TRANSFORMING WASTE INTO STRENGTH: A COMPREHENSIVE INVESTIGATION OF THE EFFECTS OF IRON SLAG AS PARTIALLY REPLACED FINE AGGREGATE IN TERMS OF MECHANICAL STRENGTH & HIGH TEMPERATURE RESISTANCE OF CONCRETE

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering.



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Dedicated

to

"***Our Respected Teachers***"

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ABSTRACT

The escalating demand for concrete in construction has led to an increased depletion of natural resources which is raising environmental concerns. Moreover, now a days frequently conflagrations are being observed. Considering these two phenomena this thesis investigates the potential of iron slag, a byproduct of steel production, as a partial replacement of fine aggregate in concrete. The study examines the mechanical properties and different high-temperature resistance of concrete incorporating varying proportions of iron slag. This study evaluates the mechanical strength of concrete in which fine aggregate is partially replaced (0%, 5%, 15%, 25%) by iron slag after being exposed to 0, 100, 150 & 200 °C for 0, 60,120 & 180 minutes.

This thesis delves into the following key aspects:

Mechanical properties: The impact of iron slag replacement on the compressive strength is evaluated.

High-temperature resistance: The performance of concrete containing iron slag under gradually increased high temperatures is evaluated.

Therefore, it is expected that the iron slag has merits to be used in conjunction with sand as fine aggregate in producing concrete.

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CHAPTER 1
INTRODUCTION

1.1 General

Now a days sustainable development has received more attention than before. To balance natural resources, engineers and scientists are trying to recycle materials and searching for constructive ways to use waste materials. Moreover, now a days frequently conflagrations are being observed. The civil engineering society has its fair share of responsibility in these regard, as the most widely used material in the construction industry ‘concrete’ is produced using aggregates as one of the ingredients, which come from natural sources. Concrete is a composite material where 60%-75% of the volume is provided by aggregates [1]. Conventionally, sand and stone chips are obtained from natural sources to meet this requirement in the form of fine and coarse aggregate, respectively. As aggregates act as filler in concrete production, iron slag, a by-product of the steel industry, can be a good option for fine aggregate. If iron slag can be proved to be applicable as a partial replacement of sand, it will make concrete production economical, more fire resistant, ensure proper use of waste materials, and keep natural resources in a balanced condition. And thus, it is important to find a method of using iron slag in an effective and engineered way as a potential replacement of sand without sacrificing the desired properties of concrete. Earlier studies assessed the applicability of iron slag in different capacities for producing concrete. Das [2] explored the use of blast furnace slag to reduce cement manufacturing costs. Jalil [3] investigated the applicability of industrial waste slag from a steel mill as a replacement for cement [3]. Mishra [4] and Palanisamy [5] used iron slag as a replacement for fine aggregate in producing concrete. Raza [6], Padmapriya [7] and Thangaselvi [8] used iron slag as a replacement for coarse aggregate for producing concrete and determined the required dose of iron slag for optimum compressive strength. It is interesting to note that these three studies [6-8] reported different doses of iron slag ranging from 30% to 60% for optimum compressive strength. This could be due to the difference in properties of iron slag collected from different steel production units. And thus, it is required to conduct a similar investigation in Bangladesh to assess the applicability of locally produced iron slag as a potential replacement for conventional fine aggregate in producing concrete. The objective of this study is to evaluate the effect of iron slag collected from a local source as a replacement of sand on different properties of concrete. In this study, the physical properties of individual ingredients were evaluated; later on, the workability, unit weight, and compressive strength of concrete were measured for comparison.

1.2 Objective of the Study

To compare the effect of temperature on the compressive strength of normal-weight concrete and the concrete made with partially replaced slag as fine aggregate.

1.3 Organization of the thesis

Chapter 1: Introduction and Objective: This chapter provides the background and motivations for the research. The overall objective and expected outcomes are also described in this chapter.

Chapter 2: Literature Review: This chapter reviews the related works in the partially replaced slag as fine aggregate of concrete, with a special focus on varying percentages of slag and temperature.

Chapter 3: Methodology: This chapter describes the methodology adopted to carry out the research.

Chapter 4: Results and Discussion: This chapter describes the results of the time-dependent effect of temperature on the compressive strength of concrete made with partially replaced slag as fine aggregate.

Chapter 5: Conclusions and Future Work: This chapter summarizes the conclusions and major contributions of this study and provides recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Research Background

Industrial by-products' productive use grant a chance to relocate the utilization of limited natural resources on a large scale. As Iron slag is a byproduct obtained in the manufacture of pig iron in the blast furnace and is produced by the blend of down-to-earth constituents of iron ore with limestone flux. Iron and steel slag can be distinguished by the cooling process when removed from the furnace in the industry. Mostly, the slag consists of magnesium, aluminum silicates, calcium, and manganese in various arrangements. Even though the chemical composition of slag is the same, the physical properties of the slag vary with the varying method of cooling. The slags can be used as cement's major constituents as they have greater pozzolanic properties.

The history of the use of iron and steel slag dates back a long way. The European Slag Association (2006) has reported on the earliest reports on the use of slag, where in it is mentioned that Aristotle used slag as a medicament as early as 350 B.C. In the past, the application of steel slag was not noticeable because enormous volumes of blast furnace slag were available. Through awareness of environmental considerations and, more recently, the concept of sustainable development, extensive research and development have transformed slag into a modern industrial product that is effective and beneficial.

The American Society of Testing and Materials (ASTM) (1999) defines blast furnace slag as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition at the same time as iron in a blast furnace." Slag was considered essential in the production of iron, but once it served its purpose in refining the metal, it was strictly a nuisance with little or no use. The use of slag became a common practice in Europe at the turn of the 19th century, where the incentive to make all possible use of industrial by-products was strong and storage space for by-products was lacking. Shortly after, many markets for slag opened in Europe, the United States, and elsewhere in the world.

2.2 Cement

One of the most important building materials is cement which is a binding agent that sets and hardens to adhere to building units such as stones, bricks, tiles, etc. Cement generally refers to a very fine powdery substance chiefly made up of limestone (calcium), sand or clay (silicon), bauxite (aluminum), and iron ore and may include shells, chalk, marl, shale, clay, blast furnace slag, and slate [3].

In cement production plants raw ingredients are processed and heated to form a rock-hard substance, which is then ground into a fine powder to be sold. Cement mixed with water causes a chemical reaction and forms a paste that sets and hardens to bind individual structures of building materials.

Cement has become an integral part of urban infrastructure. It is used to make concrete as well as mortar and to secure the infrastructure by binding the building blocks. Concrete is

made of cement, water, sand, and gravel mixed in definite proportions, whereas mortar consists of cement, water, and lime aggregate. These are both used to bind rocks, stones, bricks, and other building units, fill or seal any gaps, and make decorative patterns.

Cement mixed with water silicates and aluminates, making a water-repellent hardened mass that is used for water roofing [4]. Cement is a binder, a substance used in construction that sets, hardens, and adheres to other materials, binding them together. Cement is seldom used solely, but it is used to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry or with sand and gravel aggregates to produce concrete.

Cements used in construction are usually inorganic, often lime or calcium silicate-based, and can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster).

Non-hydraulic cement will not set in wet conditions or underwater; rather, it sets as it dries and reacts with carbon dioxide in the air. It is resistant to attack by chemicals after setting [4].

Hydraulic cements (e.g., Portland cement) set and become adhesive due to a chemical reaction between the dry ingredients and water.

Results in mineral hydrates that are not very water-soluble and are therefore quite durable in water and safe from chemical attack. This allows setting in wet conditions or underwater and further protects the hardened material from chemical attack [5].

In Britain particularly, good-quality building stone became ever more expensive during a period of rapid growth, and it became a common practice to construct prestige buildings from the new industrial bricks and to finish them with stucco to imitate stone. Hydraulic lines were favored for this, but the need for a fast set time encouraged the development of new cements. Most famous was Parker's "Roman cement". This was developed by James Parker in the 1780s and finally patented in 1796. It was, in fact, nothing like the material used by the Romans, but a "natural cement" made by burning sectarian nodules that are found in certain clay deposits and that contain both clay minerals and calcium carbonate [5]. The burned nodules were ground to a fine powder. This product, made into a mortar with sand, sets in 5–15 minutes. The success of "Roman cement" led other manufacturers to develop rival products by burning artificial hydraulic lime cements of clay and chalk. Roman cement quickly became popular but was largely replaced by Portland cement in the 1850s. In addition to the benefits of cement, the construction industry apparently was unaware of Seaton’s work. The same principle was identified by Frenchman Louis Vicar in the first decade of the nineteenth century. Vicar went on to devise a method of combining chalk and clay into an intimate mixture and burning this produced "artificial cement" in 1817, considered the "principal forerunner "of Portland cement, and "Edgar Dobbs of Southward patented a cement of this kind in 1811".

In Russia, Eger created a new binder by mixing lime and clay. His results were published in 1822 in his book A Treatise on the Art of Preparing a Good Mortar, published in St. Petersburg. A few years later, in 1825, he published another book, which described the various methods of building and embankments.

William Aspin is considered the inventor of "modem" Portland cement. Portland cement, the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and non-specialty grout, was developed in England in the mid-19th century and usually originates from limestone. James Frost produced what he called "British cement" in a similar manner around the same time, but did not obtain a patent until 1822. In 1824, Joseph Aspin patented a similar material, which he called Portland cement, because the render made from it was in color similar to the prestigious Portland stone, which was quarried on the Isle of Portland, Dorset, England. However, Aspdins' cement was nothing like modern Portland cement but was a first step in its development, called proto-Portland cement [1]. Joseph Aspins' son, William Aspdin, had left his father's company and, in his cement manufacturing, apparently accidentally produced calcium silicates in the 1840s, a middle step in the development of Portland cement. William Aspin's innovation was counterintuitive for manufacturers of "artificial cements", because they required more lime in the mix (a problem for his father), a much higher kiln temperature (and therefore more fuel), and the resulting clinker was very hard and rapidly wore down the millstones, which were the only available grinding technology at the time. Manufacturing costs were therefore considerably higher, but the product set reasonably slowly and developed strength quickly, thus opening up a market for use in concrete [2]. The use of concrete in construction grew rapidly from 1850 onward and was soon the dominant use for cement. Thus, Portland cement began to play a predominant role. Isaac Charles Johnson further refined the production of meso-Portland cement (the middle stage of development) and claimed to be the real father of Portland cement.

Setting time and "early strength" are important characteristics of cements. Hydraulic limes, "natural" cements, and "artificial" cements all rely on their belite content for strength development. Belite develops strength slowly. Because they were burned at temperatures below 1,250 °C (2,280 °F), they contained no alite, which is responsible for the early strength of modern cements. The first cement to consistently contain alite was made by William Aspdin in the early 1840s. This was what we call today "modem" Portland cement. Because of the air of mystery with which William Aspdin surrounded his product, others (e.g., Vicat and Johnson) have claimed precedence in this invention, but recent analysis of both his concrete and raw cement has shown that William Aspdin's product made at Northfleet, Kent, was a truealite-based cement. However, Aspdin's methods were "rules of thumb." Vicat is responsible for establishing the chemical basis of these cements, and Johnson established the importance of sintering the mix in the kiln. The next development in the manufacture of Portland cement was the introduction of the rotary kiln, which allowed for a stronger, more homogeneous mixture and a continuous manufacturing process.

2.2.1 Modern Cements

Modern hydraulic cements began to be developed from the start of the Industrial Revolution (around 1800), driven by three main needs.

- Hydraulic cement render (stucco) for finishing brick buildings in wet climates.
- Hydraulic mortars for masonry construction of harbor works, etc., in contact with sea water.
- Development of strong concretes. Modern cements are often Portland cement or Portland cement blends, but other cements are used in industry.

Table 2.1: Chemical Composition of Ordinary Portland Cement

Ingredient	Percentage
Lime (CaO)	62
Silica (SiO2)	22
Alumina (Al2O2)	5
Calcium Sulphate (CaSO4)	4
Iron Oxide (Fe2O3)	3
Magnesia (MgO)	2
Sulphur (S)	1
Alkali	1
Total	100

2.3 Properties of Cement

It is always desirable to use the best cement in constructions. Therefore, the properties of cement must be investigated. Although desirable cement properties may vary depending on the type of construction, generally cement possesses following properties (which depend upon its chemical composition, thoroughness of burning and fineness of grinding).

- Provides strength to masonry.
- Stiffens or hardens early.
- Possesses good plasticity.
- An excellent building material.
- Easily workable.
- Good moisture-resistance

2.4 Sand

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. Sand can also refer to a textural class of soil or soil type, i.e., a soil containing more than 85% sand-sized particles by mass. The composition of sand varies depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or sio2), usually in the form of quartz. The second most common type of sand is calcium carbonate, for example, aragonite, which has mostly been created over the past half billion years by various forms of life, like coral and shellfish. It is the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years, like the Caribbean [2]. Sand is a loose, granular material blanketing the beaches, riverbeds, and deserts of the world. Composed of different materials that vary depending on location, sand comes in an array of 10 colors, including white, black, green, and even pink. The most common component of sand is silicon dioxide in the form of quartz. The earth's landmasses are made up of rocks and minerals, including quartz, feldspar, and mica [3].

2.5 Properties of Sand

Quartz is a very hard mineral, ranking a 7 on the Mohs hardness scale. Pure quartz is transparent to translucent, and the crystals are often hexagonal. A lot of sand, especially that found on beaches, is made of basalt, an igneous rock extruded from volcanoes. Much of the crust of the earth's oceans is made out of basalt, which is magic, which means that it's made of iron and magnesium minerals, such as plagioclase and pyroxene. Other types of sand are made up of tiny bits of coral and crushed snail and clam shells [5]. Sand can also come in many colors. Some beaches in Hawaii are famous for black sand, whereas beaches in the Caribbean are famous for pink sand. Because sand is composed of so many materials, it is possible to study grains of sand under a microscope and discover where they are from and what they are made of.

2.6 Types of Sand Available in Bangladesh

Chemicals determined by x-ray analysis for local sands This test was conducted by the Atomic Energy Commission. A graded sample for individual particle size was used for Ottawa sand. A graph of x-ray analysis was given in Figures 16 through 21 with typical values. The samples retained on sieves #30, #40, #50, and #100 are analyzed. The percentages of #30, #40, #50, and #100 are 2, 28, 45, and 25, respectively. The value of #40 can be divided between #30 and #50 equally. So the weight age values of #30, #50, and #100 were 0.16, 0.59, and 0.25, respectively. Figure 22: Variation of quartz content in different sands The quartz content in sand is very important since it is chemically inert and strong enough to carry loads. From X-ray analysis, the values of quartz content were plotted in a bar, which shows that. Sand II W is best suited with Ottawa sand based on the consideration of quartz content. From X-ray analysis, the values of quartz content with grain size were plotted in a bar, which shows that the percentage of quartz content increases with the decrease in grain size. 11 This is because in larger particles, there is a tendency to adhere

foreign particles to their surface. On the other hand, in smaller particles, there is a low tendency to adhere foreign particles. So, there are fewer impurities in smaller particles, and for that reason, the quartz content is comparatively higher than that of larger particles. Figure 23, Variation of quartz content with grain size in different sands from the bur chart, shows that quartz content decreases after acid washing for both sands. This is because disintegration of particles results from acid action, i.e., relatively smaller particles get smaller. In smaller particles, the quantity of quartz is relatively high, and after acid washing, this smaller particle disintegrated and washed out. As a result, quartz content decreases. Another reason is the presence of acid. Fe reacts with SiO2 and forms Fe3Si. As a result, it decreases. On the other hand, Fe is very strong and is not disintegrated upon acid action rather than reacting with Si02. So, for decreasing quartz content, the relative proportion of Fe may increase, or for reacting with SiO2, Fe content may decrease. The Fe content of the acid-washed sample is the result of the above two actions. In sand 1, Fe content increases, and in sand II, Fe content decreases after acid washing.

2.7 ASTM Standard Graded Sand

Sand is produced by processing silica rock particles obtained by hydraulic mining of the ortho-quartzite situated in open-pit deposits near Ottawa, Illinois.

1. Made of local (French-sourced) natural silica sand (silica content: 99%).
2. Having a water content lower than 0.1%.
3. The constituent grains of this sand are uncrushed and of rounded form.
4. The sand is used for testing hydraulic cement in accordance with ASTM C109.

Table 2.2: The Average Grading is as Follows:

Square Mesh Size in (mm)	Percent Passing Sieve (%)	
	Average Grading	C778
16 (1.180)	100	100
30 (0.600)	97	96 to 100
40 (0.425)	69	65 to 75
50 (0.300)	26	20 to 30
100	1	0 to 4

2.8 Partially Replaced Fine Aggregate (Slag)

Slag is basically iron dust collected from rod factories. materials are used for various purposes. The use of rod slag as a partial replacement for aggregate is a new and innovative idea. Its use greatly increases the compressive strength of concrete. Due to the use of slag, the compressive strength of slag-admixed concrete is relatively higher than that of normal concrete, even after a certain period of fire. The use of rod slag as a replacement for fine aggregate in multi-story buildings is a breakthrough step that can protect the structure from fire hazards.

2.9 Aggregate

The inert materials used in concrete are termed as ‘aggregate’. It is defined as: "Aggregates are the inert materials that are mixed in fixed proportions with a binding material to produce concrete". The inert materials means they don't interact chemically with the other components. These can be consider as the "bones" of the concrete, bulking it up and influencing its strength. The quality of the aggregate directly affects how well the concrete mixes, hardens, and lasts over time. To ensure strong, long-lasting concrete, the aggregate must be clean and free of soft particles or organic matter, like soil. These impurities can weaken the concrete by causing unwanted chemical reactions.

2.10 Function of Aggregate in Concrete

Aggregate is a crucial component of concrete, constituting 60-80% of its volume and 70-80% of its mass. It plays a critical role in shaping the concrete's properties. Primarily, aggregate provides bulk to the concrete, around which the binding materials form a thin film. Ideally, the voids in the coarse aggregate are filled by the fine aggregate, and the remaining gaps are occupied by the binding materials. These binding materials, as their name suggests, function by adhering to individual aggregate particles and solidifying them into a cohesive mass with the assistance of water.

Beyond its role in providing volume, aggregate offers a multitude of benefits to the final product. These include enhanced stability, resistance to wear and erosion, and the achievement of other desired physical characteristics. Notably, the use of aggregate as a filler presents a significant cost advantage for concrete producers. Since cement can be seven to eight times more expensive than stone and sand, incorporating well-graded aggregates, which are considerably cheaper, can maintain strength without compromising on budget.

The significance of aggregate extends beyond its economic benefits. It plays a vital role in shaping the concrete's strength, thermal and elastic properties, dimensional stability, and volume stability. Furthermore, aggregate helps to mitigate shrinkage, a property that primarily affects cement. By incorporating aggregate into the concrete mix, the level of shrinkage can be effectively controlled, thereby preventing the formation of cracks.

2.11 Strength of Aggregate

The strength of concrete is demonstrably influenced by a confluence of factors, including the binding materials, water, and the characteristics of the aggregates themselves. These aggregate properties encompass size, shape, surface texture, grading, and mineralogy, each exerting a variable degree of influence. Consequently, achieving the desired concrete strength necessitates a meticulous approach, involving the selection of appropriate aggregate types and the determination of their optimal composition within the mix.

In Bangladesh, construction projects commonly utilize two primary types of coarse aggregate: brick aggregate and stone chips. Notably, stone chips generally exhibit superior strength compared to brick aggregate. The growing scarcity of natural sand in Bangladesh compels researchers to explore alternative sources and partial replacements with brick fines to enhance concrete strength. Encouragingly, studies have yielded promising results with the incorporation of brick fines as a substitute for natural sand in varying proportions. These findings bolster the pursuit of suitable alternatives within the realm of brick fines.

Furthermore, the use of high-quality brick fines demonstrably accelerates the early-age development of compressive strength in concrete. This translates to achieving the desired strength even before the projected timeframe, signifying a highly advantageous outcome. It becomes evident that the compressive strength of concrete is significantly dictated by the nature of the aggregate. Consequently, the identification of suitable replacements for coarse aggregates, such as slag, has become increasingly crucial.

Due to the inherent difficulty of measuring the crushing strength of individual aggregate particles, the necessary information must be gleaned from indirect tests. These tests may include the crushing value of bulk aggregate or its resistance to abrasion.

2.12 Types of Aggregate

Classification of Aggregates Based on Size

Aggregates are available in nature in different sizes. The size of aggregate used may be related to the mix proportions, type of work, etc. The size distribution of aggregates is called the "grading of aggregates.

Following are the classifications of aggregates based on size:

Aggregates are classified into 2 types According to Size

1. Fine aggregate
2. Coarse aggregate

2.12.1 Fine Aggregate

When the aggregate is sieved through a 4.75-mm sieve, the aggregate passed through it is called "fine aggregate. Natural sand is generally used as a fine aggregate; silt and clay also fall under this category. The soft deposit consisting of sand, silt, and clay is termed "loam. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and act as a workability agent. The fine aggregate should not be larger than 3/16 inch in diameter.

2.12.2 Coarse Aggregate

When the aggregate is sieved through a 4.75-mm sieve, the aggregate retained is called coarse aggregate. Gravel, cobble, and boulders fall under this category. The maximum size of aggregate used may be dependent on some conditions. In general, 40-mm-size aggregate is used for normal strengths, and 20-mm-size aggregate is used for high-strength concrete. The size range of various coarse aggregates is given below.

2.13 Qualities of Aggregates

Since at least three-quarters of the volume of concrete is occupied by aggregate, it is not surprising that its quality is of considerable importance. Not only is the aggregate limiting the strength of concrete, as weak aggregates cannot produce strong concrete, but the properties of the aggregate also greatly affect the structural performance of the concrete.

- Aggregates should be strong, hard, dense, durable, clear, and free from veins and adherent coatings.
- Aggregates should be free from injurious amounts of disintegrated pieces, alkalis, vegetable matter, and other deleterious substances.
- Flaky and elongated pieces should not be present in aggregate mass.
- Aggregate crushing value should not exceed 45 percent for aggregate used for concrete other than for wearing surfaces and 30 percent for concrete for wearing surfaces, such as runways, roads, and pavements.
- Aggregate impact value should not exceed 45 percent by weight for aggregates used for concrete other than for wearing surfaces and 30 percent by weight for concrete for wearing surfaces, such as runways, roads, and pavements.

The abrasion value of aggregate, when tested using a Los Angeles machine, should not exceed 30 percent by weight for aggregates to be used in concrete for wearing surfaces and 50 percent by weight for aggregates to be used in other concrete.

2.14 Water Cement Ratio:

Within concrete, the single most critical factor influencing a multitude of properties is undeniably the quantity of water employed in the mixture. In the realm of concrete mix design, a specific ratio is established, termed the water-to-cement ratio (w/c). This ratio expresses the relationship between the weight of water and the weight of cement used within the mix. These two crucial ingredients are responsible for the cohesive properties of concrete.

The w/c ratio exerts a profound influence on the ultimate strength of the cured concrete. A lower w/c ratio signifies a lesser amount of water relative to the cement content. This translates to a denser and stronger concrete. Conversely, a higher w/c ratio indicates a greater proportion of water, resulting in a more porous and weaker concrete.

CHAPTER 3
METHODOLOGY

3.1 Introduction

Following the successful completion of the target concrete mix design, the necessary materials were procured for concrete production. The core objective of this investigation centers on the influence of elevated temperatures on the strength characteristics of concrete formulated with a partial replacement of fine aggregate (RFA). In this experiment, iron slag was employed as the RFA.

3.2 Methodology Overview

The initial phase of our work involved the collection of all necessary materials. Subsequently, these materials were transported to a laboratory setting for comprehensive testing. For the purpose of this study, the concrete formulation included cement, sand, stone, a predetermined percentage of iron slag as a replacement aggregate, and water.

3.3 Collection of Materials

The procurement of materials for the concrete production process was conducted as follows. Stone obtained from UAE and sand obtained from Nalitabari, Sherpur, iron slag collected from the Chittagong BSRM Rod Factory. Ordinary Portland Cement (OPC) was acquired from Bashundhara Cement.



Figure 3-1: Cement



Figure 3-2: Coarse Aggregate



Figure 3-3: Fine Aggregate



Figure 3-4: Partially Replaced Fine Aggregate (Slag)

3.4 Sieves Analysis of Aggregate

First, we completed sieve analysis of fine aggregate and partially replaced aggregate through NO. 100, NO. 50, NO. 30, NO. 16, NO. 8, NO. 4 sieves. Then coarse aggregate sieve analysis was completed by NO.100, NO.50, NO.30, NO.16, NO.8, NO.4, 3/8in, 3/4in, 3/2in, and 3in sieves. For particle size distribution for both fine aggregates, partially aggregate, and coarse aggregate, the sieve analysis method was used according AASHTO T27.



Figure 3-5: Sieve Analysis

3.5 Specific Gravity & Absorption of Aggregate (Coarse, Fine and Partially Replaced Fine Aggregate):

The specific gravity & absorption of coarse, fine and partially replaced fine aggregate (RFA) was determined according to AASHTO T84.



Figure 3-6: Specific Gravity

3.6 Unit Weight of Fine Aggregate, Partially Replaced Fine Aggregate and Coarse Aggregates:

The unit weight of fine aggregate, and partially replaced aggregate (RFA) and coarse aggregate was determined according to AASHTO T19.



Figure 3-7: Unit Weight Test

3.7 Mix Design

The mixing process was conducted on a smooth, waterproof platform. An around 1:1.5:2.5 mixing ratio of cement, fine aggregate (including the partially replaced aggregate), and coarse aggregate was employed. Initially, the coarse aggregate was measured and spread evenly over the platform. Subsequently, the fine aggregate was measured and spread over the coarse aggregate. The cement, acting as the binding material, was then measured and spread uniformly over the combined aggregates. Following this, all ingredients were thoroughly mixed until a uniform color throughout the mixture was achieved. Once homogenous, the concrete mortar was prepared by incorporating potable water.





Figure 3-8: Mixing Materials Before Watering



Figure 3-9: Mixing Materials After Watering

Mix design calculation according to ACI 211.1-91

3.7.1 Material description:	
Cement	OPC (Bashundhara)
Coarse Aggregate (Maximum nominal size)	20mm (UAE)
Fine Aggregate	Sand (2.57 FM) (Nalitabari Sherpur) Iron Slag (2.954 FM) (B.S.R.M)
3.7.2 Specification requirement:	
Target Strength	35 MPa
Water Cement Ratio	0.47 [Table able A1.5.3.4 (a)]
Slump	100mm to 25mm [Table A.1.5.3.1]
3.7.3 Material properties:	
BSG_{SSD} of Coarse Aggregate	2.876
BSG_{SSD} of Fine Aggregate (Sand)	2.625
BSG_{SSD} of Fine Aggregate (Iron slag)	2.735
BSG_{OD} of Coarse Aggregate	2.863
BSG_{OD} of Sand	2.581
BSG_{OD} of Iron Slag	2.654
Absorption of Coarse Aggregate (OD)	0.462%
Absorption of Sand (OD)	1.693%
Absorption of Iron Slag (OD)	3.050%
Unit Weight of C.A (Dry & Rodded)	1691 Kg/m^3
Specific Gravity of Cement	3.15
Entrapped Air	2% [Table A.1.5.3.3]
3.7.4 Properties of Fine Aggregate (Sand + Slag):	
(Slag 0%) BSG_{SSD}	2.625
(Slag 5%) BSG_{SSD}	2.63 $[\frac{(BSG_{SSD(Slag)}\times 5)+(BSG_{SSD(Sand)}\times 95)}{100}]$
(Slag 15%) BSG_{SSD}	2.64
(Slag 25%) BSG_{SSD}	2.65
(Slag 0%) Absorption (OD)	1.693%
(Slag 5%) Absorption (OD)	1.76%
(Slag 15%) Absorption (OD)	1.90%
(Slag 25%) Absorption (OD)	2.03%
(Slag 0%) FM	2.57
(Slag 5%) FM	2.59
(Slag 15%) FM	2.63
(Slag 25%) FM	2.67

3.7.5 Volume of Dry Rodded Coarse Aggregate per m^3 concrete:

Table A1.5.3.6

% of Slag		0%	5%		15%	25%	
FM Size	2.40	2.57	$[\frac{(FM_{(Slag)}\times 5)+(FM_{(Sand)}\times 95)}{100}]$ =2.59	2.60	2.63	2.67	2.80
19	0.66			0.64			0.62
20	0.668	0.651	0.649	0.648	0.645	0.641	0.628
25	0.71		0.69				0.67

3.7.6 Weight of Coarse Aggregate (OD):

(Slag 0%) = (Volume × Unit Weight)
= 0.651×1691 = 1100.841 kg
(Slag 5%) = 0.649×1691 = 1097.459 kg
(Slag 15%) = 0.645×1691 = 1090.695 kg
(Slag 20%) = 0.641×1691 = 1083.931 kg

3.7.7 Weight of Coarse Aggregate (SSD):

(Slag 0%) = (Unit Weight_{OD}+ Unit Weight_{OD} × Absorption)

= 1100.841+ (1100.841× $\frac{0.462}{100}$)
= 1105.93 kg
(Slag 5%) = 1102.53 kg
(Slag 15%) = 1095.73 kg
(Slag 25%) = 1088.94 kg

3.7.8 Weight of Cement:

Weight of Cement = $\frac{Weight\ of\ Water}{Water\ Cement\ Ratio}$

= $\frac{203}{0.47}$ [Table a1.5.3.3 Wt. of water 203 kg]
= 431.91 kg

3.7.9 Volume of Fine Aggregate (Sand + Slag) (SSD):

Slag 0% = 1- ($\frac{W_C}{G_c\times \Upsilon_w}$ + $\frac{W_{Ca}}{G_{ca}\times \Upsilon_w}$ + $\frac{W_w}{G_w\times \Upsilon_w}$ + 0.02) [From table a1.5.3.3 Wt. Air Content = 2%]

= 1- ($\frac{431.91}{3.15\times1000} + \frac{1105.93}{2.876\times1000} + \frac{203}{1\times1000} + 0.02$)

= 0.2553 m3

Slag 5% = 0.2565 m^3

Slag 15% = 0.2589 m^3

Slag 25% = 0.2613 m^3

3.7.10 Weight of Fine Aggregate (Sand + Slag) (SSD):

(Slag 0%) = 0.2553 × 2.625 × 1000 = 670.16 kg

(Slag 5%) = 0.2565 × 2.63× 1000 = 674.60 kg

(Slag 15%) = 0.2589 × 2.64 × 1000 = 683.50 kg

(Slag 25%) = 0.2613 × 2.65 × 1000 = 692.45 kg

3.7.11 Unit Weight of Concrete:

(Slag 0%) = Wt. of Cement + Wt of C.A + Wt of F.A + Wt of Water

= 431.91 + 670.16 + 1105.93 + 203 = 2411 kg/m^3

(Slag 5%) = 2412.04 kg/m^3

(Slag 15%) = 2414.14 kg/m^3

(Slag 25%) = 2416.63 kg/m^3

3.7.12 Weight Ratio (Cement: Sand+Slag : Chips):

(SSD):

(Slag 0%) = 431.91 : 670.16 : 1105.93

(Slag 5%) = 431.91 : 674.60 : 1102.53

(Slag 15%) = 431.91 : 683.50 : 1095.73

(Slag 25%) = 431.91 : 692.45 : 1088.94

(Dry):

(Slag 0%) = 431.91 : 659.00 : 1100.841

= 1 : 1.53 : 2.55

[$Absorption = \frac{Wt.of\ sample\ (SSD) - Wt.of\ sample\ (OD)}{Wt.of\ sample\ (OD)}$,1.693 = $\frac{670.16-x}{x}$, x= 659.00]

(Slag 5%) = 431.91 : 662.93 : 1097.459

= 1 : 1.53 : 2.54

(Slag 15%) = 431.91 : 670.76 : 1090.695

= 1 : 1.55 : 2.53

(Slag 25%) = 431.91 : 678.67 : 1083.931

= 1: 1.57 : 2.51

3.7.13 Extra Water for Absorption of Fine & Coarse Aggregate:

(Slag 0%) =$(Wt.of\ F.A\ (OD) \times Absorption) + (t.of\ C.A\ (OD) \times Absorption)$

$= \left(659 \times \frac{1.693}{100}\right) + (1100.841 \times \frac{0.462}{100})$

= 16.24 kg

(Slag 5%) = 16.74 kg

(Slag 15%) = 17.78 kg

(Slag 25%) = 18.78 kg

Total Water for casting (Per batch 35 Nos Cylinder)

Cylinder size 4"×8"

Cylinder Volume = $\frac{\pi}{4} \times (4 \times \frac{2.54}{100})^2 \times 8 \times \frac{2.54}{100} \times 35$

= 0.057659 m^3

(Slag 0%) W_w = (16.24 + 203) × 0.057659

= 12.64 kg

(Slag 5%) W_w = 12.67 kg

(Slag 15%) W_w = 12.73 kg

(Slag 25%) W_w = 12.79 kg

3.7.14 Bulk Specific Gravity (OD) of Sand + Iron Slag:

(Slag 0%) = 2.581

(Slag 5%) = $\frac{(2.581 \times 95) + (2.654 \times 5)}{100}$

= 2.585

(Slag 15%) = 2.592

(Slag 25%) = 2.599

3.7.15 Dry Weight of Sand + Slag for 35 nos sample:

Cylinder Volume = 0.057659 m^3

(Slag 0%) = 0.057659 × 659 = 38 kg

(Slag 5%) = 0.057659 × 662.93 = 38.22 kg

(Slag 15%) = 0.057659 × 670.76 = 38.68 kg

(Slag 25%) = 0.057659 × 678.67 = 39.14 kg

Slag:

0% weight of slag = 0 Kg

5% weight of slag = Volume of F.A × 5% × S.G of Slag × 1000

= $\frac{Weight\ of\ F.A}{S.G\ of\ F.A \times 1000} \times 5\% \times 2.654 \times 1000$

= $\frac{38.22}{2.585 \times 1000} \times 5\% \times 2.654 \times 1000 = 1.962$ kg

15% weight of slag = 5.94 kg

25% weight of slag = 10 kg

Sand:

0% weight of sand = 38 kg

5% weight of sand = 38.22-1.962 = 36.26 kg

15% weight of sand = 38.68-5.94 = 32.74 kg

25% weight of sand = 39.14-10 = 29.14 kg

3.7.16 Material Batching for 35 nos Cylinder:

(Slag 0%)		
Cement	24.9	(431.91×.057659)
Sand	38	
Slag	0	
Stone	63.47	(1100.841×.057659)
Water	12.64	

(Slag 5%)	
Cement	24.9
Sand	36.26
Slag	1.962
Stone	63.28
Water	12.67

(Slag 15%)	
Cement	24.9
Sand	32.74
Slag	5.94
Stone	62.89
Water	12.73

(Slag 25%)	
Cement	24.9
Sand	29.14
Slag	10
Stone	62.50
Water	12.79

3.8 Water Cement Ratio

In accordance with mix design, a water-to-cement ratio of 0.47 was maintained. This signifies that for every 50 kg of cement incorporated into the concrete mix, 23.5 liters of water were added.

3.9 Materials Ratio

The concrete mix design for a target compressive strength of 35MPa was accomplished using the volume-based method. This methodology entailed employing a specific ratio of ingredients, which in this case, was around 1:1.5:2.5 for Cement, fine aggregate (including the partially replaced aggregate) and coarse respectively. All constituent materials were proportioned according to mix design calculation.

3.10 Casting Cylinder

Cylindrical molds with dimensions of 4 inches in diameter and 8 inches in height were utilized for specimen preparation. The concrete was then cast into these molds in three distinct layers. Each layer was compacted using a 5/8-inch steel tamping rod for a total of 25 compactions. During the filling process, the remaining concrete within the mixing pan was periodically stirred and scraped together to prevent segregation of materials. Once filled, the molds were leveled by smoothing the top surfaces. For proper identification, each mold was assigned a unique identifier consisting of the date and the corresponding percentage of partially replaced aggregate.



Figure 3-10: Cylinder Casting.

3.11 Curing for Specified Time

After removing the cylinders from the mold, the cylinders were numbered according to the date and the percentage of partially replaced aggregate. Then the numbered cylinders were kept completely submerged in water for 21 days.



Figure 3-11: Cylinder Curing

3.12 Compressive Strength Test of Cylinder by Different Temperature, Time and Percent of Partially Replaced Fine Aggregate:

Following a 21-days curing period, the cylinders were removed from the water and allowed to air-dry for one day. Subsequently, the compressive strength of concrete cylinders was evaluated under various conditions. The initial test assessed cylinders without any partially replaced fine aggregate (0% RFA) at a temperature of zero degrees Celsius.

Further testing involved oven drying cylinders containing 0% RFA at temperatures of 100°C, 150°C and 200°C for durations of 60 minutes, 120 minutes, and 180 minutes. This procedure was then repeated for concrete cylinders containing 5%, 15% and 25% RFA, with oven drying temperatures of 100°C, 150°C, and 200°C, maintaining the same durations.

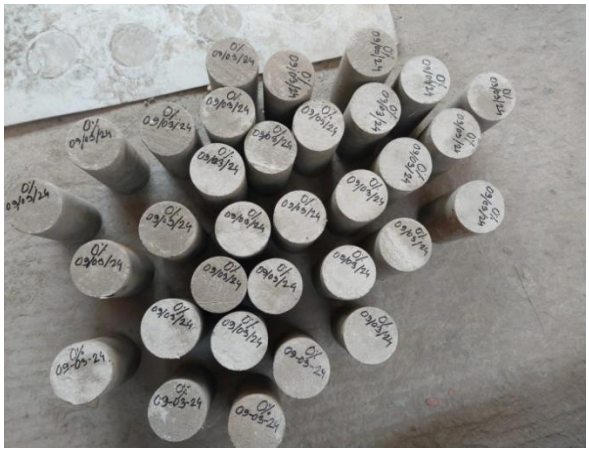




Figure 3-12: Concrete Cylinder before Heating









Figure 3-13: Cylinder Heating in Oven



Figure 3-14: Concrete Cylinder after Crashing

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results of the compressive strength testing conducted on cylindrical specimens produced with varying percentages of normal aggregate and partially replaced fine aggregate (RFA).

4.2 Sieve Analysis for Fine Aggregate

Particle Size Analysis Fine Aggregate Test Result

(AASHTO T27)

Type of material: Coarse Sand
Source of material: Nalitabari Sherpur
Location of Test
Purpose of use:
Location of sampling:

Document No :
Date of sampling
Date of testing 21 Feb 2024

Sieve size		Weight retained	Weight retained	% Retained	% Passing	Specification	
Sieve No	(mm)	Individual	Cumulative			Min	Max
3/8	10.00	0	0	0	100	100.00 -	100.00
4	4.75	6.0	6.00	1.20	98.80	95.00 -	100.00
8	2.36	14.0	20.00	4.00	96.00	-	
16	1.18	98.0	118.00	23.60	76.40	45.00 -	80.00
30	0.60	139.0	257.00	51.40	48.60	-	
50	0.30	152.0	409.00	81.80	18.20	10.00 -	30.00
100	0.15	66.0	475.00	95.00	5.00	2.00 -	10.00
200	0.075	13.0	488.00	97.60	2.40		
Pan		12.0					
Total		500		257			

FM= 2.570

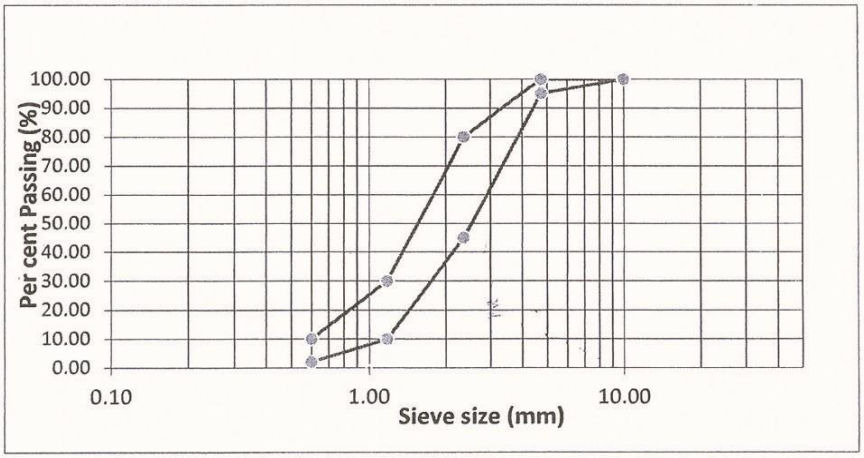


Table 4.1: Data Sheet for Sieve Analysis of Fine Aggregate

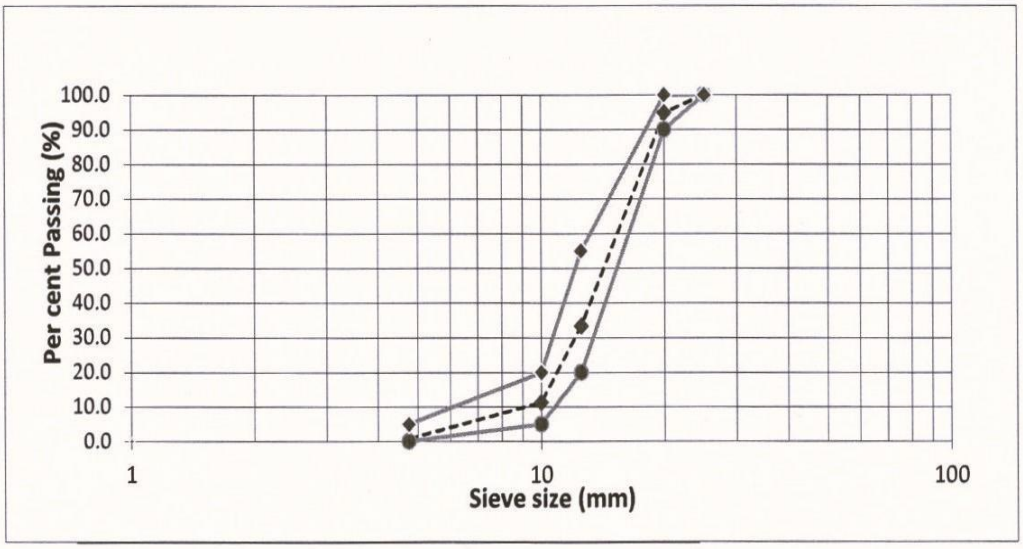
4.3 Sieve Analysis for Coarse Aggregate

Sieve Analysis for Coarse Aggregate

(AASHTO T27)

Type of material : 20 mm Stone Chips
Source of material : UAE — Document No :
Location of Test : — Date of sampling :
Purpose of use : Concrete — Date of Testing :
Location of sampling :

Sieve size	Weight Retained (gm)	Retained	% Retained	% Total passing	Specification	
(mm)	Individual	Cumulative	Cumulative		Min	Max
25	0	0.0	0.00	100.0	100 -	100
20	677	677.0	5.21	94.79	90 -	100
12.5	7991	8668.0	66.68	33.32	20 -	55
10	2858	11526.0	88.66	11.34	5 -	20
4.75	1373	12899.0	99.22	0.78	0 -	5
Pan	101					
Total	**13000.0**					



REMARKS:

Table 4.2: Data Sheet for Sieve Analysis of Coarse Aggregate

4.4 Sieve Analysis for Fine Aggregate (Slag)

Particle Size Analysis Fine Aggregate Test Result

(AASHTO T27)

Type of material: Iron Slag
Source of material: B.S.R.M
Location of Test
Purpose of use:
Location of sampling:

Document No :
Date of sampling
Date of testing : 21 Feb 2024

Sieve size		Weight retained	Weight retained	% Retained	% Passing	Specification	
Sieve No	(mm)	Individual	Cumulative			Min	Max
3/8	10.00					100.00 -	100.00
4	4.75	0	0	0		95.00 -	100.00
8	2.36	113	113	22.6	77.4	-	
16	1.18	119	232	46.4	53.6	45.00 -	80.00
30	0.60	84	316	63.2	36.8	-	
50	0.30	69	385	77.00	33.00	10.00 -	30.00
100	0.15	46	431	86.2	13.8	2.00 -	10.00
200	0.075	39	470	94.0	6.0		
Pan		30	500				
Total		500		295.4			

FM= $\frac{295.4}{100}$

≈ 2.954

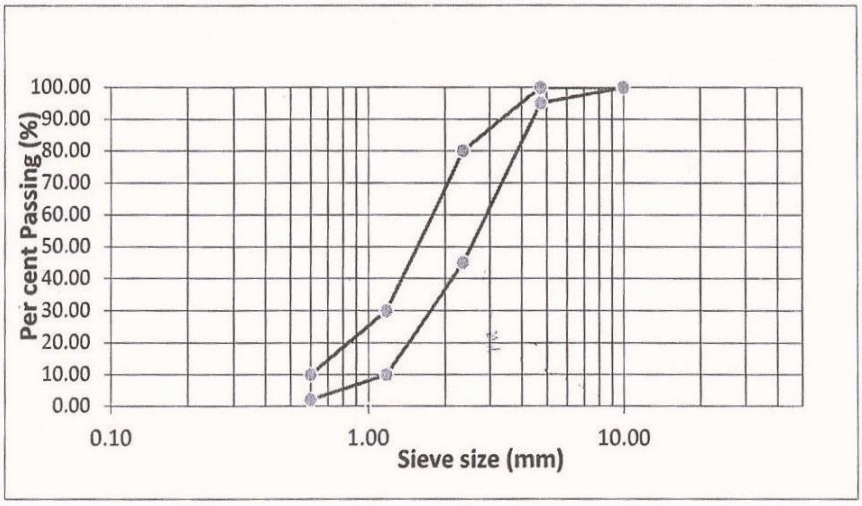


Table 4.3: Data Sheet for Sieve Analysis of Slag Aggregate

4.5 Specific Gravity & Absorption Test for Fine Aggregate

SPECIFIC GRAVITY AND ABSORPTION TEST OF FINE AGGREGATE

(AASHTO T84)

Type of material : Coarse Sand
Source of material : Nalitabari Sherpur
Location of Test : Document No
Purpose of use : Concrete Date of sampling
Location of sampling : Date of testing

Fine Aggregate	Unit	No 1	No 2	Remarks/ Average
Weight of sample oven dry in air, (A)	gm	393.40	245.80	
Weight of flask filled with water to calibration mark, (B)	gm	666.20	331.20	
Weight of flask + water + sample to calibration mark, (C)	gm	914.10	485.80	
Weight of sample saturated surface - dry, (D)	gm	400.0	250.0	
Bulk specific gravity (oven - dry basis) $\frac{A}{(B+D-C)}$	-	2.586	2.577	2.581
Bulk specific gravity (saturated surface - dry basis) $\frac{D}{(B+D-C)}$	-	2.630	2.621	2.625
Apparent specific gravity $\frac{A}{(B+A-C)}$	-	2.704	2.695	2.699
Absorption $\frac{(D-A)}{A} \times 100$	%	1.678	1.709	1.693

Remarks :

Table 4.4: Data Sheet for Specific Gravity & Absorption Test of Fine Aggregate

4.6 Specific Gravity of Partially Replaced Fine Aggregate (Slag)

SPECIFIC GRAVITY AND ABSORPTION TEST OF FINE AGGREGATE

(AASHTO T84)

Type of material: Iron Slag
Location of Test B.S.R.M
Purpose of use:
Location of sampling:

Document No :
Date of sampling : 21 Feb 2024
Date of testing : 23 Feb 2024

Fine Aggregate	Unit	No 1	No 2	Remarks/ Average
Weight of sample oven dry in air, (A)	g	485.2		
Weight of flask filled with water to calibration mark, (B)	g	696.9		
Weight of flask + water + sample to calibration mark, (C)	g	1014.1		
Weight of sample saturated surface - dry, (D)	g	500.0		
Bulk specific gravity (oven - dry basis) $\frac{A}{(B+D-C)}$	-	2.654		
Bulk specific gravity (saturated surface - dry basis) $\frac{D}{(B+D-C)}$	-	2.735		
Apparent specific gravity $\frac{A}{(B+A-C)}$	-	2.888		
Absorption $\frac{(D-A)}{A} \times 100$	%	3.050		

Remarks :

Table 4.5: Data Sheet for Specific Gravity of Fine Aggregate (Slag)

4.7 Specific Gravity & Absorption Test for Coarse Aggregate

SPECIFIC GRAVITY AND ABSORPTION TEST OF 20 mm COARSE AGGREGATE

(AASHTO T85)

Type of material : 20 mm Stone Chips

Source of material : UAE — Document No :

Location of Test : — Date of sampling :

Purpose of use : Concrete — Date of testing :

Location of sampling :

Deascription	Unit	Test No 1	Test No 2	Average
Weight of sample oven dry in air, (A)	gm	1494.2	1494.5	
Weight of sample saturated surface - Dry in Air, (B)	gm	1501.0	1501.5	
Weight of sample in Water, (C)	gm	979.10	979.50	
Bulk specific gravity (oven - dry basis) $\frac{A}{(B-C)}$	-	2.863	2.863	2.863
Bulk specific gravity (saturated surface - dry basis) $\frac{B}{(B-C)}$	-	2.876	2.876	2.876
Apparent specific gravity $\frac{A}{(A-C)}$	-	2.901	2.902	2.901
Absorption $\frac{(B-A)}{A} \times 100$	%	0.455	0.468	0.462

Remarks :

Table 4.6: Data Sheet for Specific Gravity & Absorption Test of Coarse Aggregate

4.8 Unit Weight of Coarse Aggregate

UNIT WEIGHT TEST FOR COARSE AGGREGATE

TEST METHOD AASHTO T19

Type of material : 20 mm Stone Chips
Source of material : UAE — Document No :
Location of Test : — Date of sampling
Purpose of use : Concrete — Date of testing
Location of sampling :

Rodded Unit Weight

Test items			Test result		
			1	2	3
Weight of Mould (gm)	=	(A)	3368	3368	3368
Weight of Mould + Aggregate, (gm)	=	(B)	15812	15882	15919
Weight of Aggregate, gm	=	(C=B-A)	12444	12514	12551
Volume of Mould, (m^3)	=	(D)	0.007396	0.007396	0.007396
Unit Weight, kg/m^3.	=	(E=C/D)	1683	1692	1697
Average Unit Weight, kg/m^3	=		1691		
Acceptance Criteria :					

Remarks : Dry Basis Unit Weight (Rodded Unit Weight)

Table 4.7: Data Sheet for Unit Weight of Coarse Aggregate

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4.9 Unit Weight of Fine Aggregate

UNIT WEIGHT TEST FOR FINE AGGREGATE

TEST METHOD AASHTO T19

Type of material : Coarse Sand
Source of material : Nalitabari Sherpur — Document No :
Location of Test : — Date of sampling :
Purpose of use : Concrete — Date of testing :
Location of sampling :

Looses Unit Weight

Test items			Test result		
			1	2	3
Weight of Mould (gm)	=	(A)	1243	1243	1243
Weight of Mould + Aggregate, (gm)	=	(B)	5513	5555	5543
Weight of Aggregate, gm	=	(C=B-A)	4270	4312	4300
Volume of Mould, (m^3)	=	(D)	0.002865	0.002865	0.002865
Unit Weight, kg/m^3.	=	(E=C/D)	1490	1505	1501
Average Unit Weight, kg/m^3	=		1499		
Acceptance Criteria :					

Remarks : Dry Basis Unit Weight (Looses Unit Weight)

Table 4.8: Data Sheet for Unit Weight of Fine Aggregate

4.10 Unit Weight of Fine Aggregate (Slag)

UNIT WEIGHT TEST FOR FINE AGGREGATE

TEST METHOD AASHTO T19

Type of material: Iron slag
Source of material: B.S.R.M
Location of Test
Purpose of use:
Location of sampling:

Document No :
Date of sampling
Date of testing 21. Feb 2024

Loose Unit Weight

Test items			Test result 1	2	3
Weight of Mould (gm)	=	(A)	1243	1243	1243
Weight of Mould + Aggregate, (gm)	=	(B)	5637	5540	5525
Weight of Aggregate, gm	=	(C=B-A)	4394	4297	4282
Volume of Mould, (m^3)	=	(D)	0.002865	0.002865	0.002865
Unit Weight, kg/m^3.	=	(E=C/D)	1533.68	1499.83	1494.59
Average Unit Weight, kg/m^3	=		1509.37 kg/m3		
Acceptance Criteria :					

Remarks : Dry Basis Unit Weight (Loose Unit Weight)

Table 4.9: Data Sheet for Unit Weight of Fine Aggregate (Slag) (Loose)

UNIT WEIGHT TEST FOR FINE AGGREGATE

TEST METHOD AASHTO T19

Type of material: Iron slag
Source of material: B.S.R.M
Location of Test
Purpose of use:
Location of sampling:

Document No :
Date of sampling
Date of testing : 21 Feb 2024

Rodded Unit Weight

Test items			Test result		
			1	2	3
Weight of Mould (gm)	=	(A)	1243	1243	1243
Weight of Mould + Aggregate, (gm)	=	(B)	6200	6239	6240
Weight of Aggregate, gm	=	(C=B-A)	4957	4996	4997
Volume of Mould, (m^3)	=	(D)	0.002865	0.002865	0.002865
Unit Weight, kg/m^3.	=	(E=C/D)	1730.20	1743.80	1744.15
Average Unit Weight, kg/m^3	=		1739.38 kg/m3		
Acceptance Criteria :					

Remarks : Dry Basis Unit Weight (Rodded Unit Weight)

Table 4.10: Data Sheet for Unit Weight of Fine Aggregate (Slag) (Rodded)

4.11 Compressive Strength Test Sheet of Cylinder

Area = $\frac{\pi}{4} \times (100)^2$

= 7856 mm^2

(Cylinder Crashing Report Group-3)

Correction Factor: 0.9821 x -7.7368

= (0.9821×267.55-7.7368)× $\frac{1000}{7854}$

= 32.47 mpa

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day): 22 days				
Str: 0% , 0˚, 0 hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4104	267.55	32.47	
2	4064	288.39	35.08	
3	4138	292.06	35.54	
Average (Mpa)			34.36	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day): 22 days				
Str: 0% , 100˚, 1hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4013	264.38	32.07	
2	4062	287.00	34.90	
3	4369	297.60	36.23	
Average (Mpa)			34.4	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day): 22 days				
Str: 0% , 100˚, 2hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4341	278.93	33.90	
2	4459	258.34	31.32	
3	4178	224.00	27.02	
Average (Mpa)			30.75	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day): 22 days				
Str: 0% , 100˚, 3hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4009	241.80	29.25	
2	4072	226.19	27.30	
3	4006	241.28	29.19	
Average (Mpa)			28.58	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day): 22 days				
Str: 0% , 150˚, 1hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4121	242.49	29.34	
2	4017	215.28	25.93	
3	4014	248.67	30.11	
Average (Mpa)			28.46	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day): 22 days				
Str: 0% , 150˚, 2hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3970	235.60	28.48	
2	3969	245.19	29.67	
3	4034	260.38	31.57	
Average (Mpa)			29.91	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day): 22 days				
Str: 0% , 150˚, 3hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3831	295.24	35.93	
2	4030	294.48	35.84	
3	3956	310.56	37.85	
Average (Mpa)			36.54	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day): 22 days				
Str: 0% , 200˚, 1hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4047	265.36	32.20	
2	4034	259.44	31.46	
3	3881	255.23	30.93	
Average (Mpa)			31.53	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day) : 22 days				
Str: 0% , 200˚, 2hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3860	291.72	35.49	
2	4022	263.01	31.90	
3	3862	274.84	33.38	
Average (Mpa)			33.59	

Casting Date: 9/3/2024				Type of Fracture
Date of Test: 1/4/2024				
Age (Day) : 22 days				
Str: 0% , 200˚, 3hr				
Slump:90mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3889	263.48	31.96	
2	3878	280.81	34.13	
3	3805	254.85	30.88	
Average (Mpa)			32.32	

Table 4.11: Data Sheet for Compressive Strength of Cylinder (0% Slag)

(Cylinder Crashing Report Group-3)

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day): 22 days				
Str: 5% , 0˚, 0 hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4180	250.14	30.29	
2	4036	252.09	30.54	
3	4229	292.98	35.65	
Average (Mpa)			32.16	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day): 22 days				
Str: 5% , 100˚, 1hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4219	238.43	28.83	
2	4162	273.0	33.15	
3	4372	313.96	38.27	
Average (Mpa)			33.42	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day): 22 days				
Str: 5% , 100˚, 2hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4100	256.67	31.11	
2	4278	288.21	35.05	
3	4071	276.43	33.58	
Average (Mpa)			33.25	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day): 22 days				
Str: 5% , 100˚, 3hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3993	238.53	28.84	
2	4018	248.0	30.03	
3	4189	245.95	29.77	
Average (Mpa)			29.55	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day): 22 days				
Str: 5% , 150˚, 1hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4112	269.54	32.72	
2	4093	262.08	31.79	
3	4121	273.79	33.25	
Average (Mpa)			32.59	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day)				
Str: 5% , 150˚, 2hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4043	208.83	25.13	
2	4058	236.57	28.60	
3	4014	238.43	28.83	
Average (Mpa)			27.52	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day)				
Str: 5% , 150˚, 3hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3931	278.62	33.85	
2	4045	246.34	29.82	
3	3893	270.76	32.87	
Average (Mpa)			32.18	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day): 22 days				
Str: 5% , 200˚, 1hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3856	252.50	30.59	
2	3960	260.51	31.59	
3	3957	272.17	33.05	
Average (Mpa)			31.74	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day) : 22 days				
Str: 5% , 200˚, 2hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3994	276.06	33.53	
2	4007	290.40	35.33	
3	3891	294.13	35.80	
Average (Mpa)			34.89	

Casting Date: 10/3/2024				Type of Fracture
Date of Test: 2/4/2024				
Age (Day) : 22 days				
Str: 5% , 200˚, 3hr				
Slump:52mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3752	265.52	32.22	
2	3827	281.29	34.19	
3	4028	300.65	36.61	
Average (Mpa)			34.34	

Table 4.12: Data Sheet for Compressive Strength of Cylinder (5% Slag)

(Cylinder Crashing Report Group-3)

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day): 22 days				
Str: 15% , 0˚, 0 hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4367	289.32	35.19	
2	4149	273.36	33.20	
3	4289	262.73	31.87	
Average (Mpa)			33.42	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day): 22 days				
Str: 15% , 100˚, 1hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4114	297.28	36.19	
2	4063	291.56	35.47	
3	4203	280.03	34.03	
Average (Mpa)			35.23	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day): 22 days				
Str: 15% , 100˚, 2hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4088	274.57	33.35	
2	4093	263.38	31.95	
3	4296	235.14	28.42	
Average (Mpa)			31.24	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day): 22 days				
Str: 15% , 100˚, 3hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4106	248.71	30.11	
2	4069	234.33	28.32	
3	4157	248.96	30.15	
Average (Mpa)			29.53	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day): 22 days				
Str: 15% , 150˚, 1hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4162	286.74	28.62	
2	4110	245.38	29.70	
3	4052	252.58	30.60	
Average (Mpa)			29.64	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day)				
Str: 15% , 150˚, 2hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4267	278.24	33.81	
2	3982	270.56	32.85	
3	4063	202.53	24.34	
Average (Mpa)			30.33	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day)				
Str: 15% , 150˚, 3hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3888	300.29	36.56	
2	3840	278.47	33.84	
3	3994	298.72	36.67	
Average (Mpa)			35.59	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day): 22 days				
Str: 15% , 200˚, 1hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3987	238.80	28.88	
2	4032	261.77	31.75	
3	4075	286.37	34.82	
Average (Mpa)			31.82	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day) : 22 days				
Str: 15% , 200˚, 2hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3931	227.23	27.43	
2	3889	269.26	32.68	
3	3899	282.68	34.36	
Average (Mpa)			31.49	

Casting Date: 11/3/2024				Type of Fracture
Date of Test: 3/4/2024				
Age (Day) : 22 days				
Str: 15% , 200˚, 3hr				
Slump:95mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3829	285.23	34.68	
2	3923	293.19	35.68	
3	3917	282.98	34.40	
Average (Mpa)			34.92	

Table 4.13: Data Sheet for Compressive Strength of Cylinder (15% Slag)

(Cylinder Crashing Report Group-3)

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day): 22 days				
Str: 25% , 0˚, 0 hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4338	265.19	32.18	
2	4175	262.21	31.80	
3	4276	276.01	33.53	
Average (Mpa)			32.50	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day): 22 days				
Str: 25% , 100˚, 1hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4322	315.66	38.49	
2	4098	315.11	38.42	
3	4380	309.78	37.75	
Average (Mpa)			38.22	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day): 22 days				
Str: 25% , 100˚, 2hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4154	262.51	31.84	
2	4235	246.95	29.89	
3	4137	271.78	32.99	
Average (Mpa)			31.57	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day): 22 days				
Str: 25% , 100˚, 3hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4007	246.50	29.84	
2	4084	225.77	27.25	
3	3971	229.58	27.72	
Average (Mpa)			28.27	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day): 22 days				
Str: 25% , 150˚, 1hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4162	247.19	29.92	
2	4118	223.72	26.99	
3	4349	254.18	30.80	
Average (Mpa)			29.24	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day)				
Str: 25% , 150˚, 2hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4156	205.39	24.70	
2	4073	240.80	29.13	
3	4124	212.95	25.64	
Average (Mpa)			26.49	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day)				
Str: 25% , 150˚, 3hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3920	275.49	33.46	
2	3924	275.65	33.48	
3	3938	285.07	34.66	
Average (Mpa)			33.87	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day): 22 days				
Str: 25% , 200˚, 1hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3953	246.88	29.89	
2	4014	229.95	27.77	
3	3904	228.06	27.53	
Average (Mpa)			28.40	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day) : 22 days				
Str: 25% , 200˚, 2hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	4050	264.89	32.14	
2	3994	272.99	33.15	
3	3912	288.07	35.04	
Average (Mpa)			33.44	

Casting Date: 12/3/2024				Type of Fracture
Date of Test: 4/4/2024				
Age (Day) : 22 days				
Str: 25% , 200˚, 3hr				
Slump:30mm		Temp:		
No of Cylinder:		Grade: 35		
ID	Wt. (gm)	Load (KN)	Mpa	
1	3964	242.68	29.36	
2	3862	237.24	28.68	
3	3870	284.25	34.56	
Average (Mpa)			30.87	

Table 4.14: Data Sheet for Compressive Strength of Cylinder (25% Slag)

4.12 Comparative Compressive Strength of the Cylinders

Time/ Temperature	0˚	100˚	150˚	200˚
0hr	34.36			
1hr		34.4	28.46	31.53
2hr		30.75	29.91	33.59
3hr		28.58	36.54	32.32

Table 4.15: Summary of Compressive Strength of Cylinder (0% Slag)

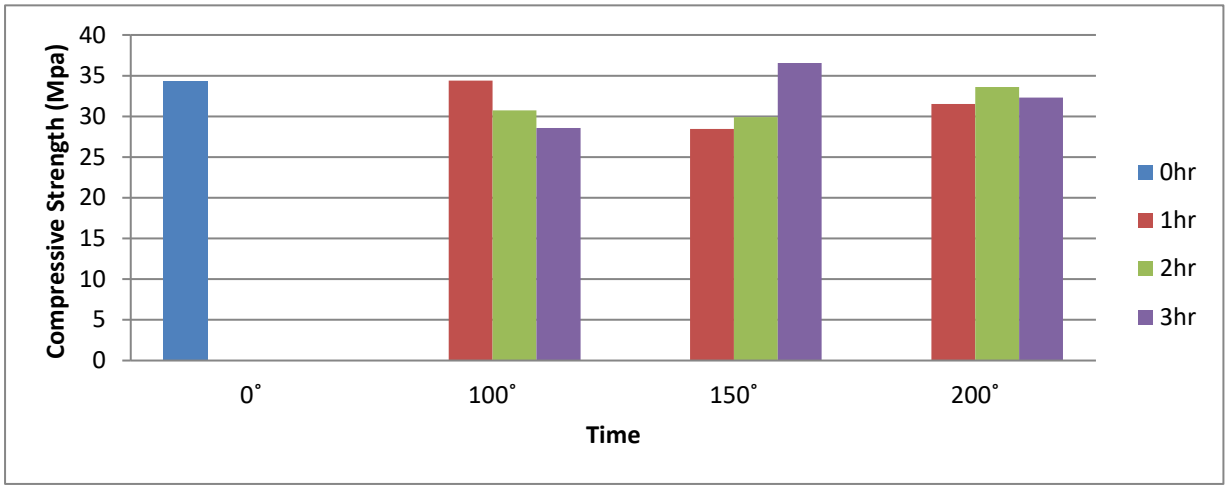


Figure 4.1: Compressive Strength Vs. Heating Time (0% Slag)

Time/ Temperature	0˚	100˚	150˚	200˚
0hr	32.16			
1hr		33.42	32.59	31.74
2hr		33.25	27.52	34.89
3hr		29.55	32.18	34.34

Table 4.16: Summary of Compressive Strength of Cylinder (5% Slag)

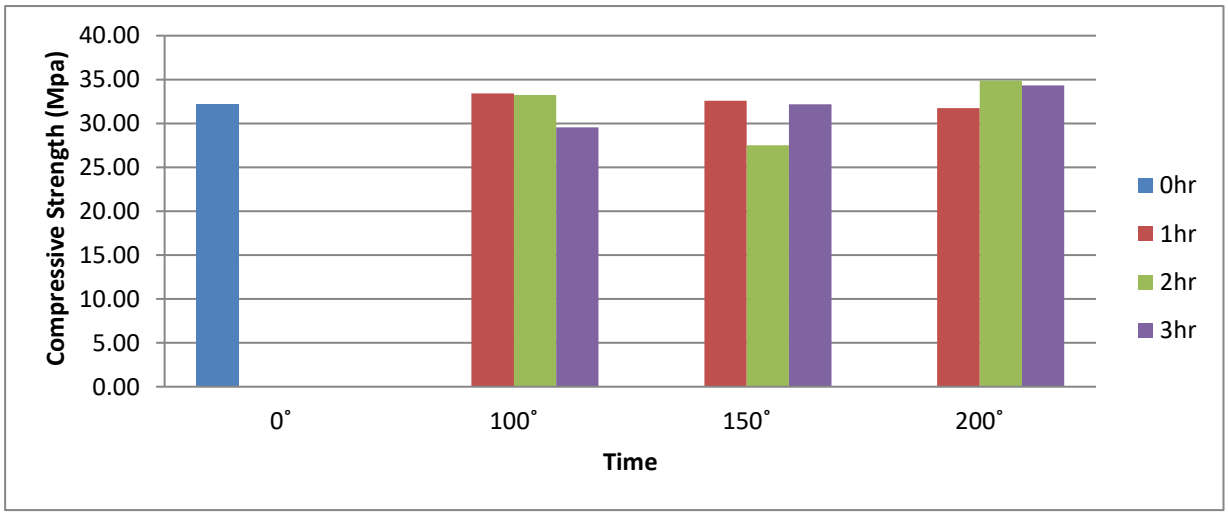


Figure 4.2: Compressive Strength Vs. Heating Time (5% Slag)

Time/Temperature	0˚	100˚	150˚	200˚
0hr	33.42			
1hr		35.23	29.64	31.82
2hr		31.24	30.33	31.49
3hr		29.53	35.59	34.92

Table 4.17: Summary of Compressive Strength of Cylinder (15% Slag)

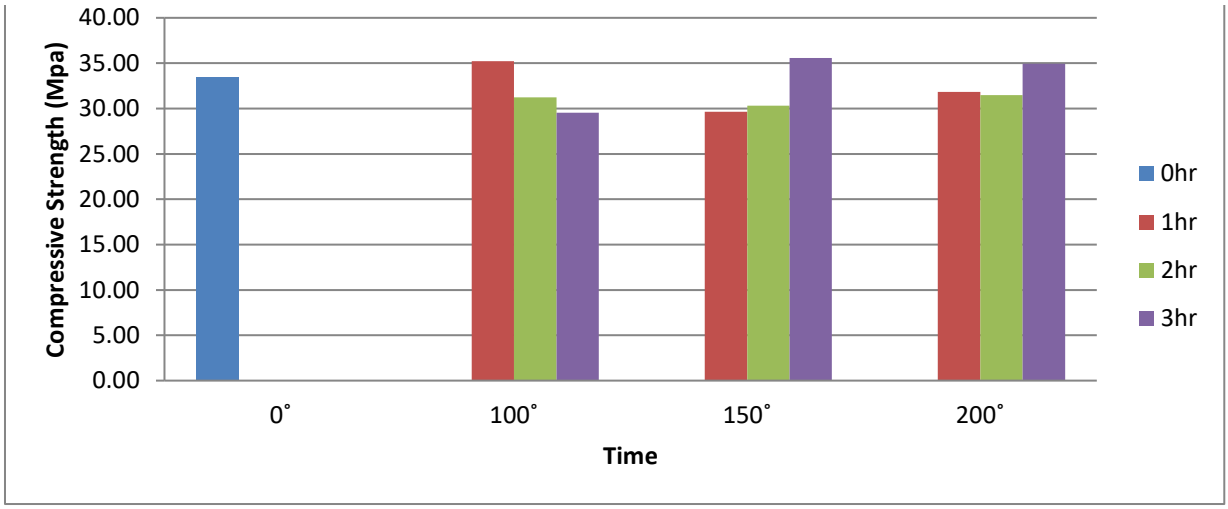


Figure 4.3: Compressive Strength Vs. Heating Time (15% Slag)

Time/ Temperature	0˚	100˚	150˚	200˚
0hr	32.50			
1hr		38.22	29.24	28.40
2hr		31.57	26.49	33.44
3hr		28.27	33.87	30.87

Table 4.18: Summary of Compressive Strength of Cylinder (25% Slag)

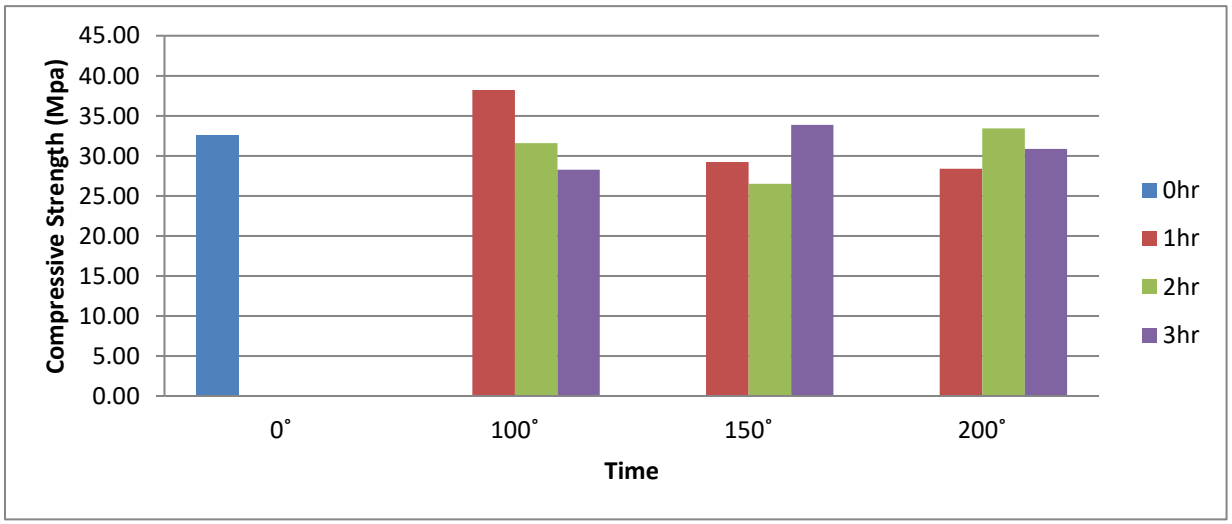


Figure 4.4: Compressive Strength Vs. Heating Time (25% Slag)

Slag %	Date of Casting	Date of Crashing (22 days)	Temp.	0˚	100˚			150˚			200˚		
			Time	0hr	1hr	2hr	3hr	1hr	2hr	3hr	1hr	2hr	3hr
0%	9/3/2024	1/4/2024	Compressive Strength (MPa)	34.36	34.4	30.75	28.58	28.46	29.91	36.54	31.53	33.59	32.32
5%	10/3/2024	2/4/2024		32.16	33.42	33.25	29.55	32.59	27.52	32.18	31.74	34.89	34.34
15%	11/3/2024	3/4/2024		33.42	35.23	31.24	29.53	29.64	30.33	35.59	31.82	31.49	34.92
25%	12/3/2024	4/4/2024		32.50	38.22	31.57	28.27	29.24	26.49	33.87	28.40	33.44	30.87

Table 4.19: Summary of Compressive Strength of Cylinder (Slag - 0%, 5%, 15%, 25%)

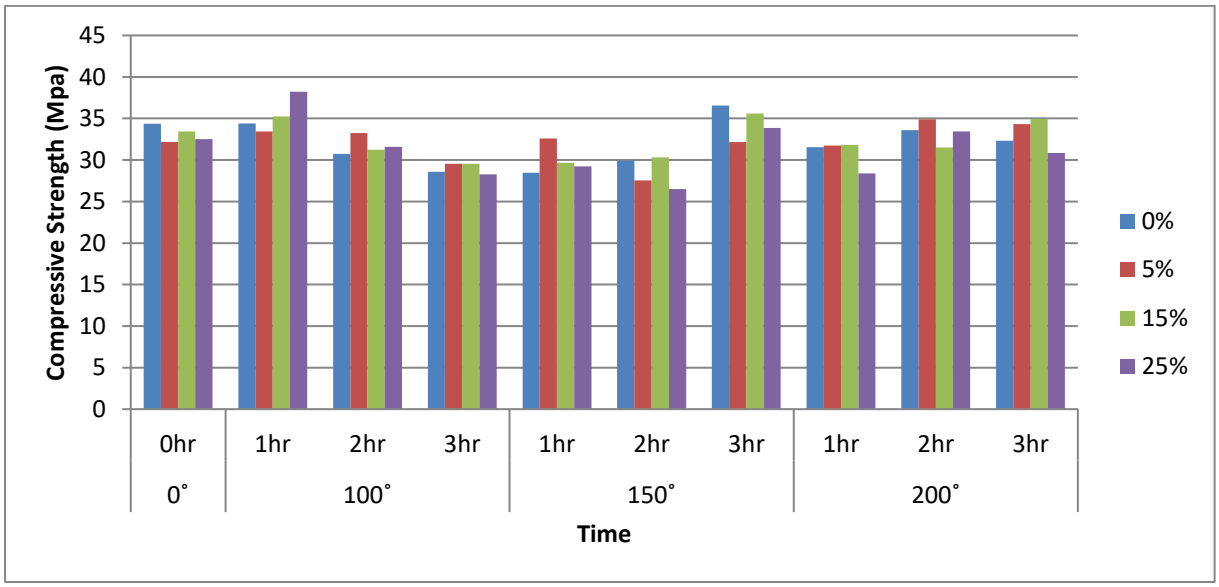


Figure 4.5: Compressive Strength Vs. Heating Time (Slag - 0%, 5%, 15%, 25%)

CHAPTER 5

CONCLUSIONS

5.1 Conclusions

This study investigates the potential application of iron slag as a substitute for conventional fine aggregate in concrete production. Various concrete mixtures were prepared using a combination of Sylhet sand as the fine aggregate, iron slag as a fine aggregate replacement, and traditional stone chips as coarse aggregate. A control batch was produced without incorporating any iron slag. To assess the influence of iron slag content, three additional concrete batches were formulated with iron slag replacements of 10%, 20%, and 30% by volume of the intended fine aggregate. A water-to-cement ratio of 0.45 was maintained to achieve regular-strength concrete. The properties of the resultant concrete specimens were evaluated and compared with those of the control batch without iron slag. Furthermore, a separate evaluation was conducted to compare the properties after exposure to elevated temperatures.

This investigation yielded the following key findings:

- Incorporation of using Iron slag partially replacement of fine aggregate we didn't find any prominent change in terms of Mechanical properties & High-temperature resistance.
- The amount of iron slag shows minimal effect on the workability of fresh concrete as measured by the slump values of 25mm to 100mm, which are equal to normal concrete.
- The time-dependent effect of temperature on the compressive strength of concrete made with partially replaced slag as fine aggregate shows irregular compressive strength of concrete made with different percentages of slag.
- A further more comprehensive investigation is needed to find the effects of iron slag as partially replaced fine aggregate in terms of mechanical strength & high temperature resistance.

5.2 Limitations

- Lack of safety equipment
- Lack of accurate results.
- Lack of skilled technicians.
- Lack of safety equipment.
- Limitation of oven temperature.

5.3 Recommendations for Future Works

- Due to the different characteristics of slags, the possibilities for their reuse in the concrete production sector are very wide.
- The different characteristics of slags and the possibilities to replace them with coarse aggregates.
- In the future one might want to try an admixture with a slug to see if there is any change in compressive strength.
- By increasing the temperature further, it can be seen how much the compressive strength of concrete changes.
- Iron and steel slags are an economically viable and environmentally acceptable alternative material for replacing natural aggregates in roads and civil construction.
- Through the combined efforts of all stakeholders working together to maximize the utilization of this continuously increasing resource, slag products that add value to the sustainability of the industry and environment can be made into a real success story.

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