TIME DEPENDENT EFFECT OF TEMPERATURE ON THE COMPRESSIVE STRENGTH OF CONCRETE MADE WITH PARTIALLY REPLACED RECYCLED SLAG AS FINE AGGREGATE

By

MD. EMRAN HOSSAIN
MD. AL-AMIN HOSSEN JONI
MD. HABIBULLAH SHANTH
MD. SHAH JALAL
MD. JAHANGIR ALAM
SHAMIMA NASRIN

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

Department of Civil Engineering
Sonargaon University
147/I, Green Road, Dhaka-1215, Bangladesh
Section: 18A
Spring-2023

TIME DEPENDENT EFFECT OF TEMPERATURE ON THE COMPRESSIVE STRENGTH OF CONCRETE MADE WITH PARTIALLY REPLACED RECYCLED SLAG AS FINE AGGREGATE

BY

MD. EMRAN HOSSEN	BCE1903018151
MD. AL-AMIN HOSSEN JONI	BCE1903018084
MD. HABIBULLAH SHANTH	BCE1903018051
MD. SHAH JALAL	BCE1903018073
MD.JAHANGIR ALAM	BCE1602008159
SHAMIMA NASRIN	BCE1903018029

Supervisor
Md. Ferdous Wahid
Assistant Professor
Department of Civil Engineering
Sonargaon University

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

Department of Civil Engineering
Sonargaon University
147/I, Green Road, Dhaka-1215, Bangladesh
Section: 18A
Spring-2023

BOARD OF EXAMINERS

The thesis titled “Time dependent effect of temperature on the compressive strength of concrete made with partially replaced recycled slag as fine aggregate” submitted by Md. Emran Hossain, ID: BCE1903018151, Md. Al-amin Hossen Joni, ID: BCE1903018084, Md. Habibullah Shanth, ID: BCE1903018051, Md. Shah Jalal, ID: BCE1903018073, Md. Jahangir Alam, ID: BCE1602008159, Shamima Nasrin, ID: BCE1903018029, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineering on Date-of-Defense. 19-05-2023

………………………………………

1. Md. Ferdous Wahid Assistant professor Department of Civil Engineering Sonargaon University	Chairman

………………………………………

2. Internal / External Member	Member

………………………………………

3. Internal / External Member	Member

DECLARATION

This is to declare that the work and material presented in the report has been carried out by us and has not previously been submitted to any University / College/ Organization for any Academic Qualification.

We hereby ensure that the work that been presented does not breach existing copyright. We undertake to indemnify the university against any loss or damage arising from breach of the foregoing obligation.

Thanking You
Sincerely your

STUDENT NAME	STUDENT ID.	SIGNATURE
MD. EMRAN HOSSAIN	BCE1903018151	
MD. AL-AMIN HOSSEN JONI	BCE1903018084	
MD. HABIBULLAH SHANTH	BCE1903018051	
MD. SHAH JALAL	BCE1903018073	
MD. JAHANGIR ALAM	BCE1602008159	
SHAMIMA NASRIN	BCE1903018029	

Dedicate

To

“Our Beloved Parents”

ACKNOWLEDGEMENTS

Regardless of our efforts, the success of this dissertation is largely dependent on the encouragement and direction of many others. we would like to take this opportunity to thank everyone who contributed to the successful completion of this thesis. First and foremost, we would like to praise and thank Allah, the almighty, for bestowing countless blessings, knowledge, and opportunities on the writer, allowing us to finally complete the thesis, without which we would not have been able to complete this work on time. We would like to express our heartfelt gratitude to our guide, the Department of Civil Engineering at Sonargaon University, for their invaluable assistance.

We would first like to thank our supervisor **Md. Ferdous Wahid**, Assistant Professor, Department of Civil Engineering Sonargaon University for unwavering support and guidance over the course of this research.

I would also like to thank the many other individuals who had a direct hand in helping with our research. Namely, the Civil Engineering Department Lab Assistant Md. Robiullah whose help during this research was simply invaluable, whose efforts left me more than one framework with which to work.

Authors
Member of the thesis group -01
Section: (18A)
Spring-2023
Sonargaon University (SU)

ABSTRACT

Conventionally, stone and sand are considered the coarse and fine aggregates of concrete; however, any manufactured inert material can also be used as the aggregates. These conventional aggregates, such as stone and sand, are usually collected from natural sources. As continued extraction of stone and sand from natural sources results in an imbalance in the natural ingredients and affects the environment adversely, the recent advancement of using waste materials as aggregates in concrete production has gained momentum to create a greener environment. This study focuses on the applicability of iron slag (a by-product of steel production) as a replacement for conventional fine aggregate in concrete production. Primarily, physical properties of iron slag, such as grain size distribution, dry density, specific gravity, and absorption capacity values, were measured. Then this iron slag sample was mixed with the sand at different doses (0%, 10%, 20%, and 30% of total fine aggregate). To observe the effect of this blended fine aggregate (a mixture of iron slag and sand), concrete cylindrical specimens were produced with the mixing ratio of cement fine aggregate and coarse aggregate to be 1:1.5:2.5 and tested under compression up to failure. It was found that the different doses of iron slag and sand yielded increased compressive strength values of the concrete compared to a batch where only sand was used as fine aggregate. It was also found that the different doses of iron slag and sand yielded similar compressive strength values after heating compared to a batch where only sand was used as fine aggregate. Therefore, it is expected that the iron slag has merits to be used alone or in conjunction with sand as fine aggregate in producing concrete.

TABLE OF CONTENT

CHAPTER-1

CHAPTER-2

CHAPTER-3

CHAPTER 4

CHAPTER-5

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 General

Sustainable development has received more attention in recent days than before. To balance natural resources, engineers and scientists are trying to recycle materials and searching for constructive ways to use waste materials. The civil engineering society has its fair share of responsibility in this 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 replacement % for sand, it will make concrete production economical, 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 % for 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 local sources as a replacement for 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. The durability test was beyond the scope of this study.

1.2 Objectives of the Study

(i) To identify the effect of slag on the compressive strength of concrete.

(ii) To evaluate the time-dependent effect of temperature on the compressive strength of normal-weight concrete.

(iii) To evaluate the time-dependent effect of temperature on the compressive strength of concrete made with partially replaced slag as fine aggregate.

(iv) 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 objectives and expected outcomes are also described in this chapter.

Chapter 2: Literature Review. This chapter reviews the related works in the partially replaced recycled 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 recycled 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

As slag is an industrial by-product, its productive use grants a chance to relocate the utilization of limited natural resources on a large scale. 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 usefulness of slag was realized with the first ore smelting process. 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

Cement, one of the most important building materials, 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].

The raw ingredients are processed in cement production plants 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 is 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 limes 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.

It was not as durable, especially for highways, to the point Frenchman Stephan Sorelthat some states stopped building highways and roadscement. Bertrainh. wait, an engineer whose company had worked NewconstrCityon CatskilleAqueductity's catskill aqueduct, was impressed with the durabilty of Rosendale cement, and came Theh a blend in the us the first large-scale use of 6 cement was rosendale cement, a natural cement mined from a massive deposit of a large dolostone rock deposit discovered in the eRosendale cNewury n. Rosendaleale, new York rosendale cement was extremely popular for the foe.g.iothe StatueuildLiberty .thetCapitol Building, theerty, capiBridgeilding, Brooklyn bridge). Sorelining water pipes sorel cement was patented in 1867 by frenchmanstanislassorel and was stronger than Portland cement, but its poor water resistance and corrosive qualities limited its use in building construction. 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 (SiO_2)	22
Alumina (Al_2O_2)	5
Calcium Sulphate ($CaSO_4$)	4
Iron Oxide (Fe_2O_3)	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, 17, #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 SiO_2 and forms Fe_3Si. 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 SiO_2, 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 Recycled Fine Aggregate (Slag)

Slag is basically iron dust collected from rod factories. Recycled materials are used for various purposes. The use of rod slag as a partial replacement for recycled aggregate is a new and innovative idea. Its use greatly increases the compressive strength and durability 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

Concrete is an artificial stone manufactured from a mixture of binding materials and inert materials with water. The inert materials used in concrete are termed "aggregate. It is defined as: "Aggregates are the inert materials that are mixed in fixed proportions with a binding material to produce concrete". These act as fillers or volume-increasing components on the one hand and are responsible for the strength, hardness, and durability of the concrete on the other. Aggregate is an essential ingredient in making concrete used in construction. The quality of the material strongly influences the performance of concrete, including how well it mixes and hardens as well as its durability over the long term. A quality aggregate will be clean and free of any soft particles or vegetable matter. If organic compounds such as soil are included in the mix, this can cause chemical reactions that compromise the strength and properties of the concrete.

2.10 Function of Aggregate in Concrete

Aggregates are the important constituents of the concrete, which give it body and also reduce shrinkage. Aggregates occupy 70 to 80% of the total volume of concrete. The aggregate gives volume to the concrete, around which the binding materials adhere in the form of a thin film. In theory, the voids in the coarse aggregate are filled up with fine aggregate, and again, the voids in the fine aggregate are filled up with binding materials. Finally, the binding materials, as the name implies, bind the individual units of aggregates into a solid mass with the help of water. The aggregate gives volume, stability, resistance to wear or erosion, and other desired physical properties to the finished product. Using aggregate as a filler can help concrete producers save a lot of money. Cement usually costs seven- or eight-times what stone and sand cost. Cement is necessary, but strength can still be retained when using well-graded aggregates that cost significantly less. Aggregates make up 60–80% of the volume of concrete and 70–80% of the mass of concrete. Aggregate is also very important for the strength, thermal, and elastic properties of concrete, dimensional stability, and volume stability. Cement is more likely to be affected by shrinkage. Including aggregate in the mix can control the shrinkage level and prevent cracking.

2.11 Strength of Aggregate

Water and binding materials are important factors affecting the strength of concrete. The size of the aggregates, shape, surface texture, grading, and mineralogy are known to affect concrete strength in varying degrees. So the strength of concrete depends on the type of aggregate used, and it is a mere obligatory approach to find out the suitable composition of aggregate in order to attain the desired concrete strength. Generally, in Bangladesh, two types of coarse aggregates are frequently used in construction work. One of them is brick aggregate, and the other is stone chips. Among them, generally, stone chips have higher strength than brick aggregates. As the availability of natural sand in Bangladesh is in huge demand, the investigators find it imperative to look forward to enhancing the concrete strength by finding and utilizing alternative sources and also trying different partial replacements with brick fine aggregates. Again, some investigators have found some progressive results while using brick fine aggregate as an alternative material to natural sand at different ratios, which influence our search for a suitable alternative material in brick fine aggregate. Use of 1st-class brick fine aggregate accelerates the rate of gain in compressive strength at the early age of concrete, which is a very good sign as it gives desired strength even before the probable time period estimated. So, we can clearly see that the compressive strength of aggregate is dictated to a great extent by the nature of aggregate, and hence finding a suitable alternative to coarse aggregate in the form of slag has become more essential. Since the testing of the crushing strength measurement of individual aggregate particles is very difficult, the desired information has to be obtained from indirect tests like the crushing value of bulk aggregate or 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 durability and 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:

In concrete, the single most significant influence on most or all of the properties is the amount of water used in the mix. In concrete mix design, the ratio of the amount of water to the amount of cement used (both by weight) is called the water to cement ratio (w/c). These two ingredients are responsible for binding everything together. The water-to-cement ratio largely determines the strength and durability of the concrete when it is cured properly. The w/c ratio refers to the ratio of the weights of water and cement used in the concrete mix. A w/c ratio of 0.45 means that for every 100 kg of cement used in the concrete, 45 liters of water are added.

CHAPTER 3

METHODOLOGY

3.1 Introduction

First, we have completed the desired concrete mix design. Then we collected the materials to make the desired concrete. Our work is basically dependent on the effect of heat on the strength properties of concrete made with partially replaced recycled fine aggregate. We used iron slag as recycled fine aggregate.

3.2 Methodology Overview

In our work, the materials were first collected. Then all the materials were taken to the laboratory and tested. All the materials used in making the concrete used in our study are cement, sand, stone, rod slag as a percentage as replacement aggregate, water, etc.

3.3 Collection of Materials

We have collected coarse aggregate and fine aggregate from Gabtali. Collected iron slag from the Chittagong BSRM Rod Factory.

We collected OPC cement from Mohammadpur Rashed Tedders.

Figure 3-1 Cement

Figure 3-2 Coarse Aggregate

Figure 3-3 Fine Aggregate

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

3.4 Sieves Analysis of Aggregate

First, we completed sieve analysis of fine aggregate and partially replaced recycled aggregate through NO. 100, NO. 50, NO. 30, NO. 16, NO. 8, NO. 4, and 3/8 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 recycled aggregate, and coarse aggregate, the sieve analysis method was used according to ASTM C136.

Figure 3-5 Sieve Analysis

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

Specific gravity testing of fine aggregate and partial replacement recycled aggregate based on oven-dry and SSD conditions The specific gravity of course aggregate is tested based on oven-dry and SSD conditions.

Figure 3-6 **Specific Gravity**

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

We determine the unit weight of cement fine aggregate, partial recycled aggregate, and coarse aggregate by three methods. The three procedures are:

a) Shoveling procedure
b) Roding procedure
c) Jiggling procedure

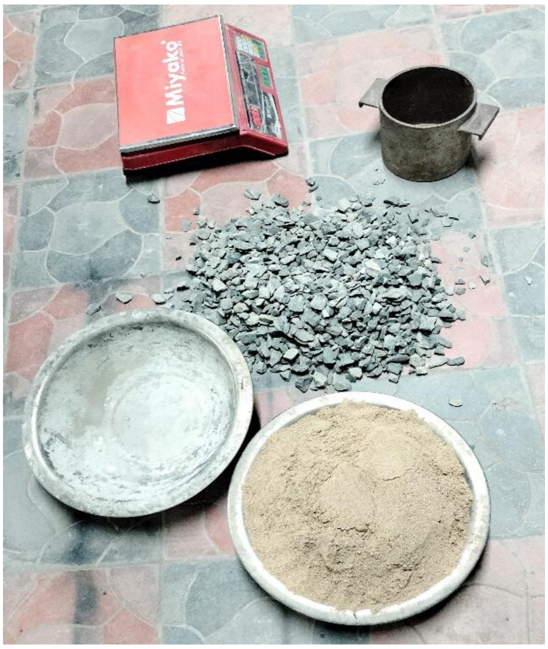

Figure 3-7 **Unit Weight Test**

3.7 Mix Design

A smooth and waterproof platform was selected. Our mixing ratio is 1:1.5:2.5. First, the coarse aggregate is spread evenly on the platform according to the specified measurements. Then the fine aggregate is spread over the coarse aggregate according to the specified measurements. The fine aggregate is then spread over the partially recycled aggregate percentage. Then the cement used as binding material is spread evenly over the pre-applied aggregates in the specified quantity. Then all the ingredients are properly mixed until the mixture becomes uniform in color. Once the mixture is properly mixed, concrete mortar is made with potable water.

Figure 3-8 Mixing Materials Before Watering

Figure 3-9 Mixing Materials After Watering

3.8 Water Cement Ratio

As per mix design, the water-to-cement ratio is fixed at 0.45. For example, if we use 10 kg of cement in a concrete mix, we will use 4.5 liters of water.

3.9 Materials Ratio

We complete the concrete mix design for 4000 PSI-strength concrete by the volume basis method. The ratio of different ingredients in our concrete was 1:1.5:2.5. The proportions of different ingredients were measured according to this mixing ratio of concrete.

3.10 Casting Cylinder

4x8-inch cylindrical specimen. Fill each mold with concrete in three layers. Tamping each layer 25 times with a 5/8-inch steel tamping rod While filling the molds. Occasionally stir and scrape together the remaining concrete in the mixing pan to keep the materials from separating. Fill the molds completely and smooth off the tops evenly. Numbering the molds by date and percent of partially replaced recycled aggregate

Figure 3-10 Cylinder After 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 recycled aggregate. Then the numbered cylinders were kept completely submerged in water for 28 days.

Figure 3-11 Curing Time

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

After 28 days, the cylinders were lifted from the water. Then the cylinders were kept for one day to air dry. Then the compressive strength of concrete cylinders is tested at zero degrees Celsius without any partially replaced aggregate. Then the compressive strength test of concrete cylinders was done by oven drying at 100 degrees Celsius, 150 degrees Celsius, 200 degrees Celsius, and 250 degrees Celsius in the presence of zero percent partial replacement aggregate for 60 minutes, 120 minutes, and 180 minutes. Then, in the presence of 10 percent partial replacement aggregate, concrete cylinders were tested for compressive strength by oven drying at 100 degrees Celsius, 200 degrees Celsius, and 250 degrees Celsius for 60 minutes, 120 minutes, and 180 minutes, respectively. Then, in the presence of 20 percent partial replacement aggregate, the compressive strength test of concrete cylinders was done by oven drying at 100 degrees Celsius, 150 degrees Celsius, 200 degrees Celsius, and 250 degrees Celsius for 60 minutes, 120 minutes, and 180 minutes. Then, in the presence of 30 percent partial replacement fine aggregate, concrete cylinders were tested for compressive strength by oven drying at 100°C, 150°C, 200°C, and 250°C for 60 minutes, 120 minutes, and 180 minutes.

Figure 3-12 Replaced Recycled Aggregate Concrete Cylinder Before Crashing

Figure 3-13 Maximum Heating Time of Cylinder

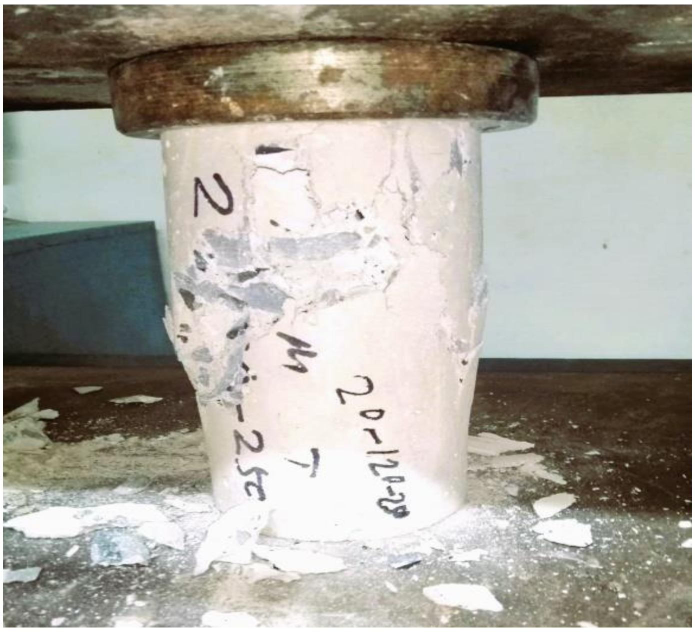

Figure 3-14 Replaced Recycled Aggregate Concrete Cylinder After Crashing

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the finding of the compressive strength test of cylinder with varying percentage of normal aggregate and partially replaced recycled aggregate.

4.2 Sieve Analysis for Fine Aggregate

Table 4.1: Sieve Analysis of Fine Aggregate

Sieve Aperture (No.)	Retaining (gm)	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)	FM
4	0	0	0	100	$\frac{207.8}{100}$ =2.08
8	8	0.80	0.80	99.2	
16	29	2.9	3.70	96.3	
30	173	17.3	21.00	79	
50	639	63.9	84.90	15.1	
100	125	12.5	97.40	2.6	
Pan	26	2.6			
Total	1000		207.8		

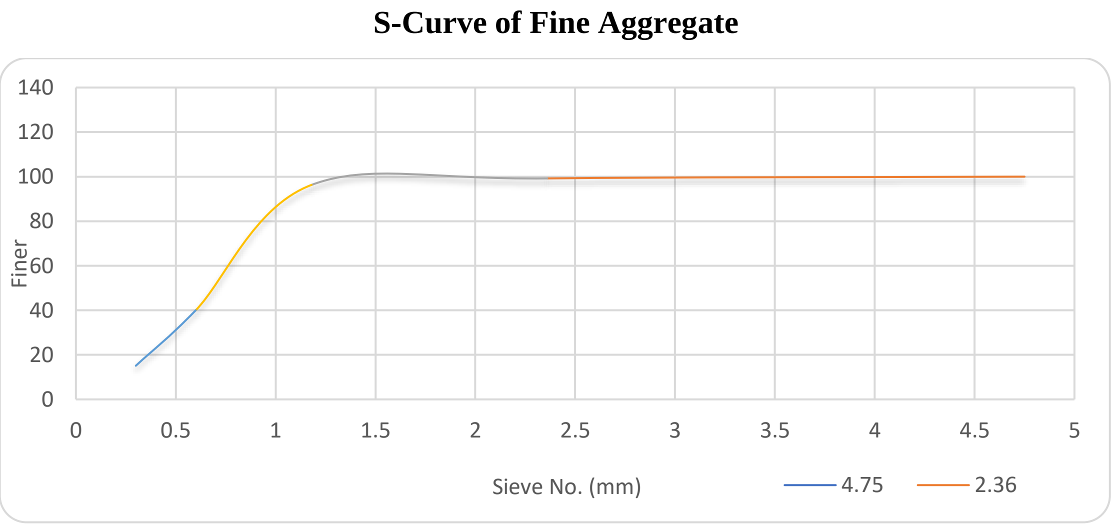

Figure 4-1 S-Curve from Sieve Analysis of Fine Aggregate

From the table-01 and figure-4.1, it is observed that, the collected sylhet sand, as a fine aggregate is a well graded mixture.

4.3 Sieve Analysis for Coarse Aggregate

Table 4.2: Sieve Analysis of Coarse Aggregate

Sieve aperture	Sieve Opening (mm)	Retaining (gm)	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)	FM
3”	75	0	0	0	100	$\frac{704.33}{100} = 7.04$
3/2”	37.5	0	0	0	100	
3/4”	19	135	9	9	91	
3/8”	9.5	1295	86.33	95.33	4.6	
#4	4.75	70	4.67	100	0	
#8	2.36	0	0	100	0	
#16	1.18	0	0	100	0	
#30	0.60	0	0	100	0	
#50	0.30	0	0	100	0	
#100	0.15	0	0	100	0	
Pan		0	0			
Total		1500		704.33		

From table-02 and figure 4-2, the sieve analysis of normal stone aggregate gives a result of uniform graded mixture.

S-Curve of Stone Aggregate

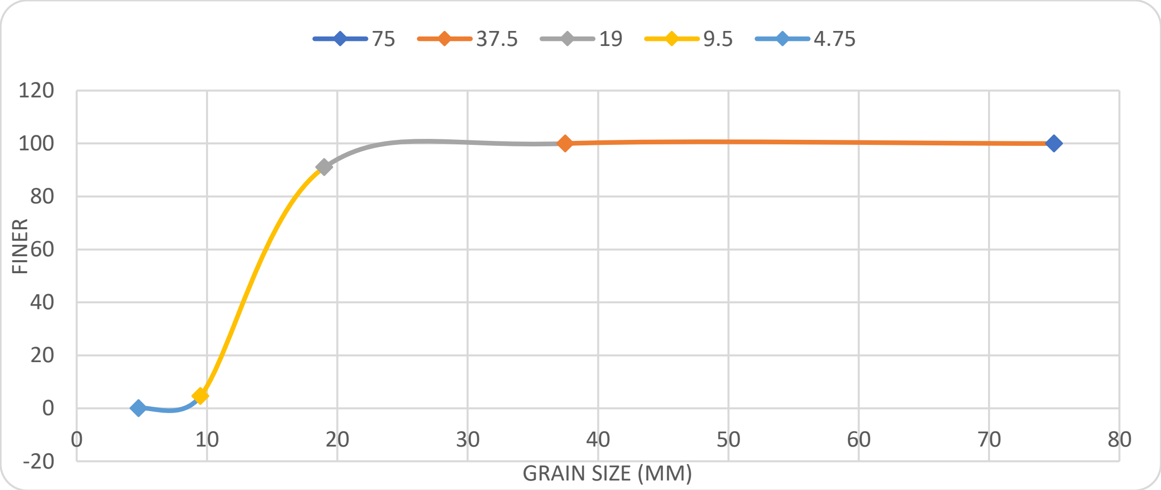

Figure 4-2 S-Curve from Stone Aggregate from Sieve Analysis

4.4 Sieve Analysis for Fine Aggregate (Slag)

Table 4.3: Sieve Analysis of Slag Aggregate

Sieve Aperture (No.)	Retaining (gm)	Retained (%)	Cumulative Retained (%)	Cumulative Passing (%)	FM
4	0	0	0	100	$\frac{430}{100} = 4.30$
8	613	61.3	61.3	38.7	
16	263	26.3	87.6	12.4	
30	30	3	90.6	9.4	
50	13	1.3	91.9	8.10	
100	67	6.7	98.6	1.4	
Pan	14	0			
Total	1000		430		

S-Curve of Slag Aggregate

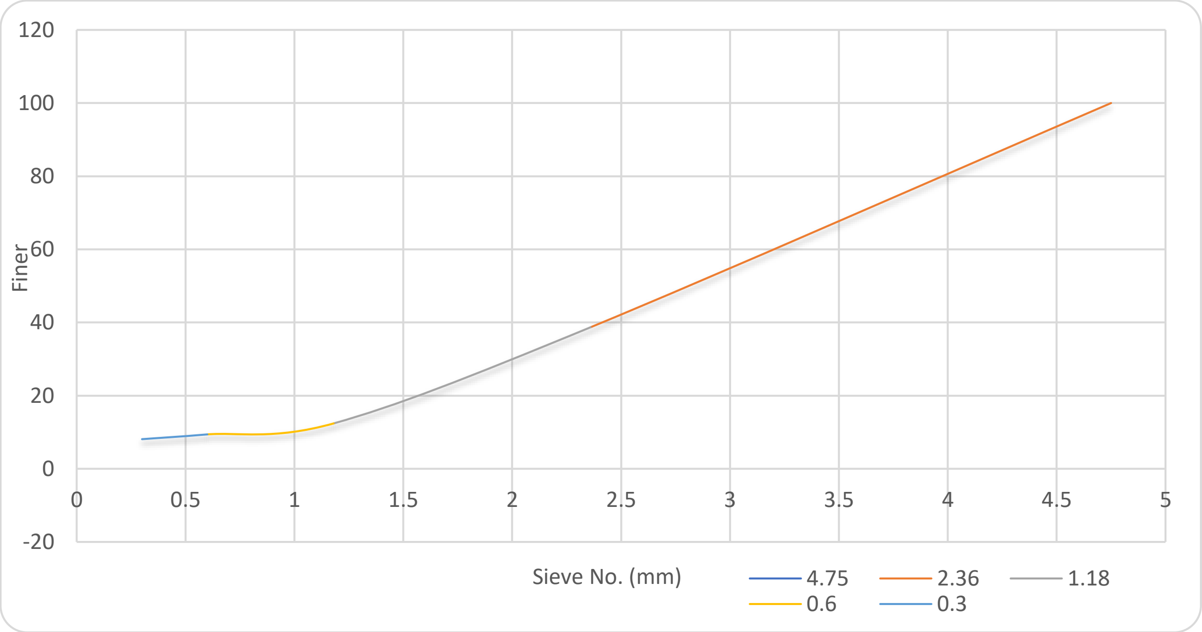

Figure: 4-3 S-Curve from Sieve Analysis of Slag Aggregate

From the table-03 and figure-4.3, it is observed that, the collected Slag aggregate from BSRM Factory is a well graded mixture.

4.5 Specific Gravity for Fine Aggregate

Table 4.4: Data Sheet for Specific Gravity of Fine Aggregate

Wt. of pycnometer filled with water to calibration, B gm	Oven dry Wt. in air, A gm	Wt. of pycnometer with specimen and water to calibration mark, C gm	Wt. of saturated surface dry specimens S (gm)
653	300	838	309

Table 4.5: Specific Gravity of Fine Aggregate

Test	Formula	Calculation	Result
Apparent Specific Gravity	$\frac{A}{B+A-C}$	$\frac{300}{653+300-838}$	2.61
Bulk Specific Gravity (Oven dry basic)	$\frac{A}{B+S-C}$	$\frac{300}{653+309-838}$	2.42
Absorption Capacity, D%	$\frac{(S-A)x100}{A}$	$\frac{(309-300)x100}{300}$	3
Bulk Specific Gravity (S.S.D. Basic), G	$\frac{S}{B+S-C}$	$\frac{309}{653+309-838}$	2.50

The specific gravity of the normal fine aggregate after oven drying was found 2.42, We found the specific gravity of the apparent to be 2.61 and bulk specific gravity (S.S.D) was found 2.50

4.6 Specific Gravity of Partially Replaced Recycled Fine Aggregate (Slag)

Table 4.6: Data Sheet for Specific Gravity of Fine Aggregate (Slag)

Wt. of pycnometer filled with water to calibration, B gm	**Oven dry Wt. in air, A gm**	**Wt. of pycnometer with specimen and water to calibration mark, C gm**	**Wt. of saturated surface dry specimens S (gm)**
653	300	854	308

Table 4.7: Specific Gravity of Slag as Fine Aggregate

Test	**Formula**	**Calculation**	**Result**
Apparent Specific Gravity	$\frac{A}{B+A-C}$	$\frac{300}{653+300-854}$	3.03
Bulk Specific Gravity (Oven dry basic)	$\frac{A}{B+S-C}$	$\frac{300}{653+308-854}$	2.80
Absorption Capacity, D%	$\frac{S-A}{A}x100$	$\frac{(308-300)x100}{300}$	2.67
Bulk Specific Gravity (S.S.D. Basic), G	$\frac{S}{B+S-C}$	$\frac{308}{653+308-854}$	2.88

The specific gravity of the normal recycle aggregate (Slag) after oven drying was found 2.80, We found the specific gravity of the apparent to be 3.03 and bulk specific gravity (S.S.D) was found 2.88

4.7 Specific Gravity for Coarse Aggregate

Table 4.8: Data Sheet for Specific Gravity of Coarse Aggregate

Wt. S.S.D sample in air, B (gm)	**Wt. S.S.D sample in water, C (gm)**	**Oven dry wt. of sample in air, A (gm)**
1580	995	1560

Table 4.9: Specific Gravity of Coarse Aggregate

Test	**Formula**	**Calculation**	**Result**
Apparent Specific Gravity	$\frac{A}{A-C}$	$\frac{1560}{1560-995}$	2.76
Bulk Specific Gravity (Oven dry basic)	$\frac{A}{B-C}$	$\frac{1560}{1580-995}$	2.67
Absorption Capacity, D%	$\frac{(B-A)x100}{A}$	$\frac{(1580-1560)x100}{1560}$	1.28
Bulk Specific Gravity (S.S.D. Basic), G	$\frac{B}{B-C}$	$\frac{1580}{1580-995}$	2.70

The specific gravity of the coarse aggregate after oven drying was found 2.67. We found the specific gravity of the apparent to be 2.76 and bulk specific gravity (S.S.D) condition 2.70 .

4.8 Unit Weight of Coarse Aggregate

Table 4.10: Unit Weight of Coarse Aggregate

Condition	**G (kg)**	**Wt. of Bucket empty T (kg)**	**V=$\frac{\pi D^2}{4} xh$**	**M=$\frac{G-T}{V}$, (kg/m^3)**	**Average (kg/m^3)**
Free Condition	7.718	4	2.77x10^{-3}	1338	1494
Roding Condition	8.332	4	2.77x10^{-3}	1559	
Jiggling Condition	8.404	4	2.77x10^{-3}	1584	

4.9 Unit Weight of Fine Aggregate

Table 4.11: Unit Weight of Fine Aggregate

Condition	**G (kg)**	**Wt. of Bucket empty T (kg)**	**V=$\frac{\pi D^2}{4} xh$**	**M=$\frac{G-T}{V}$, (kg/m^3)**	**Average (kg/m^3)**
Free Condition	7.691	4	2.77x10^{-3}	1328	1464
Roding Condition	8.166	4	2.77x10^{-3}	1499	
Jiggling Condition	8.354	4	2.77x10^{-3}	1566	

4.10 Unit Weight of Fine Aggregate (Slag)

Table 4.12: Unit Weight of Fine Aggregate (Slag)

Condition	**G (kg)**	**Wt. of Bucket empty T (kg)**	$V=\frac{\pi D^2}{4} xh$	$M=\frac{G-T}{V}$, (kg/m^3)	**Average (kg/m^3)**
Free Condition	8.157	4	$2.77\text{x}10^{-3}$	1496	1596
Roding Condition	8.482	4	$2.77\text{x}10^{-3}$	1613	
Jiggling Condition	8.669	4	$2.77\text{x}10^{-3}$	1680	

4.11 Compressive Strength Test of Cylinder

Table 4.13: Normal Concrete Cylinder Compressive Test Results (NTP)

Recycle Aggregate (Slag)	**Cylinder-1 (Psi)**	**Cylinder-2 (Psi)**	**Cylinder-3 (Psi)**	**Average (Psi)**
0%	3860.23	4022.77	3839.91	3907
10%	4672.91	4672.91	4551.01	4632
20%	4611.96	4876.08	4530.69	4673
30%	4307.20	4876.08	5323.05	4835

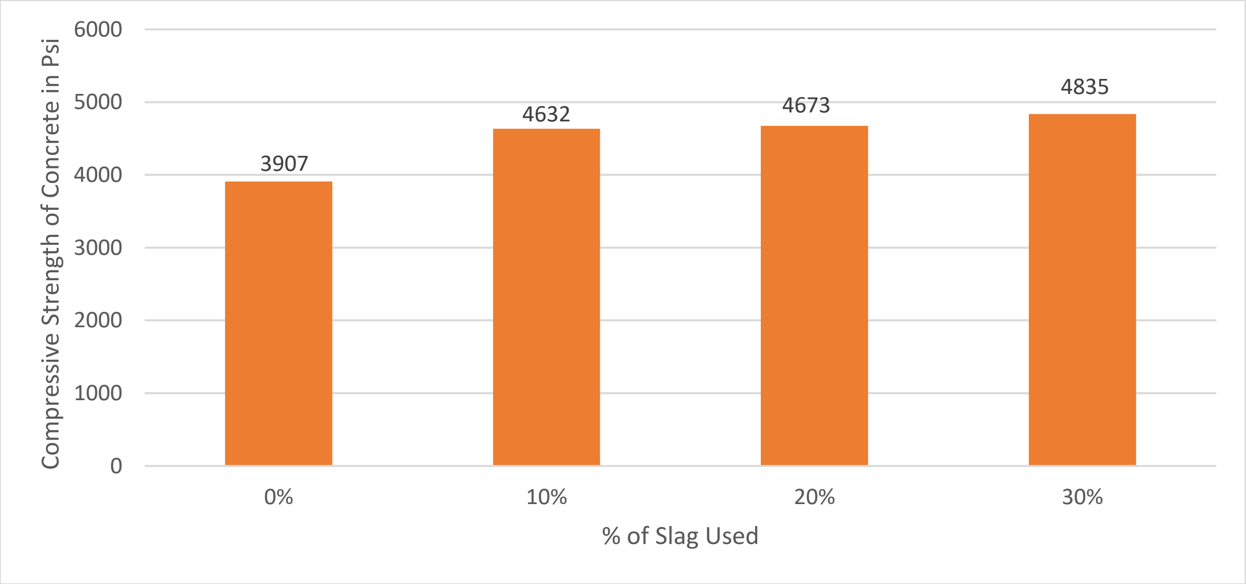

Figure 4-4 Compressive Strength (Psi) VS % of Slag Used no Heat Effect

Table 4.14: Concrete Compressive Strength Test Results (Temperature at 100°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi))	Average (Psi)	Time (Min)
0%	4234.99	4331.22	4203.77	4256	60
10%	4266.57	4478.98	4220.40	4322	60
20%	4957.35	5106.96	4903.79	4989	60
30%	4876.08	5119.88	4778.19	4925	60

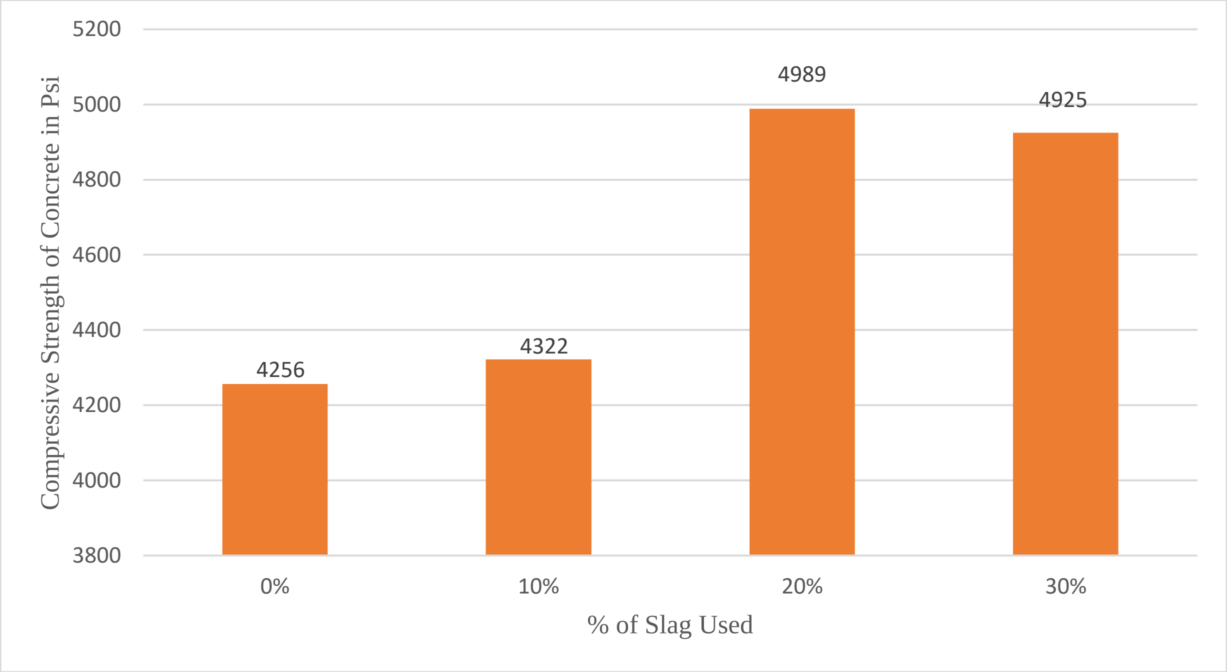

Figure 4-5 Compressive Strength (Psi) VS % of Slag Used for 60min of Heat

Table 4.15: Concrete Compressive Strength Test Results (Temperature at 100°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3738.33	3924.88	3886.09	3849	120
10%	3758.65	4133.59	3721.71	3821	120
20%	4632.28	5095.87	4214.85	4647	120
30%	5038.62	5275.03	4822.52	5045	120

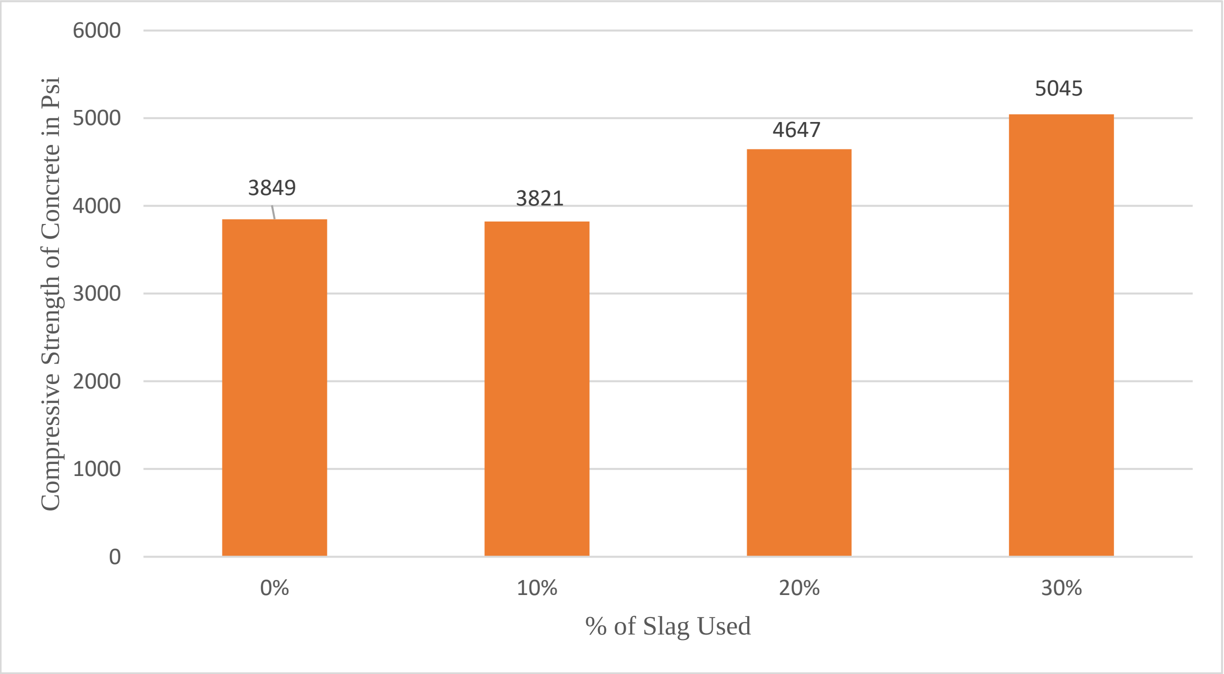

Figure 4-6 Compressive Strength (Psi) VS % of Slag Used for 120min of Heat

Table 4.16: Concrete Compressive Strength Test Results (Temperature at 100°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3697.69	3882.39	3660.75	3747	180
10%	4063.40	4266.57	3897.17	4076	180
20%	4977.67	5077.40	4876.08	4977	180
30%	5282.42	5441.26	5175.29	5286	180

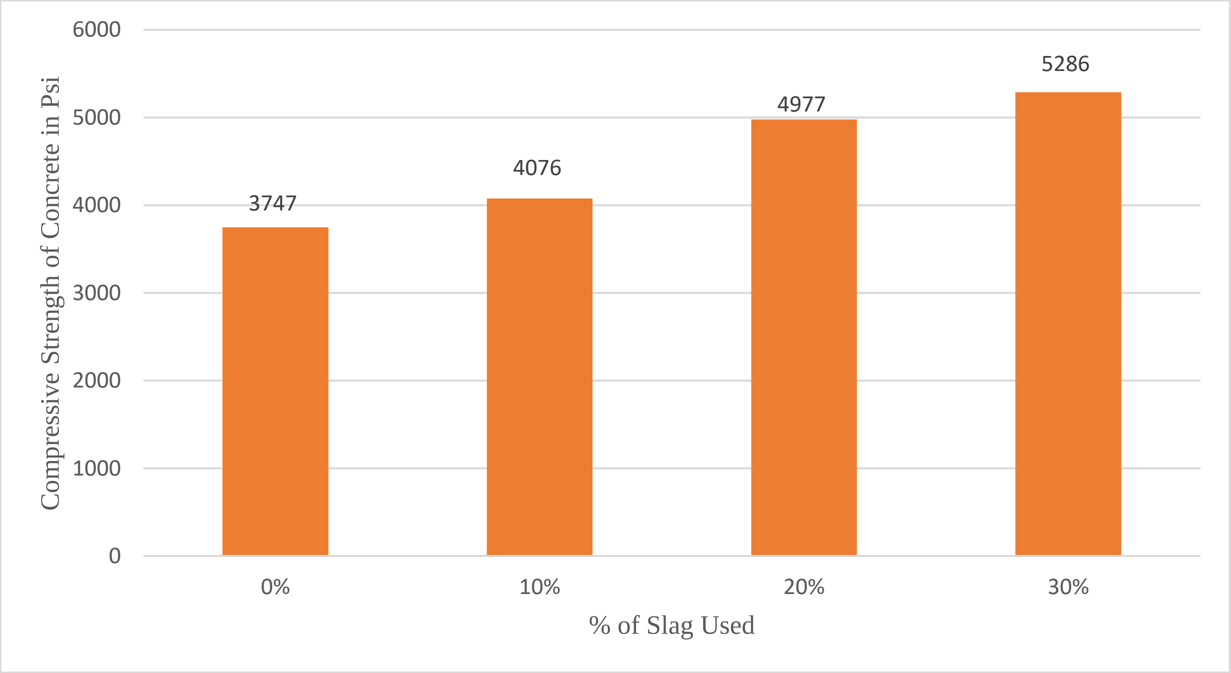

Figure 4-7 Compressive Strength (Psi) VS % of Slag Used for 180min of Heat

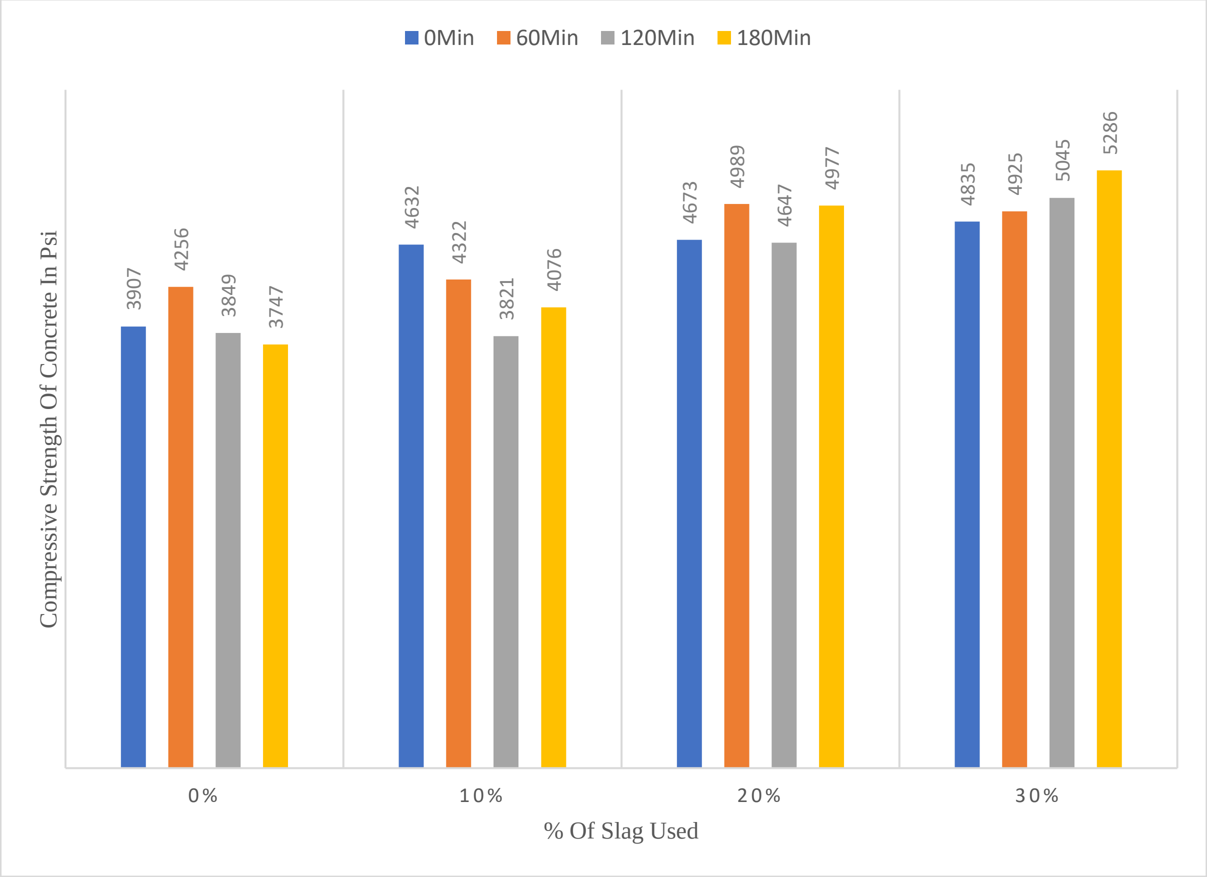

Figure 4-8 Compressive Strength (Psi) VS % of Slag Used Different Time of Heat

Table 4.17: Concrete Compressive Strength Test Results (Temperature at 150°C)

Recycle Aggregate (Slag)	**Cylinder-1 (Psi)**	**Cylinder-2 (Psi)**	**Cylinder-3 (Psi)**	**Average (Psi)**	**Time (Min)**
0%	4144.67	4351.90	3961.82	4153	60
10%	4469.74	4617.50	4358.92	4482	60
20%	5384.01	5485.59	5263.95	5378	60
30%	4571.33	4432.80	4802.20	4602	60

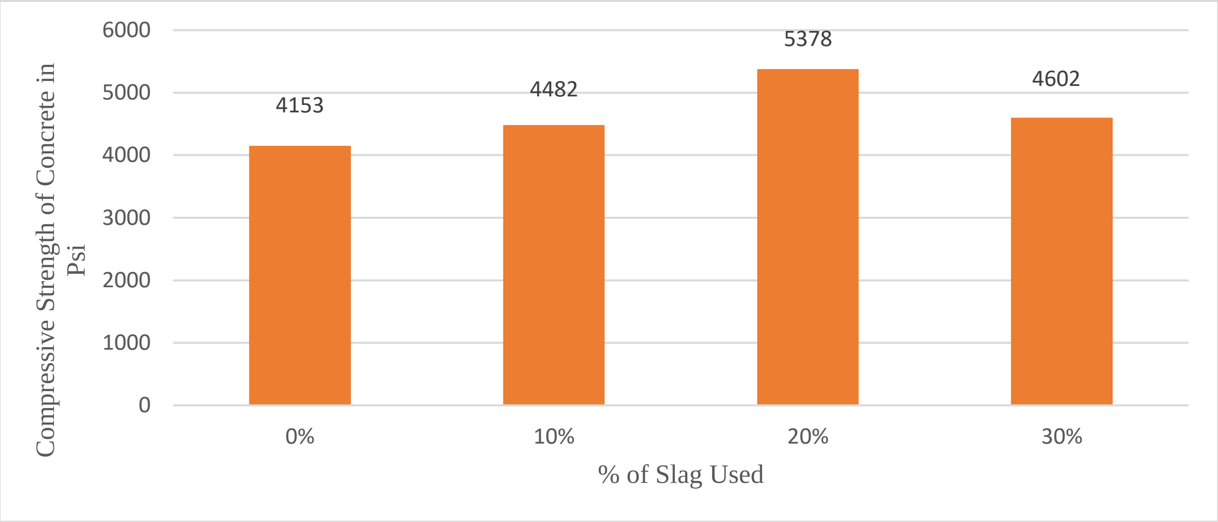

Figure 4-9 Compressive Strength (Psi) VS % of Slag Used for 60min of Heat

Table 4.18: Concrete Compressive Strength Test Results (Temperature at 150°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3372.62	3564.71	3416.95	3451	120
10%	3758.65	3878.70	3694.00	3777	120
20%	4368.16	4432.80	4340.45	4380	120
30%	3758.65	3971.05	3786.35	3838	120

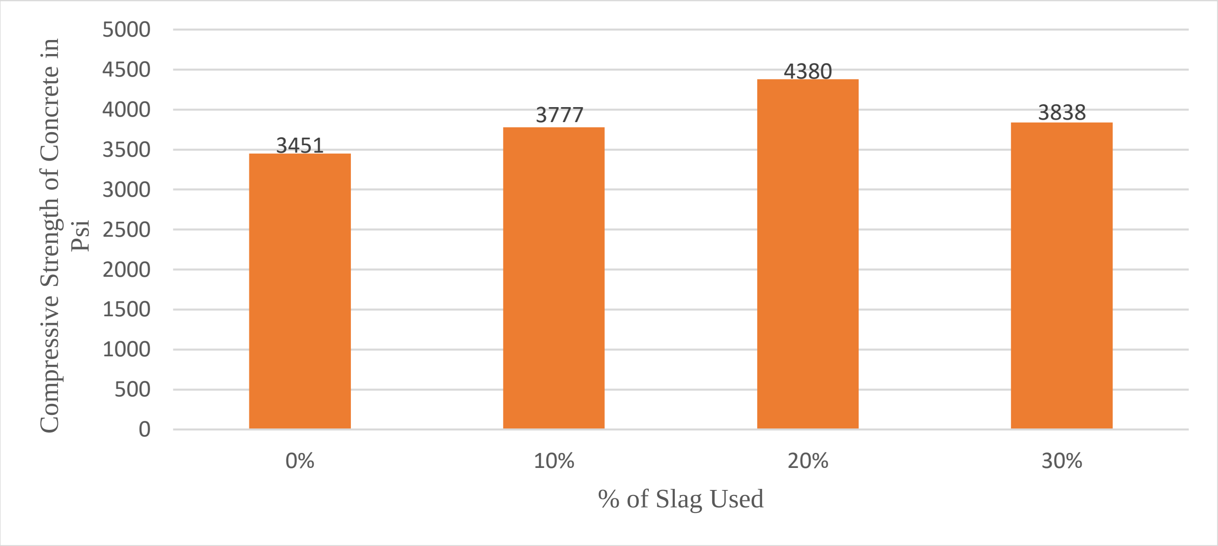

Figure 4-10 Compressive Strength (Psi) VS % of Slag Used for 120min of Heat

Table 4.19: Concrete Compressive Strength Test Results (Temperature at 150°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3352.31	3509.30	3416.95	3426	180
10%	4063.40	4248.10	3971.05	4094	180
20%	4063.40	4321.98	3878.70	4088	180
30%	4429.11	4340.45	4525.15	4431	180

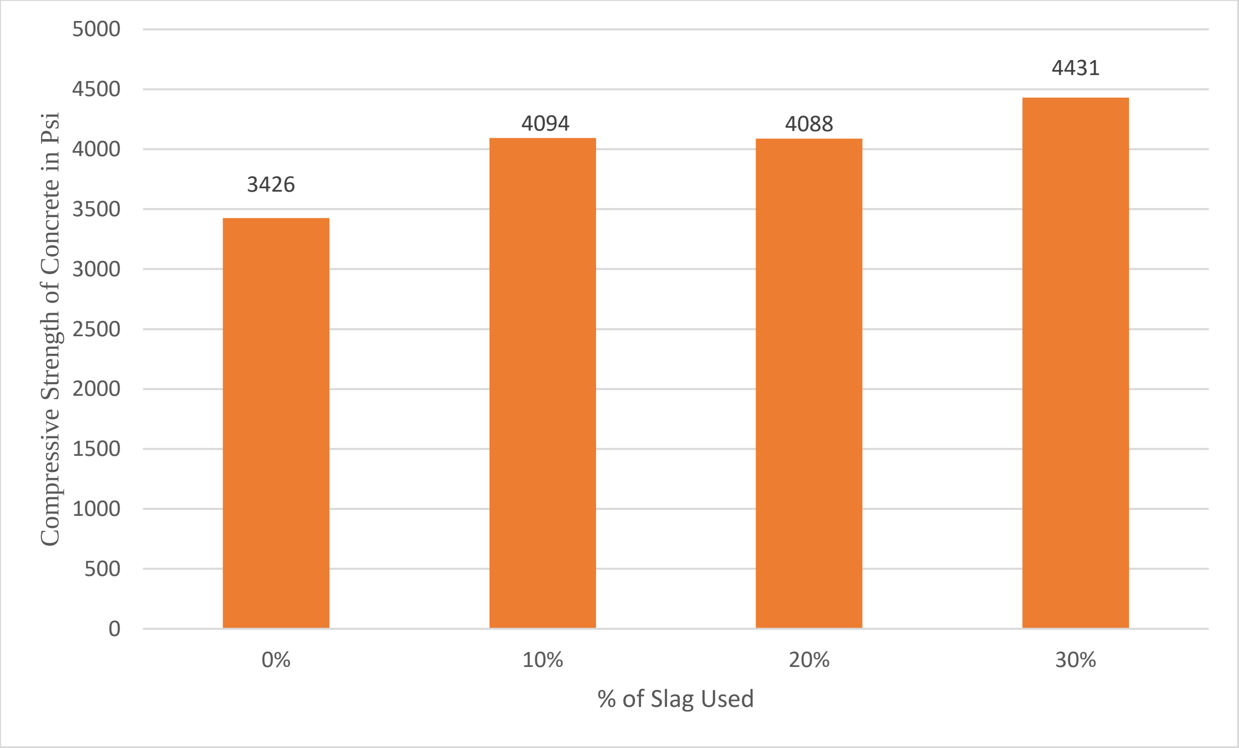

Figure 4-11 Compressive Strength (Psi) VS % of Slag Used for 180min of Heat

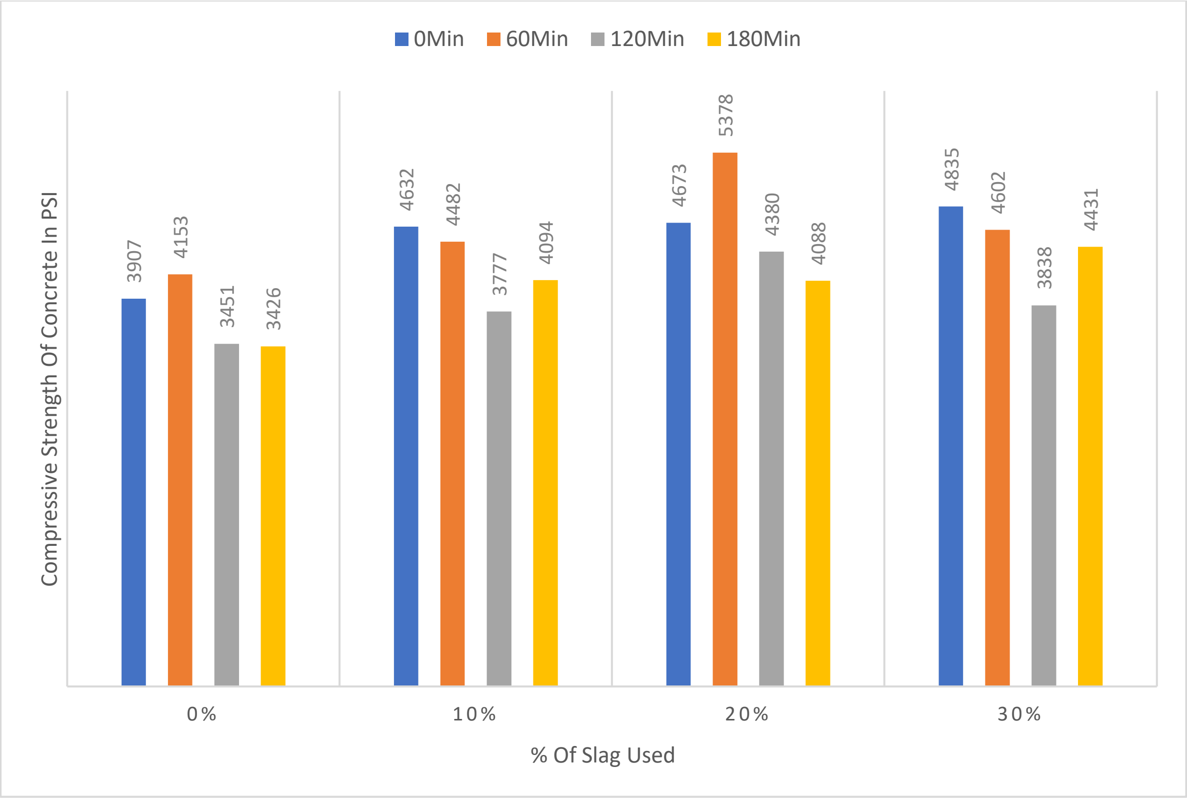

Figure 4-12 Compressive Strength (PSI) VS % of Slag Used Different Time of Heat

Table 4.20: Concrete Compressive Strength Test Results (Temperature at 200°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	4205.62	4395.86	4063.40	4221	60
10%	4876.08	4802.20	4949.96	4876	60
20%	4672.91	4876.08	4506.68	4685	60
30%	5241.79	5153.13	5341.52	5245	60

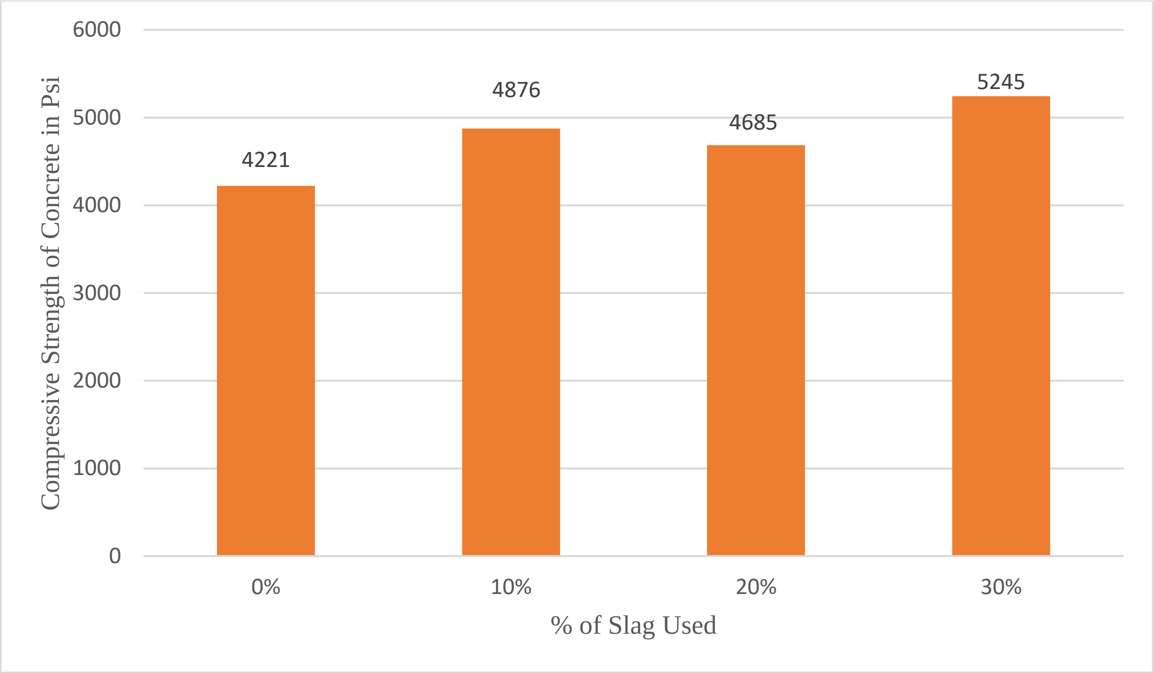

Figure 4-13 Compressive Strength (Psi) VS % of Slag Used for 60min of Heat

Table 4.21: Concrete Compressive Strength Test Results (Temperature at 200°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3291.35	3490.83	3232.25	3338	120
10%	3250.72	3509.30	3139.90	3300	120
20%	3555.48	3758.65	3416.95	3577	120
30%	4368.16	4432.80	4321.98	4374	120

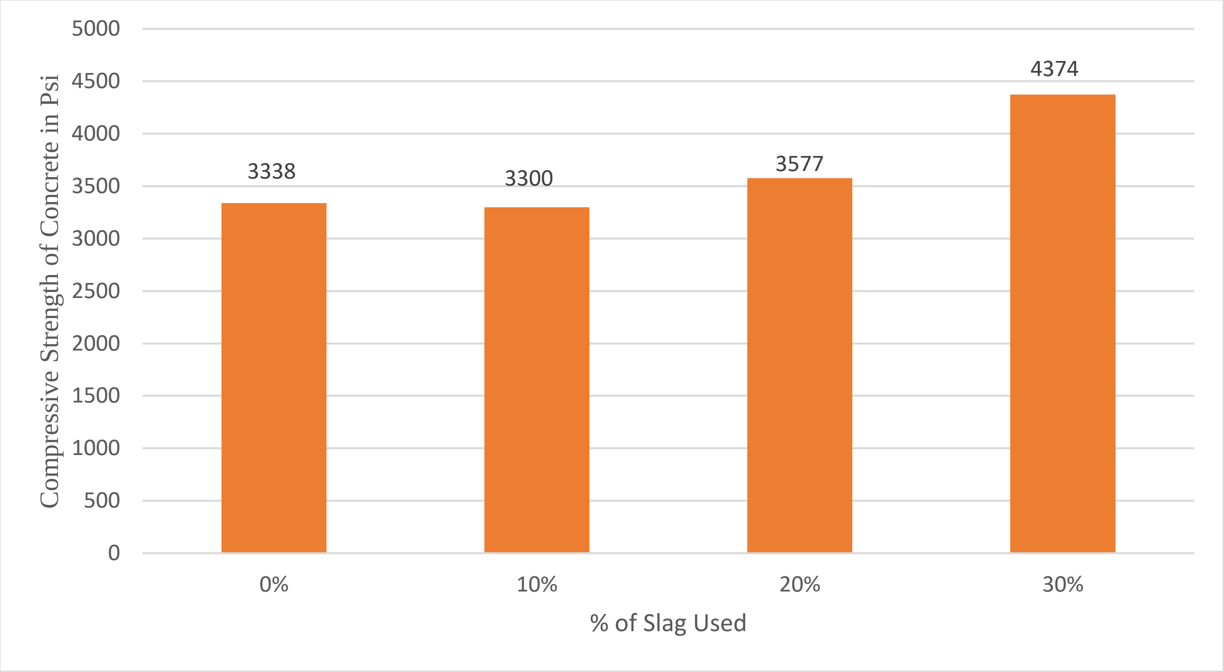

Figure 4-14 Compressive Strength (Psi) VS % of Slag Used for 120min of Heat

Table 4.22: Concrete Compressive Strength Test Results (Temperature at 200°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3250.72	3435.42	3324.60	3336	180
10%	3453.89	3509.30	3426.19	3463	180
20%	4083.72	4451.27	3878.70	4138	180
30%	3982.13	4248.10	3897.17	4042	180

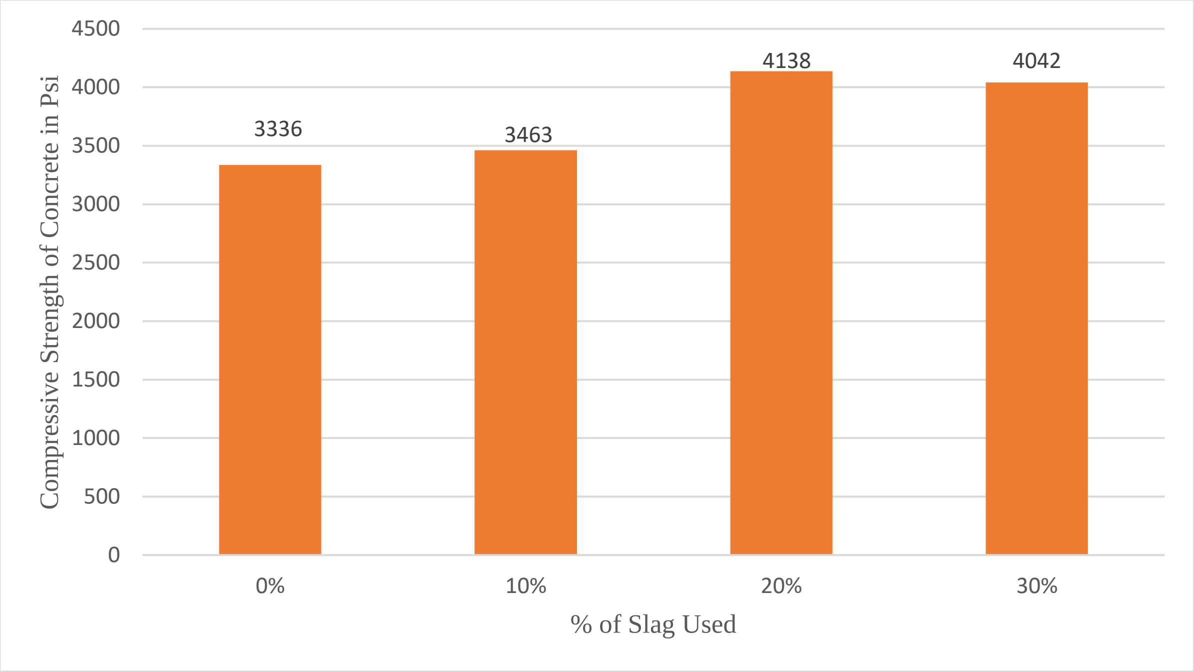

Figure 4-15 Compressive Strength (Psi) VS % of Slag Used for 180min of Heat

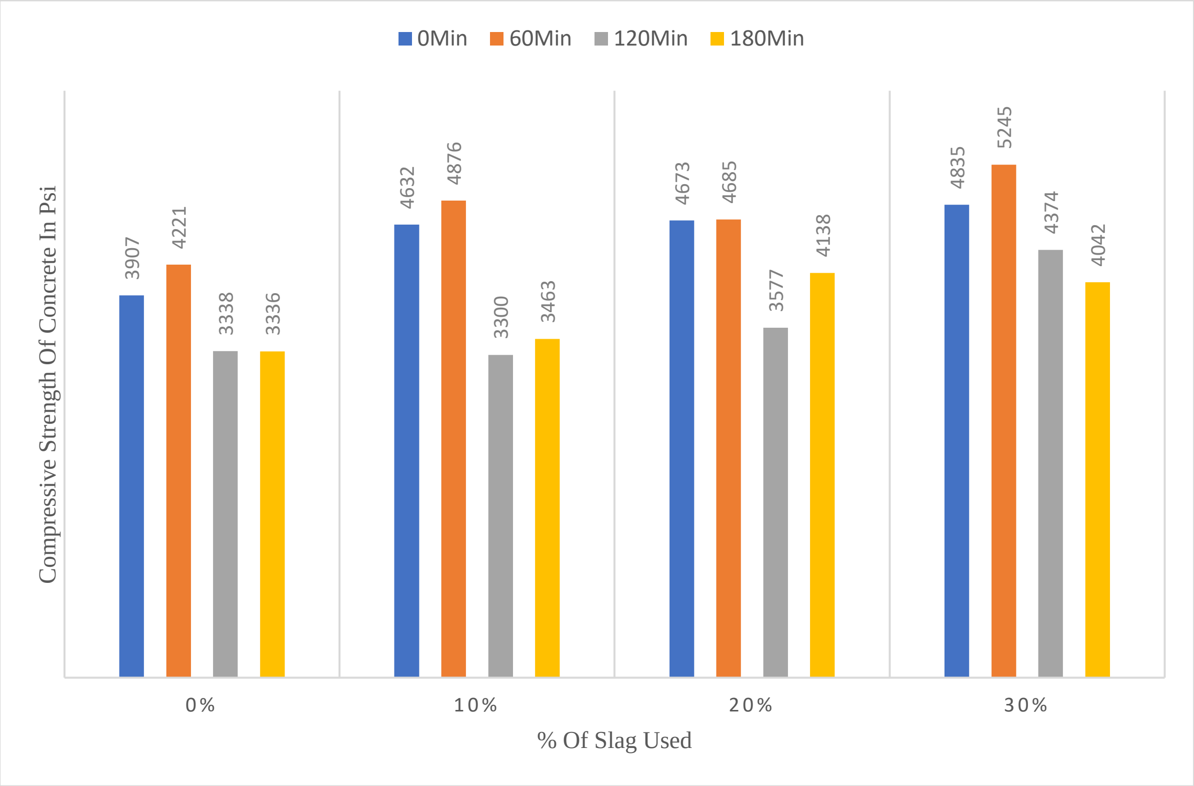

Figure 4-16 Compressive Strength (Psi) VS % of Slag Used Different Time of Heat

Table 4.23: Concrete Compressive Strength Test Results (Temperature at 250°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3860.23	4044.93	3694.00	3866	60
10%	3657.06	3509.30	3841.76	3669	60
20%	4063.40	4340.45	3878.70	4094	60
30%	4266.57	4155.75	4488.21	4303	60

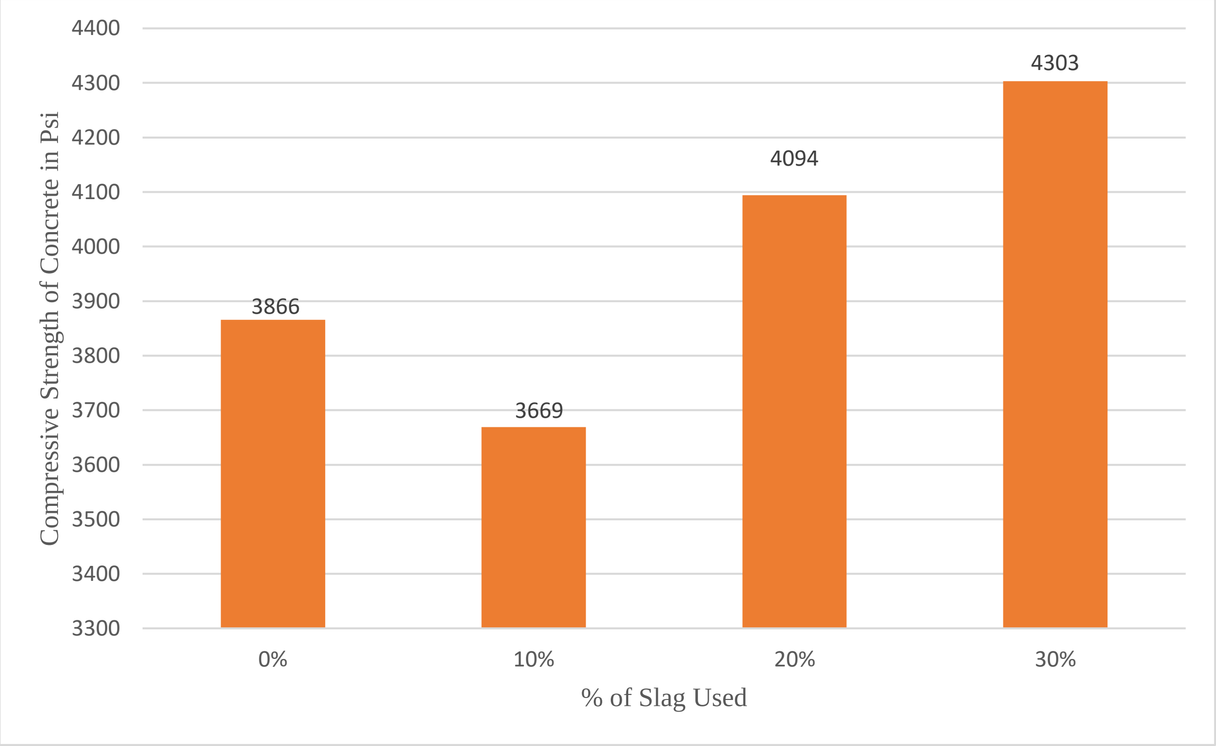

Figure 4-17 Compressive Strength (Psi) VS % of Slag Used for 60min of Heat

Table 4.24: Concrete Compressive Strength Test Results (Temperature at 250°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3758.65	3694.00	3878.70	3777	120
10%	3657.06	4063.40	3878.70	3866	120
20%	3961.82	3878.70	4155.75	3998	120
30%	4408.79	4525.15	4285.04	4406	120

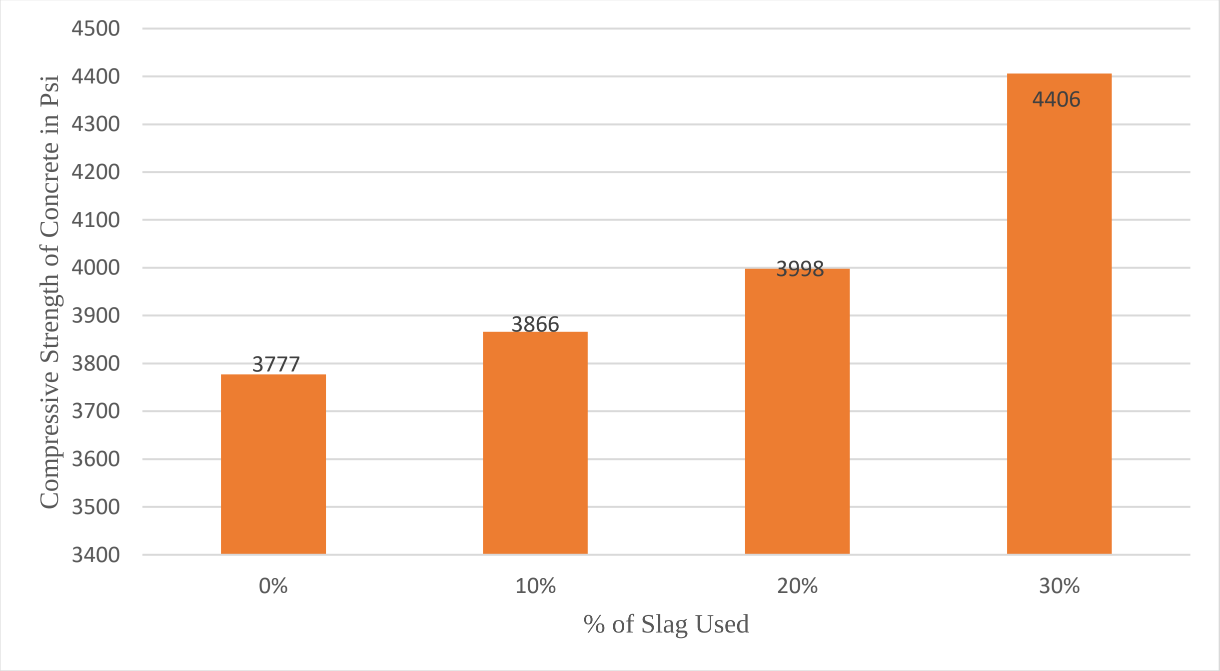

Figure: 4.18 Compressive Strength (Psi) VS % of Slag Used for 120min of Heat

Table 4.25: Concrete Compressive Strength Test Results (Temperature at 250°C)

Recycle Aggregate (Slag)	Cylinder-1 (Psi)	Cylinder-2 (Psi)	Cylinder-3 (Psi)	Average (Psi)	Time (Min)
0%	3657.06	3694.00	3878.70	3743	180
10%	3758.65	3952.58	3703.24	3805	180
20%	4063.40	4155.75	4026.46	4082	180
30%	4469.74	4580.56	4395.86	4482	180

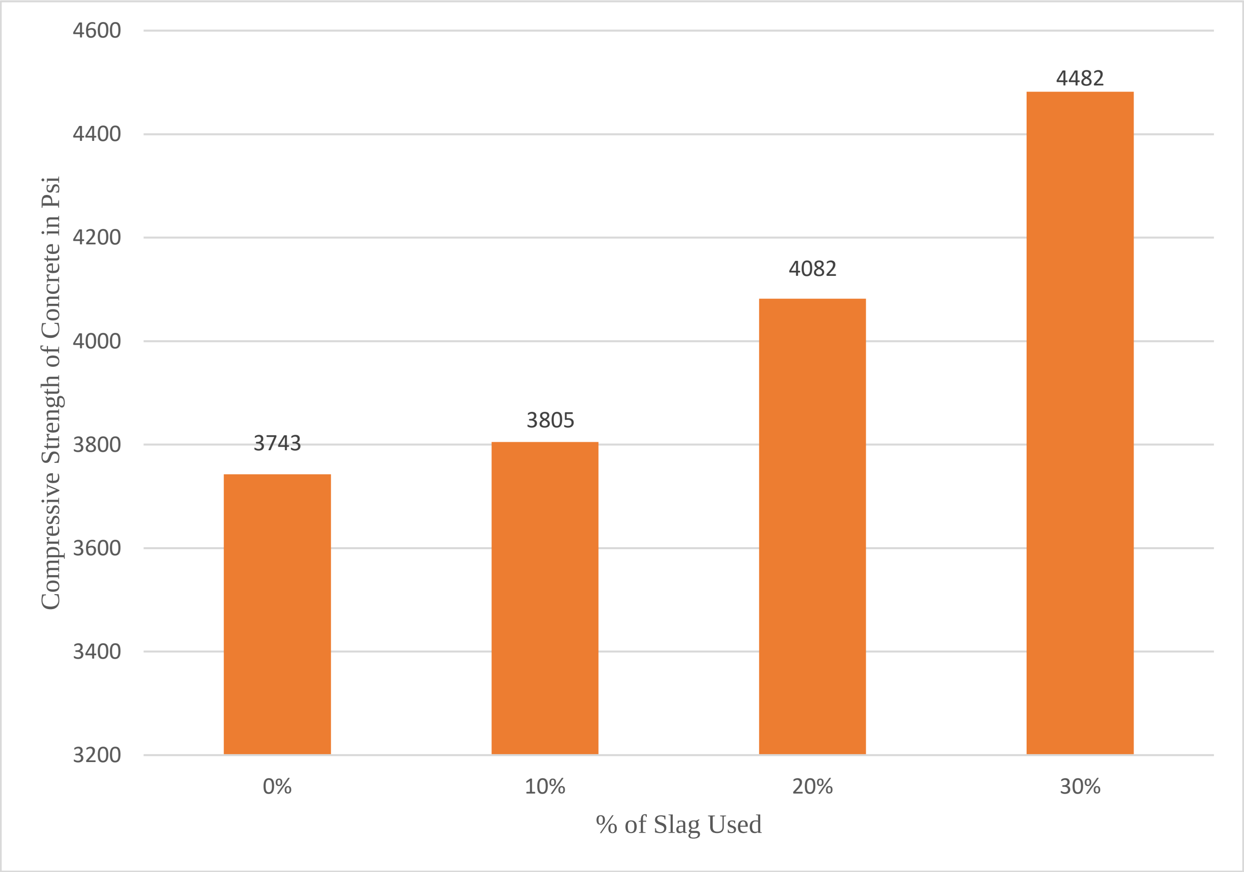

Figure 4-19 Compressive Strength (Psi) VS % of Slag Used for 180min of Heat

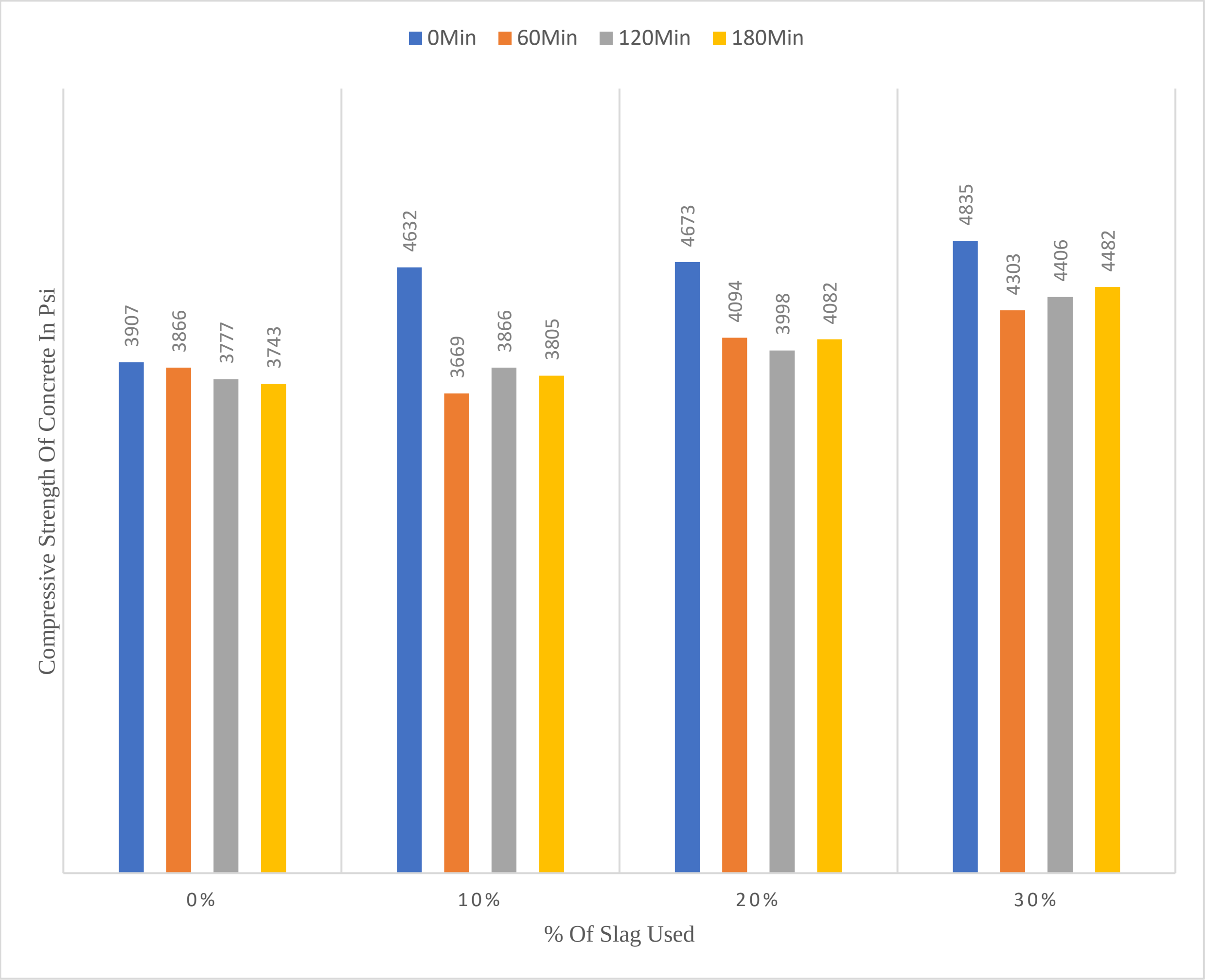

Figure 4-20 Compressive Strength (Psi) VS % of Slag Used Different Time

CHAPTER 5

CONCLUSIONS

5.1 Conclusions

The applicability of iron slag as a potential replacement of conventional fine aggregate in producing concrete is evaluated in this study. Different batches of concrete were produced using a blend of Sylhet sand as fine aggregate, iron slag as coarse aggregate, and stone chips as coarse aggregate. In the control batch, no iron slag was used. Three different batches of concrete were produced using iron slag with doses of 10%, 20%, and 30% by bulk volume of the required fine aggregate. A water-cement ratio of 0.45 was used to produce regular-strength concrete. The properties of the concrete were evaluated and compared with those of the batch where no iron slag was used. The properties of the concrete were evaluated and compared with those of the batch where no iron slag was used after heating.

The major findings from this study are as follows:

- A 30% replacement of fine aggregate with slag is observed to increase concrete compressive strength by 23.75% at normal temperatures.
- It was also found that the compressive strength of concrete increases by 41% with a 30% replacement of fine aggregate with slag up to 100 °C. After 100 °C when the temperature increases gradually, the compressive strength of the concrete slightly decreases or remains unchanged in some cases.
- It was observed that after 200 °C, the compressive strength of the concrete made with partially replaced slag as fine aggregate increases gradually in all cases. The compressive strength increases by 20% for 30% replacement of fine aggregate with slag.
- The amount of iron slag shows minimal effect on the workability of fresh concrete as measured by the slump values of 2 inches to 4 inches, 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 increases the compressive strength of concrete made with different percent’s of slag.
- A slight change in compressive strength was observed after burning at 100 °C, 150°C, 200°C, and 250°C of concrete prepared without iron slag and with different percentages of iron slag at different times.

Several aspects related to this study deserve additional attention. It is recommended to determine if the findings of this study are applicable to high-strength concrete as well. The durability of iron slag and its long-term effect on concrete should be investigated, which was beyond the scope of this study.

5.2 Limitations

- Inadequate lab facilities.
- Limitations of modern 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.

REFERENCES

[1] Mamlouk, M. S., and Zaniewski, J. P. (2014). Materials for civil and construction engineers. London, UK: Pearson.

[2] Das, B., Prakash, S., Reddy, P. S. R., and Misra, V. N. (2007). An overview of utilization of slag and sludge from steel industries. Resources, conservation and recycling, 50(1), 40-57.

[3] Jalil, A., Khitab, A., Ishtiaq, H., Bukhari, S. H., Arshad, M. T., and Anwar, W. (2019). Evaluation of steel industrial slag as partial replacement of cement in concrete. Civil Engineering Journal, 5(1), 181-190.

[4] Mishra, B. K., and Bharosh, R. (2018). Evaluation strength and durability characteristic of concrete use steel slag. Int. J. Adv. Res. Ideas Innov. Technol, 4, V4I5-V1376.

[5] Palanisamy, S. P., Maheswaran, G., Annaamalai, M. G. L., and Vennila, P. (2015). Steel slag to improve the high strength of concrete. Int J Chem Tech Res, 7, 2499-2505.

[6] Raza, K., Singh, A., and Patel, R. D. (2014). Strength analysis of concrete by using iron slag as a partial replacement of normal aggregate (coarse) in concrete. International Journal of Science and Research (IJSR), 3(10), 190-193.

[7] Padmapriya, R., Bupesh Raja, V. K., Kumar, V. G., and Baalamurugan, J. (2015). Study on replacement of coarse aggregate by steel slag and fine aggregate by manufacturing sand in concrete. International Journal of ChemTech Research, 8(4), 1721-1729.

[8] Thangaselvi, K. (2015). Strength and durability of concrete using steel slag as a partial replacement of coarse aggregate in concrete. International journal of advanced research trends in engineering and technology, 2(7), 1-6.

[9] ASTM, C. (2005). 136, Standard test method for sieve analysis of fine and coarse aggregates. American Society for Testing and Materials, Philadelphia, PA.

[10] ASTM C09 Committee. (2015). Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate. ASTM International: West Conshohocken, PA, USA.

[11] Standard, A. S. T. M. (2014). C128-15 (2015). Standard test method for relative density (specific gravity) and absorption of fine aggregate. ASTM International, West Conshohocken, PA.

[12] Astm, A. S. T. M. (2009). C29/C29M-09, Standard test method for bulk density (“Unit Weight”) and voids in aggregate. West Conshohocken: ASTM International.

[13] ASTM, C. (2010). 143/C143M: Standard Test Method for Slump of Hydraulic-Cement Concrete. Annual Book of ASTM Standards, 4, 89-91.

[14] ASTM, C. (2009). 39/C 39M-05" Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. Annual Book of ASTM Standards, 4.

[15] ASTM, C. (2003). Standard specification for concrete aggregates. Philadelphia, PA: American Society for Testing and Materials