RESEARCH ARTICLE OPEN ACCESS

Partial Replacement of Cementitious Material in Self Compacting Concrete by Using Ground Granulated Blast Furnace Slag (GGBS)

Pranav R. Dengale, Kushal R. Jain, Dhananjay S. Kapase, Mohal R. Kapse
Department of Civil Engineering, Gokhale Education Society's R. H. SAPAT College of engineering, Management Studies and Research, Nashik - 422005
Department of Civil Engineering, Gokhale Education Society's R. H. SAPAT College of engineering, Management Studies and Research, Nashik - 422005
Department of Civil Engineering, Gokhale Education Society's R. H. SAPAT College of engineering, Management Studies and Research, Nashik - 422005
Department of Civil Engineering, Gokhale Education Society's R. H. SAPAT College of engineering, Management Studies and Research, Nashik - 422005

ABSTRACT
The utilization of supplementary cementation materials is well accepted, since it leads to several possible improvements in the concrete composites, as well as the overall economy. The present paper is an effort to quantify the strength of ground granulated blast furnace slag (GGBS) at various replacement levels and evaluate its efficiencies in concrete. Cement with GGBS replacement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, energy savings, cost savings, environmental and socio-economic benefits. This research evaluates the strength and strength efficiency factors of hardened concrete, by partially replacing cement by various percentages of ground granulated blast furnace slag for M35 grade of concrete at different ages. From this study, it can be concluded that, since the grain size of GGBS is less than that of ordinary Portland cement, its strength at early ages is low, but it continues to gain strength over a long period. The optimum GGBFS replacement as cementation material is characterized by high compressive strength, low heat of hydration, resistance to chemical attack, better workability, good durability and cost-effectiveness.
Fly Ash and GGBS is obtained as waste by-products from the thermal and IRON industries. The utilization of thermal industry waste fly ash and iron industry waste GGBS can reduce the consumption of natural resources, reduce the quantity of expensive cement and reduce environmental pollution. Investigations were carried out to gainful utilization of fly ash and GGBS in concrete mixtures. This research work describes the gainful utilization of the fly ash and GGBS in concrete production as partial replacement of cement by weight. The cementitious material (cement + fly ash) has been replaced by GGBS accordingly in the range of 0% (GGBS), 10%, 15% and 20% by weight of cementitious material for M-30 mix. Concrete mixtures were produced, tested and compared in terms of compressive strength to the conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results for compressive strength up to 28 days.
Keywords – Cementitious material, Compressive strength, GGBS, Replacement of cement, Self-compacting concrete.

I. INTRODUCTION

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. The creation of durable concrete structures requires adequate compaction by skilled workers. However, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures independent of the quality of construction work is the into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction. The necessity of this type of concrete was proposed by Okamura in 1986. A committee was formed to study the properties of SCC, inducing the fundamental investigation on the workability of concrete, which was carries out by Ozawa at the University of Tokyo. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, have been carried out by Ozawa and Maekawa at the University of Tokyo employment of self-compacting concrete, which can be compacted and was named "high performance concrete", and later proposed as "self compacting concrete".

Self compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in section with congested reinforcement. Use of SCC can also help minimize hearing-related damages on the worksite that are induced by vibration of concrete. Another advantage of SCC is that the time required to place large sections is considerably reduced. The SCC has gained wide use in many countries for different application and structural Configurations SSC require a high slump that can be achieved by incorporating several chemical admixtures. The super plasticiser influences the rheological behaviour; the viscosity and the yield value of the fresh concrete are reduced in certain concrete mix. The super plasticiser ensures high fluidity and reduces water powder ratio. Super plasticiser greatly improves pump-ability and the slump value can be greatly increased. The use of viscosity modifying admixtures increases segregation resistance of concrete and increases the deformability without segregation and then to lead high optimum self-compatibility. Self-compacting concrete plays a major role in increasing the use of industrial by products like slag, fly ash and silica fume. SSC offers possibility for utilization of dusts which are currently waste products demanding with no practical applications and which are costly to dispose off. The SCC technology is now being adopted in many countries. In the absence of suitable standardized test methods it is necessary to examine critically the existing test methods and identify or develop test methods suitable for acceptance as standards which must be capable of rapid and reliable assessment of properties of SCC on a site.

1.1 OBJECTIVES

- To investigate the utilization of GGBS as supplementary cementitious material.
- To produce low cost concrete by blending various ratios of cement with GGBS.
- To reduce disposal and pollution problems due to GGBS it is most essential to develop profitable building materials from GGBS.
- Influence of GGBS on the strength on concretes made with different cement replacement levels.
- To find out the optimum percentage for replacement of cement by GGBS in self compacting concrete.

Coarse Aggregate - The fractions from 80 mm to 4.75 mm are termed as coarse aggregate.
Fine Aggregate - Those fractions from 4.75 mm to (Ozawa 1989, Okamura 1993 & Maekawa 1999). The first use able version of SCC was completed in 1988

1.2 SCOPE OF WORK

The effect of replacement of cementitious material by GGBS on mechanical properties of self compacted concrete is studied i.e. effect on Compressive strength was studied. Also self compacted concrete (SCC) is developed using Super Plasticizer and Viscosity Modifying Agent (VMA). The following recommendations are suggested for the future research:

- Effect of GGBS on other properties like Modulus of Elasticity, Bond etc.
- Effect of change of molecular weight of on self compacting concrete.
- The durability performance of SCC such as resistances to corrosion, alkali aggregate reaction, sulfate attack, and freezing and thawing should be investigated.
- Effect of natural climate factors such as sunlight, ambient temperature and humidity during self curing on the properties may be studied.
- The change in flowablity properties due to the addition of GGBS and Fly Ash.

II. PROPERTIES OF MATERIAL

Cement - The most common cement is used is ordinary Portland cement. The Type 1 is preferred according to IS: 269-1976, which is used for general concrete structures. Out of the total production, ordinary Portland cement accounts for about 80-90 percent. Many tests were conducted to cement some of them are consistency tests, setting tests, soundness tests, etc.

Aggregate - Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Good grading implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste will mean less quantity of cement and less water, which will further mean increased economy, higher strength, lower shrinkage and greater durability.

Aggregate comprises about 55% of the volume of mortar and about 85% volume of mass concrete. Mortar contains of size of 4.75 mm and concrete contains aggregate up to a maximum size of 150 mm.

150 micron are termed as fine aggregate.

Water - Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

Ground Granulated Blast Furnace Slag (GGBS) - Slag is a by-product obtained in the manufacture of pig-iron. It is a product formed by the combination of the earthy constituents of iron-ore with the limestone flux at high temperature inthe blast furnace (about 15000c). The molten slag is rapidly quenched by a hose of water to yield a glassy granular product called granulated blast furnace slag. Hydrated slag's, granulated or palletized, give the same hydrates as Portland cement i.e., C-S-H and AF1 phases. As they react more slowly with water than Portland cement, they can be activated by different ways: chemically in presence of lime and sulphate activators, physically by grinding or thermally. Slag, which is obtained by grinding the granulated blast furnace slag, is highly pozzolanic in nature. Cement replacement levels of slag can be much higher than that of other pozzolanic materials, such as, Fly ash and silica fume. Generally, GGBS has higher 'CaO' content than other pozzolanas. The chemical properties of GGBS are given in TABLE.

Table 1 - Chemical characteristics of GGBS

CHEMICAL COMPONENTS	VALUES
Silicon dioxide (SiO_2)	33.78%
Aluminum Oxide (Al_2O_3	17.08%
Calcium Oxide (CaO)	39.87%
Magnesium Oxide (MgO)	7.10%

III. METHODOLOGY

MIX DESIGN:-

M30 grade mix was designed as per IS 10262-2009 and the mix proportion was found by trial and error method. Specimens were casted and compressive strength of concrete were determined.

CALCULATIONS REQUIRED FOR QUANTITY OF CONCRETE:-

1) Volume for 1 cube = (150^3) = 0.003375 m^3
2) Volume for 9 cubes = 9 x 0.003375=0.030375 m^3
3) 35% of addition for wastage = 0.030375 x 1.35 = 0.04100625 m^3

Table 2 – Estimation of Quantities for 9 cubes

SR NO.	CONSTITUENTS	For 1 m^3	For 9 CUBES
1)	Cement	4.75 kg/m^3	19.47 kg
2)	Fly Ash	142.5 kg/m^3	5.84 kg
3)	Coarse Agg.	755.16 kg/m^3	30.96 kg
4)	Fine Agg.	922.9 kg/m^3	37.84 kg
5)	Water	186 kg/m^3	7.63 kg
6)	Super-Plasticizer	0.75% of cementitious material	189 gm
7)	VMA	0.5% of cementitious material	126 gm

By replacing cementitious material (cement + fly ash) by 5% (1.26kg),10% (2.53kg) and 15% (3.79) by GGBS and studying compressive strength of concrete and from those tests deciding the optimum dosage of GGBS in concrete.

3.1 COMPRESSIVE TEST

Standard metallic cube moulds (150x150x150 mm) were casted for compressive strength. The specimens were demoulded after 24 hours and subsequently immersed in water for different age of testing. For each age three specimens were tested for the determination of average compressive strength. The test was performed on compression testing machine.

Compressive strength of concrete:

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc.

Test for compressive strength is carried out on cubes. Various standard codes recommends concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard Test Method for Compressive Strength on cubes. For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used.

This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is

curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete

Fig 3.1 - Metallic Mould for Casting Cube

NOTE - Minimum three specimens should be tested at each selected age. If strength of any specimen varies by more than 15 per cent of average strength, results of such specimen should be rejected.

3.2 U BOX TEST

About 20 litre of concrete is needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surface of the apparatus, remove any surplus water, fill the vertical section of the apparatus with the concrete sample. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the other compartment. After the concrete has come to rest, measure the height of the concrete in the compartment that has been filled, in two places and calculate the mean (H1). Measure also the height in the other equipment (H2). Calculate H1-H2, the filling height. The whole test has to be performed within 5 minutes.

U box test method on SCC :

The test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Sometime the apparatus is called a "box shaped" test. The test is used to measure the filing ability of self compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments; an opening with a sliding gate is fitted between the two sections. Reinforcing bar with nominal diameter of 134 mm are installed at the gate with centre to centre spacing of 50 mm. this create a clear spacing of 35 mm between bars. The left hand section is filled with about 20 liter of concrete then the gate is lifted and the concrete flows upwards into the other section. The height of the concrete in both sections is measured.

Assessment of test :

This is a simple test to conduct, but the equipment may be difficult to construct. It provides a good direct assessment of filling ability-this is literally what the done by putting cement paste and spreading smoothly on whole area of specimen. These specimens are tested by compression testing machine after 7 days.

between the sections of reinforcement may be considered too close. The question remains open of what filling height less than 30cm is still acceptable.

Equipment :

- U box of a stiff non absorbing material
- Scoop
- Trowel
- Stopwatch

Fig 3.2 - U box test Apparatus

Procedure for U Box Test on Self Compacting Concrete :

About 20 liter of concrete is needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surface of the apparatus, remove any surplus water, fill the vertical section of the apparatus with the concrete sample. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the other compartment. After the concrete has come to rest, measure the height of the concrete in the compartment that has been filled, in two places and calculate the mean (H1). Measure also the height in the other equipment (H2). Calculate H1-H2, the filling height. The whole test has to be performed within 5 minutes.

Interpretation of the result :

If the concrete flows as freely as water, at rest it will be horizontal, so H1-H2=0. Therefore the nearest this test value, the 'filling height', is to zero, the better the flow and passing ability of the concrete.

3.3 L BOX TEST

About 14 litre of concrete needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surface of the apparatus, remove any surplus water, fill the vertical

concrete has to do- modified by an unmeasured requirement for passing ability. The 35 mm gap
200 and 400 marks. When the concrete stops flowing, the distances 'H1' and 'H2' are measured. Calculate H2/H1, the blocking ratio. The whole has tom performed within 5 minutes.

L Box Test on Self Compacting Concrete :

This test is based on a Japanese design for under water concrete, has been described by Peterson. The test assesses the flow of the concrete and also the extent to which it is subjected to blocking by reinforcement. The apparatus is shown in the figure. The apparatus consist of rectangular section box in the shape of an 'L', with a vertical and horizontal section, separated by a movable gate, in front of which vertical length of reinforcement bar are fitted. The vertical section is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section.

It indicates the slope of the concrete when at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted. The horizontal section of the box can be marked at 200mm and 400mm from the gate and the times taken to reach these points measured. These are known as the T20 and T40 times and are an indication for the filling ability. The section of bar con be of different diameters and are spaced at different intervals, in accordance with normal reinforcement considerations, 3x the maximum aggregate size might be appropriate. The bar can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete.

Assessment of test :

This is a widely used test, suitable for laboratory and perhaps site use. It asses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. Unfortunately there is no arrangement t on materials or dimensions or reinforcing bar arrangement, so it is difficult to compare test results.

There is no evidence of what effect the wall of the apparatus and the consequent 'wall effect' might have on the concrete flow, but this arrangement does, to some extent, replicate what happens to concrete on site when it is confined within formwork. Two operators are required if times are measured, and a degree of operator error is inevitable.

Equipment :

- L box of a stiff non absorbing material

section of the apparatus with the concrete sample. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the horizontal section. Simultaneously, start the stopwatch and record the time for the concrete to reach the concrete

Fig 3.3 - L box test Apparatus

Procedure of L Box Test :

About 14 litre of concrete needed to perform the test, sampled normally. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it. Moisten the inside surface of the apparatus, remove any surplus water, fill the vertical section of the apparatus with the concrete sample. Leave it stand for 1 minute. Lift the sliding gate and allow the concrete to flow out into the horizontal section. Simultaneously, start the stopwatch and record the time for the concrete to reach the concrete 200 and 400 marks. When the concrete stops flowing, the distances 'H1' and 'H2' are measured. Calculate H2/H1, the blocking ratio. The whole has tom performed within 5 minutes.

Interpretation of the result :

If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1=1. Therefore the nearest this test value, the 'blocking ratio', is unity, the better the flow of concrete. The EU research team suggested a minimum acceptable value of 0.8. T20 and T40 time can give some indication of ease of flow, but no suitable values have been generally agreed. Obvious blocking of coarse aggregate behind the reinforcement bars can be detected visually.

3.4 T50 TEST

During the slump flow test, the viscosity of the SCC mixture can be estimated by measuring the time taken for the concrete to reach a spread diameter of 20 inches (500 mm) from the moment the slump cone is lifted up. This is called the T_{20} (T_{50}) measurement and typically varies between 2 and 10 seconds for SCC. A higher T_{20}(T_{50}) value indicates a more viscous mix which is more appropriate for concrete in applications with congested reinforcement or in deep sections. A

- Trowel
- Scoop
- Stopwatch

test method for determining the slump .T diameter of the concrete circle is a measure for the filling ability of the concrete.

Assessment of test :

This is a simple, rapid test procedure, though two people are needed if the T50 time is to be measured. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without booking, but may give some indication of resistance to segregation. It can be argued that the completely free flow, unrestrained by any foundries, is not representative of what happens in concrete construction, but the test can be profitably be used to assess the consistency of supply of supply of ready-mixed concrete to a site from load to load.

Equipment :

- Mould in the shape of a truncated cone with the internal dimensions 200 mm diameter at the base, 100mm diameter at the top and a height of 300 mm.
- Base plate of a stiff none absorbing material, at least 700mm square, marked with a circle marking the central location for the slump cone, and a further concentric circle of 500mm diameter
- Trowel
- Scoop
- Ruler
- Stopwatch(optional)

Fig 3.4 - T50cm test

Procedure of T50 Test :

About 6 liter of concrete is needed to perform the test, sampled normally. Moisten the base plate and inside of slump cone, place base plate on level stable ground lower T_{20} (T_{50}) value may be appropriate for concrete that has to travel long horizontal distances without much obstruction.

The slump flow test is used assess the horizontal free flow of in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the.

circle (This is the T50 time).floatable test, might be appropriate. The T50 time is secondary indication of flow. A lower time indicates greater flow ability. The BriteEuRam research suggested that a time of 3-7 seconds is acceptable for civil engineering applications, and 2-5 seconds for housing applications. In case of severe segregation most coarse aggregate will remain in the Centre of the pool of concrete and mortar and cement paste at the concrete periphery. In case of minor segregation a border of mortar without coarse aggregate can occur at the edge of the pool of concrete. If none of these phenomena appear it is no assurance that segregation will not occur since this is a time related aspect that can occur after a longer period.

Interpretation of the result :

The slump flow time T50 is the period between the moment the cone leaves the base plate and SCC first touches the circle of diameter 500 mm. T50 is expressed in seconds to the nearest 1/10 seconds. It is expressed in mm to the nearest 5 mm.

IV. OBSERVATION TABLES

4.1 Compressive strength test :

Table 3 – Partial Replacement with 0% GGBS

Days	Compressive Strength		
	Block 1,4,7	Block 2,5,8	Block 3,6,9
3	9.05	7.61	6.45
7	13.55	12.587	11.51
28	28.53	27.85	27.45

Table 4 – Partial Replacement with 10% GGBS

Days	Compressive Strength		
	Block 1,4,7	Block 2,5,8	Block 3,6,9
3	5.33	5.96	6.23
7	26.67	27.56	18.66
28	30.3	25.6	26.4

and the slump cone centrally on the base plate and hold down firmly. Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel. Remove any surplus concrete from around the base of the cone. Raise the cone vertically and allow the concrete to flow out freely.

Simultaneously, start the stopwatch and record the time taken for the concrete to reach the 00mm spread

Table 5 – Partial Replacement with 15% GGBS

Days	Compressive Strength		
	Block 1,4,7	**Block 2,5,8**	**Block 3,6,9**
3	19.12	18.57	16.45
7	28.60	29.77	23.37
28	22.56	19.26	25.40

Table 6 – Partial Replacement with 20% GGBS

Days	Compressive Strength		
	Block 1,4,7	**Block 2,5,8**	**Block 3,6,9**
3	13.90	15.2	24.8
7	22.2	17.8	16.2
28	25.7	26.98	30.72

4.1 Workability Test

4.1.1 Partial Replacement with 0% GGBS

Table 7 – U Box Test

TEST	HEIGHT
H_1	22.5 mm
H_2	19.5 mm
H_1/H_2	22.5/19.5 =0.86

Table 8 – L Box Test

TEST	TIME
T_{20}	0.8 sec
T_{30}	1.5 sec

Table 9 – T50 Test

TEST	TIME
T_{50}	0.94 sec

4.1.1 Partial Replacement with 20% GGBS

Table 16 – U Box Test

TEST	HEIGHT
H_1	17.8 mm

4.1.2 Partial Replacement with 10% GGBS

Table 10 – U Box Test

TEST	HEIGHT
H_1	16.2mm
H_2	18.4mm
H_1/H_2	16.2/18.2=0.88mm

Table 11 – L Box Test

TEST	TIME
T_{20}	0.76sec
T_{30}	1.48sec

Table 12 – T50 Test

TEST	TIME
T_{50}	0.95 sec

4.1.3 Partial Replacement with 15% GGBS

Table 13 – U Box Test

TEST	HEIGHT
H_1	17.5mm
H_2	19.2mm
H_1/H_2	17.5/19.2=0.91mm

Table 14 – L Box Test

TEST	TIME
T_{20}	0.82 sec
T_{30}	1.50 sec

Table 15 – T50 Test

TEST	TIME
T_{50}	0.90 sec

V. RESULT

Average compressive strength of the concrete cube (at 3 days)

H_2	18.8 mm
H_1/H_2	17.8/18.8=0.94 mm

Table 17 – L Box Test

TEST	TIME
T_{20}	0.78 sec
T_{30}	1.49 sec

Table 18 – T50 Test

TEST	TIME
T_{50}	0.86 sec

For 0 % = 07.70 N/mm^2
For 10 % = **0**5.84 N/mm^2
For 15 % = 18.04 N/mm^2
For 20 % = 17.96 N/mm^2

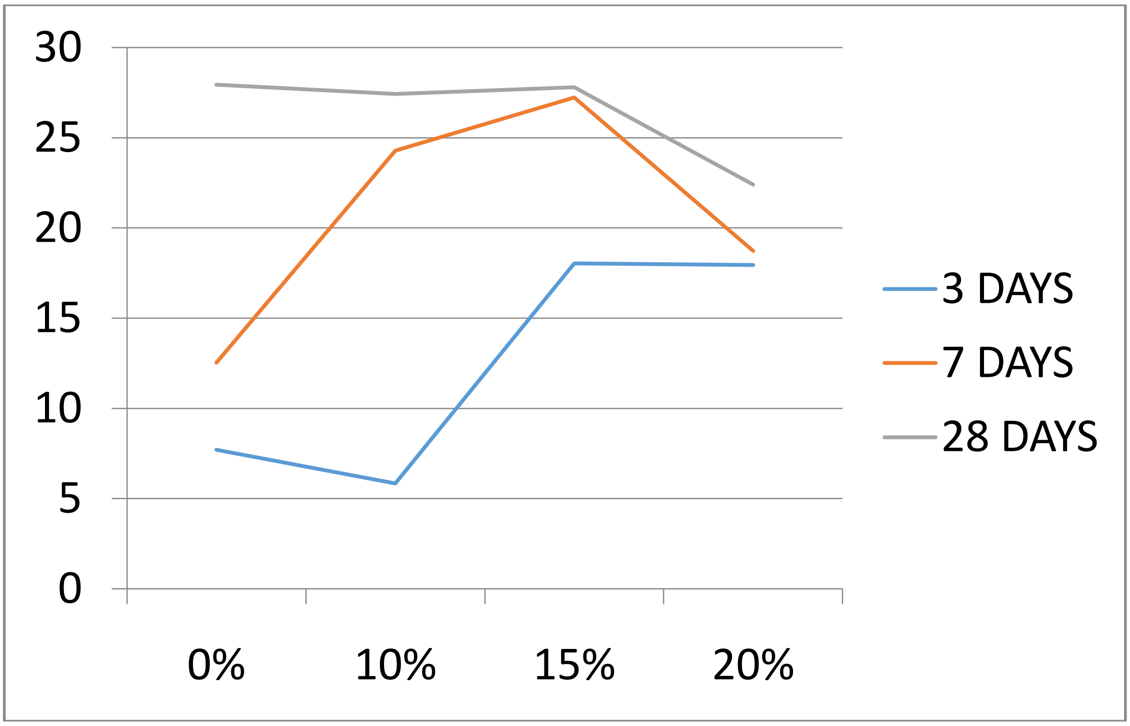
Average compressive strength of the concrete cube (at 7 days)

For 0 % = 12.54 N/mm^2
For 10 % = 24.29 N/mm^2
For 15 % = 27.24 N/mm^2
For 20 % = 18.73 N/mm^2

Average compressive strength of the concrete cube (at 28 days)

For 0 % = 27.94 N/mm^2
For 10 % = 27.43 N/mm^2
For 15 % = 27.80 N/mm^2
For 20 % = 22.41 N/mm^2

GRAPH FOR AVERAGE COMPRESSIVE STRENGTH



VI. CONCLUSION

- Replacing cementitious material by GGBS increased the compressive strength of concrete.
- Also the addition of GGBS did not affect the flowability of the concrete.
- All the properties of Self Compacting Concrete

[4] Nileena, M.S. And Mathew, P., " Effect Of GGBS And GBS On The Properties Of self Compacting Concrete.", *International Journal of Innovative Research in Advanced Engineering (IJIRAE)* ISSN: 2349-2163,Volume 1 ,Issue 9, 2014

[5] Pai, B.H.V. , Nandy, M. , Krishnamurthy, A. , Sarkar, P. And Ganapathy, C., "Experimental Study

were achieved after the addition of GGBS.

- We have concluded from the graph that –

1. The rate of change for 3 days compressive strength at 0% replacement was 7.7 mpa which decreased to 5.84 mpa at 10% replacement and increased considerably to 18.04 mpa for 15% replacement after which it remained constant for 20% replacement.
2. The rate of change for 7 days compressive strength at 0% replacement was 12.54 mpa which increased nearly twice to 24.29 mpa for 10% replacement and 27.24 mpa for 15% replacement but the increase was considerably less for 20% replacement and was 18.73 mpa.
3. For rate of change for 28 days strength there was no increase seen relative to the 0% replacement strength that was 27.94 Mpa and was 27.43 Mpa , 27.80 Mpa for 10% and 15% replacement respectively but decreased to 22.41 Mpa for 20% replacement.

Thus , the 15% replacement was most beneficial for developing concrete which yields high 3 days and 7 days strength that is early strength but the ultimate strength remains the same as conventional concrete.

REFERENCES

[1] Arivalagan, S. "Sustainable Studies on Concrete with GGBS As a Replacement Material in Cement", *Jordan Journal of Civil Engineering*, Volume 8, No. 3, 2014

[2] Bharali, B. "Experimental Study On Self Compacting Concrete (SSC) Using GGBS And Fly Ash", *International Journal Of Core Engineering & Management (IJCEM)* Volume 2, Issue 6, 2015

[3] Joe, A.M. And Rajesh, M.A. "Study on the Effect of GGBS & M Sand in Self Compacting Concrete", *International Journal Of Engineering And Science (IJES)*, Volume 4, PP -12-18, 2015

On Self Compacting Concrete Containing Industrial By Products", *European Scientific Journal* ,vol.10, No.12, 2014

[6] Suresh, D. And Nagaraj, K., "Ground Granulated Blast Slag (GGBS) In Concrete – A Review*", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)* Volume 12, Issue 4 Ver. VI , PP 7682, 2015

[7] Swetha, N. And Karunakar, P., "A Study On Self-Compacting Concrete By Partial Replacement Of Cement With Silica Fume And Ground-Granulated Blast-Furnace Slab (GGBS OR GGBFS)", *International Journal For Technological Research In Engineering* Volume 4, Issue 4, PP2347 – 47, 2016