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A Dissertation Project Report on

"EXPERIMENTAL STUDY ON THE CHEMICAL RESISTIVITY OF CONCRETE INCORPORATED WITH BLAST FURNACE SLAG"

Submitted in partial fulfilment for the award of the degree of

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CIVIL ENGINEERING

BY

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Certificate

This is to certify that the project work entitled **"EXPERIMENTAL STUDY ON THE CHEMICAL RESISTIVITY OF CONCRETE INCORPORATED WITH BLAST FURNACE SLAG"** has been successfully completed by Mr. SHALAN MUSHRAF KHAZI (USN 1CR16V056), Mr. VISHWANATH REDDY Y GUDUDOOR (USN 1CR16CV072), Mr. MOHITH SINGH S (USN 1CR17CV410) & SHASHANK B T (USN 1CR17CV418) bonafide students of CMR Institute of technology in partial fulfilment of the requirement for the award of degree of Bachelor of Engineering in Civil Engineering of the **"VISVESVARYA TECHNOLOGICAL UNIVERSITY",** Belgaum during the academic year 2019-20. It is certified that all corrections indicated for internal assessment has been incorporated in the Report. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said Degree.

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DECLARATION

We, **Mr. Shalan Mushraf Khazi, Mr. Vishwanath Reddy Y Gududoor, Mr. Mohith Singh S** & **Mr. Shashank B T** bonafide students of CMR Institute of Technology, Bangalore, hereby declare that dissertation entitled **"EXPERIMENTAL STUDY ON THE CHEMICAL RESISTIVITY OF CONCRETE INCORPORATED WITH BLAST FURNACE SLAG"** has been carried out by us under the guidance of **Dr. Asha M Nair (HOD), Dr. Surajit Munshi (Assistant Professor)**, Department of Civil Engineering, CMR Institute of Technology, Bangalore, in partial fulfilment of the requirement for the award of degree of Bachelor of Engineering in **Civil Engineering** of the Visvesvaraya Technological University, Belgaum during the academic year 2019-2020. The work done in this dissertation report is original and it has not been submitted for any other degree in any university.

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ABSTRACT

Cement concrete with Ordinary Portland Cement (OPC) continues to be the pre-eminent construction materials due to its commendable performance in terms of strength aspects, but durability of this is not satisfactory particularly when it is exposed to aggressive environment. Present global environmental requirements suggest the civil engineers for reducing the consumption of OPC. Use of mineral admixtures in concrete may be a suitable solution in such situation. The iron industries produce huge quantity of Blast furnace slag as a by-product, which is a non-biodegradable waste material. In the present investigation, the Blast Furnace Slag (BFS) from local industries has been utilized in concrete as a cement replacement admixture. Cement is going to be replaced by Blast Furnace Slag at the percentage of 5%, 10%, 15%, 20% and 25%, respectively. And a controlled specimen has to prepare to study the variations in mechanical and chemical properties of concrete incorporated with and without BFS. Experiments like specific gravity, consistency, sieve analysis, initial and final setting time, compressive strength and water permeability tests are performed to study the variations of mechanical properties of concrete using BSF. To study the effect of chemicals on concrete incorporated with BSF, investigations related to sulphate reactivity and chloride reactivity has been studied throughout the research.

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CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

Concrete is a mixture of cement, aggregates, water, etc. which are economically available. Concrete is made up of granular materials. It looks like coarse aggregates embedded in a matrix bound together with cement or binder which fills the space between the particles and glues them together. Almost three quarter volume of concrete is made of aggregates. To meet the global demand of concrete in the future, it is becoming a more challenging task to find sustainable ways of construction. Sustainable construction mainly aims to reduce the negative environmental impacts generated by construction industry. Over a period of time, waste management is becoming one of the most challenging problem in the world. The rapid growth of industrialization is giving birth to various kinds of wastes which are very dangerous to our environment. The consumption of slags in concrete not only helps in reducing green house gases but also helps in making environmentally friendly. During the production of iron and steel, fluxes (limestone and/or dolomite) are charged into blast furnace along with coke as fuel. The coke after combustion produces carbon monoxide, which converts the iron ore into molten iron product. Slag is a non-metallic inert waste consisting of mainly silicates, alumino silicates and calcium-alumina-silicates. Iron cannot be prepared in blast furnace without blast furnace slags. The use of granulated blast furnace slag (GBFS) aggregates in concrete by replacement of natural aggregates is very promising concept because its impact strength is quite more than natural aggregate. Steel slag aggregates are already being used as aggregates in asphalt paving road m due to their mechanical strength, stiffness, porosity, wear resist and water absorption capacity. OPC based concrete continues to be the pre-eminent construction materials for use in any type of civil engineering structures because of its easiness in construction, its satisfying performance in strength requirements, better durability in normal environment, in comparison to other construction materials like steel, timber etc but at the same time some problems are also associated with this. First is environmental pollution and large energy requirement in the production of OPC. Production of one tonne OPC required approximate 4.0 G Joule energy and produced approximate one tonne CO_2 gas in the environment. At present the cement industries produced approximate 7% of total CO_2 produced in the world, which is very alarming to our protective Ozone layer. Second problem is the lower durability in aggressive environment.

Concrete with OPC, which performed, very well over a period of about 100 years in the normal environment showed substantial damage within a few years of construction in the aggressive environment. Use of mineral admixtures like Ground Granulated Blast Furnace Slag (GGBFS), Silica Fume (SF), Fly Ash (FA) etc. in concrete may be the better solution in above conditions. These admixtures also offer benefits with respect to the cost of concrete.

1.2 BUILDING MATERIAL

It is any material which is used for construction purposes. For the materials to be appropriate to the needs of developing countries, they must be indigenous, locally available in abundance with low energy input in terms of production, maintenance and transportation costs, and be labour intensive.

- **Properties of Building Materials**
  - **i.** Bulk Density
  - **ii.** Porosity
  - **iii.** Durability
  - **iv.** Density
  - **v.** Density Index
  - **vi.** Specific Gravity
  - **vii.** Fire resistance
  - **viii.** Frost resistance
  - **ix.** Weather resistance
  - **x.** Spalling resistance
  - **xi.** Water absorption
  - **xii.** Water permeability
  - **xiii.** Refractories
  - **xiv.** Co-efficient of softening

1.3 ADMIXTURE

It is defined as the fifth ingredient of concrete which is added to concrete before or during mixing of concrete to improve the properties of concrete in its fresh or hardened state. The most often used admixtures are air-entraining agents, water reducers, water-reducing retarders and accelerators.

The admixtures are classified as:

i. Air-entraining admixtures

ii. Water-reducing admixtures
iii. Plasticizers
iv. Accelerating admixtures
v. Retarding admixtures
vi. Hydration-control admixtures
vii. Corrosion inhibitors
viii. Shrinkage reducers
ix. Alkali-silica reactivity inhibitors
x. Coloring admixtures
xi. Miscellaneous admixtures such as workability, bonding, dampproofing, permeability reducing, grouting, gas-forming, antiwashout, foaming, and pumping admixtures.

Concrete should be workable, finishable, strong, durable, watertight, and wear resistant. These qualities can often be obtained easily and economically by the selection of suitable materials rather than by resorting to admixtures (except air-entraining admixtures when needed).

The major reasons for using admixtures are:

i. To reduce the cost of concrete construction
ii. To achieve certain properties in concrete more effectively than by other means
iii. To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions
iv. To overcome certain emergencies during concreting operations

1.4 BLAST FURNACE SLAG

Blast-furnace slag (BFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Blast furnace slag is highly cementitious and high in CSH (calcium silicate hydrates) which is a strength enhancing compound which increases the strength, durability and appearance of the concrete.

Blast Furnace Slag is a by product obtained in the manufacturing of Pig iron in the Blast furnace and is formed by the combination of earthy constituents of iron ore with lime stone flux. Quenching process of molten slag by water is converting it into a fine, granulated slag of whitish color. This granulated slag when finely ground and combined with OPC has been found to exhibit excellent cementitious properties. Glass particles of GGBFS are the active part and consist of Mono-silicate (Q^0-type), like those in OPC clinker, which dissolve on activation by any medium. Glass content in GGBFS is normally more than 85% of total volume. Specific gravity of GGBFS is approximately 2.7-2.90, which is lower than of OPC. Bulk density of GGBFS is varying from 1200-1300 kg/m^3.

Hydration products of GGBFS are poorly crystalline Calcium Silicate Hydrate broadly similar to that formed from hydration of OPC, but with lower Ca/Si ratio (Jimenez et al., 2003). Due to lower Ca/ Si ratio, these hydrates have more alkali retention capacity. Hydration products of GGBFS effectively fill up the pores and increase the strength and durability of concrete. GGBFS requires activation to initiate hydration and the availability of a medium for continuing the hydration process. Slag hydration can be activated by using alkalies, lime, sulphate etc (Chemically activation), or by fine grinding (Mechanically activation) or by increasing temperature of concrete (Thermal activation). Various alkalies activators like Sodium hydroxide, Sodium carbonate, Sodium sulphate, Sodium silicate (Water glass) etc. can be used for slag. Water glass activated slag produced most cross-linked structures that results in increased mechanical strength of hydration products, while Sodium hydroxide make hydration process of slag more intensive (Garcia et. al., 2003). Due to higher activation energy of blast furnace slag relative to OPC, it has advantage of thermal activation on its hydration (Roy and Idorn, 1982).

1.5 ORGANIZATION OF THE DISSERTATION

Chapter 2 discusses the literatures studied for the investigation of the present research. This chapter also demonstrates the Scope and Objective of the present study.

CHAPTER 2

LITERATURE SURVEY

2.1 PREAMBLE

This chapter describes the literature survey of the broad topic of interest regarding various mineral admixtures with a special reference to Blast Furnace Slag. Few of the investigations done by researchers on the use of Blast Furnace Slag in construction has been demonstrated.

2.2 REVIEW ON LITERATURE

2.2.1 STUDY ON THE DURABILITY OF CONCRETE USING GRANULATED BLAST FURNACE SLAG AS FINE AGGREGATE

In order to assessing the durability of concrete using granulated blast furnace slag (GBS) as fine aggregate and compare it with natural river sand concrete, three different size of specimen were produced by using the same mix proportion with 3 different water cement ratios and 3 replacement ratios, and using it to measure the three aspects on the durability of concrete including freeze-thaw performance, dry-shrinkage performance and anti-chloride-permeability performance. In this paper, the test results show that using GBS as fine aggregate can slightly improve anti-chloride-permeability performance and dry-shrinkage performance of concrete in the condition of low water cement ratio, on the other hand, using GBS or natural river sand as fine aggregate has almost similar durability of concrete.

In this paper, the experiment about three aspects on the durability of concrete using GBS as fine aggregate was done, and the three aspects include freeze-thaw performance, drying shrinkage properties and anti-chloride-permeability performance. And the results were analyzed to evaluate the durability of concrete using GBS as fine aggregate.

Some of the experiments carried out and the results are tabulated:

TABLE 2.1 Physical and mechanical properties about aggregates of concrete

Materials	Fineness modulus	Moisture content (%)	Crushing index (%)	Apparent Density (kg/m^3)
Natural river sand	2.79	2.02	17.0	2738
GBS	2.70	1.05	93.0	2521

In this experiment, according to "GB/T50082-2009", freeze-thaw performance and anti-chloride-permeability performance of GBS concrete of 28 days age were tested respectively. Firstly, the freeze-thaw performance of concrete was measured by slow freezing method, the size of the cubic specimen used for measuring freeze-thaw performance of concrete was 100×100×100 mm3 . And the compressive strength of concrete that were cured 28 days, 25 times and 50 times freeze-thaw cycle and same standard curing time were tested respectively. Secondly, rapid chloride penetrability test was used for measuring anti-chloride-permeability performance of concrete, and using the cylindrical specimen with diameter of 100 mm ± 1 mm and 50 mm ±2 mm in height. In dry-shrinkage performance test, the size of cuboid test specimen was 100×100×400 mm^3, and the specimens that begin to dry were maintained at 20 ± 2℃ and relative humidity 60 ± 5%. The instrument of static strain measurement was used to measure drying shrinkage of concrete at age of 1, 2, 3, 7, 14, 28, 60, 90, 120, 150 and 180 days after the beginning of drying.

Conclusion:

- **i.** For the same concrete mixture ratio, the freeze-thaw performance of GBS concrete is slightly better than natural sand concrete.
- **ii.** When the W/C is low, there is relatively better anti-chloride-permeability performance of concrete, and using GBS as fine aggregate can improve the anti-chloride-permeability performance of concrete.
- **iii.** When the W/C is low, using GBS as fine aggregate can improve dry-shrinkage performance of concrete slightly. And the regression equation is almost applicable for this dry-shrinkage performance test results.
- **iv.** Using GBS or natural sand as fine aggregate has almost similar durability of concrete, including freeze-thaw performance, dry-shrinkage performance and anti-chloride-permeability performance.

2.2.2 STUDY OF GRANULATED BLAST FURNACE SLAG AS FINE AGGREGATES IN CONCRETE FOR SUSTAINABLE INFRASTRUCTURE

Growing environmental restrictions to the exploitation of sand from river beds leads to search for alternatives particularly near the larger metropolitan areas. This has brought in severe strains on the availability of sand forcing the construction industry to look for alternative construction materials without compromising the strength criteria of concrete. Granulated blast furnace slags are one of the promising sustainable solutions as they are obtained as solid wastes generated by industry. Hence it reduces the solid waste disposal problem and other environmental issues. Present experimental work explores the possibility of using GBFS as replacement of natural sand in concrete. In this study an attempt is done to understand the variation in compressive strength of concrete with GBFS content. Along with that cost analysis is also done to suggest the most optimized percentage of GBFS to be used in various conditions.

The present infrastructure development is creating immense pressure on construction industry. One of the most important materials in construction is concrete. Approximately five billion tonnes of concrete are used around the world each year. The huge requirement of concrete is putting question marks on sustainability of natural sand reserves of all the countries. These environmental issues are forcing engineers to look forward for more sustainable construction materials. As a solution for this, various alternatives such as quarry dust, wastes from demolished concrete, industrial wastes like copper slag, eco sand etc have been used. This research is a small attempt in the direction of sustainable infrastructure. It explores the possibility of using GBFS (a industrial waste) in construction industry as a substitute of natural sand. It focuses on providing the most optimum and economical percentage of GBFS in concrete for the construction of structures not only on land but also in sea. The research findings will help the researchers to understand the behaviour of GBFS concrete in a better way.

The concrete cylinders were tested for the compressive strength under UTM after 28 and 90 days of curing. The load versus displacement curve for G4 and GM4 specimens are shown in below. It is quite clear that after a certain point in load vs deflection curve there is a sudden increase in deflection which confirms the failure of specimen.

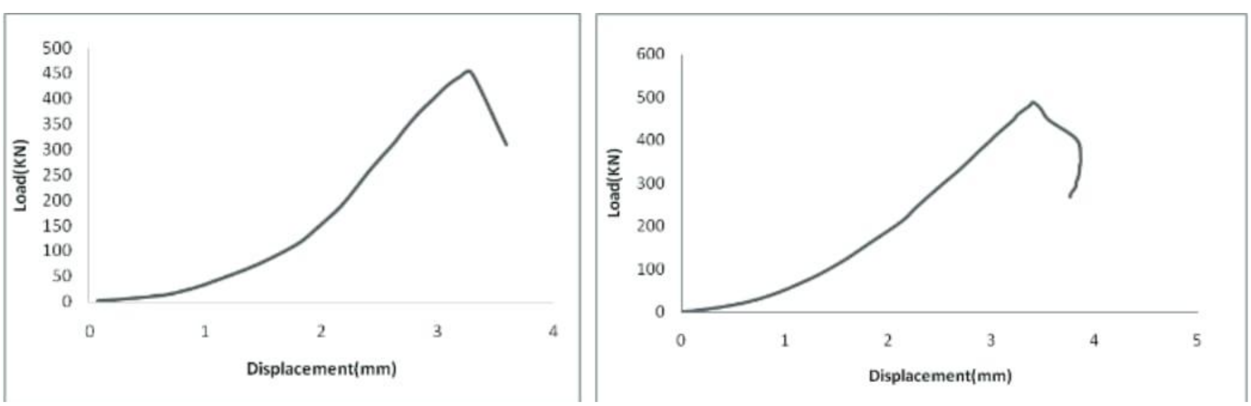


Fig 2.1Compressive strength graph

Conclusion:

- **i.** The compressive strength of concrete increases with increase in GBFS percentage up to a certain percentage and after that it decrease following a Gaussian Model.
- **ii.** Gaussian Equation based on the observed behaviour is developed to estimate the strength in concrete after for a particular percentage of GBFS subjected to normal and marine conditions.
- **iii.** The most optimum percentage of GBFS to be used in normal conditions considering both strength and economy factor is from 40% to 50% and for marine conditions its from 50% to 60%.
- **iv.** The long term strength development of GBFS concrete is almost double of normal concrete in both normal and marine conditions.

2.2.3 USE AND PROPERTIES OF BLAST FURNACE SLAG AS A BUILDING MATERIAL

This paper aims at bringing a literature review on the uses and properties of popular industrial and mineral byproduct slag. At the present, most industrial slags are being used without taking full advantage of their properties or disposed rather than used. The use of slag in replacing Portland cement by GGBFS is not very common. The traditional way to utilize metallurgical slags in cementing materials is to partially replace Portland cement. The practice of using such mineral admixtures in construction will reduce the need of portland cement and its use in various parts of the world, thus greatly reducing the amount of pollution and pave a way for a cleaner and more economical construction material, of which India is in a great need.

The behaviour of concrete samples were also investigated with some agents, i.e. samples with some extra chemical admixtures, air entraining agents. Also differentiation was done on the basis of formation of slag aggregates, i.e. the variation in properties of slag based construction materials vary when slag is created employing different techniques.

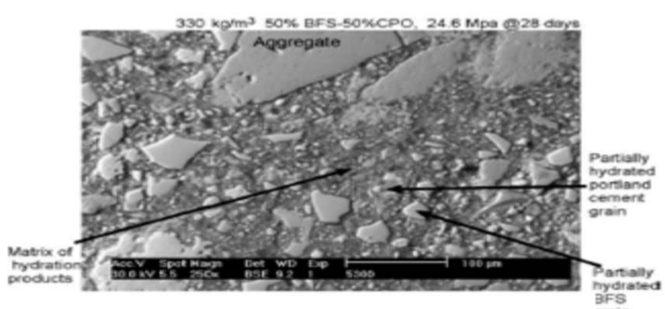


Fig. 2.2 Micro Structures of polished concrete

Conclusion:

- **i.** Slag is potentially an all purpose building material which can be used anywhere and in any type of construction.
- **ii.** . An increase in fineness always encouraged to speed up hydration, increase setting time and improve most of the qualities of slag cement.
- **iii.** Though reactions of slag particles are slow, It can still be used with an activator, be it Thermal or Alkaline activator.
- **iv.** . It has been unanimously agreed that water glass is a better activator than KOH. But, owing to the negative effects of alkaline activator, Thermal activation is a better option. In Indian context, Thermal activation suits best owing to the temperature conditions in India.
- **v.** . The Durability criteria for slag cement offered several advantages, nemely low chloride ingress, high sulphate resistance and acid attack.
- **vi.** However slag cement still showed some disadvantages like high carbonation depth, low resistance to freeze and thaw cycles and surface scalling.

2.2.4 EXPERIMENTAL STUDY ON EFFECT OF GROUND GRANULATED BLAST FURNACE SLAG OF STRENGTH AND DURABILITY OF SAND CONCRETE

Concrete used for building structures in the marine environment requires a high level of durability, and as such an effective method to improve the level is the use of ground granulated blast furnace slag (GGBFS). The paper presents an experimental study on the effect of the replacement cement by 20%, 30%, 40%, 50% GGBFS on workability, mechanical properties and durability of sand concrete (SC). The results show SC containing 20% GGBFS had the highest compressive strength, splitting tensile strength, elastic modulus and abrasion resistance. The lowest chloride penetration corresponded to SC containing 30% GGBFS.

The study used cement PC40 which conforms to TVCN 2682: 2009. Fly ash (FA) conforms to TCVN 10302: 2014. GGBFS conforms to TCVN 11586: 2016. The chemical composition and physical properties of cement, FA and GGBFS are presented in Table 1. Fine sand (FS) - Local sand has its properties and grading shown in Table 2. MasterGlenium ACE 8509 conforms to ASTM C494 type F

Table 2.2 Sieve analysis and properties of fine sand

Sieve Size(mm)	9.5	4.76	2.36	1.18	0.6	0.3	0.15	0.075	Fineness modulus	Density (g/cm^3)	Absorption (%)
Passing (%)	100	100	100	100	100	12.5	1.0	0	1.85	2.71	2.24

The selection of aggregate mix for SC was based on the principle of optimizing the compacted volume of dry mix [3, 8]. The most optimal dry mix of compacted volume had the ratio of FA: FS determined to be 30:70. The proportions of SC mixture were designed on the basis of the absolute volume of constituent materials [4]. GGBFS was incorporated with the replacement level 0%, 20%, 30%, 40%, 50% by cement weight. One control mixture without GGBFS was prepared for comparison purpose.

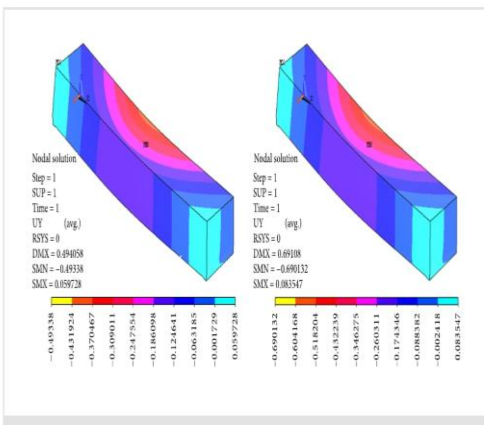
2.2.5 PERFORMANCE AND BEHAVIOUR OF GROUND GRANULATED BLAST FURNACE SLAG IMPARTED TO GEOPOLYMER CONCRETE STRUCTURAL ELEMENTS AND ANALYSED WITH ANSYS

This paper deals with the behaviour of geopolymer concrete using ground granulated blast furnace slag and steel fibre to compare with M40 grade cement concrete. The cast GPC specimens were placed in a hot curing chamber at 60°C temperature for 24 hours and tested after 1, 7, 14, and 28 days of ambient curing to find the strength and durability of hardened concrete. The optimum value of compressive strength was attained at 12 Molarities. Fly ash was replaced by GGBS in GPC with different proportions such as 0% to 60% at 5% interval; the optimum strength value was obtained on 40% replacement. From the test results, the compressive, split-tensile, and flexural strength of GPC specimens were 20%, 43%, and 53% higher than those of the control specimens. Based on the optimum strength mix proportion, the structural elements were cast to investigate the stress-strain relations. The GPC beam and L-section showed 33% and 16% higher value. From the results of acid and sulphate resistance tests, it was found that the strength and weight ratio of GPC were higher than the control specimens. From the simulations, it was found that the experimental test results were approximately equal to the ANSYS.

The objective of this paper is to study the strength and durability properties of GPC in order to use it as alternative for conventional concrete (CC). The performance of ground granulated blast furnace slag (GGBS) and steel fibre used in GPC is to be assessed. The strength properties like compressive strength, split-tensile strength, and flexural strength of GPC specimens compared with CC are to be determined. The strength and weight loss of GPC and CC specimens when immersed in acid and sulphate solution are to be found. The stress versus strain and load versus deformation behaviours and cracks patterns of GPC elements compared with CC elements are to be determined. The strength properties of GPC elements like beam and L-section using ANSYS compared with the experimental results are to be assessed.

From the experimental research results, it is concluded that GPC structural elements withstand higher load carrying capacity, resistance to deformation, and deflection than the CC elements.

From the initial test results, it is found that compressive strength of GPC cube, split-tensile strength of GPC cylinder, and flexural strength of prism were 20%, 43%, and 53% increased compared with CC specimens.



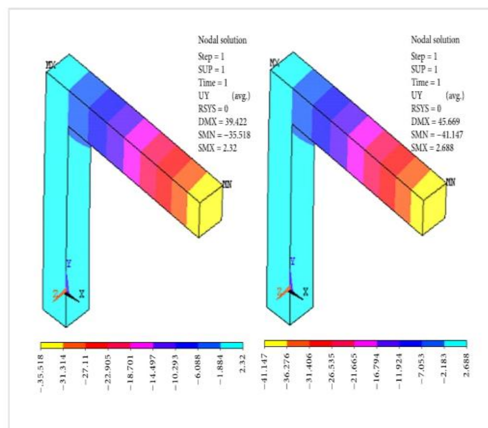


Fig 2.3 Flexural behaviour of RCC beam L-Beam in CC and GPC

Fig. 2.4 Flexural behaviour of RCC in CC and GPC

It is determined that the flexural strengths of GPC structural elements such as straight beam and L-beam were increased by 50% and 52% compared with CC. The deflection was reduced to 16% and 10% compared with CC. The stress versus strain relation of GPC was compared with CC and it is found that it increases by 34% and 20% in GPC compared with CC. The durability properties such as acid and sulphate resistance tests were conducted for both GPC and CC and results were compared and it is found that GPC resists acid and sulphate attack 19% and 20% better than CC.

All the experimental results were compared with ANSYS software results and it is found that there is an only negligible variation in both GPC and CC elements. Geopolymer technology not only contributes to the reduction of greenhouse gas emissions but also reduces disposal costs of industrial waste. Geopolymer technology encourages recycling of waste and finally it will be an important step towards sustainable concrete industry.

2.2.6 EFFECT OF PARTIAL REPLACEMENT OF GROUND GRANULATED BLAST FURNACE SLAG FOR CEMENT IN CONVENTIONAL CONCRETE EXPOSED TO MARINE ENVIRONMENT

At present, the usage of concrete is increasing day by day. In future days cement may find its scarcity due to over usage. After water, cement is the second most consumed product in the world. This scarcity may affect the construction industry. The rapid production of cement may create several environmental issues also, for which solution is to be found out. In the production process of cement, CO2 emission takes place. One ton of CO2 gets emitted for one ton of OPC manufacture. And cement production requires the availability of lime which will be soon in the list of limited resource available. Hence it is necessary to find a replacement to cement in concrete as a substitute to it.. Ground Granulated Blast Furnace Slag (GGBS) is been continuously used as a replacement material for cement. But a very little knowledge about GGBS concrete behaviour in marine environment is available. Nowadays due to a revolutionary improvement in marine structure and due to which the present study holds importance.

As per the review of a number of papers related to GGBS concrete in marine environment, GGBS concrete has shown a great improvement in Chloride ion penetration, Compressive strength and Tensile strength. GGBS concrete with 40% replacement of cement has shown a great improvement in strength and durability aspects in marine exposure. According to one of the papers, artificial marine environment can be simulated in a temperature controlled curing tank of dimensions 2m X 1.5m X 0.5m. A solution of 3% NaCl + CaCl2 with 0.5% MgSO4 is to be prepared in the curing tank, the solution is to be circulated throughout the curing tank using a standard electric pump. By testing the samples in this artificial marine environment for durability and strength aspects, it was found that GGBS concrete is highly stable in marine environment.

Conclusion: The rate of strength development in GGBS concrete is slow at early stages. This may be due to delayed pozzolanic activity, however at later stages the strength development increases. GGBS concrete develops strength at low rate and hence heat of hydration will be less. Thus concrete does not develop any thermal crack. Initial setting time of GGBS concrete will be more since GGBS reacts slowly with water in the initial stages. GGBS makes the concrete denser and hence there will be less bleeding in the initial stages of concrete. In hardened state the concrete shows better compressive strength and split tensile strength along with a great improvement in durability properties like Acid attack, Water permeability, Chloride attack. Hence overall GGBS replacement is highly beneficial with respect to both strength and durability aspects of conventional concrete in normal environment as well as in marine exposure.

2.2.7 STRENGTH DEVELOPMENT CHARACTERISTICS OF CONCRETE PRODUCED WITH BLENDED CEMENT USING GROUND GRANULATED BLAST FURNACE SLAG (GGBS) UNDER VARIOUS CURING CONDITIONS

To reduce the embodied carbon dioxide of structural concrete, Portland cement (PC) in concrete can be partially replaced with ground granulated blast furnace slag (GGBS). In this research effect of partial replacement of cement with GGBS on strength development of concrete and cured under summer and winter curing environments is established. Three levels of cement substitution i.e., 30%, 40% and 50% have been selected. Early-age strength of GGBS concrete is lower than the normal PC concrete which limits its use in the fast-track construction and post-tensioned beams which are subjected to high early loads. The strength gain under winter curing condition was observed as slower. By keeping the water cement ratio low as 0.35, concrete containing GGBS up to 50% can achieve high early-age strength. GGBS concrete gains more strength than the PC concrete after the age of 28 day till 56 day. The mechanical properties of blended concrete for various levels of cement replacement have been observed as higher than control concrete mix having no GGBS.

The non-uniform physical properties of slag found in various parts of the world and limited research data on the performance of concrete produced with cement having GBBS has been the major motivation for this research. It is expected that the results of the research will add to the existing data on use of blended cement in concrete and its performance under various curing conditions. The early-age strength of blended concrete is relatively less than the normal concrete, which restricts its use in many important projects. Based on various trial mixing, the optimal level of water cement ratio, chemical admixtures and replacement of cement by slag has been established under various curing conditions. This will help in further research in standardising the properties and mixing of the concrete made with blended cements.

Fig. 2.5 Test cubes under summer curing environment

Fig. 2.6 Test cubes under water curing environment

Fig 2.7 Test cubes under winter curing environment

Partial replacement of cement by GGBS up to 50% has little impact on the compressive strength at 56 days, as the compressive strength achieved has a reasonable value for use in structural works. This can offer greater opportunity for saving of cement and CO2 emissions, thereby making concrete relatively sustainable. The strength development results show that at low water/ cement ratio (0.35), concrete containing GGBS up to 50% gains enough high early-age strength to be used in posttensioned concrete and fast-track construction. The results shows that there are significant reductions in the rate of strength gain of concrete cured under winter curing conditions (7C), as compared to those of summer curing and under water (20C). In winter conditions, for concrete containing GGBS up to 50%, special care should be taken regarding temperature increase of the curing environment at the early age to gain enough strength. This can be achieved at covering the concrete in sealed conditions. The heating of concrete buildings to increase the temperature for curing is a common practice in cold areas. From the compressive strength development of GGBS concrete results, it is concluded that concrete containing GGBS up to 50% has almost the same 28-day compressive strength as PC concrete, when cured under summer temperatures (20C) and gains more strength than the PC concrete at the age of 56 days. Concrete containing 40% GGBS has the highest compressive strength compared to the other concrete mixes at the age of 56 days and is 15.5% more than the strength of PC concrete. The strength gain in GGBS concrete is more obvious between the ages of 28 and 56 days. This supported the earlier research to use 56 days' compressive strength of blended concrete. Figure 9. Flexural strength of GGBS concrete at the age of 28 days. Figure 10. Modulus of elasticity of GGBS concrete at the age of 28 days. Table 7. The 28-day flexural strength and modulus of elasticity. Concrete mix Compressive cylinder strength (MPa) Flexural strength (MPa) Modulus of elasticity (GPa) Curing conditions C1 C2 C3 C1 C2 C3 C1 C2 C3 70PC/30GGBS 56.5 49.0 58.5 6.5 6.0 7.0 40.0 38.5 40.5 60PC/40GGBS 57.0 48.0 58.0 6.5 6.0 7.0 40.5 39.0 41.0 50PC/50GGBS 53.0 47.5 54.0 6.5 6.0 7.0 40.5 38.5 40.0 100PC-Control 56.0 55.0 57.5 6.0 6.0 7.0 39.8 38.5 39.8 Strength development characteristics of concrete produced 1211 Concrete containing GGBS up to 50% have higher values of flexural strength than the PC concrete when cured under the summer curing environment (20C). The 28-day flexural strength of 30%, 40% and 50% GGBS concrete mixes are 3.3%, 8.2% and 4.9% higher, respectively, than the PC concrete mix cured under the summer temperature. Curing environments have an effect on the flexural strength of GGBS concrete mixes and this is reduced after being cured under winter environments (7C) compared to summer temperatures of 20C in sealed plastic bags or under water. GGBS concrete and the PC concrete mixes cured under water at 20C have higher flexural strength than the concrete cured in sealed plastic bags at 20C.

2.2.8 BEHAVIOR OF GROUND GRANULATED BLAST FURNACE SLAG AND LIMESTONE POWDER AS PARTIAL CEMENT REPLACEMENT

One of the main ingredients used for the production of concrete is the Ordinary Portland Cement (OPC). Carbon-dioxide (CO_2) gas which is a major contributor in green house effect and the global warming, is produced in the production of cement, hence it is needed either to search for another material or partially replace cement by some other material.[2] In recent years ground granulated blast furnace slag (GGBS) and Limestone powder (LP) when replaced with cement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, energy savings, and cost savings, environmental and socio-economic benefits.[1]. This paper investigates the possibility of utilizing Blast Furnace Slag (BFS) and Limestone powder (LP) as a cement substitute in concrete, in order to reduce environmental problems due to manufacturing of cement and waste disposal. The present study reports the results of an experimental study, conducted to evaluate the strengths and strength of hardened concrete, by partially replacing the cement by various percentages of blast furnace slag and Limestone powder for M25 grade of concrete at 7 and 28 days. In this study w/c ratio of 0.42 is used. The compressive strengths at various ages are studied. From this study it is observed that BFS and LP could be utilized partially as alternative construction material for replacement of cement in concrete.

Slump test are carried out and results are discussed below:

Table 2.3 Slump test of M25 concrete with various percentage of slag and LP

Mix	**Slump Value**
M-1	77
M-2	92
M-3	102
M-4	114

Conclusion:

This paper has described the variation of compressive strength, flexure strength and tensile strength, also workability and durability of different specimens having different percentage of GGBS and LP as a partial replacement of cement. From the results following conclusions are concluded:-

i. The workability of the concrete increases with the increase in the replacement levels.

ii. From the results it is clear that maximum compressive strength is at 5-10% replacement of LP and GGBS. The compressive strength of M-1 (control mix) and M-3 (10-20% replacement of LP and GGBS) is near about same.

iii. From the results it is clear that maximum tensile strength is at 5-10% replacement of LP and GGBS. The tensile strength of M-1 (control mix) and M-3 (10-20% replacement of LP and GGBS) is near about same.

iv. From the results it is clear that maximum flexure strength is at 5-10% replacement of LP and GGBS. The flexure strength of M-1 (control mix) and M-3 (10-20% replacement of LP and GGBS) is near about same.

v. From the results of water absorption test it is concluded that durability of the concrete increases with the increase in replacement levels.

Therefore limestone powder and ground granulated blast furnace slag can be used up to 30% (10%LP and 20% GGBS) as a partial replacement of concrete.

2.2.9 PROPERTIES OF BLAST FURNACE SLAG CEMENT CONCRETE SUBJECTED TO ACCELERATED CURING

Accelerated curing is used for mass production in the precast concrete industry. Autogenous shrinkage and drying shrinkage occur in concrete, during and after accelerated curing. Thus, thermal cracks may occur in concrete due to both heating and cement hydration at early age, whereas drying shrinkage causes cracks after demolding. Ground granulated blast-furnace slag cement (GGBS), a byproduct in steel manufacture, has been used to improve concrete strength development during accelerated curing but poses a challenge of increased shrinkage. In this paper, two types of granulated blast-furnace slag cements were used to study mechanical and shrinkage properties of water cured and concrete subjected to accelerated curing. Limestone powder and gypsums, with two different types of fineness, were other additives used. An accelerated one day curing cycle was adopted that consisted of a 3 h delay period, heating to 65 °C, a peak temperature maintained for 3 h, and, finally, cooling. The results indicated that increment in gypsum fineness increased concrete expansion at one day for both sealed and accelerated cured concrete. In drying condition, similar shrinkage was observed. The addition of gypsum provided slightly lower shrinkage, and this may help to reduce cracking of concrete. Limestone powder improved concrete strength at early age. The difference in blast-furnace cement fineness did not have significant differences in compressive strengths, especially at 28 days.

Conclusions:

This study investigated the fresh, mechanical, and shrinkage properties of concrete made with S3000 and S4000 cement as main mineral admixtures and subjected to accelerated curing by heating. On the basis of the results from the laboratory tests, conclusions were drawn and summarized as follows:

i. Fine gypsum contributed to higher expansion at early age in sealed and accelerated cured concrete. A combination of limestone powder and fine gypsum had the highest expansion in concrete
ii. Limestone powder contributed to compressive strength of concrete at early age whereas gypsum addition showed significant influence on concrete strength at 28 days
iii. There was an insignificant difference in compressive strength, especially at 28 days, between two types of slag cements even when additives such as limestone powder and gypsum were used
iv. Similar drying shrinkage was observed at later age. Concrete containing fine gypsum showed slightly lower shrinkage which may help in cracking resistance.

2.3 SCOPE OF THE STUDY

- To study the freeze and thaw reaction of concrete and mortar using blast furnace slag.
- To investigate the effect of alkali-silica reaction of the concrete incorporated with blast furnace slag
- To study the variations of different water cement ratio of both concrete and mortar using blast furnace slag
- To study the physical and chemical characterizations of blast furnace slag from different industries and its utilization as a construction material.
- To analyse the durability of concrete and mortar using blast furnace slag at different percentage level.

2.4 OBJECTIVES

Going through various literature review, it has been observed that the use of blast furnace slag is effective as a pozzolanic material in cement concrete as it helps in increasing the strength of concrete. But the affect of chemicals on concrete incorporated with blast furnace slag is studied by very less researchers. So, the objective of the research is

- To study the variation of mechanical properties of concrete incorporated with and without blast furnace slag.
- To study the water permeability of concrete using blast furnace slag.
- To study the degradation of BFS concrete due to the affect of several chemicals.
- To compare the effect of chemicals on the strength of concrete incorporated with BSF as a cement replacement admixture.

CHAPTER 3

MATERIALS USED

3.1 MATERIALS

- Cement
- Coarse aggregate
- Fine aggregate
- Admixture
- Water

3.1.1 CEMENT

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is only behind water as the planet's most-consumed resource.

In this study, ordinary Portland cement (OPC) of 53-grade has been used conforming IS: 12269-1987, which is known for its rich quality and high durability issued. Specific gravity of cement used here is 2.15. OPC of grade-53 provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure. Being a high strength cement, it provides numerous advantages wherever concrete for special high strength application is required, such as in the construction of skyscrapers, bridges, flyovers, chimneys, runways, concrete roads and other heavy load bearing structures. Not only is this grade of cement stronger than other grades , it is also more durable. OPC Grade 53 cement attains higher early strength as compared to any other grade of cement but because of early gain, does not increase much after 28 days. In addition, due to faster hydration process, the cement releases heat of hydration at a much faster rate initially and therefore, the chances of micro cracking of concrete is much greater. Thus, during initial setting period of concrete, the higher heat of hydration can lead to damage arising out of micro cracks within the concrete structure, which may not be visible on the surface. Grade 53 should therefore be used only where such application is warranted for making the concrete of higher strength, where good supervision and quality assurance measures are in place and where proper precautions are taken to relieve the higher heat of hydration through a proper curing process.

Fig. 3.1 Cement opc grade 53

3.1.2 AGGREGATE

'Aggregate' is a term for any particulate material. Aggregates in any particular mix of concrete are selected for their durability, strength, workability and ability to receive finishes. Fine aggregates are usually sand or crushed stone that are less than 4.75mm in diameter. Fine aggregate is on of the major constituents of concrete which can influence concrete mix design substantially. Various factors such as fine aggregate fineness modulus, moisture content, specific gravity, and silt content affect the mix proportions of concrete. Fineness modulus specifies how much fine aggregate is required in a given mix design.

Fine aggregate moisture content influences the mix proportion substantially. It specifies the amount of water that may be added to subtracted to the mixture. Mix design of concrete cannot be carried out without specific gravity of fine aggregate, and higher specific gravity produced stronger concrete. Finally, the presence of silt in sand would increase water demand in concrete mixture and may reduce concrete strength. In this study we use M-sand as fine aggregate.

3.1.2.1 M-SAND

Manufactured sand (M-Sand) is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing..The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm. Manufactured sand is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word.

Due to the depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased. Another reason for use of M-Sand is its availability and transportation cost. Since manufactured sand can be crushed from hard granite rocks, it can be readily available at the nearby place, reducing the cost of transportation from far-off river sand bed. Thus, the cost of construction can be controlled by the use of manufactured sand as an alternative material for construction. The other advantage of using M-Sand is, it can be dust free, the sizes of m-sand can be controlled easily so that it meets the required grading for the given construction.

ADVANTAGES OF M-SAND

- It is well graded in the required proportion.
- It does not contain organic and soluble compound that affects the setting time and properties of cement, thus the required strength of concrete can be maintained.
- It does not have the presence of impurities such as clay, dust and silt coatings, increase water requirement as in the case of river sand which impair bond between cement paste and aggregate. Thus, increased quality and durability of concrete.
- M-Sand is obtained from specific hard rock (granite) using the state-of-the-art International technology, thus the required property of sand is obtained.
- M-Sand is cubical in shape and is manufactured using technology like High Carbon steel hit rock and then ROCK ON ROCK process which is synonymous to that of natural process undergoing in river sand information.
- Modern and imported machines are used to produce M-Sand to ensure required grading zone for the sand.

Fig 3.2 M-SAND

3.1.2.2 COARSE AGGREGATE

Coarse aggregate is one of the essential components of concrete and occupies the largest volume in the mix. That is why it greatly affects the concrete mix design. Its properties such as strength, maximum size, shape, and water absorption influence water demand, the quantity of cement and fine aggregate in concrete mixture. Coarse aggregates are irregular broken stone or naturally-occurring rounded gravel used for making concrete. Materials which are large to be retained on 4.36 mm sieve size are called coarse aggregates, and its maximum size can be up to 60 mm.

Coarse aggregates are generally obtained by blasting in stone quarries or by breaking them by hand or by crushers. Machine - crushed stones consist of stones of various sizes whereas Hand - broken aggregates consist of only single size stones. To produce graded aggregates for high-class concrete, they are again mixed in specific proportions .They should be washed well before using in concrete. Coarse aggregates for structural concrete consist of broken stones of hard rock like granite and limestone (angular aggregates) or river gravels (rounded aggregates). For non-structural mass concrete of low strength, broken bricks, foamed slag, clinker, etc., may be also used as coarse aggregates. Foreign materials in coarse aggregates such as coal, lignite, soft fragments and clay lumps should not exceed 5 per cent of its weight.

It is reported that, high maximum coarse aggregate size leads to lower water demand in the mixture since such aggregate has lower surface area compare with small coarse aggregate size. As far as shape is concerned, rounded shape aggregate provides economical mix design for normal strength concrete. However, angular coarse aggregate is desired in the case of high strength concrete. This possibility of segregation is minimized if coarser aggregate is properly graded. This explains how important is good grading for concrete mix design.

As far as strength is concerned, higher aggregate strength would produce higher concrete strength provided that other controlling factors have been dealt with properly. Coarse aggregate maximum size of coarse aggregates which will be used area of 20mm. Well graded cubical or rounded aggregates are desirable. Aggregates should be uniform quality with respect to shape and grading. Specific gravity of coarse aggregate used here is 2.6.

Fig. 3.3 Coarse Aggregate

3.1.3 ADMIXTURE

An admixture is a material other than water, aggregates, or cement which is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional qualities to concrete. Admixtures are natural or manufactured chemicals which are added to the concrete before or during mixing. The most often used admixtures are air-entraining agents, water reducers, water-reducing retarders and accelerators.

Admixtures are used to give special properties to fresh or hardened concrete. Admixtures may enhance the durability, workability or strength characteristics of a given concrete mixture. Admixtures are used to over-come difficult construction situations, such as hot or cold weather placements, pumping requirements, early strength requirements, or very low water-cement ratio specifications. In this study we use Blast Furnace Slag(BFS) as an admixture.

3.1.3.1 BLAST FURNACE SLAG

The blast furnace slag (BFS) is a by-product of iron manufacturing which when added to concrete improves its properties such as workability, strength and durability. This material is obtained by the heating of iron ore, limestone and coke at a temperature about 1500 degree Celsius. The process is carried out in a blast furnace. The by-product of iron manufacturing is a molten slag and molten iron. The molten slag consists of alumina and silica, also with the certain amount of oxides.

This slag is later granulated by cooling it. For this, it is allowed to pass through a high-pressure water jet. This result in quenching of the particles which results in granules of size lesser than 5mm in diameter. The main constituents of blast furnace slag are CaO, SiO_2, $Al2O_3$ and MgO. These are the minerals that are found in most of the cementitious substances. The particles are further dried and ground in a rotating ball mill to form a fine powder, known as ground granulated blast furnace slag cement.

ADVANTAGES OF BFS IN CONCRETE

The incorporation of ground blast furnace slag in concrete manufacture gains many advantages which are mentioned below:

- BFS in concrete increases the strength and durability of the concrete structure.
- It reduces voids in concrete hence reducing permeability
- BFS gives a workable mix.
- It possesses good pumpable and compaction characteristics
- The structure made of BFS constituents help in increasing sulphate attack resistance.
- The penetration of chloride can be decreased.
- The heat of hydration is less compared to conventional mix hydration.
- The alkali-silica reaction is resisted highly.
- These make the concrete more chemically stable
- Gives good surface finish and improves aesthetics
- The color is more even and light.
- Lower chances of efflorescence.

Fig. 3.4 Blast Furnace Slag

3.1.4 WATER

Water is the key ingredient, which when mixed with cement, forms a paste that binds the aggregate together. The water causes the hardening of concrete through a process called hydration. The role of water is important because the water to cement ratio is the most critical factor in the production of "perfect" concrete. The common specifications regarding quality of mixing water is water should be fit for drinking. Such water should have inorganic solid less than 1000 ppm. This content lead to a solid quantity 0.05% of mass of cement when w/c ratio is provided 0.5 resulting small effect on strength. The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products. Aggregates are chemically inert, solid bodies held together by the cement.

CHAPTER 4
EXPERIMENTAL METHODOLOGY

4.1 EXPERIMENTAL METHODS

In this study several experiments are conducted to investigate the various mechanical properties and chemical reactivity on concrete using the blast furnace slag sample at different percentages. The experiments are namely

- Specific gravity test
- Consistency test
- Sieve analysis
- Initial and final setting time
- Compressive strength test
- Water permeability test
- Sulphate reactivity test
- Chloride reactivity test

4.1.1 SPECIFIC GRAVITY TEST

The specific gravity is normally defined as the ratio between the weight of a given volume of material and weight of an equal volume of water. It is directly proportional to workability and the strength of a bonding. If the cement has already more moisture in it then, the value of water-cement ratio will actually affect the workability and strength rather than increasing it. The specific gravity of cement and BSF are determined using the density bottle and fine aggregate using pycnometer and coarse aggregate using mesh wire basket.

We calculate specific gravity of any substance to know the behavior of the material in water. And we can know the material will sink or floats in the water. All of the materials in our environment have a fixed specific gravity. The usual range is 1-100. If the specific gravity is greater than 1, then it sinks in water. If the specific gravity Is less than 1 it floats in water. So if the specific gravity of any substance is known to us we can use the materials in suitable place of any work. Every material consists off so many little pores, which may contain voids in it. And a material becomes useless when any void present in the material. If the cement covered by extreme moisture content due to bad weather conditions, then the specific gravity of cement may go up to 3.19. If the specific gravity value reaches 3.19, then the pores in cement are filled with the moisture. Cement undergoes a chemical reaction when it is reacted with the atmospheric moisture this process is termed as hydration. Moisture is very harmful to cement. Cement becomes useless once it is hydrated with water. The presence of excessive moisture is the reason for finding a lot of lumps in old cement is due to content in it.

- **Procedure for Specific Gravity Test**
  - The flask is allowed to dry completely and made free from liquid and moisture. The weight of the empty flask is taken as W1.
  - The bottle is filled with cement to its half (Around 50gm of cement) and closed with a stopper. The arrangement is weighed with stopper and taken as W2.
  - To this kerosene is added to the top of the bottle. The mixture is mixed thoroughly and air bubbles are removed. The flask with kerosene, cement with stopper is weighed and taken as W3.
  - Next, the flask is emptied and filled with kerosene to the top. The arrangement is weighed and taken as W4.

    Specific Gravity of Cement given by the formula,

$$S_g = \frac{W2 - W1}{(W2 - W1) - (W3 - W4) \times 0.79}$$

Fig. 4.1 Pycnometer

Fig 4.2 Density Bottle

4.1.2 CONSISTENCY TEST

It is necessary to determine consistency because the amount of water affects the setting time of the cement. Consistency is resistance to shear deformation. ... Consistency plays a vital role in the determination of compressive strength of concrete or workability test for concrete. Consistency of concrete means ability of concrete to flow. Concrete with better consistency increases the workability and performance . A good consistent concrete reduces the placing and compaction efforts and reduces the time of concreting work.

When water is mixed with cement, it starts hydration. Excessive addition of water in cement results in an increase in Water cement ratio & ultimately cement loses its strength when it hardens. If less water is added than required, Cement isn't properly hydrated and results in loss of strength. The normal consistency of cement varies due to:

- Weather condition
- The excessive composition of silica
- The fineness of cement
- Cement produced by different companies doesn't have the same consistency

➢ **Procedure to determine consistency of cement**

- Weigh approximately 400g of cement and mix it with a weighed quantity of water. The time of gauging should be between 3 to 5 minutes.
- Fill the Vicat mould with paste and level it with a trowel.
- Lower the plunger gently till it touches the cement surface.
- Release the plunger allowing it to sink into the paste.
- Repeat the above procedure taking fresh samples of cement and different quantities of water until the reading on the gauge is 5 to 7mm.

Fig 4.3 Vicat Apparatus

4.1.3 SIEVE ANALYSIS

Sieve analysis is a technique used to determine the particle size distribution of a powder. This method is performed by sifting a powder sample through a stack of wire mesh sieves, separating it into discrete size ranges. A sieve shaker is used to vibrate the sieve stack for a specific period of time. The base of the instrument is a shaker, which facilitates the filtering. Sieve analysis is important for analyzing materials because particle size distribution can affect a wide range of properties, such as the strength of concrete, the solubility of a mixture, surface area properties and even their taste. Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates .This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

The sieve analysis, commonly known as the gradation test, is a basic essential test for all aggregate technicians. The sieve analysis determines the gradation (the distribution of aggregate particles, by size, within a given sample) in order to determine compliance with design, production control requirements, and verification specifications. The gradation data may be used to calculate relationships between various aggregate or aggregate blends, to check compliance with such blends, and to predict trends during production by plotting gradation curves graphically, to name just a few uses. Used in conjunction with other tests, the sieve analysis is a very good quality control and quality acceptance tool.

➢ **PROCEDURE:**

- The test sample is dried to a constant weight
- The sample is sieved by using a set of IS Sieves.
- On completion of sieving, the material on each sieve is weighed.
- Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.
- Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.

4.1.4 INITIAL AND FINAL SETTING TIME

Initial setting time of cement is the time lapse between the addition of water and the instant cement paste starts to lose its plasticity. Final setting time is the time lapse between the addition of water to the instant the cement paste completely loses its plasticity. For OPC initial setting time is 30 minutes. The initial setting time is the exact moment when the concrete starts to harden. In theory, this time starts as soon as the water is added to the cement. The final setting time is the moment the concrete has hardened enough so that a five-millimeter square needle no longer penetrates the surface.

Initial Setting Time of Cement as per IS 4031, IS 269. Initial setting time of concrete is the time period between addition of water to cement till the time at 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5mm to 7mm from the bottom of the mould. Initial setting time duration is required to delay the process of hydration or hardening. Final setting time is the time when the paste completely loses its plasticity. It is the time taken for the cement paste or cement concrete to harden sufficiently and attain the shape of the mould in which it is cast.

- **Procedure**
  - Take 400 g of cement and prepare a neat cement paste with 0.85P of water by weight of cement.
  - Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time (T_1).
  - Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould.
  - Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle.
  - Lower the needle gently until it comes in contact with the surface of test block and quick release, allowing it to penetrate into the test block.
  - Repeat this procedure i.e. quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. Note this time (T_2).
  - For determining the final setting time, replace the needle of the Vicat's apparatus by the needle with an annular attachment.
  - The cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; the needle makes an impression thereon, while the attachment fails to do so. Record this time (T_3).

Initial setting time=T_2-T_1

Final setting time=T_3-T_1

Where,

T_1 =Time at which water is first added to cement

T_2 =Time when needle fails to penetrate 5 mm to 7 mm from bottom of the mould

T_3 =Time when the needle makes an impression but the attachment fails to do so.

4.1.5 COMPRESSIVE TEST

Compressive strength test, mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The test piece, usually in the form of a cube, prism, or cylinder, is compressed between the platens of a compression-testing machine by a gradually applied load. Compressive strength is measured by breaking cylindrical concrete specimens in a compression-testing machine. Compressive strength is calculated from the failure load divided by the cross-sectional area resisting the load and reported in units of pound-force per square inch (psi) or megapascals (MPa).

The compressive strength of the concrete cube test provides 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 the production of concrete, etc. Test for compressive strength is carried out either on a cube or cylinder. Various standard codes recommend a 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 of Cylindrical Concrete Specimens.

For most of the works cubical molds of size 15cm x 15cm x 15cm are commonly used. This concrete is poured in the mold and appropriately tempered so as not to have any voids. After 24 hours, molds 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 done by placing cement paste and spreading smoothly on the whole area of the specimen .These specimens are tested by compression testing machine after seven days 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.

- **Procedure**
  - Remove the specimen from the water after specified curing time and wipe out excess water from the surface.
  - Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
  - Align the specimen centrally on the base plate of the machine.
  - Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
  - Apply the load gradually without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails
  - Record the maximum load and note any unusual features in the type of failure.
  - Compressive stress= $\frac{P}{A}$ N/mm^2

4.1.6 WATER PERMEABILITY TEST

Water permeability test determines the resistance of concrete against water under hydrostatic pressure. The permeability test should be considered the dominant test to evaluate the case whereby concrete is subjected to hydrostatic pressure. Durability testing is important to determine the lifespan of your structure. In simple words, Presence of voids in concrete makes permeable which in turn allows water or gas to flow into it. The permeability of concrete is the ability of concrete to resist the water flow or any other substance into it when the external force is applied.

Permeability of cement mortar or concrete is of particular significance in structures which are intended to retain water or which come into contact with water. Besides functional considerations, permeability is also intimately related to the durability of concrete, specially its resistance, against progressive deterioration under exposure to severe climate, and leaching due to prolonged seepage of water, particularly when it contains aggressive gases or minerals in solution. The determination of the permeability characteristics of mortar and concrete, therefore, assumes considerable importance. The test consists in subjecting the mortar or concrete specimen of known dimensions, contained in a specially designed cell, to a known hydrostatic pressure from one side, measuring the quantity of water percolating through it during a given interval of time and computing the coefficient of permeability. The test permits measurement of the water entering the specimen as well as that leaving.

- **Procedure**
  - Specimens shall be cylindrical in shape with height equal to the diameter. The standard size of specimen shall have diameter (and height) of 150 mm
  - The mortar or concrete mix shall be cast in split moulds of the required size, with removable collar of about half the height set on the top. The material shall compacted either by hand rodding or vibration, as proposed to be done during construction
  - The standard test pressure head to be applied to the water in the reservoir should be 10 kg/cm2
  - The specimen shall be surface-dried and the dimensions measured to the nearest 0.5 mm. It shall then be centred in the cell, with the lower end resting on the ledge.
  - It is essential that the seal is watertight. This may be checked very conveniently by bolting on the top cover plate, inverting the cell and applying an air pressure of 1 to 2 kg/cm2 from below
  - With the system completely filled with water, the desired test pressure shall be applied to the water reservoir and the initial reading of the gauge-glass recorded
  - At the same time a clean collection bottle shall be weighed and placed in position to collect the water percolating through the specimen. The quantity of percolate and the gauge-glass readings shall be recorded at periodic intervals. In the beginning, the rate of water intake is larger than the rate of outflow.

    The Coefficient of Permeability shall be calculated as follows:

    K = Q / (A*T*H/L)

    where,

    K= Coefficient of permeability (cm/sec),

    Q= quantity of water in millimeters percolating

    A= area of the specimen face in cm2

    T= time in seconds over which Q is measured, and

    H/L= ratio of the pressure head to thickness of specimen.

4.2 MIX PROPORTIONS

- M_{20} Grade
- Proportion: 1:1.5:3
- Cube Size: 15*15*15 cm or 0.15*0.15*0.15 m

- Volume: 0.003375 m^3
- Density of concrete: 2400 kg/m^3
- Density = Mass/Volume

  2400 = Mass/0.003375

  Mass = 8.1 Kg

CALCULATION OF CONTENTS

- Cement = $\frac{(8.1\times1)}{(1+1.5+3)}$ = 1.472 Kg
- Sand = $\frac{(8.1\times1.5)}{(1+1.5+3)}$ = 2.20 Kg
- Aggregate = $\frac{(8.1\times3)}{(1+1.5+3)}$ = 4.41 Kg

USING 5% BLAST FURNACE SLAG

Blast furnace slag req = 5% (cement content)

= 5% (1.472)

= 0.0736 Kg for 1 cube

= 0.0736*3

= 0.2208 Kg

Cement= 1.472*3 = 4.416 Kg

Actual Cement req = 4.416-0.2208 = 4.195 Kg

Sand = 2.20*3 = 6.6Kg

Aggregate = 4.41*3 = 13.23 kg

USING 10% BLAST FURNACE SLAG

Blast furnace slag req = 10% (cement content)

= 10% (1.472)

= 0.1472 Kg for 1 cube

= 0.1472*3

= 0.4416 Kg

Cement= 1.472*3 = 4.416 Kg

Actual Cement req = 4.416-0.4416 = 3.974 Kg

Sand = 2.20*3 = 6.6Kg

Aggregate = 4.41*3 = 13.23 kg

USING 15% BLAST FURNACE SLAG

Blast furnace slag req = 15% (cement content)

= 15% (1.472)

= 0.2208 Kg for 1 cube

= 0.2208*3

= 0.6624Kg

Cement= 1.472*3 = 4.416 Kg

Actual Cement req = 4.416-0.6624 = 3.75 Kg

Sand = 2.20*3 = 6.6Kg

Aggregate = 4.41*3 = 13.23 kg

USING 20% BLAST FURNACE SLAG

Blast furnace slag req = 20% (cement content)

= 20% (1.472)

= 0.2944 Kg for 1 cube

= 0.2944*3

= 0.8832 Kg

Cement= 1.472*3 = 4.416 Kg

Actual Cement req = 4.416-0.8832 = 3.53 Kg

Sand = 2.20*3 = 6.6Kg

Aggregate = 4.41*3 = 13.23 kg

USING 25% BLAST FURNACE SLAG

Blast furnace slag req = 25% (cement content)

= 25% (1.472)

= 0.368 Kg for 1 cube

= 0.368*3

= 1.104 Kg

Cement= 1.472*3 = 4.416 Kg

Actual Cement req = 4.416-1.104 = 3.974 Kg

Sand = 2.20*3 = 6.6Kg

Aggregate = 4.41*3 = 13.23 kg

- **TOTAL MATERIALS REQ FOR 15 CUBES**
  i. Cement = 18.761 Kg
  ii. Sand = 33 Kg
  iii. Aggregate = 66.15 Kg
  iv. Blast Furnace Slag = 3.312 Kg

4.3 CURING

Curing of Concrete is a method by which the concrete is protected against loss of moisture required for tand kept within the recommended temperature range. Curing will increase the strength and decrease the permeability of hardened concrete. Curing is also helps in mitigating thermal and plastic cracks, which can severely impact durability of structures.

Fig 4.4 Curing

CHAPTER 5
RESULTS AND DISCUSSIONS

5.1 SPECIFIC GRAVITY OF CEMENT

The dry specific gravity bottle is weighed as W1 grams. The bottle is filled with distilled water and weighed as W2 grams. The specific gravity bottle is dried and filled with kerosene and is weighed as W3 grams. Some of the kerosene is poured out and introduced with and weight quantity of cement and the weight is measured as W4 grams. 100 grams weight of cement is taken as W5 grams. Specific gravity of cement (g) = (w2-w1)/(w2-w1)-(w3-w4)x0.79

Fig 5.1 Density Bottle

Table 5.1 Specific Gravity of Cement

Sl No	DESCRIPTION	TRAIL 1	TRAIL 2	TRAIL 3
1	Weight of empty bottle(W1)	48	48	48
2	Weight of bottle + water (W2)	145	145	145
3	Weight of bottle + kerosene (W3)	123	123	123
4	Weight of bottle + kerosene + cement (W4)	143	140	141

5	Weight of cement (W5)	26.55	22.8	24.64
6	Specific gravity	3.10	3.02	2.87

Specific Gravity of Cement used is 2.99

5.2 SPECIFIC GRAVITY OF FINE AGGREGATE

Specific gravity is defined as the ratio of the weight of a given volume of soil at a given temperature to the weight of an equal volume of distilled water at that temperature. The specific gravity test is done by using the pychnometer. With the use of pycnometer, specific gravity of each constituent is known. Specific gravity of aggregate is required in mix design for different grades with the workability measurements. Average specific gravity of the various soils Materials varies from 2.6 and 2.8. Pycnometer method is also quick method of determining the specific gravity of soil sample. This method is suitable for fine grained soils only.

Fig 5.2 Pycnometer

The pycnometer is cleaned thoroughly and the mass of the pycnometer with brass cap is weighed as W1gram. Take200gm to 100gm of the dried soil in the pycnometer, weighed as W2gram. The pycnometer is filled with water up to the top mix it thoroughly with glass rod and stir it. The pycnometer with soil and water is weighed and denoted asW3. Finally empty the pycnometer and clean thoroughly and is weighed as W4 grams.
Specific gravity of coarse aggregate =$W2-W1W2-W1-(W3-W4)$

Table 5.2 Specific gravity of fine aggregate

Sl. NO	DESCRIPTION	TRAIL 1	TRAIL 2	TRAIL 3
1	Weight of pycnometer (W1	461	461	461
2	Weight of pycnometer + sand (W2)	616	605	620
3	Weight of pycnometer + sand + water (W3)	1356.5	1358	1356
4	Weight of pycnometer + water (W4)	1260	1261	1260
5	Specific gravity	2.65	2.86	2.56

Specific gravity of fine aggregate used is 2.69

5.3 SPECIFIC GRAVITY OF COARSE AGGREGATE

Specific gravity is defined as the ratio of the weight of a given volume of soil at a given temperature to the weight of an equal volume of distilled water at that temperature. The specific gravity test is done by using the wire basket.BIS 882:1992 prescribes the following maximum values of the average of sample,25% when the aggregates is to be used in heavy-duty concrete floor finishes,30% when the aggregates is to be used in concrete pavement wearing surfaces 45% when the aggregates is to be used in other concrete.

Specific gravity of coarse aggregate = $W2-W1$ / $W2-W1$ – $(W3-W4)$

Fig 5.3 Wire Basket

Table 5.3 Specific gravity of coarse aggregate

S.NO	DESCRIPTION	TRAIL 1	TRAIL 2	TRAIL 3
1	Weight of container (W1)	1.255	1.255	1.255
2	Weight of container + coarse aggregate(W2)	2.187	2.1	3.574
3	Weight of the container + coarse aggregate + water (W3)	3.509	3.478	4.402
4	Weight of container + water (W4)	2.899	2.899	2.925
5	Specific gravity of coarse Aggregate	2.894	3.17	2.75

Specific Gravity of coarse aggregate used is 2.95

5.4 SPECIFIC GRAVITY OF BLAST FURNACE SLAG

The dry specific gravity bottle is weighed as W1 g. The bottle is filled with distilled water and weighed as W2 .The specific gravity bottle is dried and filled with kerosene and is weighed as W3 g. Some of the kerosene is poured out and introduced with and weight quantity of coir and the weight is measured as W4 g.

Specific gravity of GGBS (g) = (w2-w1)/(w2-w1)-(w3-w4)x0.79

Specific gravity of chemical admixture

Average specific gravity of chemical admixture = 2.92

5.5 SIEVE ANALYSIS TEST

The size distribution for the construction materials are determined by sieve analysis. A sieve analysis can be performed on any type of non-organic or organic materials. To differentiate particle size, sieve analysis is most probably adopted. The sieves used in the sieve analysis test are 4.75 mm, 2 mm, 1 mm, 0.6 mm, 0.3 mm, 0.212 mm and 0.150 mm and an empty pan.

Fig 5.4 Mechanical sieve shakers

The sieves are placed one below the other in the order of their mesh size. Largest aperture sieve being kept at the top and the smallest aperture sieve kept at bottom descending order. An empty pan is kept at the bottom and a cover is kept at the top of the whole assembly. The soil sample of about 1Kg is put on the top sieve, and the whole assembly is fitted on a sieve shaking machine. The sieve process gets started and allowed to shake for about 10 minutes. The amount of shaking depends upon the shape and the number of particles. The residue of the soil sample retained on each sieve is weighed. The percentage of soil retained on each sieve is calculated on the basis of the cumulative weight retained on the sieve. And for coarse aggregate the 20mm down size aggregates are taken.

5.6 INITIAL AND FINAL SETTING TIME

5.6.1 INITIAL SETTING TIME

Lower the needle gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after sometime when the paste starts losing its plasticity, the needle may penetrate only to a depth of 33-35 mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the block to a depth equal to 33-35 mm from the top is taken as initial setting time.

Fig 5.5 vicat appartus

Initial setting time: For opc 53 grade the initial setting time is 30 minutes.

5.6.2 FINAL SETTING TIME

Replace the needle of the Vicat's apparatus by a circular attachment. The cement shall be considered as finally set when, upon, lowering the attachment gently cover the surface of the test block, the centre needle makes an impression , while the circular cutting edge of the attachment fails to do so. The paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

Final setting time : for opc 53 grade the final setting time is 600 minutes.

5.7 NORMAL CONSISTENCY

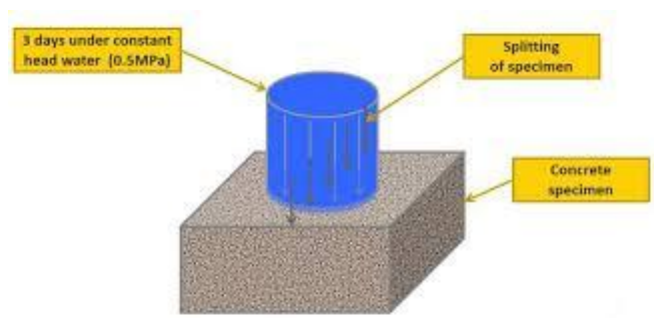
Normal consistency test is used to determine the optimum percentage of water content required for a cement paste. It is a datum for all the tests on cement. Today I am giving he test procedure for normal consistency of a cement paste. The standard consistency or normal consistency of a cement paste is defined as the amount of water (in percentage by weight of dry cement) that permits the vicat plunger to penetrate to a depth of 5 to 7 mm from the bottom of the vicat mould. Reference: IS: 269 – 1976 and IS: 4031 – 1968.

The amount of water content that brings the cement paste to a standard condition of wetness is called "normal consistency". It has a marked effect upon the time of set as well as upon other properties of cement. The paste at normal consistency is fairly stiff and is used only for the determination of time of set and soundness of cement. It is necessary to fix the quantity of water to be mixed in cement while experimenting on it. The normal consistency of a cement paste is defined as that consistency (% of water) which will permit the vicat plunger to penetrate to a point 10 mm from the top of the vicatmould. The usual range of values being between 22 to 30 percent by weight of dry cement. Normal consistency is also called standard consistency.

Normal consistency: to prepare the mix of cement paste 0.27 of water is added to the cement.

5.7 WATER PERMEABILITY TEST

Over the past couple of weeks we have been going over a number of different methods to use for durability testing. The first was the absorption test, which gives a good result, yet could be better. The Rapid Chloride Permeability test is another used with wide popularity because it is quick and easy to execute; however, does give unreliable and unrealistic results. The 3^{rd} and most accurate way of testing for all important durability is the water permeability test. As stated in the first post on durability testing, the relationship between permeability and durability allows the durability of a mix to be determined by testing the permeability of the mix in question. Therefore, the water permeability test determines the true resistance of concrete against the penetration of water under hydrostatic pressure. This permeability test should be considered the dominant test to evaluate the case whereby concrete is subjected to hydrostatic pressure.



5.6 Water permeability test

Water permeability test determines the resistance of concrete against water under hydrostatic pressure.

5.8 SULPHATE REACTIVITY TEST

The sulphates attack, such the more common type and typically occurs where water containing Dissolved sulphate penetrates the concrete. A fairly well-defined reaction front can often be seen in polished sections; ahead of the front the concrete is normal, or near normal. Behind the reaction front, the composition and microstructure of the concrete will have changed. These changes may vary in type or severity but commonly include:

- Extensive cracking

- Expansion
- Loss of bond between the cement paste and aggregate.

The chloride attack leads to corrosion of the reinforcing steel and a subsequent reduction in the strength, serviceability, and aesthetics of the structure. The affects the time for chlorides to reach the reinforcing bars and, consequently, the corrosion initiation time. The concrete structure, in fact the low permeability and dense microstructure proved to extend the time needed for corrosion to occur.

5.8.1 Sulphate attack in concrete

The sulphate attack on concrete might show itself in different forms depending on:

- The chemical form of the sulphate.
- The atmospheric environment which the concrete is exposed

When sulphates enters into concrete:

- It combines with the C-S-H, or concrete paste, and begins destroying the paste that holds the concrete together. As sulphate dries, new compounds are formed, often Called ettringite.
- These new crystals occupy empty space, and as they continue to form, they cause the paste to crack, further damaging the concrete.

Developing the sulphate attack is divided in two different sources:

- Internal Sources
- External Sources

The internal Sources- are more rare but, originates from such concrete-making materials as hydraulic

Cements fly ash, aggregate, and admixtures. The presence of this type is focused on the:

- Portland cement might be over-Sulphated.
- Presence of natural gypsum in the aggregate.
- Admixtures also can contain small amounts of sulphates.

The external Sources- are more common and usually are a result of high-sulphate soils and ground waters, or can be the result of atmospheric or industrial water pollution.

- Soil may contain excessive amounts of gypsum or other Sulphate
- The water be transported to the concrete elements, retaining walls, and other structure elements

- Industrial waste waters

5.9 CHLORIDE REACTIVITY TEST

Chloride attack is one of the most important aspects for consideration when we deal with the durability of concrete. Chloride attack is particularly important because it primarily causes corrosion of reinforcement. Statistics have indicated that over 40 per cent of failure of structures is due to corrosion of reinforcement. Due to high alkalinity of concrete a protective oxide film is present on the surface of steel reinforcement. The protective passivity layer can be lost due to carbonation. This protective layer also can be lost due to the presence of chloride in the presence of water and oxygen. In reality the action of chloride in inducing corrosion of reinforcement is more serious than any other reasons. One may understand that Sulphates attack the concrete whereas the chloride attacks steel reinforcements. The amount of chloride required for initiating corrosion is partly dependent on the pH value of the pore water in concrete. At a pH value less than 11.5 corrosion may occur without the presence of chloride. At pH value greater than 11.5 a good amount of chloride is required.

5.9.1 Physical process of Chloride Attack:

The presence of the chloride in real structures shows that the surface chloride content is different in different structures, but may also vary in time .For structures exposed like capillary absorption and diffusion, depending on the relative position with respect to the mean water level, wave height, tidal cycle and so on Moreover the cyclic wetting and drying (with different cycle lengths for tidal and splash zones) may cause accumulation of chloride; exposure to prevailing wind and precipitation may wash out previously absorbed chloride, and carbonation will release bound chloride. Most of these factors also depend on the concrete composition (cement type, chloride binding, absorption, permeability for water vapor). The effect is that chloride penetration is a complex function of position, environment and concrete.

CHAPTER 6
CONCLUSION

6.1 CONCLUSIONS

- Few experiments were carried out. And some of the properties were found out.
- The specific gravity of cement is 2.99
- The specific gravity of coarse aggregate is 2.95
- The specific gravity of fine aggregate is 2.69
- The specific gravity of Blast furnace slag is 2.92
- The normal consistency of cement is 0.27

6.2 SCOPE OF THE STUDY

- To study the freeze and thaw reaction of concrete and mortar using blast furnace slag.
- To investigate the effect of alkali-silica reaction of the concrete incorporated with blast furnace slag.
- To study the variations of different water cement ratio of both concrete and mortar using blast furnace slag.
- To study the physical and chemical characterizations of blast furnace slag from different industries and its utilization as a construction material.
- To analyse the durability of concrete and mortar using blast furnace slag at different percentage level.

REFERENCES

- *Al – Baijat, H and Sarireh, M. (2019)., "The use of Fine Blast Furnace Slag in Improvement of Properties of Concrete". Open Journal of Civil Engg 9, 95-105*
- *D Shi, Q Liu, X Xue, P He, (2018). Et al., "Study on the durability of concrete using granulated blast furnace slag as fine aggregate".*
- *N T Sang, N T Khoa , (2019)., "Experimental Study on Effect of Ground Granulated Blast Furnace Slag of Strength and Durability of Sand Concrete".*
- *Yüksel İsa, Bilir Turhan and Özkan Ömer ,(2007)., "Durability of concrete incorporating non-ground blast furnace slag and bottom ash as fine aggregate" Building and Environment 2651-2659*
- *Zhu Beirong, Lin Feng, Zhang Shuqing and Yang Quanbing ,(2008)., "Study on Physical and Mechanical Performance of Mortar and Concrete Containing Blast Furnace Slag Aggregates" Journal of Building Materials 11 387-391*
- *Demirbo (G)A. R. and G (U)L. R. ,(2006)., "Production of high strength concrete by use of industrial by-products" Building and Environment 1124-1127*
- *Khatib, J.M. and J.J. Hibbert, (2005)., "Selected engineering properties of concrete incorporating slag and metakaolin" Construction and Building Materials 19(6), 460-472.*
- *A.M, N., Properties of concrete. Fifth Edition. Pearson Education, London. (2011)*
- *Anil Kumar Sharma and P.V. Sivapullaiah (2012). Improvement of Strength of Expansive soil with waste Granulated BlastFurnace Slag. ASCE:Geo Congress, 39203928.*
- *EceCelik and ZaliheNalbantoglu (2013).Effects of ground granulated blast furnace slag (GGBS) on the swelling properties of lime-stabilized sulphate-bearing soils. Engineering Geology, 163, 20–25.*
- *ErdalCokca, VeyselYazici and VehbiOzaydin (2009).Stabilization of Expansive Clays Using Granulated Blast Furnace Slag (GBFS) and GBFS-Cement. Geotech Geol Eng, 27,489–499.*
- *IS SP 36: Part 1: 1987 Compendium of Indian standards on soil engineering: Part 1 Laboratory testing of soils for civil engineering purposes.*
- *LaxmikantYadu and Tripathi, R.K., (2013).Effects of Granulated Blast Furnace slag in the Engineering Behaviour of Stabilised soil. Procedia Engineering, 51,125-131. [*
- *Obuzor, G.N., J.M. Kinuthia and R.B. Robinson (2012). Soil stabilisation with lime-activated-GGBS-A mitigation to flooding effects on road structural layers/embankments constructed on flood plains. Engineering Geology, 151,112119*
- *Wild S., Kinuthia J.M., Robinson R.B. and Humphries I.(1996). Effects of Ground Granulated Blast Furnace Slag (GGBS) on the strength and swelling properties of limestabilised kaolinite in the presence of sulphates. Clay Minerals, 31, pp 423-433.*
- *Wild S., Kinuthia J.M., Jones G.I. and Higgins D.D.(1998). Effects of partial substitution of lime with Ground Granulated Blast Furnace Slag on the strength properties of lime stabilized sulphate bearing clay soils. Engineering Geology, Vol.51 (1), pp 37-53.*

- *S. Arivalagan (2014), "Sustainable Studies on Concrete with GGBS As a Replacement Material in Cement", Jordan Journal of Civil Engineering,8(3)-263 Dr. M.G.R. University, Chennai, Tamil Nadu, India.*
- *D. Suresh and K. Nagaraju, "Ground Granulated Blast Slag (GGBS) In Concrete – A Review", IOSR Journal of Mechanical and Civil Engineering(2015).*
- *Li, Yao, Wang and P. Claisse, "Effect of Steel Slag and Portland Cement in the rate of Hydration and Strength of Blast Furnace Slag Pastes",Journal of materials in civil engineering, ASCE, pp.153-160(2011).*
- *G. Singhand and S. Dasa, "Study of Granulated Blast Furnace Slag as Fine Aggregates in Concrete for Sustainable Infrastructure",Elsevier,pp. 2272 –2279(2015).*