STUDY OF THE PROPERTIES OF CONCRETE BY USING PORTLAND POZZOLONA CEMENT AND ULTRA FINE SLAG AT DIFFERENT AGE OF CURING

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ABSTRACT

In Indian iron and steel industry Blast furnace slag is discharged as waste . The recycling of these slag's will become an important measure for the environmental protection. Iron and steel are basic materials in present day world. Slag which was regarded as waste has now found its application in various sectors thus helping in safe-guarding the environment due to many years of research. Slag has some quality and properties that are difficult to find in natural materials. The primary constituents of slag are lime (CaO) and silica (SiO_2). Portland cement also contains these constituents. Slag is soluble in water and exhibits an alkalinity like that of cement or concrete. Ground Granulated Blast Furnace Slag (GGBS) and Ultra Fine Ground Granulated Blast Furnace Slag (UFGGBS) are a by-product from the manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of Granulated slag. Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag and Further Ground Granulated Blast furnace Slag (GGBS) is granulated into Ultra Fine Ground Granulated Blast Furnace Slag (UFGGBS) by grinding mills. UFGGBS essentially consists of silicates and alumina silicates of calcium and other bases that are developed in a molten condition simultaneously with iron in a blast furnace. The chemical composition of in UFGGBS is similar to that of Portland cement but the proportion varies. Use of industrial wastes and byproducts as an aggregate or raw material is of great practical significance for environment

CERTIFICATE

This is to certify that project report entitled “Study of the properties of concrete using Portland Pozzolana cement and ultra fine slag at different age of curing”, submitted by LAKSHENDRA SINGH in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering to Jaypee University of information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree or diploma.

Project Guide: Mr. Abhilash Shukla

Date:

Signature:

Signature: Head of Department

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CHAPTER1

INTRODUCTION

1 GENERAL

Creating quality concrete in today’s world does not depend only on achieving a high strength property. Increasing the durability of the concrete so as to increase the life of the concrete and producing a environment friendly concrete are the main reasons in obtaining quality concrete. Some industrial by-products such as Ultra fine Ground Granulated Blast-furnace Slag (UFGGBS) can be partially replaced with Portland Pozzolona Cement (PPC) in the concrete .GGBS is a by-product formed when molten iron blast furnace slag is rapidly chilled by immersing it in water. GGBS is then fed in grinding mills to produces UFGGBS which is more fine in nature. When finely ground and mixed with PPC, it will produce binding properties. The production of slag is more environmentally friendly compared to the production of PPC, thus producing a more environmentally friendly concrete than the PPC concrete Due to the reduced fineness of the UFGGBS and increased Blaine surface area there will be increase in the rate of hydration and Pozzolonic reaction which will increase the early strength of the blended concrete significantly. Higher compressive strength for 7 days curing with 8%ultra fine GGBS (UFGGBS) is observed.

2 CONCRETE

Concrete is a mixture of fine aggregates, coarse aggregates, cement and water. Cement and water form a paste which coats the surface of the fine and coarse aggregates. Chemical reaction known as hydration takes place which makes the paste to hardens and gain strength to form concrete which is rock like in nature. The concrete thus forms is plastic and malleable when newly mixed, and when hardened becomes strong and durable. Skyscrapers, bridges, sidewalks and superhighways, houses and dams are constructed due to properties explained above. The ratio of the materials in the paste influence the strength of the paste known water-cement ratio. The water-cement ratio is the weight of the mixing water divided by the weight of the cement. Lesser water cement ratio corresponds to higher strength of concrete but the workability of the fresh concrete should not be sacrificed, allowing it to be properly placed, consolidated, and cured. Other cementitious materials such as fly ash and slag cement, serve as a binder for the aggregate.

The word concrete comes from the Latin word "concretus" (meaning compact or condensed),[4] the perfect passive participle of "concrescere", from "con-" (together) and "crescere" (to grow).

Perhaps the earliest known occurrence of cement was twelve million years ago. A deposit of cement was formed after an occurrence of oil shale located adjacent to a bed of limestone burned due to natural causes. These ancient deposits were investigated in the 1960s and 1970s.

On a human time-scale, small usages of concrete go back for thousands of years. The ancient Nabatea culture was using materials roughly analogous to concrete at least eight thousand years ago, some structures of which survive to this day.

German archaeologist Heinrich Schliemann found concrete floors, which were made of lime and pebbles, in the royal palace of Tiryns, Greece, which dates roughly to 1400-1200 BC. Lime mortars were used in Greece, Crete, and Cyprus in 800 BC. The Assyrian Jerwan Aqueduct (688 BC) made use of fully waterproof concrete. Concrete was used for construction in many ancient structures.

The Romans used concrete extensively from 300 BC to 476 AD, a span of more than seven hundred years. During the Roman Empire, Roman concrete (or *opus caementicium*) was made from quicklime, pozzolana and an aggregate of pumice. Its widespread use in many Roman structures, a key event in the history of architecture termed the Roman Architectural Revolution, freed Roman construction from the restrictions of stone and brick material and allowed for revolutionary new designs in terms of both structural complexity and dimension.

Concrete, as the Romans knew it, was a new and revolutionary material. Laid in the shape of arches, vaults and domes, it quickly hardened into a rigid mass, free from many of the internal thrusts and strains that troubled the builders of similar structures in stone or brick.

Fig 1: Fresh concrete

Fig 2: Hardened Concrete

2.1 CEMENT

Cement is defined as adhesive substances capable of uniting fragments or masses of solid matter to a compact whole. Cement is a fine powder which when mixed with water sets after a few hours after that in few days time it hardens into a solid, strong material. The main purpose of cement is to bind fine sand and coarse aggregates together in concrete.

calcium, silicon, aluminum, iron and gypsum are the main ingredients of cement other common materials which are used to manufacture cement include limestone, shells, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore. These ingredients when undergo combustion in a closely controlled manner produce rock-like substance that is finally ground into the fine powder known as cement.

Bricklayer Joseph Aspdin of Leeds, England first made Portland cement early in the 19th century by burning powdered limestone and clay in his kitchen stove. With this crude method, he laid the foundation for an industry that annually processes literally mountains of limestone, clay, cement rock, and other materials.

Size of the smallest particle of the cement: 1.5 micron

Avg size of cement particle: 10 micron

Most widely used cements: (OPC) ordinary Portland cement and (PPC) Pozzolona Portland cement

Non-hydraulic cement, such as slaked lime (calcium hydroxide mixed with water), hardens by carbonation in the presence of carbon dioxide naturally present in the air. First calcium oxide is produced by lime calcination at temperatures above 825 °C (1,517 °F) for about 10 hours at atmospheric pressure:

$CaCO_3 \rightarrow CaO + CO_2$

The calcium oxide is then spent (slaked) mixing it with water to make slaked lime:

$CaO + H_2O \rightarrow Ca(OH)_2$

Once the water in excess from the slaked lime is completely evaporated (this process is technically called setting), the carbonation starts:

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

This reaction takes a significant amount of time because the partial pressure of carbon dioxide in the air is low. The carbonation reaction requires the dry cement to be exposed to air, for this reason the slaked lime is a non-hydraulic cement and cannot be used under water. This whole process is called the lime cycle.

Conversely, the chemistry ruling the action of the hydraulic cement is hydration. Hydraulic cements (such as Portland cement) are made of a mixture of silicates and oxides, the four main components being:

Belite ($2CaO \cdot SiO_2$);

Alite ($3CaO \cdot SiO_2$);

Celite ($3CaO \cdot Al_2O_3$);

Brownmillerite ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$).

The silicates are responsible of the mechanical properties of the cement, the celite and the brown millerite are essential to allow the formation of the liquid phase during the kiln sintering (firing). The chemistry of the above listed reactions is not completely clear and is still the object of research.

Fig 3: Cement

2.2 COARSE AGGREGATES

These are those particles which have size greater than 4.75mm and less than 80mm. The diameter of these particles is between 9.5mm to 37.5mm in diameter. They can either be from Primary, Secondary or Recycled sources.

aggregates include gravel and crushed rock. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder.

The size of aggregates to be used in concrete governed by the thickness of section, spacing of reinforcement, clear cover, mixing, handling and placing methods. Aggregate of size less than 20 mm are used for reinforced cement concrete structural members.

Fig.4 **:** Coarse aggregates

2.3 FINE AGGREGATES

Aggregate passing through 4.75 mm sieve are defined as fine. They may be natural sand deposited by rivers or crushed stone sand obtained by crushing stones and crushed gravel sand. The smallest size of fine aggregate (sand) is 0.06 mm. Depending upon the particle size, fine aggregates are described as fine, medium and coarse sands. On the basis of particle size distribution, the fine aggregates are classed into four zones; the grading zones being progressively finer to coarser from grading zone I to grading zone IV (IS: 383). fine aggregate are basically obtained from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources

Fig 5: Fine aggregates

3. ULTRA FINE SLAG

Ultrafine Fine ground granulated blast furnace slag is a powder made from granulated blast furnace eslag using the state-of-art grinding technology. The average particle size is well below 5 microns, or Blaine fineness is between 800 ~ 900 m2/kg, which is 2-3 times higher than common ground granulated blast-furnace slag (GGBS). During manufacturing process, Ultra Fine Slag is intensively treated with proprietary additives to further enhance its reactivity. As a result of ultra fineness and high reactivity, Ultra Fine Slag is superior to GGBS in producing quality concrete, mortar and grouts where high early strength development is desired.

Applications :

1. **High strength concrete** (HSC) with improved workability.

2. **High performance concrete** (HPC) with improved workability, high early strength, low permeability and enhanced durability.

3. **Shotcrete** with improved workability and high early strength.

4. **High strength mortar** where improved workability, high strength and enhanced durability are required.

5. **High strength grout** with improved workability, fluidity and high strength.

Benefits :

1. Improve cohesion/resistance to segregation

2. Enhance compressive strength

3. Reduce permeability

4. Improve corrosion resistance

5. Improve resistance to chloride, sulphate and various other forms of chemical attack

Fig 6: Alccofine slag

Table 1.1 Properties of UFGGBS

Properties	UFGGBS
Blaine Surface area(m_2/kg)	870
BET Surface area(m_2/kg)	4968
Particle mean diameter(um)	4.09
Density(kg/m_3)	2720
Density(kg/m_3)	31.2
Density(kg/m_3)	9
Fe_2O_3	1
CaO	35.1
SO_3	0.1
MgO	11.8

3 **WATER**

The strength of concrete is affected partly by the relative proportion of cement and of the fine and coarse aggregates but the water-cement ratio is another important factor. There is an optimum amount of water that will produce a concrete of maximum strength from a particular mix of fine and coarse aggregate and cement . The ease of working with the concrete or the workability also depends on the quality of water used. The use of less than the optimum amount of water may make setting difficult and reduce workability. On the other hand, greater shrinkage and a reduction in strength will occur when more water than the optimum amount is used. The best water-cement ratio, therefore, depends on the particular concrete mix. Water for mixing and curing should be clean, free from organic and inorganic materials and substances deleterious to concrete and steel.

pH >6.

Fig 7: water added to concrete

CHAPTER 2

LITERATURE REVIEW

Throughout the history of the steel and iron industries, ways have been found to make effective use of these slag, but their traditional use as landfill material came to an limit due to the massive expansion of the steel industry since the mid 1970's. As a result, 98% of slag is now useful material, employed by many national agencies including construction works and it has gained both high acclaim and certification.

Li, Yao, Wang, Lin studied and found that the high performance concrete can be obtained using steel slag powder and blast furnace slag so the recycling of steel slag can bring enormous benefits. Ground granulated blast furnace slag is commonly used in combination with Portland cement in concrete for many applications. The research reported in this study, blast furnace slag powder obtained from steel plant Bhilai is used as a cement replacement material in concrete mix. The optimum slag percentage is chosen based on concrete mix design .The ultimate rivet of this work is to determine the performance of concrete mix containing blast furnace powder and compare it with the plain concrete mix (1:1.67:3.2). This is expected to provide:

1. To partially replace cement content in concrete as it
directly influences economy in construction.
2. Environmental friendly disposal of waste steel slag.
3. To boost the use of industrial waste.

Roy and Idorn (1982): The heat of hydration depends upon the Portland cement and the Slag used. It found a relation of heat of hydration and strength potential of various mixes of GGBF slag and Portland cement.

1. The early age strength of mixtures containing slag is highly dependent on temperature, under standard curing conditions, slag mortars gain strength too slower than Portland cement mortars.
2. Partial replacement of Portland cement with GGBF slag is found to improve the sulfate resistance of concrete.

Ved Prakash Tripathi and Pradeep Kumar: Studied and found that the use of Slag with Portland cement is economical and protects our environment from the pollution caused by huge generation of the waste produced by the industries. The slag utilization by the construction industry is a great contribution towards environment.

Apart from this, the durability of structures made with the use of slag increases in proportion with the percentage blending of the slag. The heat of hydration also goes down. With decrease in the heat of hydration, other benefits in many aspects at construction sites, like curing expenses (water demand), manpower skill to reduce plastic and drying shrinkage etc. are found.

Darren T.Y. Lim, Da Xu, B. Sabet Divsholi, B. Kondraivendhan and Susanto Teng: In this work, a total of four mixes were studied. The first one has a w/c ratio of 035 and 450kg on cementitious materials and the second one has a w/c ratio of 0.28 and 520kg of cementitious materials. The Ultrafine slag replacement was set at 30%. The samples were water cured in lab temperatures of close to 25 °C for 3, 7, 28, 56 and 90 days.

The specimens containing 30% of UFGGBS achieved higher compressive strength compared to its companion concrete Mix without UFGGBS as early as 3 days curing. The UFGGBS leads to a higher rate of hydration and Pozzolanic reaction compared to conventional GGBS. UFGGBS is also able to fill up the pores in interfacial transition zone.

As UFGGBS has a larger surface area so more area is available for Pozzolanic reaction and hydration, better workability and higher consistency. Permeability of concrete is reduced because of which chloride penetration into the concrete is reduced.

C M Dordi , A N Vyasa Rao and Manu Santhanam: In this work both cementitious and Pozzolana reactivity were studied respectively. This leads to more quantity of hydrated products and enhances strength and durability of concrete. It is also reported that the bondage between aggregates and cement paste at interfacial zone is further strengthened due to Pozzolana reactivity.

Use of fine and ultrafine mineral additives in high performance concrete is a must to have improved characteristics both in fresh and hardened states. Ultra fine ground granulated blast furnace slag is the preferred material in fly ash based high strength concrete as it has three distinct advantages such as improving workability and its retention in fresh state and durability and high strength in hardened state.

Maiti et al: He highlighted that in the procedure of concrete mix design as followed in IS 10262,the water-cement ratio should be selected between this and the 28-day compressive strength of concrete and that for concrete with mineral admixtures and superplasticiser, such relationship could also be established. Results shows that the mineral admixtures contribute to the strength development process at 28-days. The relationships however cannot be used for very high strength concrete that is for concrete having 28-day compressive strength above 80MPa,using mineral admixtures. The trial mix approach is the best for selecting mix proportions for such high strength concrete.

Malagavelli and Rao: Study investigated the characteristics of M_{30} concrete with Ground Granulated Blast Furnace Slag(GGBS) and sand with ROBO sand(crusher dust). The cubes and cylinders are tested both for compressive & tensile strengths. This resulted in the improved strength as compared to normal mix concrete.

Dordi et al: summarized the characteristics of a newly developed micro product called ultrafine slag, its performance in various tests and its successful field applications. These studies show that ultra fine slag(UFS) improves the concrete mix cohesiveness and helps in slump retention. UFS imparts higher strength while lowering concrete's shrinkage and creep. Not being a silica-based material, it also provides alkalinity to concrete helping it with its durability. He dealt with important tests using "Alccofine" in concrete in both fresh and hardened states, substantiating the advantages infield trials.

CHAPTER 3

LABORATORY WORK

To initiate the project research following tests were performed to identify the properties of concrete materials available in the laboratory. These tests are required to obtain properties of cement, fine aggregates, coarse aggregates and to find the water content absorbed by aggregates.

3.1 TESTS AND ANALYSIS:

1. Determination of Specific Gravity of Cement

This was done by using Le Chatelier Flask, also known as Specific Gravity Bottle, of 100ml capacity.

Calculations:

$$Specific\ Gravity = \frac{(\mathrm{W2} - \mathrm{W1})}{(\mathrm{W2} - \mathrm{W1}) - (\mathrm{W3} - \mathrm{W4})0.79}$$

W_1= Weight of the empty flask

W_2= Weight of water + flask

W_3= Weight of oil + flask

W_4= Weight of cement + flask + oil

W_5= Weight of cement

Result: Specific gravity of cement is 3.15 g/cc

Fig 8: flask

2. **Fineness of cement:**

   Sieve test: to check the proper grinding of cement

   100 gram of cement was passed continuously for 15 mins through sieve no 9 (BIS) the residue was weighed and this weight shoud not be more than 10% of original weight

   Result: Residue is 0.9 g that is .9% of the sample taken

3. **Normal consistency test:** The basic aim is to find out the water content required to produce a cement paste of standard consistency as specified by the IS: 4031 (Part 4) – 1988. The principle is that standard consistency of

cement is that consistency at which the Vicat plunger penetrates to a point 5-7mm from the bottom of the mould .

Fig 9:Vicat Apparatus

Result: Normal consistency is 38%

4. **Initial and Final Setting Time:** The setting and hardening of a cement is a continuous process, but two points are distinguished for test purposes. The initial setting time is the interval between the mixing of the cement with water and the time when the mix has lost plasticity, stiffening to a certain degree. It marks roughly the end of the period when the wet mix can be molded into shape. The final setting time is the point at which the set cement has acquired a sufficient firmness to resist a certain defined pressure. Most specifications require an initial minimum setting time at

ordinary temperatures of about 45 minutes and a final setting time no more than 10 to 12 hours.

We need to calculate the initial and final setting time as per IS: 4031 (Part 5) – 1988. To do so we need Vicat apparatus conforming to IS: 5513 – 1976

Amount of Water to be added: 0.85×P×Weight of sample/100

Weight of sample: 300g

P=Normal consistency= 38%

Result: initial setting time is 1 hour 17mins and final setting time is 9 hour 40 mins

5. **Water absorption test:** This test helps to determine the water absorption of coarse aggregates as per IS: 2386 (Part III) – 1963. For this test a sample not less than 2000g should be used. The apparatus used for this test are :-
Wire basket – perforated, electroplated or plastic coated with wire hangers for suspending it from the balance, Water-tight container for suspending the basket, Dry soft absorbent cloth
Weight of bucket + Aggregates + Water = 9.57 kg
Weight of surface dried Aggregates + Bucket= 9.52 kg
Result: Water absorbed when surface dries is 0.5%

6. Sieve analysis of fine aggregates

Table 3.1 Sieve analysis of fine aggregates

Sieve size	Agg retained	% Agg retained	% Passed
4.75	20	2	98
2.36	101.5	10.15	87.85
1.18	86.3	8.63	79.22
600	107.1	10.71	68.52
300	336.1	33.6	34.92
150	258	25.8	9.12
Pan	77.2	7.7	Loss = 1.42

Result: As per IS 460-1962 and the sieve analysis the sand is found to be of Zone M

Fig 10: Sieve

3.2 MIX DESIGN FOR M_{30} CONCRETE :

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

a) Design stipulations

(i) Characteristic compressive strength required in the field at 28 days= 30 MPa

(ii) Maximum size of aggregate = 10 mm

(iii) Degree of workability = 0.90 compacting factor

(iv) Degree of quality control = Good

(v) Type of Exposure = Mild

(b) Test data for Materials

(i) Specific gravity of cement = 3.15

(ii) Compressive strength of cement at 7 days = Satisfies the requirement of IS: 269–1989

(iii) 1. Specific gravity of coarse aggregates = 2.60

2. Specific gravity of fine aggregates = 2.60

(iv) Water absorption:

1. Coarse aggregate 0.50%

2. Fine aggregate 1.0%

(v) Free (surface) moisture:

1. Coarse aggregate Nil

2. Fine aggregate 2.0%

Target mean strength for mix design: The target mean compressive (*fck)* strength at 28 days is given by

$fck = fck + tS$

(where fck = characteristic compressive strength at 28 days.)

(S = The standard deviation.)

$fck = fck + 1.65\ S$

Table 3.2 : Values of tolerance factor (t)

Tolerance level (t) NO OF SAMPLES	1 in 10	1 in 15	1 in 20	1 in 40	1 in 100
10	1.37	1.65	1.81	2.23	2.76
20	1.32	1.58	1.72	2.09	2.53
30	1.31	1.54	1.70	2.04	2.46
Infinite	1.28	1.50	1.64	1.96	2.33

Table 3.3 : Assumed standard Deviation as per IS 456 of 2000

Grades of concrete	Assumed standard deviation
M 10	
M 15	3.5
M 20	
M 25	4.0
M 30	
M 35	
M 40	5.00
M 45	
M 50	

Target mean strength of concrete

$30 + 1.65 \times 4 = 36.6$ MPa

Water Cement ratio = 0.50

Table 3.4: Approximate sand and water contents per cubic meter of concrete:

Max size of aggregates	Water content including surface water per cubic meter of concrete	Sand as per cent of total aggregates by absolute volume
10	200	40
20	186	35
40	165	30

Required water content = 40 – 3.5 = 36.5% (3.5 is correction)

= 200 + 6 = 206 l/m^3

Determination of cement content :

W/C ratio = 0.50

Water = 206

Cement = 412 kg/m^3

Calculation of aggregate content :

$V = \{ W + C/S_s + 1/P \times f_a/S_{fa} \}$

$C_a = (1\text{-}P/P) \times f_a \times S_{ca}/S_{fa}$

where

V = absolute volume of fresh concrete, which is equal to gross volume (m3) minus the volume of entrapped air,

W = Mass of water (kg) per m^3 of concrete

C = Mass of cement (kg) per m^3 of concrete

Sc = Specific gravity of cement

P = Ratio of FA to total aggregate by absolute volume

fa, Ca = Total masses of FA and CA (kg) per m^3 of concrete respectively and

S_{fa}, S_{ca} = Specific gravities of saturated, surface dry fine aggregate and coarse aggregate

Table 3.5 : Approximate Entrapped Air Content:

Maximum size of aggregates	**Entrapped air, % of volume of concrete**
10	3.0
20	2.0
40	1.0

Table 3.6: Mix proportion M_{30} concrete

	Water	**Cement**	**Fine aggregates**	**Coarse aggregates**
M_{30}	0.5	1	1.725	3

3.3 EXPERIMENTAL INVESTIGATION :

In this work the compressive strength of two concrete mixes had to be studied both of M_{30} grade the sample A having 0% UFGGBS replacement and sample B having 8% UFGGBS replacement. The samples had to be water cured in lab temperature of close to 25 °C for 7, 21, 56 and 90 days. A total of eight (8) concrete cubes have to be casted. The dimensions of the cube mould are 150mm × 150mm. Approximately 10 kg concrete mix could be filled in these cube moulds.

Table 3.7: Mix proportion details for 10 kg concrete

Mix	Sample A	Sample B
Water	0.871 litre	0.871 litre
Coarse aggregates	5.280 kg	5.280kg
Fine aggregates	3.0 kg	3.0kg
UFGGBS replacement	0%	8%
UFGGBS	0 kg	0.13 kg
Cement	1.742kg	1.61kg

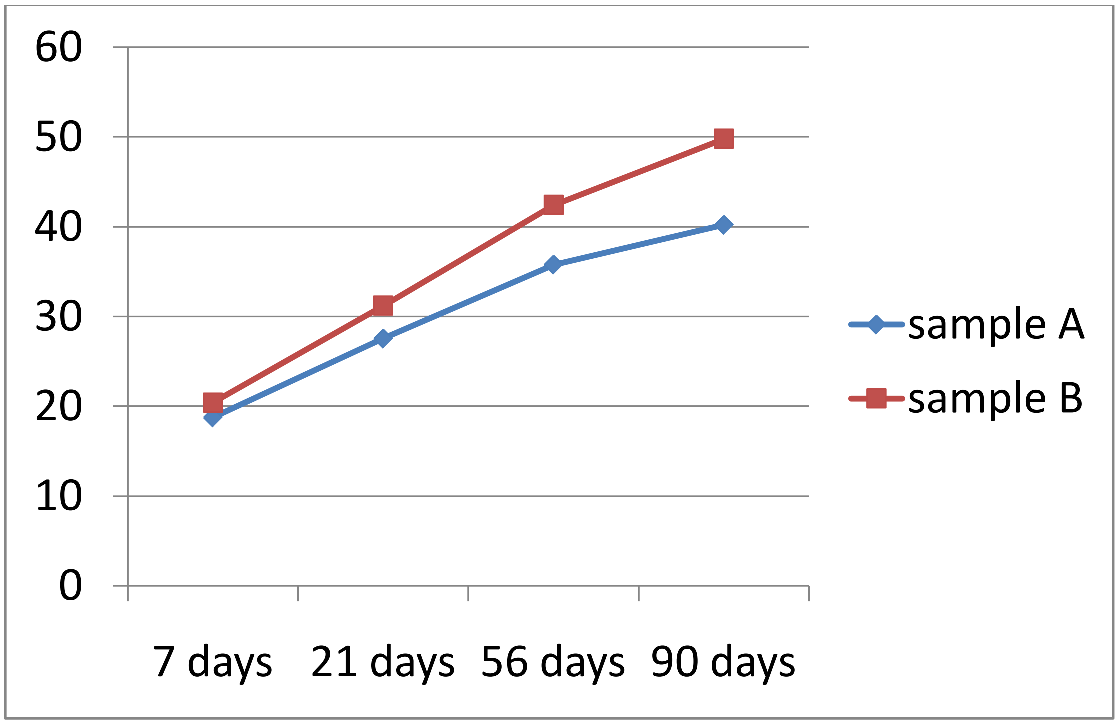
CHAPTER 4

RESULT

Table 4.1 Results

Compressive strength	**Sample A**	**Sample B**
7 days	**18.76 Mpa**	**20.44 Mpa**
21 days	**27.54 Mpa**	**31.23 Mpa**
56 days	**35.78 Mpa**	**42.43 Mpa**
90 days	**40.21 Mpa**	**46.81 Mpa**

Fig. 11: Compression testing machine



Trend in compressive strength

Compressive strength: In the study of strength of materials, the compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures.

Compressive strength is often measured on a universal testing machine; these range from very small table-top systems to ones with over 53 MN capacity. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.

CHAPTER 5

CONCLUSION

1. UFGGBS has a larger total surface area, and thus, more of it is available for hydration and pozzolanic reaction, compared to normal GGBS. In addition, better workability and higher consistency were achieved by utilizing UFGGBS. This will lead to an early strength development in terms of compressive strength, as studied. Sample B has higher compressive strength compared to the sample A even at age of 7 days. This early development of strength is contrary to well established knowledge of ordinary GGBS.

2. With the inclusion of UFGGBS into the concrete, it is possible to obtain a consistent mix, as the high surface area of UFGGBS improves the rheology of fresh concrete.

3. With the inclusion of UFGGBS, there is a significant improvement in the mechanical properties of the concrete. The improvement is more obvious for higher concrete grade.

4. With the inclusion of UFGGBS, the permeability of concrete is reduced significantly.

Due to the reduced permeability, chloride penetration into the concrete is reduced. This marked a significant improvement in the durability aspect of the concrete, especially for Mix.

CHAPTER 6

SCOPE OF FUTURE WORK

Ultrafine slag, a steel factory waste, gives strength as well as durability may be used further in combination with other various admixtures to design high performance concrete. As being a factory waste product, it is cheaper and makes the whole construction economic.

The use of different percentages of ultrafine slag other than the optimum content shall be studied to make better use of it.

REFERENCES

1. Liu, T.C. and Yang, H.M., "Ultrafine Steel Slag and Latest Advance in Blending Materials of High-performance Concrete". Metal Mine, Vol.41, Sep., 2006, pp8-13
2. Roy, D. M., and Idorn, G. M., ―Hydration, Structure, and Properties of Blast Furnace Slag Cements, Mortars, and Concrete,‖ Proceedings, ACI JOURNAL V. 79, No. 6, Nov.-Dec. 1983, pp. 445-457.
3. Ved Prakash Tripathi and Pradeep Kumar., "Ground Granulated Blast Furnace Slag in cement industry : A Sustainable Solution"**.** VSRD International Journal of Mechanical, Civil, Automobile and Production Engineering, Vol. III Issue VIII August 2013.
4. Darren T.Y. Lim; Da Xu; B. Sabet Divsholi; B. Kondraivendhan and Susanto Teng., "Effects of Ultra Fine Slag Replacement on Durability and Mechanical Properties of High strength concrete". 36th Conference on "OUR WORLD IN CONCRETE & STRUCTURES" , Singapore.

5. C M Dordi , A N Vyasa Rao and Manu Santhanam., "Microfine ground granulated blast furnace slag for high performance concrete". Third international conference on sustainable construction materials and technologies"

6. .Maiti, C.S. Agarwal, K.R. Kumar, R.(2006),"Concrete mix proportioning‟‟, Indian ConcreteJournal,23-26

7. .Malagavelli, V. Rao, P.N.(2010), "High Performance Concrete with GGBS and RoboSand‟, International Journal of Engineering Science & Technology,vol.2(10),5107-5113.

8. Dordi Cyrus, Rao Vyasa, A.N. Pathik Ajay(2011), "Micro-technology for high performance concrete‟, The Indian Concrete Journal,October,vol85,43-47

9. "Concrete Technology Theory And Practice". M.S. Shetty, S. Chand & Company Ltd.

10. " Concrete Technology" . A.M. Neville And J.J. Brooks. Pearson Education Limited