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DURABILITY DYNAMICS OF CONCRETE AS AFFECTED BY BLAST FURNACE SLAG AND EXPERIMENTAL STUDY

Misbah Ur Rashid Shah

Department of Civil Engg.

Indo Global Group of Colleges, Mohali, Punjab

ABSTRACT

Concrete is one of the most versatile construction material widely used for almost a century now. It was considered to be very durable material and required a little or no maintenance since long time. The assumption is very true, except when it is subjected to highly aggressive environments. The deterioration of concrete structures day by day due to aggressive environment is compelling engineers to assess the loss in advance so that proper preventive measure can be taken to achieve required durability to concrete structures. The compounds present in cement concrete are attacked by many salt solutions and acids. These chemicals are encountered by almost all concrete structures.

The present study has been undertaken to investigate the following aspects:-

- To study the effect of attack of chlorides with varying severity on compressive strength of ground granulated blast furnace slag concrete after immersion in salt solution for 28 days.
- To study the effect of attack of sulphates with varying severity on compressive strength of ground granulated blast furnace slag concrete after immersion in salt solution for 28 days.

Test results indicate that the durability of GGBFS concrete increases with the increase in percentage replacement of cement by GGBFS for 20% and then gradually decreases with increases in percentage of GGBFS with cement (as in the study for 40% and 60%). Also there is a increase in strength of GGBFS concrete with increase in age. Thus the durability of concrete improves when GGBFS is added as partial replacement of cement. Results shows that the strength of GGBFS concrete is less effected by chemicals as compared to conventional concrete when exposed to aggressive environment.

I. INTRODUCTION

Concrete is the most widely used construction material today. It is a man made material and has been extensively used in all types of construction activities due to its better engineering properties. The challenge for civil engineering in the present days is to build projects with the concept of sustainable development involving the use of high strength, environment friendly materials produced at reasonable cost with the lowest possible environmental impact. Concrete has certain disadvantages as well; like low tensile strength, not entirely impervious to moisture and containing soluble salts which may cause efflorescence, alkali and sulphate attack, unstable crack propagation, limited durability. It has existence of micro crack and interfacial discontinuities.

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Creep develops in concrete under sustained load. It is complex material with relatively large degree of physical and chemical complexity.

Most conventional concrete structures deteriorate rapidly and require costly repairs before their expected service life is reached. Four major types of environmental distress affect concrete structures. They are corrosion of the reinforcement, alkali-aggregate reactivity, freeze-thaw deterioration, and attack by sulphates. In each case, water or chemical solutions may penetrate the concrete and initiate or accelerate damages. By using high-performance concrete (HPC), durability and strength can be enhanced resulting in long-lasting and economical structure.

II. SCOPE AND OBJECTIVE OF THE PRESENT STUDY

2.1 Scope of present work

The aim of the study is to develop concrete of M 35 grade by using key components such as ordinary portland cement of 43 grade, locally available river sand, crushed stone aggregate, GGBFS, super plasticiser and water. It includes the comparison of M 35 grade conventional concrete with that of GGBFS concrete of the same grade. In the present experimental programme, OPC has been partially replaced with GGBFS in varying proportions of 20%, 40% and 60%. The scope of present work includes the study of durability parameters in terms of compressive strength in aggressive environment Sulphates and Chlorides having varying severity levels.

2.2. Objective of present study

The main objectives of present experimental study are as follows:To study the effect of attack of chlorides on compressive strength of GGBFS concrete after immersion in salt solution of varying severity of 2.5%. 5% and 7.5% of chlorides for 28 days.

Table 3-2. Typical composition of blast furnace slag.

Constituent	Percent							
	1949[a.]		1957[a.]		1968[a.]		1985[a.]	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Calcium Oxide (CaO)	41	34-48	41	31-47	39	32-44	39	34-43
Silicon Dioxide (SiO_2)	36	31-45	36	31-44	36	32-40	36	27-38
Aluminum Oxide (Al_2O_3)	13	10-17	13	8-18	12	8-20	10	7-12
Magnesium Oxide (MgO)	7	1-15	7	2-16	11	2-19	12	7-15
Iron (FeO or Fe_2O_3)	0.5	0.1-1.0	0.5	0.2-0.9	0.4	0.2-0.9	0.5	0.2-1.6
Manganese Oxide (MnO)	0.8	0.1-1.4	0.8	0.2-2.3	0.5	0.2-2.0	0.44	0.15-0.76
Sulfur (S)	1.5	0.9-2.3	1.6	0.7-2.3	1.4	0.6-2.3	1.4	1.0-1.9
a. Data source is the National Slag Association data: 1949 (22 sources); 1957 (29 sources); 1968 (30 sources) and 1985 (18 sources).								

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III. METHODS OF USING GGBFS IN CONCRETE

As an admixture

As a partial replacement for cement

PROBLEMS WITH THE USE OF GGBFS

Availability

Handling problem

Difficulty in entraining air

IV. EXPERIMENTIAL PROGRAMME

The present work is to study the effect of GGBFS on the durability characteristics of high strength concrete (HSC). In order to achieve the objectives of the present study, an experimental programme has been planned to develop concrete of compressive strength 3.5 N/mm^2 along with the use of superplasticisers.

The ingredients for high strength concrete are cement, fine aggregate, coarse aggregate, GGBFS, superplasticiser, and water. The laboratory tests are conducted on cement, fine aggregate and coarse aggregate whereas physical as well as chemical properties of GGBFS. The reference mix is prepared for M35 concrete with the above ingredients (GGBFS not included). The other three mixes are prepared for concrete by replacing GGBFS with cement in proportion of 20%, 40%, and 60%.

Durability of concrete in present study is measured by exposing the concrete specimen to varying severe conditions. These conditions are created by immersing concrete cubes and concrete cylinders specimens in varying saline conditions.

For creating saline conditions, magnesium chloride and magnesium sulphate was prepared having different dilutions of magnesium chloride and magnesium sulphate namely 2.5%, 5%, and 7.5%. Concrete is exposed to these conditions for about 28 days and then compressive strength of these specimens are conducted.

- Various steps of experimental programme are as under: Concrete mix design of M35 grade concrete by Indian Standard Recommended guidelines.
- Casting and curing of specimens.
- Compression strength testing of HSC reference mixes at 28 days moist curing.
- Preparation of salt solution of $MgCl_2$ and $MgSO_4$.
- Placing the specimen in different concentrations of salts for 28 days after moist curing for 28 days.
- Compressive strength test.

V. TESTING OF MATERIALS USED

The aim of studying properties of the materials used in concrete is to check the conformance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The different materials used in the present study are cement, sand, coarse aggregate, GGBFS, superplasticisers and water. Laboratory tests were conducted on these materials and their properties have been reported.

VI. CEMENT

In the present investigation, ordinary Portland Cement 43 grade conforming to IS 8112 (1989)[3] is used. The total quantity of cement needed for the investigation is obtained in one lot from a fresh stock and without any lumps. The cement is tested in accordance with the methods of test specified in IS: 8112 (1989)[3] and results obtained are shown in Table 4.1

Table 4.1: Cement Test Results (IS: 8112-1989)

Sr. No.	Characteristics	Experimental value	Specified Value as per IS: 8112-1989
1	Consistency of Cement	29 %	-
2	Specific gravity	2.84	3.15
3	Initial setting time	52 minute	>30 minute
4	Final setting time	390 minute	< 600 minutes
5	Comp. Strength (N/mm^2)		
	i) 3 days	26.48	>23
	ii) 7days	34.00	>33
	iii) 28 days	45.90	>43
6	Fineness (Dry Sieving)	1.5 %	< 10 %
7	Soundness (mm)	2.0	<10

VII. CONCLUSIONS

On the basis of the results and discussions the following conclusions are drawn:

- The durability of GGBFS concrete as compared to conventional concrete after 28 days of immersion in 2.5% magnesium chloride solution, the cube compressive strength as compared to the conventional concrete was found to be 14.02%, 11.69%, and 6.47% more for 20%, 40%, and 60% GGBFS concrete respectively. In the same manner after 28 days of immersion in 5% magnesium chloride solution, the compressive strength as compared to the conventional concrete was found to be 12.90%, 9.96%, and 5.71% for 20%, 40%, and 60% GGBFS concrete respectively. Similarly after 28 days of immersion in 7.5% magnesium chloride solution, the compressive strength as compared to the conventional concrete was found to be12.40%, 8.26%, and 3.32% for 20%, 40%, and 60% GGBFS concrete respectively. Hence it has been observed that after 28 days of immersion in 2.5% magnesium chloride solution, the cylinder compressive strength as compared to the conventional concrete was found to be 13.89%, 6.60%, and 4.55% for 20%, 40%, and 60% GGBFS concrete respectively. In the same manner after 28 days of immersion in 5% magnesium chloride solution, the compressive strength as compared to the conventional concrete was found to be 9.19%, 6.13%, and 2.83% for 20%, 40%, and 60% GGBFS concrete respectively. Similarly after 28 days of immersion in 7.5% magnesium chloride solution, the

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compressive strength as compared to the conventional concrete was found to be 18.95%, 14.28%, and 10.43% for 20%, 40%, and 60% GGBFS concrete respectively.

- The durability of GGBFS concrete as compared to conventional concrete after 28 days of immersion in 2.5% magnesium sulphate solution, the cube compressive strength 11.83%, 9.09%, and as compared to the conventional concrete was found to be 3.08% for 20%, 40%, and 60% GGBFS concrete respectively. In the same manner after 28 days of immersion in 5% magnesium sulphate solution, the compressive strength as compared to the conventional concrete was found to be10.81%, 6.73%, and 3.90% for 20%, 40%, and 60% GGBFS concrete respectively. Similarly after 28 days of immersion in 7.5% magnesium sulphate solution, the compressive strength as compared to the conventional concrete was found to be 10.09%, 6.60%, and 3.48% for 20%, 40%, and 60% GGBFS concrete respectively. Hence it has been observed that after 28 days of immersion in 2.5% magnesium sulphate solution, the cylinder compressive strength as compared to the conventional concrete was found to be13.39%, 6.47%, and 3.88% for 20%, 40%, and 60% GGBFS concrete respectively. In the same manner after 28 days of immersion in 5% magnesium sulphate solution, the compressive strength as compared to the conventional concrete was found to be 8.98%, 3.82%, and 1.79% for 20%, 40%, and 60% GGBFS concrete respectively. Similarly after 28 days of immersion in 7.5% magnesium sulphate solution, the compressive strength as compared to the conventional concrete was found to be 16.83%, 13.52%, and 8.92% for 20%, 40%, and 60% GGBFS concrete respectively.
- The durability of GGBFS concrete increases with increase in percentage replacement of GGBFS with cement for 20% and then started decreasing gradually for 40% and 60%.
- The maximum loss of strength of 0%, 20%, 40%, and 60% GGBFS concrete is due to the effect of magnesium chloride followed by magnesium sulphate.

VIII. FUTURE SCOPE OF RESEARCH

Besides the study presented here, still their remains a wide scope of research to cover the following aspects:

- Effect on the strength with the type and dosage of super plasticizer needed to produce and maintain reasonable workability and enhance the strength of concrete with slag.
- The slower development of strength associated with the introduction of slag in concrete can be studied.
- The effect on strength with higher percentage dilutions of chemicals used in present study.
- The effect on strength in chemicals with different admixture (e.g. silica fumes, fly ash etc) in partial replacement of cement may be carried out
- The stress-strain behavior, elastic modulus, and toughness of GGBFS

concrete can be researched.

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