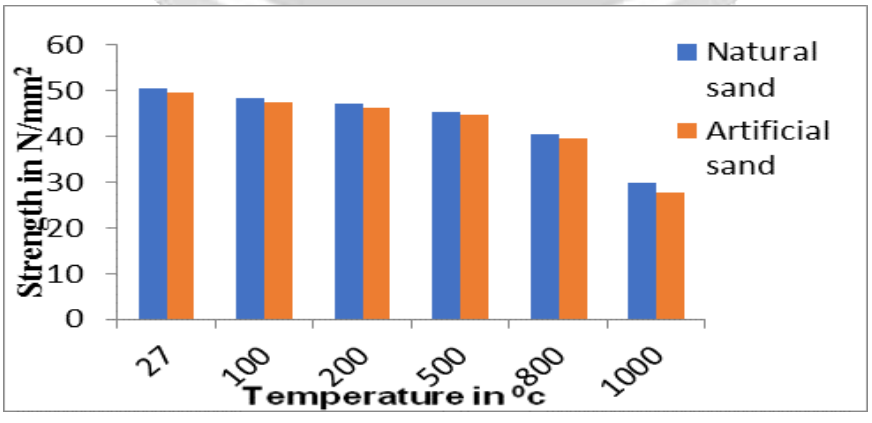

Chart -3: Comparison between M-40 concretes

Chart - 3 shows that strength loss by concrete formed from natural sand is less than strength loss by concrete formed from artificial sand. For 100ºC and 200ºC difference is about 0.31-0.18%, for 500ºC and 800ºC it is about 0.3-0.8 %. beyond that graph shows that for 1000ºC the difference is 3.51%.

Table 10: Comparison of 28 days results of M-50 concrete (fly ash)

	M-40 Natural sand		**M-40 Artificial sand**	
Tempera-ture	**Avg. strength**	**% loss**	**Avg. strength**	**% loss**
27ºC	59.63N/mm^2		58.88N/mm^2	
100ºC	48.38 N/mm^2	4.06%	47.50 N/mm^2	4.37%
200ºC	47.22 N/mm^2	6.36%	46.39 N/mm^2	6.54%
500ºC	45.50 N/mm^2	9.77%	44.64 N/mm^2	10.07%
800ºC	40.48 N/mm^2	19.33%	39.65 N/mm^2	20.12%
1000ºC	29.86 N/mm^2	40.78%	27.65 N/mm^2	44.29%

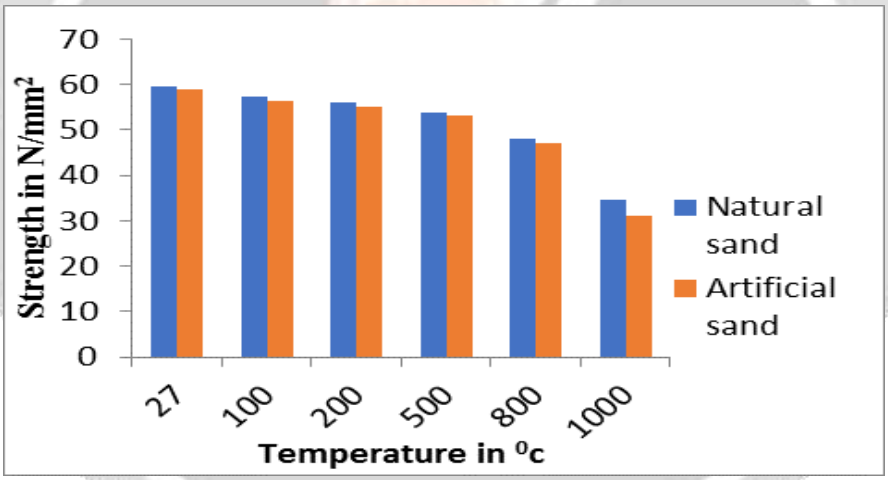

Chart -4: Comparison between M-40 concretes

Chart - 4 shows that strength loss by concrete formed from natural sand is less than strength loss by concrete formed from artificial sand. For 100ºC and 200ºC difference is about 0.19-0.43 %, for 500ºC and 800ºC it is about 0.4-0.84%. beyond that graph shows that for 1000ºC the difference is 5.2 %.

Table 11: Comparison of 14 days results of M-40 concrete (silica fume)

	M-40 Natural sand		**M-40 Artificial sand**	
Tempera-ture	**Avg. strength**	**% loss**	**Avg. strength**	**% loss**
27ºC	42.37 N/mm^2		40.97 N/mm^2	
100ºC	38.60 N/mm^2	8.90%	35.93 N/mm^2	12.30%
200ºC	36.52 N/mm^2	13.81%	34.06 N/mm^2	16.86%
500ºC	29.34 N/mm^2	30.75%	28.45 N/mm^2	30.55%
800ºC	24.99 N/mm^2	41.01%	23.84 N/mm^2	41.81%
1000ºC	19.82 N/mm^2	53.22%	17.69 N/mm^2	56.82%

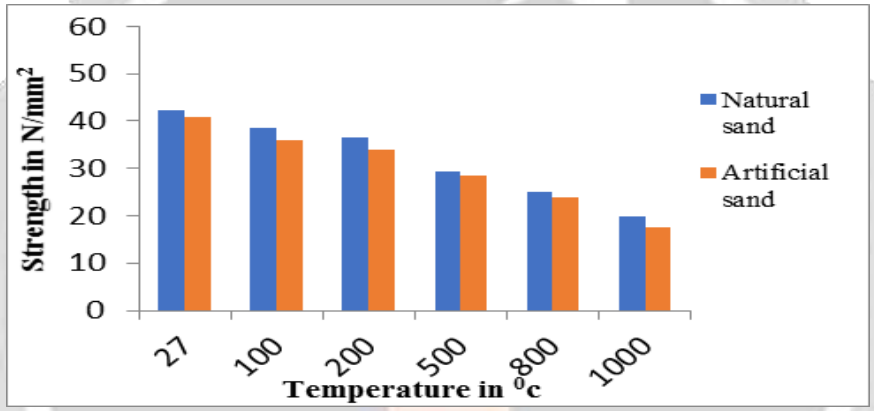

Chart -5: Comparison between M-40 concretes

Chart - 5 shows that strength loss by concrete formed from natural sand is less than strength loss by concrete formed from artificial sand. For 100ºC and 200ºC difference is about 3.4- 3.05%, for 500ºC and 800ºC it is about 0.2-0.8% beyond that graph shows that for 1000ºC the difference is 3.6 %.

Table 12: Comparison of 14 days results of M-50 concrete (silica fume)

	M-50 Natural sand		**M-50 Artificial sand**	
Tempera-ture	**Avg. strength**	**% loss**	**Avg. strength**	**% loss**
27ºC	51.7 N/mm^2		50.14 N/mm^2	
100ºC	45.23 N/mm^2	12.51%	43.72 N/mm^2	12.80%
200ºC	42.12 N/mm^2	18.52%	40.49 N/mm^2	19.25%
500ºC	37.63 N/mm^2	27.21%	36.55 N/mm^2	27.10%
800ºC	29.41 N/mm^2	43.11%	28.05 N/mm^2	44.05%
1000ºC	21.84 N/mm^2	57.75%	19.16 N/mm^2	61.78%

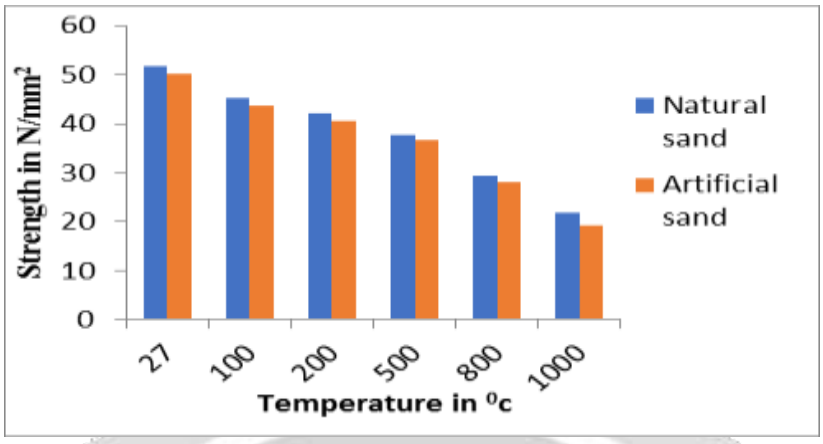

Chart -6: Comparison between M-50 concretes

Chart - 6 shows that strength loss by concrete formed from natural sand is less than strength loss by concrete formed from artificial sand. For 100ºC and 200ºC difference is about 0.3-0.75%, for 500ºC and 800ºC it is about 0.11-0.94%. beyond that graph shows that for 1000ºC the difference is 4.03 %.

Table 13: Comparison of 28 days results of M-40 concrete (silica fume)

	M-40 Natural sand		**M-40 Artificial sand**	
Temperature	**Avg. strength**	**% loss**	**Avg. strength**	**% loss**
27ºC	42.14 N/mm^2		39.74 N/mm^2	
100ºC	46.21 N/mm^2	8.77%	43.11 N/mm^2	12.00%
200ºC	43.33 N/mm^2	14.00%	40.66 N/mm^2	17.00%
500ºC	35.11 N/mm^2	30.69%	35.00 N/mm^2	30.48%
800ºC	30.66 N/mm^2	40.00%	29.33 N/mm^2	40.50%
1000ºC	24.44 N/mm^2	52.00%	21.33 N/mm^2	56.00%

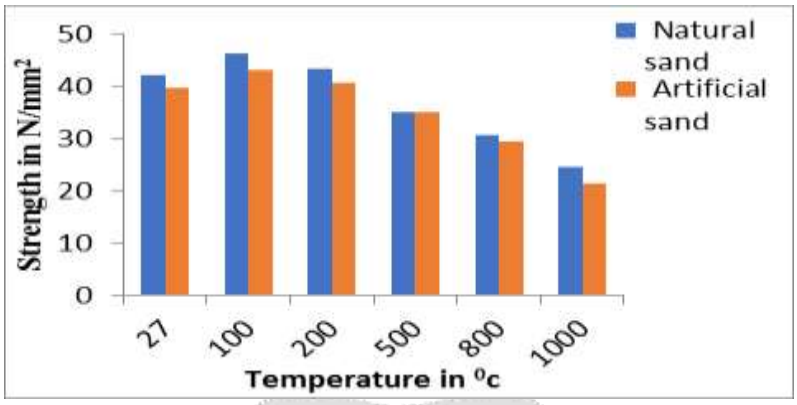

Chart -7: Comparison between M-40 concretes

Chart - 7 shows that strength loss by concrete formed from natural sand is less than strength loss by concrete formed from artificial sand. For 100ºC and 200ºC difference is about 3.23-3% but for 500ºC and 800ºC it is negligible about 0.5%. beyond that graph shows that for 1000ºC the difference is 4%.

Table 14: Comparison of 28 days results of M-50 concrete (silica fume)

	M-50 Natural sand		**M-50 Artificial sand**	
Tempera-ture	**Avg. strength**	**% loss**	**Avg. strength**	**% loss**
27ºC	60 N/mm^2		58.66 N/mm^2	
100ºC	52.66 N/mm^2	12.23%	51.33 N/mm^2	12.49%
200ºC	48.66 N/mm^2	18.00%	47.33 N/mm^2	19.00%
500ºC	45.77 N/mm^2	26.00%	43.55 N/mm^2	26.00%
800ºC	34.63 N/mm^2	42.22%	32.88 N/mm^2	43.94%
1000ºC	25.77 N/mm^2	58.00%	22.22 N/mm^2	62.00%

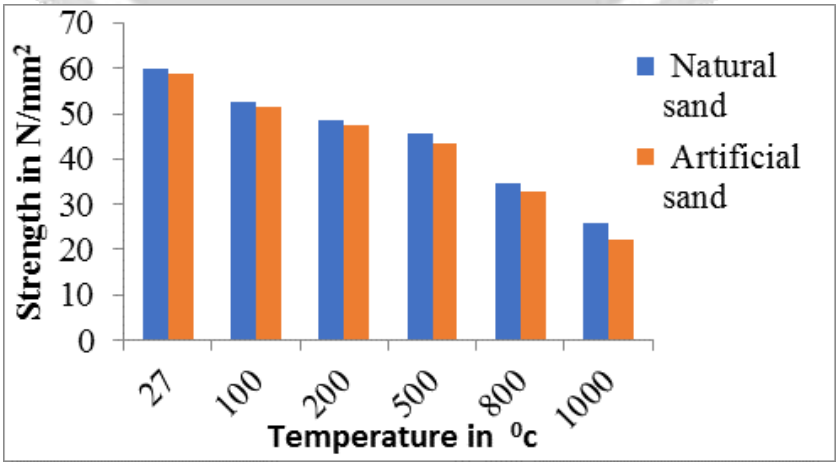

Chart -8: Comparison between M-50 concretes

Chart - 8 shows that strength loss by concrete formed from natural sand is less than strength loss by concrete formed from artificial sand. For 100ºC and 200ºC difference is about 0.26-1.0% for 500ºC it is nearly equal. 800ºC it is about 1.72 %. beyond that graph shows that for 1000ºC the difference is 4%.

6. CONCLUSIONS

1. For M-40 Grade of concrete by using Fly ash, subjected to high temperature. The loss of strength after 14 days of curing concrete formed by artificial sand was 7.4 % to 16.08 % more than that of concrete formed by natural sand.
2. For M-40 Grade of concrete by using Fly ash, subjected to high temperature. The loss of strength after 28 days of curing concrete formed by artificial sand was 5.16% to 17.18% more than that of concrete formed by natural sand.
3. For M-50 Grade of concrete by using Fly ash, subjected to high temperature. The loss of strength after 14 days of curing concrete formed by artificial sand was 2.83% to 8.6% more than that of concrete formed by natural sand.
4. For M-50 Grade of concrete by using Fly ash, subjected to high temperature. The loss of strength after 28 days of curing concrete formed by artificial sand was 4.19 % to 13.32 % more than that of concrete formed by natural sand.
5. For M-40 Grade of concrete by using Silica fume, subjected to high temperature. The loss of strength after 14 days of curing concrete formed by artificial sand was 0 % to 38.2% more than that of concrete formed by natural sand.
6. For M-40 Grade of concrete by using Silica fume, subjected to high temperature. The loss of strength after 28 days of curing concrete formed by artificial sand was 0 % to 3.94% more than that of concrete formed by natural sand.
7. For M-50 Grade of concrete by using Silica fume, subjected to high temperature. The loss of strength after 14 days of curing concrete formed by artificial sand was 0 % to 36.83% more than that of concrete formed by natural sand.
8. For M-50 Grade of concrete by using Silica fume, subjected to high temperature. The loss of strength after 28 days of curing concrete formed by artificial sand was 0% to 6.89 % more than that of concrete formed by natural sand
9. For M-40 & M-50 grade of concrete made by using natural sand gives more resistance to elevated temperature as compare to concrete made by using artificial sand.
10. Loss of compressive strength in M-40 & M-50 grade of concrete with fly ash is found to be 10%-15% less as compared to concrete made by using Silica fume.

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