Experimental investigation on mechanical properties of concrete containing Nano Silica and GGBS as partial replacement of cement

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Abstract: Cement is mainly utilized for construction in present time because of its need but simultaneously its drawbacks to environment due to emission of CO_2. Also, if we leave waste material directly to the environment, it might cause serious environmental issues. These waste materials can be utilized to produce new products so that natural resources can be used more efficiently. Due to rapid Increase in industrialization and urbanization, the use of buildings also increased which results in continuous usage of construction material leads to scarcity of the concrete materials. To overcome the issue many, research was done to use many industrial waste as alternative or substantial material for concreting so that to overcome these issues, in this work industrial waste materials replace with concrete materials such as nano silica and ground granulated blast furnace slag by means of cement. The concrete casted for M30 and M40 grade with the cement is replaced by nano silica as 0%, 0.25%, 0.50%, 0.75%, 1%,1.25%,1.50% and is ground granulated blast furnace slag as 0%,10%,15%,20%,25%,30% by weight. The cubes, cylinders, beams were casted and test for compression, Split tension, Flexural strength at 3, 7 and 28 days curing of concrete and durability at 56 days of curing of concrete. The obtain results compare with M30 and M40 grade of normal concrete.

Index Terms - ***Nano silica, ground granulated blast furnace slag, mechanical properties, durability, concrete strength.***

I. INTRODUCTION

It is well known that the production of all tonnes of common Portland cement (OPC) produces the same amount of CO_2 as the greenhouse gas, which accounts for 7 to 8% of CO_2 emissions. Therefore, the need for replacement or supplementary materials for cement replenishment is a key requirement in the construction industry. For years, researchers in the construction industry have used many industrial wastes or byproducts as Pozzolan or supplementary cementitious materials (SCMs) as a sustainable industry. Over the last four to fifty years, several studies have already confirmed that industrial byproducts such as FA, grinding blast furnace slag (GGBS), silica fume (SF), and metakaolin can be used for durable production. Utilizing these industrial by-products as aggregates of cement substitutes or concrete, energy savings and environmental benefits can be achieved.

1.1 Nano Silica

Before Silicon dioxide is also known as nanosilica. It is an oxide of silicon. It has been known since ancient time. Silica is found naturally in various organisms as well as in quartz. In many parts of the world, silica is a major component of sand. Silica is one of the most complex and abundant substances in the world, present in a variety of minerals and collectively produced. Silica is one of the most complex and abundant material groups that exist as various mineral compounds and synthetic products. Notable examples include quartz, fumed silica, silica gel and aerogels.

1.2 Ground granulated blast furnace slag

Grinded blast furnace slag is a by-product of the steel industry. Iron ore, coke and limestone are supplied to the furnace and molten slag is poured over the molten iron at temperatures between 1500 °C and 1600 °C. The molten slag has a composition of 30% to 40% silicon dioxide (SiO_2) and about 40% calcium oxide (CaO) close to the chemical composition of Portland cement. After the molten iron is removed, the remaining molten slag, which is mainly composed of the gypsum and aluminum residue is rapidly water cooled to form glass particles. These glass particles are milled to the required size known as the Dry Granulated Blast Furnace Slag. The production of 1 tonne Portland cement requires about 1.5 tonnes of mineral extraction with energy of 5000 MJ and the carbon dioxide equivalent is reported to be 0.95 tonnes. Because GGBS is a by-product of the steel industry, production of 1 ton of GGBS has produced about 0.07 tons of carbon dioxide and consumes only about 1300 MJ of energy. Replacing Portland cement with GGBS significantly reduces carbon dioxide gas emissions. India produces about 7.8 million tons of GGBS. Disposal of slag, such as waste landfills, is a problem and can pose a significant environmental risk to the expected economic growth and development of the steel industry. Production can increase the number of wrinkles and environmental problems will be a major threat. Environmentally friendly replacement of slag leads to the development of concrete that not only utilizes industrial waste but also saves many natural resources and energy. This in turn reduces cement consumption.

2. MATERIAL AND PROPERTIES

A. Cement

Cement is a binding material in a concrete with adhesive and strong properties and it is to an extraordinary degree fine grounded material. The ordinary Portland cement grade 53 is used. The cement brand is Hathi cement.

Specific gravity of cement = 3.15. Fineness of cement = 6%

B. Coarse Aggregate

Aggregates are one of the imperatives constituents of concrete and them constituent about 70 to 80% of total volume of concrete. They help in decrease of shrinkage. They also influence economy as it were. It is the most scarcest and grounded penetrable part of concrete. In the present examination, provincially accessible smashed rock of size 20mm and 1.5mm in the degree of 67% and 33% exclusively by volume were used. The larger size of aggregate affects the thickness of rib.

C. Fine Aggregate

The fraction of particles which pass through 4.75mm sieve and restrained on 150 microns is termed as fine aggregate. According to particle size the fine aggregate is divided into four zones as per IS: 383(1970). Fine aggregate screened through 4.75mm sieve to remove larger particle.

D. Water

Water is a crucial component of concrete as it is viably included in chemical responses with cement, particularly hydration. In the present study consumable water is used according to IS 456:2000 & it was used for preparation of cement. The water concrete proportion chooses the quality of cement. The workability of the concrete is controlled by various components, for instance the beginning measure of water, the reactivity of cement and its level of comparability with the particular concrete.

Table -1: Chemical Properties of Nano Silica

No	Component	Percentage
1	SiO_2	99.97
2	SiO_3	-
3	Cl	-
4	Total alkali	-
5	Moisture content	-
6	Loss of ignition	0.67
7	PH	4.1

Table -2: Chemical Properties of GGBS

No	Component	Percentage
1	SiO_2	33.77
2	CaO	33.77
3	Al_2O_3	13.24
4	MgO	8.46
5	MnO	0.05
6	Fe_2O_3	0.65
7	Sulphidesulphur	2.23
8	Sulphitesulphur	0.23
9	Total Chlorides	0.01

3. METHODOLOGY

In the methodology carried out the concrete mix design M30 and M40 grade of concrete using IS: 10262-2009. Data of mix design of M30 grade of concrete as per IS: 10262-2009 is shown in table3. Data of mix design of M40 grade of concrete as per IS: 10262-2009 is shown in table4.

Table -3: Mix design of M30 grade

Water	Cement	F.A	C.A
172	399	712	1222
0.43	1	1.78	3.06

Table -4: Mix design of M40 grade

Water	Cement	F.A	C.A
159	397	745	1218

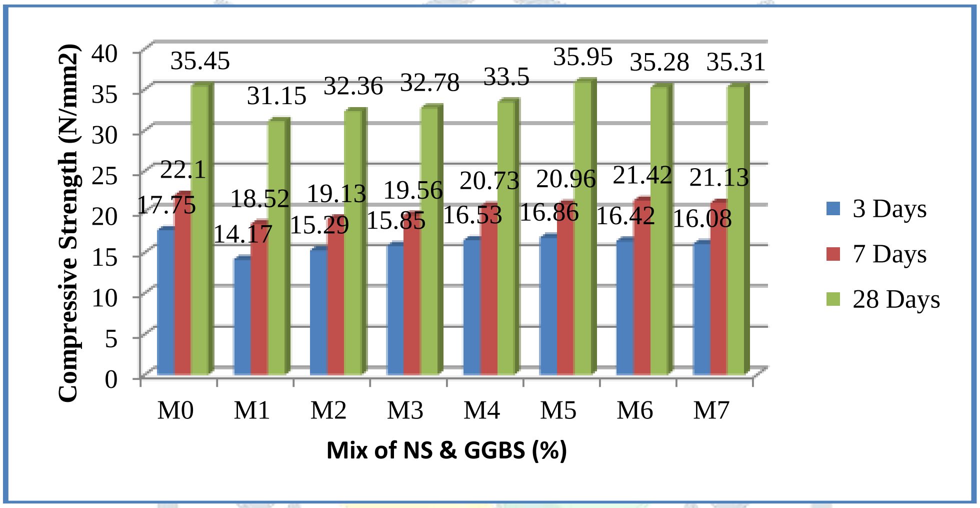
0.40	1	1.88	3.1

4. Experimental Study

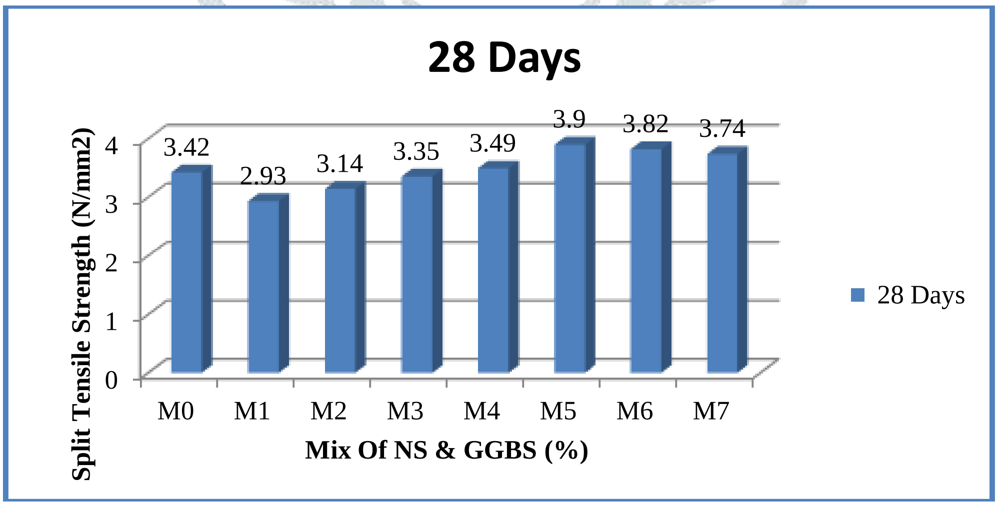
For compressive strength test, cube specimens of dimensions 150x150x150mm are casted for M30 and M40 grade of concrete. For split tensile test, cube specimens of dimensions 150mm diameter and 300mm height are casted for M30 and M40 grade of concrete. For flexural strength test, beam specimens of dimensions 150x150x750mm are casted for M30 and M40 grade of concrete.

Table -5: Mix Proportions ID

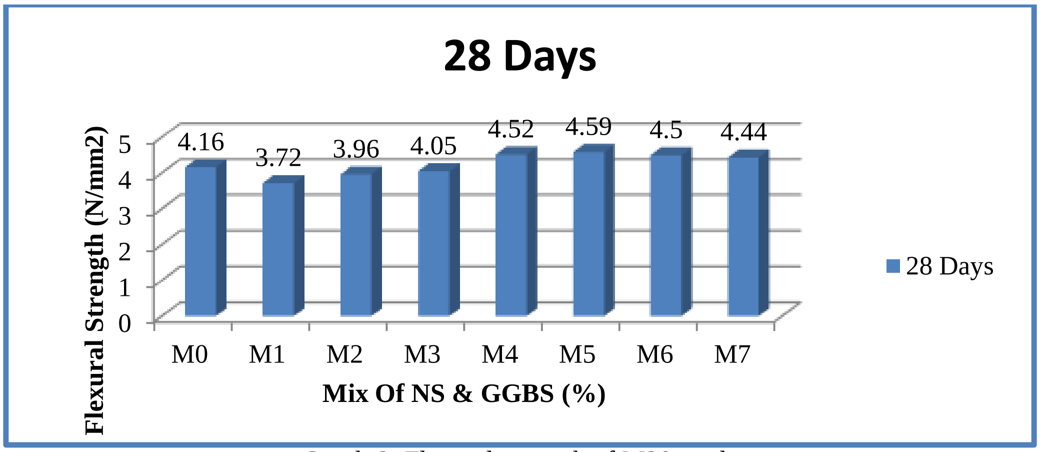
Normal	M0
30% GGBS	M1
0.25% NS + 30% GGBS	M2
0.50% NS + 30% GGBS	M3
0.75% + 30% GGBS	M4
1% + 30% GGBS	M5
1.25% + 30% GGBS	M6
1.50% + 30% GGBS	M7



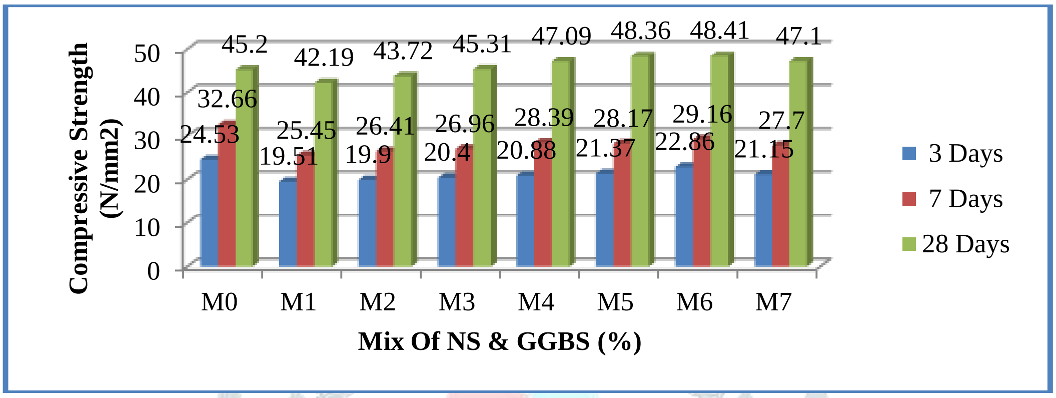
Graph-1: Compressive strength of M30 grade



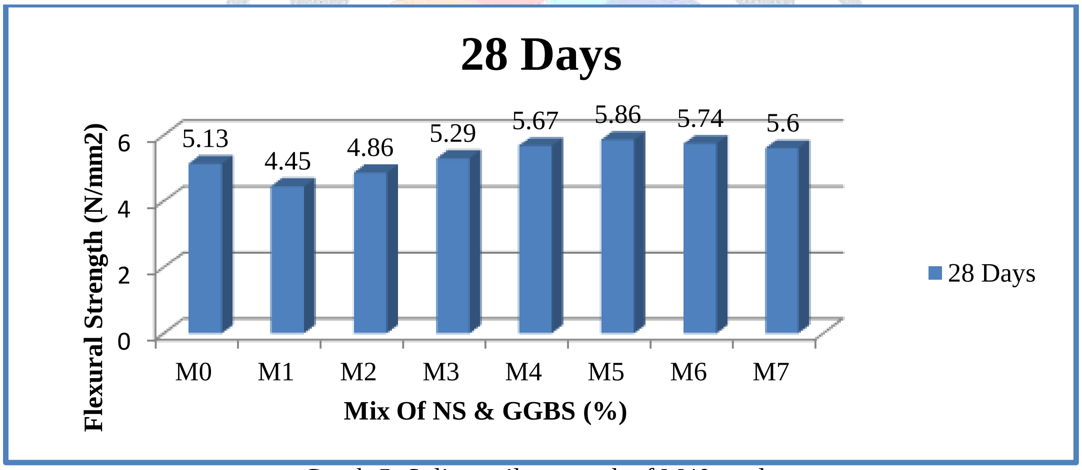
Graph-2: Split tensile strength of M30 grade



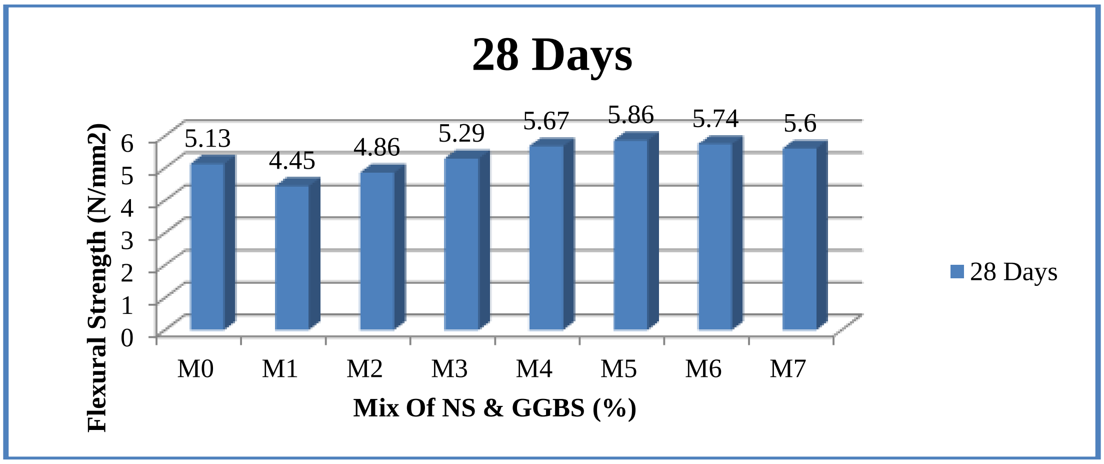
Graph-3: Flexural strength of M30 grade



Graph-4: Compressive strength of M40 grade



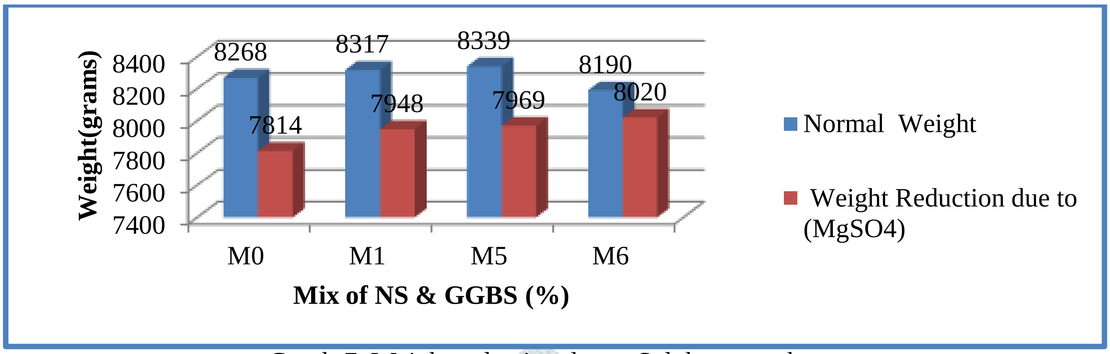
Graph-5: Split tensile strength of M40 grade



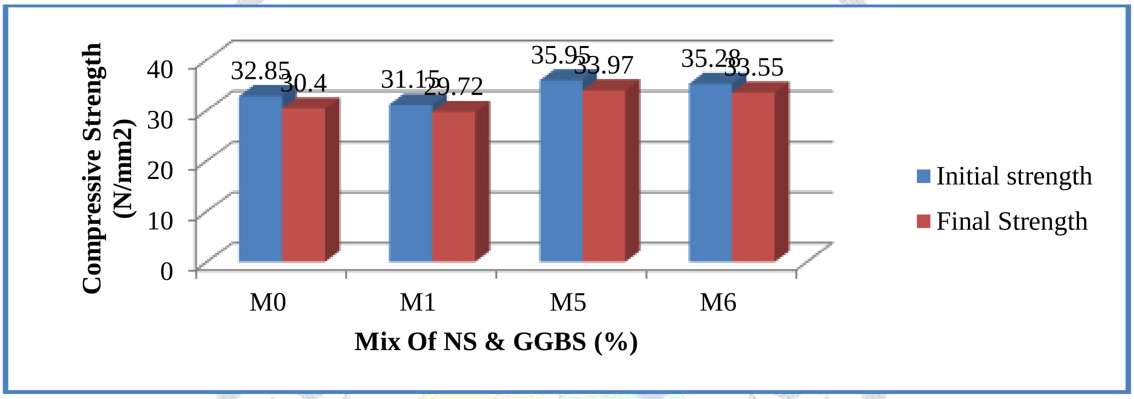
Graph-6: Flexural strength of M40 grade

5. DURABILITY TEST

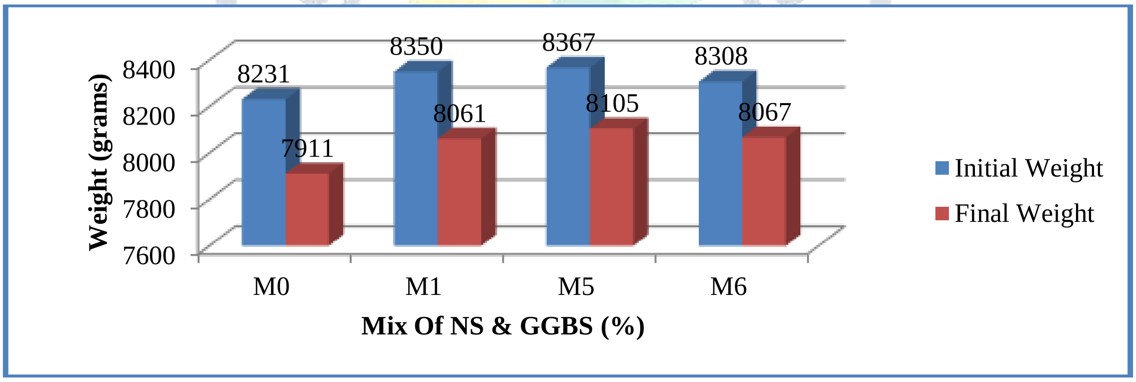
We have carried out three durability tests in this experimental work and their names are as following (1) Acid Attack Test (H_2SO_4), (2) Magnesium sulphate attack ($MgSO_4$).



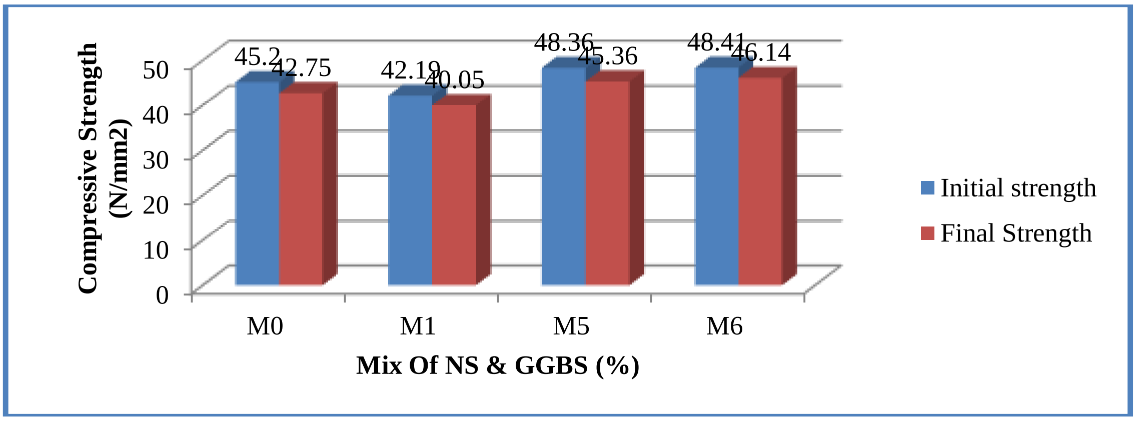
Graph-7: Weight reduction due to Sulphate attack



Graph-8: Compressive strength due to Sulphate attack



Graph-9: Weight reduction due to Acid attack



Graph-10: Compressive Strength due to Acid attack

3. CONCLUSIONS

From the above results:

1. The result obtained high Compressive strength of 35.95MPa & 48.36MPa is achieved for M30 & M40 grade of concrete respectively at 1% replacement with nano silica & at 30% replacement with ggbs.
2. For Split tensile strength, 3.90MPa & 5.21MPa is achieved for M30 & M40 grade of concrete respectively at 1% replacement with nano silica & at 30% replacement with ggbs.
3. For Flexure strength, 4.59MPa & 5.86MPa is achieved for M30 & M40 grade of concrete respectively at 1% replacement with nano silica & at 30% replacement with ggbs.
4. The Portland cement in concrete releases calcium hydroxide during the hydration process. The nano silica and GGBS reacts with the calcium hydroxide and from reactions additional binder material form.
5. The availability of additional binder leads to increase in the paste-aggregate bond, results improved strength properties of the concrete prepared with nano-silica and ggbs combination.
6. The above discussions described that the influence of NS along with cement, GGBS considerable improvement in the properties such as rheological behavior of concrete , heat of hydration, the pozzolanic activity and workability, strength and durability were reported.
7. In durability test, due to acid attack and sulphate attack it is observed that weight loss and strength loss are decreasing as compared to normal M30 and M40 grade of concrete.

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