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A Study on the Effect of Nano-Silica on Mechanical and Durability Properties of High-Performance Concrete

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Abstract: *This study presents experimentally the combined effect of using Nano-silica, Alccofine, GGBS, and steel fibers on the mechanical properties of hardened concrete. Nano-Silica, Alccofine, and GGBS are used as partial cement replacement by different percentages, and Steel Fiber is used as volume substitution by different percentages. Compressive strength, splitting tensile strength, and flexural strength are evaluated using different combinations between Nano-Silica, Alccofine, and GGBS. Significant improvement in the mechanical properties of concrete is observed on using Nano-Silica due to its high pozzolanic activity. The Optimum content of Steel Fiber is improved splitting tensile strength by 1%t percentage respectively compared to control mix concrete. Utilizing Nano-Silica and GGBS with Steel Fiber leads to improving compressive strength compared to other concrete mixes. Flexural strength is doubled for using Nano-Silica, GGBS, and Steel Fiber compared to other concrete.*

Keywords: Nano-Silica, Alccofine, GGBS, Steel Fibers, Mechanical Properties & Durability

I. INTRODUCTION

The historical development of concrete materials can be divided into several stages: the development of traditional normal-strength concrete. Then, with increasing developments in civil engineering such as high-rise buildings and long-span bridges, concrete with higher compressive strength was required. However, in some cases, compressive strength is not as important or necessary as other properties such as low penetrability, durability, and workability. Extensive research studies are being carried out in attempts to enhance the performance of construction materials and develop durable and sustainable concretes for the construction industry by implementing nanotechnology. Nanotechnology is an emerging avenue in materials science that could have a great environmental impact. Researchers are thus aiming to implement nanotechnology to improve the properties and functions of materials in the construction industry. High-Performance Concrete (HPC) is a concrete mixture, which possesses high durability and high strength when compared to conventional concrete. This concrete contains one or more cementitious materials such as fly ash, silica fume, or ground granulated blast furnace slag and is usually a superplasticizer. The use of some mineral and chemical admixtures like silica fume and superplasticizer enhances the strength, durability, and workability qualities to a very high extent.

1.1 Objectives

- To procure materials to be used for concreting and determining the physical properties of materials (Cement, Nano-silica, Alccofine, GGBS).
- Determine the mechanical properties of HPC with Nano-silica and with various proportions of cement replaced with Alccofine and GGBS.
- To determine the durability properties of HPC.

1.2 Nano-Silica

Nano-silica, also called quartz dust or silica dust, is a material that, like SF, is characterized by **its high SiO_2 percentage, over 99%**. The use of nano-silica (crystalline SiO_2) reduces cement volume and completes the aggregate mix's grading curve in the zone of the smallest sizes.

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Properties	Unit	Typical Value
Specific Surface Area (BET)	m^2/g	200+25
Average primary particle size	Nm	12
Tamped density* acc. to DIN EN ISO 787/11, Aug 1983	g/l	Approx. 50
Moisture* 2 hours at 105℃	Wt.%	<1.5
Ignition Loss 2 hours at 1000℃, based on material Dried for 2 hours at 105℃	Wt.%	<1.0
Ph in 4 % dispersion	-	3.7-4.7
SiO_2 - content Based on ignited material	Wt.%	> 99.8

1.3 GGBS

Ground-granulated blast-furnace slag (GGBS or GGBFS) is obtained by ending liquid iron slag (a by-product of iron and steel-making) from a furnace in water or steam, to supply a glassy, granular product that's then dried and ground into a fine powder. Ground-granulated blast furnace slag is extremely a building material and high in CSH (calcium silicate hydrates) which will be a strength-enhancing compound that improves the strength, durability, and appearance of the concrete.

Physical form	Off white powder
Specific gravity	2.9
Surface area	400 (m2/kg)
SiO2	32.5%
CaO	37.05%
MgO	7.81%
SO3	0.54%
MnO	0.11%

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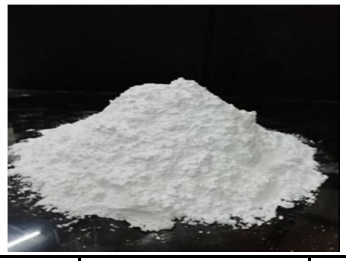
1.4 ALCCOFINE

Alccofine stands as new generation material which is micro-fine of particle size finer than cement, silica, etc. It is mass-produced in India. The distinctive property of this material is this one has optimized particle size distribution. This one is used as cement replacing material as it increases strength, and durability and it even provides resistance against chemical attacks.



Property	Unit	Value
Average particle size	Microns	4 to 6
Fineness	Cm2/gm	12000
Specific gravity	-	2.7
Bulk density	Kg/m3	600 to 700
Ca O	%	31-33
Al2O3	%	23-25
SiO2	%	33-35
Glass content	%	>90

1.5 Concrete Mix Proportion

MIX ID	Cement (%)	Alccofine (%)	Nano-Silica (%)	GGBS (%)	Steel fiber (%)	F.A (%)	C.A (%)
M1	100	0	0	0	0	100	100
M2	100	0	0	0	1	100	100
M3	75	5	0	20	1	100	100
M4	75	0	5	20	1	100	100
M5	70	0	0	30	1	100	100
M6	70	5	5	20	1	100	100

1.5 Test

Compressive Strength Test

Mix ID	Compressive Strength (N/mm^2)	
	7 days	28days
M1	25.72	39.96
M2	27.20	41.64

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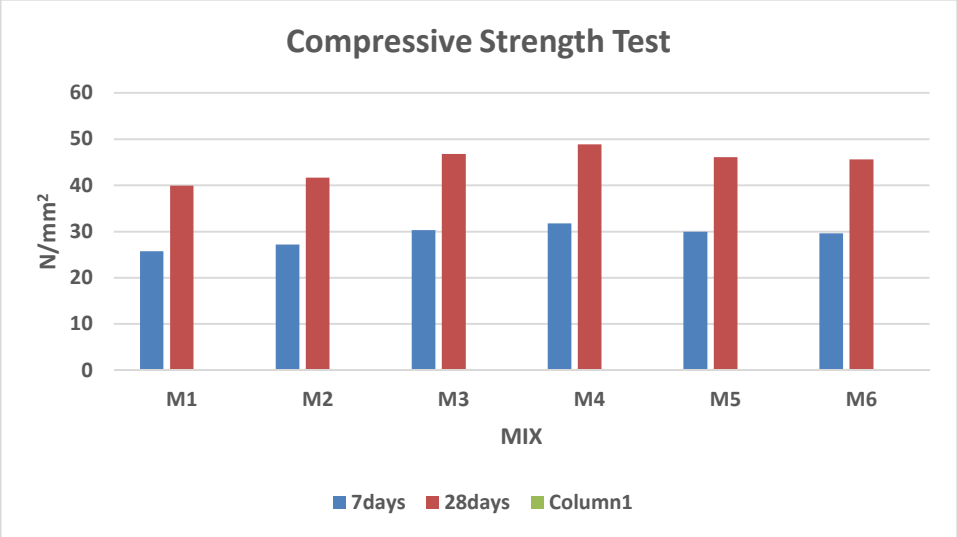
M3	30.27	46.82
M4	31.76	48.86
M5	29.95	46.07
M6	29.64	45.6

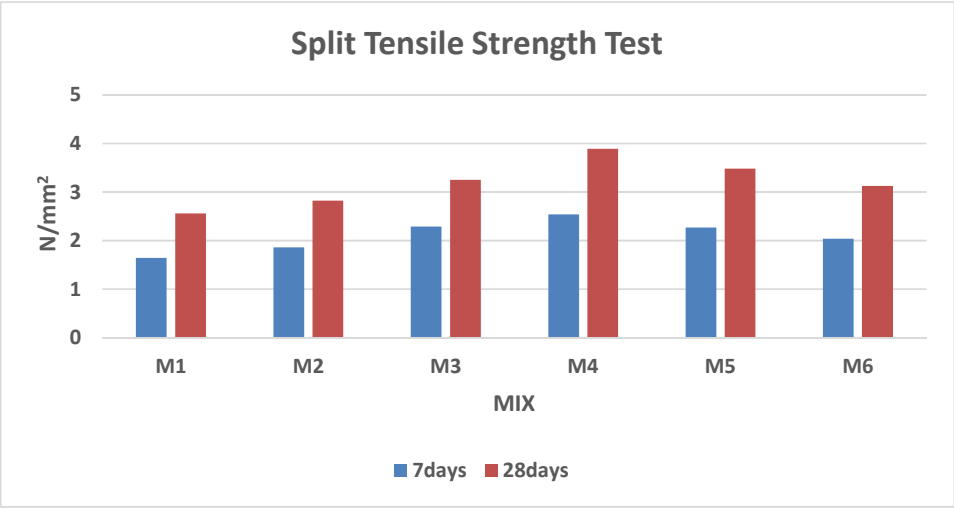
Graph:



Split Tensile Strength Test

Mix ID	Split Tensile Strength (N/mm^2)	
	7 days	28days
M1	1.64	2.56
M2	1.86	2.83
M3	2.29	3.25
M4	2.54	3.9
M5	2.27	3.49
M6	2.04	3.13

Graph:



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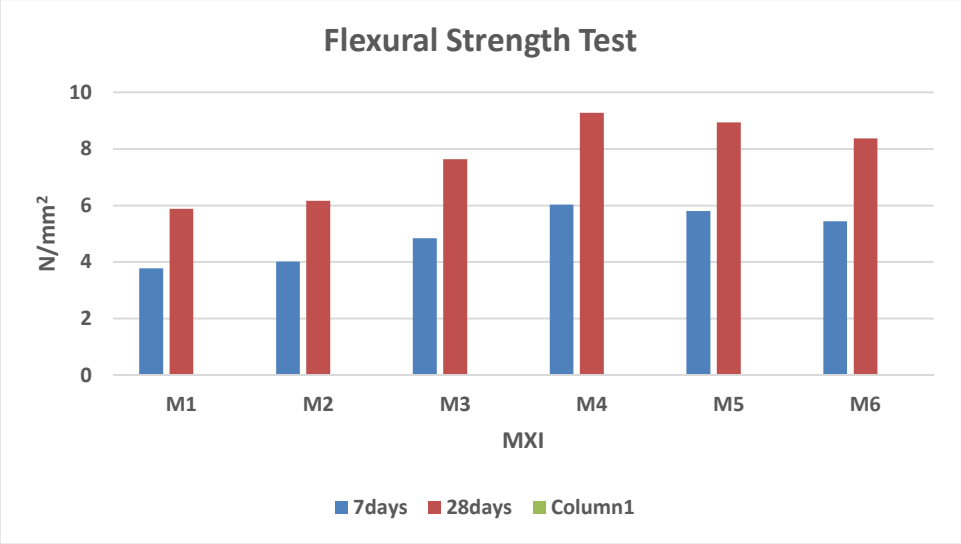
Flexural Strength Test

MIX ID	Flexure Strength (N/mm^2)	
	7 days	28days
M1	3.78	5.89
M2	4.01	6.17
M3	4.85	7.63
M4	6.03	9.28
M5	5.8	8.93
M6	5.44	8.37

Graph:



II. CONCLUSION

Tests were investigated to get the optimum percentages of Nano-Silica, Alccofine, GGBS, and Steel Fiber to be added to concrete. The conclusions derived are:

- Replacement of cement with Nano-Silica 5%, Steel Fiber 1%, and GGBS 20%. the compressive was found to be 48.86 N/mm^2.
- It is seen that the compressive strength increased by 26.4% more than the control mix.
- Replacement of cement with Nano-Silica 5% and GGBS 20%, the split tensile strength was found to be 3.9 N/mm^2.
- It is seen that the split tensile strength increased by 23.4% more than the control mix.
- Replacement of cement with Nano-Silica 5% and GGBS 20%, the flexural strength was found to be 9.28 N/mm^2.

It is seen that the flexural strength increased by 25.6% than the control mix

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