STUDY OF THE PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF POZZOLANA PORTLAND CEMENT BY ULTRA FINE SLAG

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CERTIFICATE

This is to certify that project report entitled “Study of the Properties of Concrete by partial replacement of Pozzolana Portland Cement by Ultrafine Slag”, submitted by YASH YADAV 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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CHAPTER 1

INTRODUCTION

1. GENERAL

As we know India is a developing country and developing country's growth mainly depends on how well it uses its natural resources as well as their by-products. Ultrafine Ground Granulated Blast Furnace Slag (UFGGBS), a waste product obtained from steel industries, complies with Indian standards for use in cement and concrete. Due to its better shape and particle-size distributions and the dispersing property, ultrafine slag adds good workability and cohesiveness to cement and acts like a chemical admixture. Also apart from being economic, ultrafine slag imparts great strength to concrete.

Slag is a known product and people have been using it for ages. It was recently used in construction of the tallest concrete structure in the world, Burj Khalifa. In India, many structures have also been constructed, including the bandra outfall project and its tunnel lining projects.

By finding the optimum content of slag percentage to be replaced by the cement, we can achieve a high performance, high strength concrete and also make the construction economic.

2. CONCRETE

Concrete is a mixture of paste and aggregates (rocks). The paste, composed essentially of portland cement and water, coats the surface of the fine (small) and coarse (larger) aggregates. Through a series of chemical reactions called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete.

Within this process lies the key to a remarkable trait of concrete: it's plastic and malleable when newly mixed, strong and durable when hardened. These qualities explain why one material, concrete, can build skyscrapers, bridges, sidewalks and superhighways, houses and dams.

(fig. 1 Concrete Material)

2.1 AGGREGATES

The use of coarse (fig.2) and fine aggregates (fig.3) in concrete provides significant economic benefits for the final cost of concrete in place. Aggregates make up about 60 to 75 percent of the volume of a concrete mixture, and the use of aggregates provides volume stability to the hardened concrete. The shrinkage potential of a cement paste is quite high when compared to the aggregates. Controlling shrinkage of the concrete material is important since shrinkage and cracking potential increase together. Higher shrinkage potential means more cracking when the concrete is restrained from movement by contact with the base material beneath a slab-on-grade, steel reinforcement within structural members, or contact with adjoining concrete members in a structure.

Water demand and cement content increases as the maximum coarse aggregate size decreases. The required volume of paste in a concrete mixture must increase, due to the increased surface area of smaller aggregate sizes, to coat all of the aggregate particles. With this increase in paste quantity there is a reduction of volume of the aggregates per unit of concrete produced, thus the shrinkage of the Mixture.increases.

In short, the aggregates are used to improve economy, but more importantly contribute significantly to the final properties of any concrete mixture.

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(fig.2) Coarse Aggregates

(fig.3) Fine Aggregates

2.2 CEMENT

Type of cement we used for our research is Pozzolana Portland cement.

CHEMICAL COMPOSITION

Portland cement is made up of four main compounds: tricalcium silicate ($3CaO \cdot SiO_2$), dicalcium silicate ($2CaO \cdot SiO_2$), tricalcium aluminate ($3CaO \cdot Al_2O_3$), and a tetra-calcium aluminoferrite ($4CaO \cdot Al_2O_3Fe_2O_3$). In an abbreviated notation differing from the normal atomic symbols, these compounds are designated as C_3S, C_2S, C_3A, and C_4AF, where C stands for calcium oxide (lime), S for silica, A for alumina, and F for iron oxide. Small amounts of uncombined lime and magnesia also are present, along with alkalis and minor amounts of other elements.

Mineral	**Chemical Formula**	**Oxide comp.**	**Abbreviation**
Tri-calcium silicate	Ca_3SiO_5	$3CaO.SiO_2$	C^3S
Di-calcium silicate	Ca_2SiO_4	$2CaO.SiO_2$	C_2S
Tri-calcium aluminates	$Ca_3Al_2O_4$	$3CaO.Al_2O_3$	C_3A
Tetra-calcium alumina ferrite	$Ca_4Al_nFe_{2-n}O_7$	$4CaO.Al_nFe_{2-n}O_3$	C_4AF

Table No. 1.1

The strength developed by portland cement depends on its composition and the fineness to which it is ground. The C_3S is mainly responsible for the strength developed in the first week of hardening and the C_2S for the subsequent increase in strength. The alumina and iron compounds that are present only in lesser amounts make little direct contribution to strength.

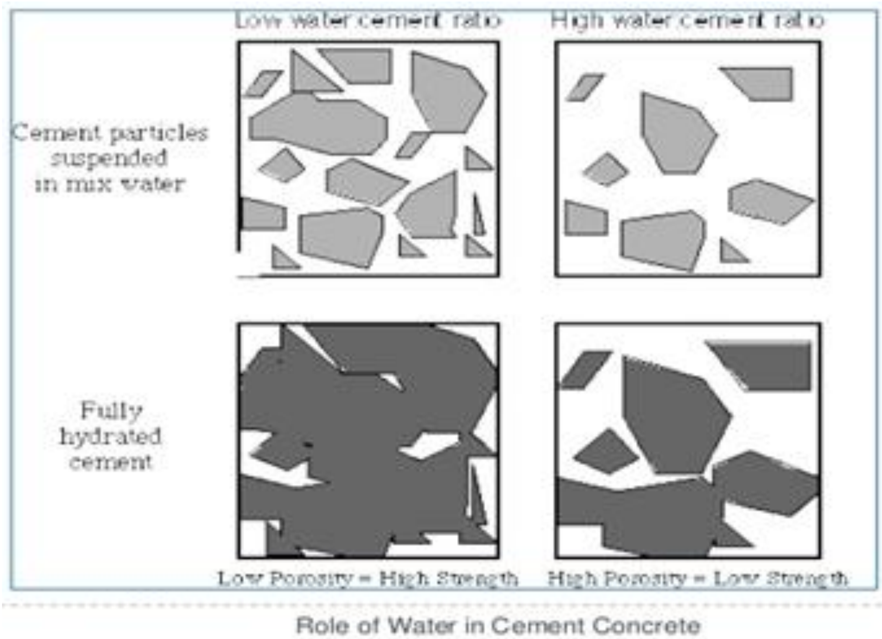
(Fig. 4) Cement

(fig.5) Cement Bag

2.3 WATER

The binder(cement paste) “glues” the filler together to form a synthetic conglomerate. The constituents used for the binder are Cement and Water, while filler are fine and coarse aggregate. Water used for mixing and curing should be free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials.

Potable wahter is generally considered satisfactory for mixing. And pH value shall not be less than 6.



(fig. 6) Role of Water in Cement Concrete

3. ULTRAFINE SLAG

Material technology in concrete has gone through a tremendous change in context with performance. Concrete requires a high-degree of cohesiveness, better workability and strength.

Ultra-fine slag are much finer than normal cement grains and coarser than other products like silica fume. It prevents the ingress of harmful chemicals in concrete and thus increases the durability. It allows denser packing between cement particles and aggregates.

3.1 THE MAKING

Initially, as a waste product in steel industries, derived from molten form, quenched and solidified into a coarse material. It is then grounded and granulated until it becomes ultrafine. Mean particle size of 5 micron makes it more reactive.

(fig. 7 Fly Ash)

3.2 PHYSICAL AND CHEMICAL PROPERTIES

Physical Properties	UFGGBS
Blaine Surface Area(m^2/Kg)	870
BET Surface Area(m^2/Kg)	4968
Particle Mean Diameter	4.09
Density(Kg/m^3)	2720

Table No.1.2

Chemical Properties	UFGGBS
SiO_2	31.2
Al_2O_3	9
Fe_2O_3	1
CaO	35.1
SO_3	0.1
MgO	11.8

Table No.1.3

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 used and the Slag used. It found a relation of heat of hydration and strength potential of various mixes of GGBF slag and Portland cement.

- 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.
- 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 .35 and 450kg on cementitious materials and the second one has a w/c ratio of .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 pozzalanic 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 reactivitywere stidied 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

GENERAL: Following tests were done to fine the various properties of materials required for concrete design. Materials like cement, fine aggregates, coarse aggregates are locally available materials present in the laboratory store.

TESTS AND ANALYSIS:

- Determination of Specific Gravity of Cement

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

  Formula Used:

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

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 2.465 g/cc

(fig. 8) flask

- Fineness of Cement: Fineness of cement is found by using the basic sieve test.

  Sieve test: To check the proper grinding of cement.

  In this test a 100 grams sample of cement was allowed to pass continuously for 15 mins through sieve no 9 (BIS). Then, the residue was weighed. The residual weight should not be more than 10% of original weight of the sample taken.

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

(fig.9) Sieves of different sizes

- Normal consistency test: 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 Vicat mould.

(fig. 10) Vicat Apparatus

Result: Normal consistency is 38%

- 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.

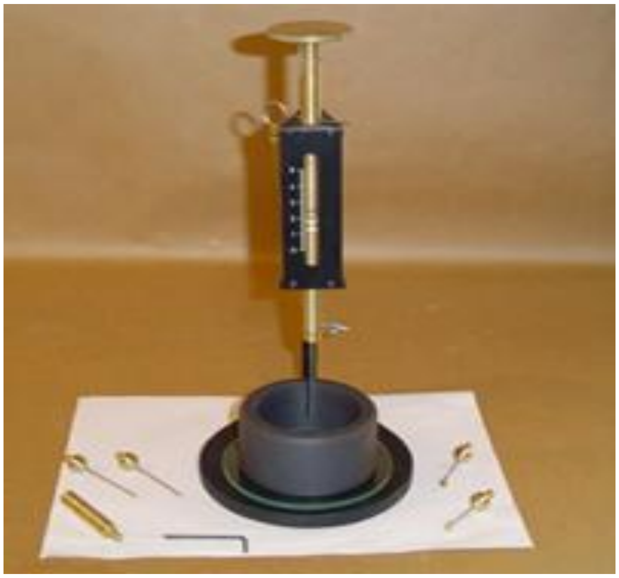
We need to calculate the initial and final setting time as per IS: 4031 (Part 5) – 1988. To do so we need Vicat apparatus conforming to IS: 5513 – 1976

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.



(fig 11) Vicat Apparatus with different needles.

- Water absorption test: This test helps to determine the water absorption of coarse aggregates. For this test a sample not less than 2000g should be used.

The apparatus used for this test:-

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= 9.06

Result: Water absorbed when surface dries is 5%

- 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

Table No. 3.1

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

3.2 CASTING OF CUBES

Cubes were casted for the concrete grade M_{50}. For this, mix design was done to fine the ratios. It was done using IS code 10262: 2009 guidelines.

Mix Design

a) Design stipulations

(i) Characteristic compressive strength required in the field at 28 days= 50 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 g/cc

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

(iii) 1. Specific gravity

1. Coarse aggregates = 2.60
2. 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 strength for a tolerance factor of 1.65 is given as:

$$f_{ck}'' = f_{ck} + tS$$

where ,

f_{ck}'' = Target average compressive strength at 28 days

f_{ck} = Characteristic compressive strength at 28days

S = The standard deviation.

t = 1.65

$f_{ck}'' = f_{ck} + 1.65\ S$

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 No. 3.2

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	

Table No. 3.3

Target mean strength of concrete

$50 + 1.65 \times 5 = 58.25$ MPa

Water Cement ratio = 0.50

Approximate sand and water contents per cubic meter of concrete for 10mm max. aggregate size.

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

Table No. 3.4

Required water content = 28 – 3.5 = 24.5% (3.5 is correction)

= 200 + 6 = 206 L/m^3

Determination of cement content :

W/C ratio = 0.50

Water = 206L/m^3

Cement = 412 kg/m^3

Calculation of Fine and Coarse aggregate content : The total aggregate content per unit volume of concrete calculated by :

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

$$C_a = \left(\frac{1-P}{P}\right) \times f_a \times \frac{S_{ca}}{S_{fa}}$$

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

Approximate Entrapped Air Content:

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

Table No. 3.5

$$0.97 = 206 + \frac{412}{3.15} + \frac{1}{.245} \times \frac{f_a}{2.60}$$

$$f_a = 470 kg/m^3$$

$$C_a = 1 - \frac{0.245}{0.245} \times 470 \times \frac{2.6}{2.6}$$

$$C_a = 1448\ kg/m^3$$

Mix proportion :

	Water	Cement	Fine aggregates	Coarse aggregates
M_{50}	0.5	1	1.140	3.50

Table No.3.6

CHAPTER 4

RESULTS

SLAG %	Days of Curing	Strength
0	7	
3	7	14.44
6	7	18.66
9	7	20.66
12	7	23.33
0	21	17.77
3	21	
6	21	
9	21	
12	21	

Table No. 4.1

***results on completion of 21days**

Fig No. 12

CHAPTER 5

CONCLUSIONS

CHAPTER 6

SCOPE OF FUTURE WORK

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