EXPERIMENTAL STUDY ON CONCRETE BY PARTIAL REPLACEMENT OF CEMENT USING GGBS AND NANOPARTICLES

G.Ramachandran[1] M.Puvitha[2,*] M.Sathiyapriya[3,*] C.Sivagami[4,*]
[1] Assistant professor, Department of Civil Engineering, Vivekanandha College of Technology for Women, Tiruchengode
[2,3,4]UG Student, Department of Civil Engineering, Vivekanandha College of Technology for Women, Tiruchengode

Article Info
Article history:
Received 25 January 2019
Received in revised form
20 February 2019
Accepted 28 February 2019
Available online 15 March 2019

Keywords
GGBS concrete; Nano Silica; Nano Titanium dioxide; Compressive strength; Split Tensile Strength; Flexural Strength

ABSTRACT
Cementitious Concrete has great practical difficulties and environmental problems so it can be reduced by the utilization of supplementary cementitious materials and non- conventional materials that would partially replace cement used in concretes. In this experimental investigation, Cement is partially replaced by 30%, 40% of Ground Granulated Blast furnace Slag(GGBS), 3 % of Nano Silica and 3% of Nano Titanium dioxide by weight. The influence of combined application of GGBS, Nano Silica, Nano Titanium dioxide on compressive strength, Split tensile strength and Flexural strength of M25 grade of concrete is studied. The test results of concrete prepared using the different proportions of GGBS, Nano Silica and Nano Titanium dioxide is compared with that of conventional concrete. The results showed that there is appreciable increase in strengths and attributed to the effective particle packing with the concrete prepared with 30% of GGBS and 3% of Nano Silica and it is the optimized mix. With the consideration of economy, the concrete with 40% GGBS and 3% Nano Silica also attributes to the higher strength properties since GGBS is replaced by higher 40 % of the cement in concrete.

1. INTRODUCTION

Concrete is typically the most massive individual material element in the built environment. Concrete is primarily comprised of Portland Cement , aggregates and water. Although Portland cement typically comprises only 12% of the concrete mass, it accounts for approximately 93% of strength necessary for design of the structures. In the present day construction practice along with the strength equal importance is given to the durability of concrete. With the increase in use of concrete, the manufacturing and consumption of cement has increased drastically. Although cement has exceptional binding properties, the manufacturing of cement results in emission of large amounts of CO_2 results in environmental pollution. Over 5% of global CO_2 emissions can be credited to Portland cement production and every one tonne of cement production releases 0.5 tonne of carbon di oxide.

The limitations of cement can be reduced by replacing the cement with alternative materials which have pozzolanic characteristics, economical as well as environmental friendly. The Sustainable development in construction involves the use of innovative materials and recycling of waste materials in order to compensate the lack of natural material. In this study, Ground granulated blast furnace slag (GGBS) is the industrial by- product which provide excellent binding properties to concrete and Nano particles such as Nano Silica , Nano Titanium dioxide are used as a supplementary materials to improve the performance of concrete and these materials serves as the replacement of cement.

2. OBJECTIVE AND SCOPE OF THIS STUDY

OBJECTIVES

- To find the influence of the combined application of GGBS and Nano materials on various strength properties of concrete.
- 30%, 40% of GGBS and 3% of Nano Silica and Nano Titanium dioxide are adopted as partial replacement of cement by weight to determine the compressive strength, Split tensile strength and Flexural strength of concrete specimens.
- To determine the most optimized mix of GGBS and Nano particles based concrete.

SCOPE

- The concrete incorporating GGBS and Nano particles is used to reduce the green gas emission and production of green concrete which is a revolutionary topic in concrete industry is achieved by utilizing industrial waste such as GGBS.
- The use of Nano silica, Nano Titanium dioxide and GGBS is to increase the durability, self compacting and self healing properties of concrete.

3.MATERIALS

a) Cement

Cement is the most important ingredient and act as a binding material. PPC of 53 grade flyash based cement is used for this study.

Table 1 : Physical Properties of Cement

S.No	Properties	Result
1.	Standard Consistency	31%
2.	Initial Setting Time	35 minutes
3.	Specific gravity	2.92
4.	Fineness	9%

ram4u88@gmail.com

b) Fine aggregates

The most important function of the fine aggregate to assist in producing workability and uniformity in mixture. In this study m – sand is used as the fine aggregate.

Table 2 : Physical properties of fine aggregates

S.No	Properties	Results
1.	Specific gravity	2.58
2.	Water absorption	1.5%
3.	Fineness modulus	3.90%

c) Coarse aggregate

The coarse aggregate is the strongest and least porous component of concrete. The presence of coarse aggregate reduces the drying shrinkage and other dimensional changes occurring an account of movement moisture. In this study hard broken stone passing through 20mm sieve is used as a coarse aggregate.

Table 3 : Physical Properties of Coarse Aggregate

S.No	Properties	Results
1.	Specific gravity	2.61
2.	Water absorption	0.5%
3.	Impact value	12.16%
4.	Fineness modulus	6.02%

d) Ground Granulated Blast furnace Slag

Ground granulated blast furnace slag is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam to produce a glassy, granular product that is then dried and ground into a fine powder. In this study, GGBS is purchased from Mark Associates, Tirupur.

Fig 1 : Ground Granulated blast furnace slag

e) Nano Silica

Nano Silica is typically a effective pozzolanic material. It normally consists of very fine vitreous particles approximately 1000 times smaller than the average cement particles by direct synthesis of silica sol or by crystallization of Nano sized crystals of quartz.

f) Nano Titanium dioxide

Nano TiO_2 is one of the concrete additives with high potentials. White cement containing Nano TiO_2 have photo-catalytic properties. This allows concrete to maintain its aesthetic characteristics over time. When it is added to concrete or finishing materials it gives the surface self-cleaning effect, therefore it is commercially applied on building facades and in concrete paving materials.

Fig 2 : Nano Silica

Fig 3 : Nano TiO_2

g) Water

The quality of mixing water for concrete has a visual effect on the resulting hardened concrete. Impurities in water may interfere with the setting of cement and will adversely affect the strength and durability of concrete with wastage.

4. MIX DESIGN

a) Mix design

The Bureau of Indian Standards recommended a set of procedure for design of concrete mix. The procedure is based on the research work carried out at national laboratories. The mix design procedures are covered in IS 10262:1982 which can be applied for both medium and high strength concrete. Mix proportion used in this study is 1 : 1.8 : 2.4 with water cement ratio 0.47.

b) % of Replacement of cement

Table 4: % of Replacement

Mix	Cement	GGBS	Nano SiO_2	Nano TiO_2
M0	100%	-	-	-
M1	67	30	3	-
M2	67	30	-	3
M3	57	40	3	-
M4	57	40	-	3

c) Mix proportion

Table 5 : Mix proportion

Ingredients	Mixes				
	M0	M1	M2	M3	M4
Cement (kg/m$^{3)}$	420	282	282	240	240
GGBS (kg/m$^{3)}$	-	126	126	168	168
Nano SiO_2 (kg/m$^{3)}$	-	12.6	-	12.6	-
Nano TiO_2 (kg/m$^{3)}$	-	-	12.6	-	12.6
Water (litres/m$^{3)}$	197	197	197	197	197
Coarse Aggregates (kg/m$^{3)}$	986	986	986	986	986
Fine Aggregates (kg/m$^{3)}$	752	752	752	752	752

ram4u88@gmail.com

5. EXPERIMENTAL PROGRAMMES

The experimental work involves casting and testing of specimens to know the compressive strength of cube, split tensile strength of cylinder and flexural strength of prism.

a) Batching : Weigh Batching is adopted for concrete production to measure cement, GGBS, Nano silica , Nano titanium di oxide and aggregates.

b) Mixing : Hand Mixing is done in this study for concrete production of M_{25} grade by adding 30% , 40% GGBS and 3% Nano silica and Nano Titanium dioxide to the cement , water and aggregates.

c) Casting of Specimen : Cube specimens of 150mm x 150mm x 150mm size for compressive strength, cylinder specimens of size 150mm diameter x 300 mm height for split tensile strength and prism size of 100mm x 100mm x 500mm for flexural strength were casted according to Indian standards.

d) Curing ***:*** The specimens are cured with water for 7 days , 14 days and 28 days for testing.

0e) Testing : In this study, Slump cone test is done to check the workability of fresh concrete with different concrete mixes and Compressive strength test, Split tensile strength test and flexural strength test is done to determine the hardened properties of concrete

f) Slump test

Slump test is used to determine the workability of fresh concrete. Slump test as per IS 1199-1959 is followed. It is an indirect measurement of concrete consistency or stiffness. The consistency or stiffness indicates how much water has been used in the mix.

Fig 4 : Slump Test

g) Compressive Strength

Out of many tests applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. Compressive strength of concrete mainly depends on water cement ratio, cement strength, quality of concrete test material and quality control during production of concrete.

Fig 5 : Compressive strength Test

h) Split Tensile Strength

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength on concrete is a method to determine the tensile strength of concrete.

Fig 6 : Split Tensile strength Test

i) Flexural Strength

Flexural strength of concrete also known a modulus of rupture or bend strength is a material property defined as the stress in a material just before it yields in a flexure test.

Fig 7 : Flexural strength Test

6. RESULTS AND DISCUSSIONS

a) Slump Values

Table 6 : Slump Values of different mix proportion

S.NO	MIX DESIGNATION	PROPORTION	SLUMP VALUE (mm)
1	M0	100% PPC	80
2	M1	67% PPC +30% GGBS + 3% N.S	75
3	M2	67% PPC +30% GGBS + 3% N.T	90
4	M3	57% PPC+ 40% GGBS + 3% N.S	100
5	M4	57% PPC+ 40% GGBS + 3% N.T	110

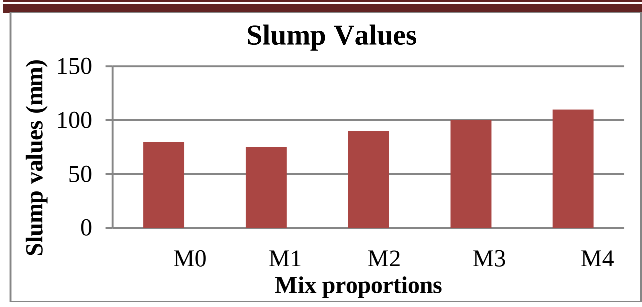


Fig 8 : Slump Values of different mix proportion

b) Compressive strength

Table 7 : Compressive strength at 7, 14, 28 days

Compressive Strength(N/mm^2)		Mix Proportion				
		M0	**M1**	**M2**	**M3**	**M4**
7 days	**Trials**	17.77	18.66	13.33	13.33	11.11
		16.8	18.22	11.11	17.77	10.66
		18.2	17.32	11.3	15.4	11.5
	Average	17.59	18.0	12	14.93	11.1
14 days	**Trials**	18.66	23.55	21.3	18.66	12.4
		17.77	24	22.22	15.55	13.33
		20.44	24	20.4	20.44	14.2
	Average	19	23.8	21.3	18.2	13.31
28 days	**Trials**	23.11	32	31.1	21.3	20
		24	32	28.8	20.44	18.66
		25	33.7	30.6	22.22	19.52
	Average	24	32.5	30	21.3	25.8

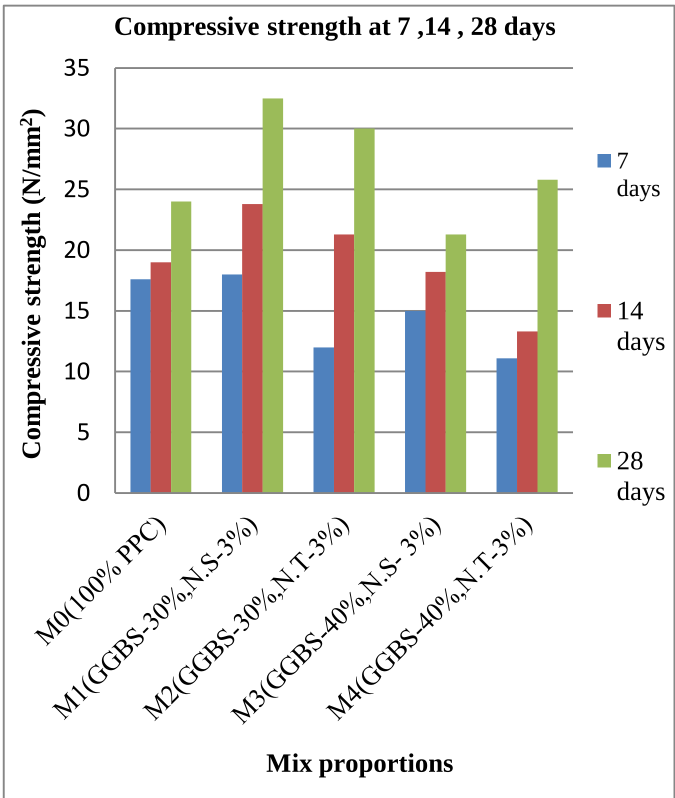


Fig 9: Compressive strength at 7, 14, 28 days

The variation of the cube compressive strength of M_{25} grade concrete with age for various proportions of GGBS, Nano silica and Nano titanium dioxide at 7days, 14 days and 28 days curing is shown. It can be observed that the compressive strength of concrete prepared using GGBS of 30 % and Nano silica of 3% exhibits more strength of 26% compared to controlled concrete and with further increase in GGBS the compressive strength decreases. The compressive strength of concrete prepared using GGBS of 30 % and Nano titanium dioxide of 3% Exhibits more strength of 20% compared to controlled concrete and with further increase in GGBS the compressive strength decreases in this case also.

c) Split Tensile strength

Table 8 : Split Tensile strength at 7, 14, 28 days

Split Tensile Strength(N/mm^2)		Mix Proportion				
		M0	**M1**	**M2**	**M3**	**M4**
7 days	**Trials**	2.5	2.12	1.69	2.26	1.41
		2.4	2.40	2.26	1.98	1.69
		2.2	2.16	2.06	2.12	1.8
	Average	2.4	2.22	2	2.12	1.64
14 days	**Trials**	2.5	2.6	2.26	2.5	2.1
		2.4	2.8	2.26	2.4	2.1
		2.4	3	2.4	2.8	2.26
	Average	2.45	2.8	2.3	2.52	2.15
28 days	**Trials**	2.4	2.8	2.26	2.5	2.26
		2.5	3	2.4	2.6	2.1
		2.5	2.8	2.4	2.8	2.26
	Average	2.46	2.86	2.35	2.64	2.20

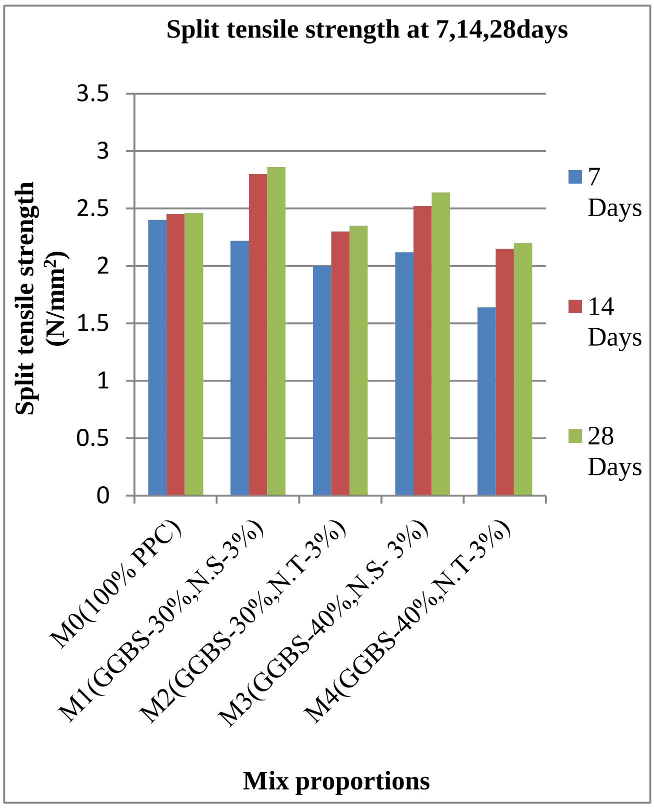


Fig 10: Split Tensile strength at 7, 14, 28 days

The variation of the split tensile strength of M_{25} grade concrete with age for various proportions of GGBS, Nano silica and Nano titanium dioxide at 7days, 14 days and 28 days curing is shown. It can be observed that the split tensile strength of concrete prepared using GGBS of 30 % and Nano silica of 3% exhibits more strength of 14% compared to controlled concrete and with further increase in GGBS the tensile strength decreases. The split tensile strength of concrete prepared using GGBS of 30 % and Nano titanium dioxide of 3% exhibits more strength of 6.8% compared to controlled concrete and with further increase in GGBS the tensile strength decreases in this case also.

d) Flexural strength

Table 8 : Flexural strength at 7, 14, 28 days

Flexural Strength(N/mm²)		Mix Proportion				
		M0	M1	M2	M3	M4
7 days	Trials	1.5	2	1.25	2.5	1.25
		2.25	2.25	1.5	2.5	1.25
		1.75	2	1.5	1.25	1.8
	Average	1.83	2.08	1.4	2.3	1.33
14 days	Trials	4.5	4.25	3	4	2.75
		4.75	4.25	3.25	4.25	2.75
		4.5	4	3.5	4.25	3
	Average	4.5	4.25	3.25	4.16	2.83
28 days	Trials	5.5	6.5	4	5.25	3.75
		5	6.75	3.75	5.75	3.5
		5.5	5.25	3.75	5.75	3.5
	Average	5.3	6.16	3.83	5.58	3.58

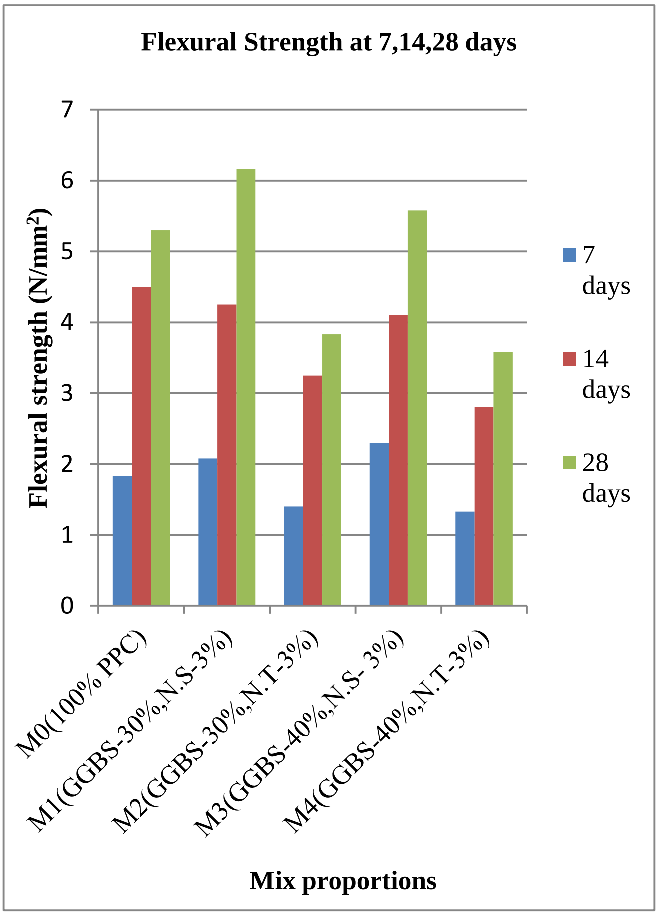
Fig 11 : Flexural strength at 7, 14, 28 days

The variation of the flexural strength of M_{25} grade concrete with age for various proportions of GGBS, Nano silica and Nano titanium dioxide at 7days, 14 days and 28 days curing is shown. It can be observed that the flexural strength of concrete prepared using GGBS of 30 % and Nano silica of 3% exhibits more strength of compared to controlled concrete and with further increase in GGBS the strength decreases. The flexural strength of concrete prepared using GGBS of 30 % and Nano titanium dioxide of 3% exhibits more strength of compared to controlled concrete and with further increase in GGBS the strength decreases in this case also.

7. CONCLUSIONS

Based on the experimental investigation the following conclusions are drawn,

1. It is observed that GGBS and Nano particles based concrete have achieved an increase in Compressive strength , Split tensile strength and flexural strength at 7 days,14 days and 28 days curing.



2. The workability of concrete was found to be increases with the increase in GGBS and Nano particles in concrete.
3. The most optimized mix of GGBS and Nano particles based concrete is found to be 30% of GGBS and 3% of Nano silica from Compressive, split tensile strength and flexural strength of concrete.

4. When compared to Nano Titanium dioxide, the Nano silica of 3% and GGBS of 40% concrete mix shows higher strength and with the economical consideration it is optimum mix proportion since 40% of cement is replaced by GGBS.
5. Nano Titanium dioxide of 3% incorporating concrete with GGBS replacement of 30 % exhibit more strength compared to controlled concrete mix and beyond 30% of GGBS replacement, the strength decreases.
6. As far as cost is concerned, the cost of the GGBS in the market is three times less than that of OPC. The replacement of cement by GGBS and Nano particles not only increases the strength properties but also reduces the cement content which eventually leads to the decrease in emission of CO_2.

8. REFERENCES

1. Balaji subbramanian, Dr. Sreevidya " Experimental study on partial replacement of OPC with flyash and GGBS in concrete"

2. B.Kaviya , Arjun Rajkumar," Study on Partial Replacement of cement by GGBS"

3. Dr.D.V.Prasad Rao , M.Pavan kumar, "Study on influence of flyash and Nano silica on strength properties of concrete".

4. Ehsan Mohseni, Malek Mohammad Ranjbar " Durability properties of High Performance Concrete Incorporating Nano- TiO_2 and Flyash"

5. International journal of Chemtech research, "Durability Study on Nano concrete", P.Vasanthi,S.Senthil selvan.

6. IS 10262 : 2009 , "Recommended guidelines for concrete mix design , Bureau of Indian Standards", New Delhi, India.

7. IS : 383- 1970, " Specifications for Coarse aggregate and fine aggregate from Natural sources for concrete", BIS,New Delhi.

8. IS 456:2000 , " Plain and reinforced concrete Indian standard Specifications".

9. IS 516- 1959, "Method of test for strength of concrete", BIS,New Delhi.

10. Mani.M , Dr.G.Nandini Devi, " Study on behavior of Nano Concrete".

11. M.S.Shetty, " Concrete Technology theory and Practice" revised edition 2005, S.Chand Company Limited, New Delhi.

12. P.Lakshmaiah chowdary, S.khaja khutubuddin, B.Vinayaka " An Experimental study on Replacement by GGBS in Cement"

13. R. Sakthivel, Dr.N. Balasundaram "Experimental Investigation on behavior of Nano Concrete"

14. Vishal porwal, Devendre kumar pal, Deepak keer " Partial replacement of cement by fly ash and Titanium dioxide (TiO_2) in concrete"

15. V. Nagendra, C. Sashidar, S.M.Prasanna kumar ,N.Venkata ramana " GGBS and Nano silica Effect on Concrete"

ram4u88@gmail.com