COMPRESSIVE STRENGTH OPTIMIZATION OF CONCRETE USING VARYING PERCENTAGES OF STEEL SLAG AS SCM

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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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Semester Year

BOARD OF EXAMINERS

A thesis titled "**Compressive Strength Optimization of Concrete Using Varying Percentages of Steel Slag as SCM**" has been investigated using ordinary Portland cement grade **OPC 43** which is mainly used for General construction, residential buildings, and RCC works.

As we replaced steel slag as a SCM with the coarse sand to understand, and optimization the characteristics of compressive strength of concrete, how it shows the variation of defined results compare with the normal concrete.

The examination is done by Prodip Barmon (BCE 1701010078), Md Shaju Ahmed (CE240303352), Md. Hanif Bhuiyan (BCE1901016156) and Alam Hossain (CE2103024139), and come up with the practical results are given while investigate the concrete compressive strength with steel slag with satisfactory and partial fulfillment of Bachelor degree of Civil Engineering on 27 November 2025.

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1. Md. Baker Hossain Chairman

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2. Internal/External Member Member

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3. Internal/External Member Member

DECLARATION

It is hereby declared that this thesis/project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedicated

to

"Our Beloved Parents"

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ABSTRACT

Compressive strength is the most important mechanical property of concrete, as it determines the load-carrying capacity and overall performance of structural elements such as columns, beams, slabs, and foundations. Conventional concrete mainly relies on natural aggregates to achieve the required compressive strength. However, due to increasing construction activities, the availability of natural aggregates is gradually decreasing, and their extraction is causing environmental problems.

Steel-slag concrete is a type of concrete in which steel slag, an industrial by-product from the steel manufacturing process, is used as a partial or full replacement for natural aggregates. Steel slag has high hardness, angular particle shape, and rough surface texture, which can significantly influence the compressive behavior of concrete. These physical properties improve particle interlocking and enhance the bond between the cement paste and aggregate, leading to improved compressive strength.

Several experimental studies have shown that concrete containing steel slag can achieve compressive strength comparable to or higher than conventional concrete, especially at later curing ages. The higher strength development is often attributed to the dense packing of slag particles and the presence of reactive compounds in steel slag that may contribute to secondary hydration reactions. As a result, steel-slag concrete tends to show improved strength gain over time.

The compressive characteristics of steel-slag concrete are strongly affected by factors such as mix proportion, water-cement ratio, slag replacement level, curing age, and specimen size. At lower water-cement ratios, steel-slag concrete generally exhibits higher compressive strength due to reduced porosity.

Proper mix design and proportioning are necessary to ensure strength, stability, and durability. Therefore, investigating the compressive characteristics of steel-slag concrete with different mixing ratios provides valuable information for developing sustainable and high-performance concrete while reducing dependence on natural aggregates and promoting industrial waste utilization

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INTRODUCTION

1.1 Background and Motivations

There is many research topics for concrete compressive strength investigation, and comparing to the conventional concrete using in the RCC work. However, to improve the concrete compressive strength using different aggregate partially with the main three ingredients of concrete gives more sustainable concrete in terms of durability and strength. Innovation always a passion for any purpose who wants to do something new, and come up with a different idea, recommendation, self-satisfaction and more idea to gather. We chose this topic which is investigation of concrete compressive strength using steel slag to demonstrate whether the compressive behavior of concrete differ than the conventional concrete or not. The result shown, it is gained more strength in a particular mixing proportion with the conventional ingredients.

1.2 Research Objectives and Overview

The research objective is to determination of the concrete compressive strength using steel slag as a partial aggregate whether it is increase or decrease than the normal conventional concrete. The study investigated 7 days, 14 days and 28 days duration steel slag mix concrete compressive strength with different proportion.

i) Investigation of the compressive strength difference while using steel slag as concrete aggregate comparing to the normal M20 concrete.

ii) Investigate sand proportion relationship with steel slag which proportion is showing most effective and increasing compressive strength of the concrete.

iii) To identify the **optimum replacement level** of steel slag for maximum strength

iv) To compare strength performance with conventional concrete

1.3 Organization of the thesis

Materials Used

- Ordinary Portland Cement (OPC)
- Fine aggregate (natural sand)
- Coarse aggregate (natural stone)
- Steel slag (used as partial replacement of course/fine aggregate)
- Potable water

Mix Proportion and Experimental Program

- Control mix (0% steel slag replacement)
- Steel slag replacement levels (e.g., 10%, 20%, 30%, 40% and 50%)
- Constant water–cement ratio maintained
- Casting of standard concrete specimens (cylinders)
- Curing periods: 7, 14, and 28 days

Steel slag can be effectively used in concrete as an aggregate replacement Suitable for structural concrete within optimal replacement limits encourages sustainable and eco-friendly concrete production.

CHAPTER 2

Literature Review

2.1 Introduction

Steel-slag concrete is a type of concrete in which steel slag, an industrial by-product from the steel manufacturing process, is used as a partial or full replacement for natural aggregates. Steel slag has high hardness, angular particle shape, and rough surface texture, which can significantly influence the compressive behavior of concrete. These physical properties improve particle interlocking and enhance the bond between the cement paste and aggregate, leading to improved compressive strength.

Several experimental studies have shown that concrete containing steel slag can achieve compressive strength comparable to or higher than conventional concrete, especially at later curing ages. The higher strength development is often attributed to the dense packing of slag particles and the presence of reactive compounds in steel slag that may contribute to secondary hydration reactions. As a result, steel-slag concrete tends to show improved strength gain over time.

The compressive characteristics of steel-slag concrete are strongly affected by factors such as mix proportion, water-cement ratio, slag replacement level, curing age, and specimen size. At lower water-cement ratios, steel-slag concrete generally exhibits higher compressive strength due to reduced porosity. However, excessive steel slag content may lead to reduced workability and potential volume instability caused by free lime (CaO) and magnesium oxide (MgO) present in the slag.

Understanding the compressive behavior of steel-slag concrete is essential for determining its suitability for structural applications. Proper mix design and proportioning are necessary to ensure strength, stability, and durability. Therefore, investigating the compressive characteristics of steel-slag concrete with different mixing ratios provides valuable information for developing sustainable and high-performance concrete while reducing dependence on natural aggregates and promoting industrial waste utilization.

2.2 Cement

Cement is one of the most essential construction materials in modern infrastructure development, serving as the primary binding agent in concrete and mortar. Its ability to chemically react with water and harden into a durable mass has made it indispensable in the construction of buildings, bridges, pavements, dams, and other civil engineering structures. Among various types, Ordinary Portland Cement (OPC) remains the most widely used due to its consistent performance and compatibility with different aggregates and admixtures.

The manufacture of cement involves the controlled processing of raw materials such as limestone, clay, and iron ore, which are heated at high temperatures in a rotary kiln to form clinker. This clinker is then finely ground with a small amount of gypsum to regulate setting time. The resulting cement undergoes hydration when mixed with water, leading to the formation of calcium silicate hydrate (C–S–H) gel and calcium hydroxide, which are primarily responsible for the development of strength and durability in cementitious materials.

From a structural engineering perspective, cement plays a crucial role in determining the mechanical properties of concrete, particularly compressive strength, stiffness, and long-term durability. Factors such as cement composition, fineness, water–cement ratio, curing conditions, and environmental exposure significantly influence the performance of cement-based materials. Consequently, understanding the fundamental characteristics of cement is essential for the design of safe, durable, and sustainable concrete structures.

In recent years, growing concerns over environmental sustainability have intensified research into reducing the carbon footprint associated with cement production, which is responsible for a significant proportion of global carbon dioxide emissions. This has led to increased interest in supplementary cementitious materials such as fly ash, ground granulated blast furnace slag, and silica fume, which partially replace cement while improving durability and long-term performance. The development and application of blended cements represent an important step toward achieving sustainable construction practices.

2.3 Portland Cement

Ordinary Portland Cement (OPC) is mainly composed of:

- Lime (CaO) – strength and soundness
- Silica (SiO_2) – strength
- Alumina (Al_2O_3) – setting time
- Iron oxide (Fe_2O_3) – color and hardness
- **Gypsum ($CaSO_4 \cdot 2H_2O$)** – controls setting time

Types of Cement (Common)

- Ordinary Portland Cement (OPC)
- Portland Pozzolana Cement (PPC)
- Portland Slag Cement (PSC)
- Rapid Hardening Cement
- Sulphate Resisting Cement

- Low Heat Cement

Properties of Cement

- Fineness
- Setting time (initial & final)
- Soundness
- Strength (compressive strength)

Uses of Cement

- Concrete (buildings, bridges, pavements)
- Mortar (brickwork, plastering)
- Grouting and repairs
- Precast elements (blocks, pipes, slabs)

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2.4 Water Cement Ratio

The water–cement ratio (w/c ratio) is one of the most critical parameters governing the behavior and performance of cement-based materials, particularly concrete. It is defined as the ratio of the mass of water to the mass of cement in a concrete mix. First introduced by Duff A. Abrams, the water–cement ratio law establishes a fundamental relationship between the w/c ratio and the resulting strength of hardened concrete, stating that, for given materials and curing conditions, the strength of concrete is primarily dependent on the water–cement ratio.

From a materials science perspective, water is required to initiate the hydration process of cement, during which cement compounds react with water to form hydration products such as calcium silicate hydrate (C–S–H) gel, which is chiefly responsible for strength development. However, only a limited amount of water is chemically necessary for complete hydration. Excess water beyond this requirement creates capillary pores within the hardened cement paste, leading to increased porosity and reduced mechanical strength. Consequently, an increase in the water–cement ratio generally results in a decrease in compressive strength, stiffness, and durability of concrete.

The influence of the water–cement ratio extends beyond strength characteristics to affect workability, permeability, shrinkage, and long-term durability. A higher w/c ratio improves workability and ease of placement but compromises resistance to aggressive environmental conditions such as sulfate attack, chloride penetration, and freeze–thaw cycles. Conversely, a lower w/c ratio enhances strength and durability but may reduce workability, necessitating the use of chemical admixtures such as superplasticizers to achieve adequate consistency without increasing water content.

In structural applications, the selection of an appropriate water–cement ratio is essential to meet both mechanical performance and durability requirements specified by design codes and standards. Codes such as ACI, BS, and IS prescribe maximum allowable water–cement ratios for different exposure conditions to ensure long-term serviceability and structural safety. Therefore, controlling the water–cement ratio during mix design and construction is a key aspect of quality control in concrete production.

2.5 Aggregates

Concrete aggregates constitute the largest proportion of concrete by volume and play a vital role in determining its mechanical, physical, and durability characteristics. Aggregates typically occupy about 60–75% of the total volume of concrete, making their quality, grading, shape, texture, and mineralogical composition critical to the overall performance of concrete. They act not only as an inert filler but also as a structural skeleton that provides dimensional stability and resistance to load-induced stresses.

2.5.1 Coarse Aggregate

Coarse aggregate is a fundamental constituent of concrete, forming the primary load-bearing skeleton within the composite material. It generally consists of particles retained on a 4.75 mm sieve and occupies a significant proportion of the concrete volume, typically ranging from 40% to 50%. Due to its dominant presence, the physical, mechanical, and mineralogical properties of coarse aggregate have a substantial influence on the strength, stiffness, durability, and overall performance of concrete.

The characteristics of coarse aggregates—such as particle size, shape, surface texture, strength, and grading—directly affect both fresh and hardened concrete behavior. Angular and rough-textured aggregates tend to provide better mechanical interlocking and stronger bonding with the cement paste, thereby enhancing compressive and tensile strength. However, such aggregates may increase water demand and reduce workability. In contrast, rounded aggregates improve workability but may lead to lower strength due to reduced interparticle friction and weaker paste–aggregate bond

Figure: Crushed Stone Chips

2.5.2 Fine Aggregate – Steel Slag

Fine aggregate plays a crucial role in concrete by filling the voids between coarse aggregate particles and contributing to the workability, cohesiveness, and overall durability of the mixture. Traditionally, natural river sand has been used as fine aggregate; however, increasing environmental concerns, depletion of natural sand resources, and restrictions on river sand mining have encouraged the exploration of alternative materials. Among these alternatives, steel slag has emerged as a promising industrial by-product for use as fine aggregate in concrete.

Steel slag is generated during the steel-making process and consists primarily of oxides of calcium, silicon, iron, and magnesium. When processed and properly graded, steel slag can be utilized as fine aggregate in concrete. Its angular shape and rough surface texture enhance mechanical interlocking and improve the bond between the aggregate and cement paste, potentially leading to higher strength and better abrasion resistance compared to conventional fine aggregates.

Figure: Steel slag

2.5.3 Fine Aggregate – Coarse Sand

Fine aggregate is an essential component of concrete, responsible for filling the voids between coarse aggregate particles and contributing to the workability, cohesiveness, and finish ability of the mix. Among various types of fine aggregates, coarse sand—characterized by relatively larger particle sizes within the fine aggregate range—plays a significant role in improving the packing density and mechanical performance of concrete. Coarse sand typically consists of particles passing the 4.75 mm sieve and retained on the 600 µm or 300 µm sieve, depending on grading classification standards. Its well-graded nature reduces the void content in concrete, thereby decreasing the required cement paste volume and enhancing the economy and durability of the mixture. Compared to finer sands, coarse sand generally improves workability by reducing water demand while maintaining adequate cohesiveness, making it suitable for structural concrete applications.

Figure: Fine Aggregate – Coarse Sand

CHAPTER 3: METHODOLOGY

3.1 Introduction

This presents the experimental methodology adopted to evaluate the **compressive strength characteristics of concrete incorporating steel slag** as a partial replacement of conventional fine aggregate and/or supplementary cementitious material (SCM). The methodology is designed to systematically assess the influence of varying steel slag replacement levels on the strength performance of concrete under controlled laboratory conditions.

The experimental program includes **material characterization**, **mix proportioning**, **specimen preparation**, **curing**, and **compressive strength testing** in accordance with relevant standards such as **ASTM** and **IS/BS codes**. Steel slag obtained from a steel manufacturing plant is processed, graded, and incorporated into concrete mixes at predetermined replacement percentages, while a conventional concrete mix is used as a control specimen for comparison.

Concrete specimens, typically in the form of **cylinders or cubes**, are cast for each mix proportion and cured under standard water-curing conditions. Compressive strength tests are conducted at specified curing ages (such as 7, 14, and 28 days) using a **Universal Testing Machine (UTM)**. The recorded test results are analyzed to determine strength development trends, optimum steel slag content, and the overall feasibility of steel slag as a sustainable construction material.

3.2 Methodology Overview

The methodology adopted in this study aims to investigate the compressive strength behavior of concrete incorporating steel slag as a partial replacement of conventional materials. The experimental program is structured to ensure consistency, accuracy, and compliance with standard testing procedures.

3.3 Preparation of Cylinder

The preparation of concrete cylinders for compressive strength testing was carried out in accordance with relevant standards such as ASTM C31/C31M and BS EN 12390. Proper specimen preparation is essential to ensure accurate and reproducible test results.

Fresh concrete was first prepared using the specified mix proportions and mixed until a uniform and homogeneous consistency was achieved. Immediately after mixing, the concrete was placed into clean, rigid, and non-absorbent cylindrical molds with standard dimensions of 150 mm diameter and 300 mm height (or 100 mm × 200 mm, where applicable). The inner surfaces of the molds were lightly oiled prior to casting to facilitate easy removal of specimens after setting.

Fig: Preparation of Cylinder (150mm x 300mm)

3.4 Concrete Mixing

All constituent materials, including cement, fine aggregates, coarse aggregates, and water, were measured accurately according to the specified mix proportions. Prior to mixing, aggregates were brought to a **saturated surface dry (SSD)** condition to minimize variations in effective water content. The mixing process was conducted using a mechanical mixer to ensure consistency and reduce human error.

The mixing process was continued until a uniform, workable, and cohesive concrete mixture was achieved, typically requiring **3–5 minutes** of total mixing time. Visual inspection was carried out to check for signs of segregation or excessive bleeding. Immediately after mixing, fresh concrete was tested for workability, and specimens were cast without delay to avoid loss of consistency.

The mixing proportion is used in this study are 1:1.5:3 and the coarse sand with steel slag mixing proportion are used 50%/50%, 60%/40, 70%/30%, 80%/20%, 90%/10% and 100%/0% respectively.

3.5 Casting of Cylinder

Concrete was placed into the molds in three equal layers for 150 mm × 300 mm cylinders. Each layer was compacted using 25 strokes of a standard tamping rod to eliminate entrapped air and ensure proper consolidation. For mixes with low workability or when specified, mechanical vibration was applied using a table vibrator, taking care to avoid segregation or excessive bleeding. After the final layer, the top surface was finished using a trowel to produce a smooth and level surface flush with the top of the mold.

Following casting, the specimens were covered with plastic sheets to prevent moisture loss and stored in a controlled environment at a temperature of approximately 20 ± 2°C for the first 24 hours. After this initial curing period, the concrete cylinders were carefully demolded and marked for identification.

The demolded specimens were then transferred to a curing tank containing clean water maintained at 20 ± 2°C until the designated testing ages, typically 7, 14, and 28 days. Proper curing was maintained to ensure full hydration of cement and to achieve representative compressive strength values.

3.6 Curing and Marking of Cylinder

Curing is essential for **hydration of cement**, which is a chemical reaction between cement and water; without sufficient moisture, concrete cannot reach its designed strength or durability.

Proper curing can **increase strength by 20–50%** compared to uncured concrete. Reduces **permeability**, preventing water leakage and chemical attack. Ensures **long-term performance** of structures.
Curing of concrete is the process of maintaining adequate **moisture, temperature, and time** immediately after placing and finishing concrete, to allow proper hydration of cement and development of desired strength and durability.

Alongside with the curing work, the prepared cylinder has marked by written (especially date) to perform test in determined days.

Figure: Concrete Cylinder marking

3.7 UTM Machine and Crushing of Cylinder

A Universal Testing Machine (UTM) is a mechanical device used to test the compressive, tensile, and bending strength of materials, including concrete.
To determine the compressive strength of concrete, which indicates the quality of concrete mix used.

Remove the cylinder from curing tank. Wipe surface to remove excess water. measure and record dimensions (diameter & height). Ensure flat and even ends using. Capping with sulfur mortar (preferred) or grinding / machining (for small labs). Proper capping ensures uniform load distribution.

Placing in UTM:
Position the cylinder vertically between the platen of the UTM.
Ensure it is centered and aligned to avoid eccentric loading.

Loading:
Apply gradually increasing load (usually 0.6–0.8 MPa/sec).
Continue until the cylinder fails or cracks.
Recording Results:
Maximum load (P) at failure is recorded

Figure: Concrete Cylinder Crushing by UTM

3.8 Compressive Strength – Record Book Keeping

Proper record keeping is essential to ensure accuracy, reliability, and traceability of compressive strength test results. During the experimental program, all relevant details related to specimen preparation, curing, and testing were systematically recorded in a compressive strength record book.
The record book included information such as mix identification number, percentage of steel slag used as SCM, water–cement ratio, specimen dimensions, casting date, curing conditions, and testing age (7, 14, and 28 days). Each concrete specimen was assigned a unique identification code to avoid ambiguity and ensure consistency throughout the testing process.

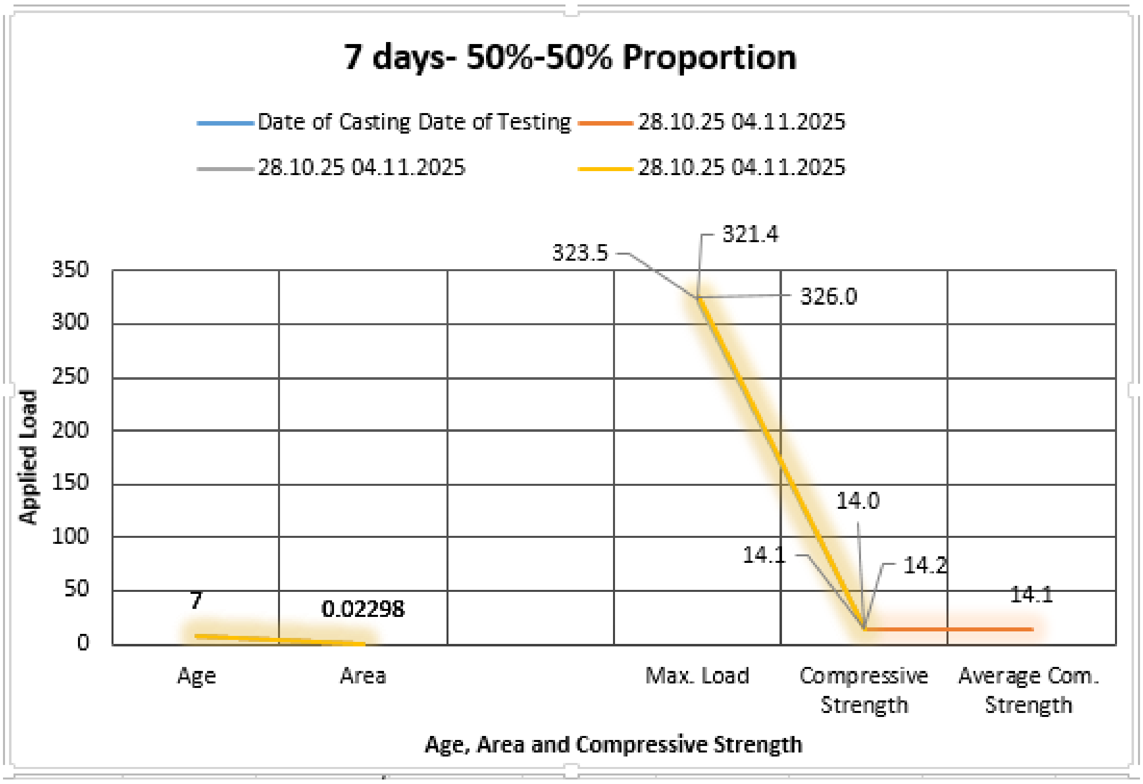
CHAPTER 4: RESULTS AND OPTIMIZATION

4.1.1 Result for 7 days (Coarse Sand 50%+ Steel Slag 50%) - Data Table: 01

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	04.11.2025	7	0.02298	323.5	14.1	14.1	
2	Cylinder	2	28.10.25	04.11.2025	7	0.02298	321.4	14.0		
3	Cylinder	3	28.10.25	04.11.2025	7	0.02298	326.0	14.2		

NOTE: -1 MN/m² = 145.038 psi and
1KN = 224.809 lb.
For Diameter / Area determination:
refer to ASTM-C-39

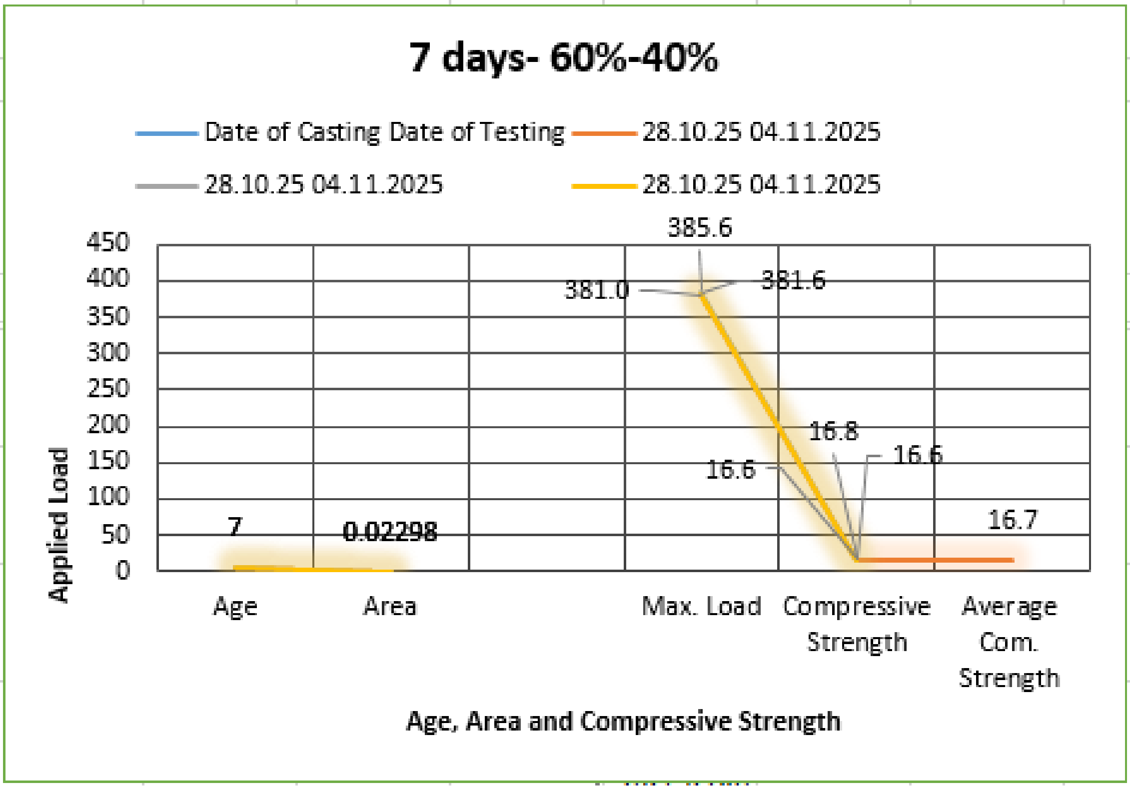


4.2.1 Result for 7 days (Coarse Sand 60%+ Steel Slag 40%) – Data Table:02

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m²)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	04.11.2025	7	0.02298	381.0	16.6	16.7	
2	Cylinder	2	28.10.25	04.11.2025	7	0.02298	385.6	16.8		
3	Cylinder	3	28.10.25	04.11.2025	7	0.02298	381.6	16.6		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.
For Diameter / Area determination: refer to ASTM-C-39

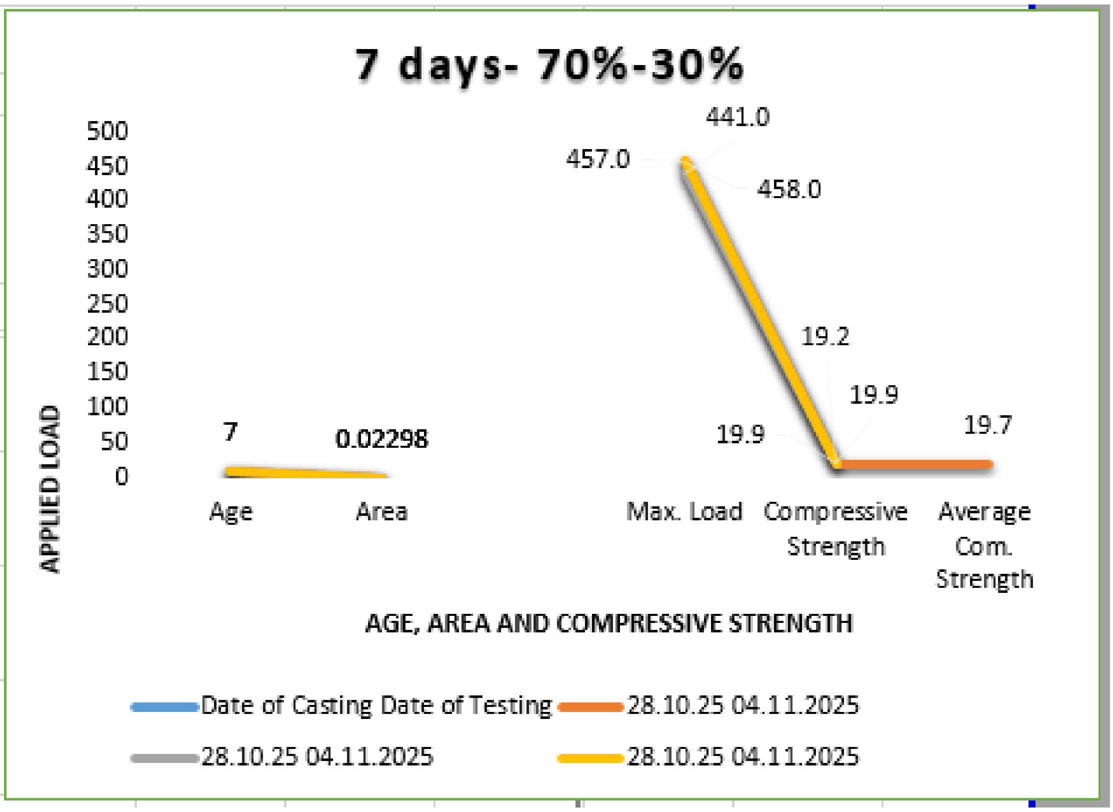


4.3.1 Result for 7 days (Coarse Sand 70%+ Steel Slag 30%) – Data Table: 03

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	04.11.2025	7	0.02298	457.0	19.9	19.7	
2	Cylinder	2	28.10.25	04.11.2025	7	0.02298	441.0	19.2		
3	Cylinder	3	28.10.25	04.11.2025	7	0.02298	458.0	19.9		

NOTE:-1 MN/m^2 = 145.038 psi and 1KN = 224.809 lb.
For Diameter / Area determination: refer to ASTM-C-39

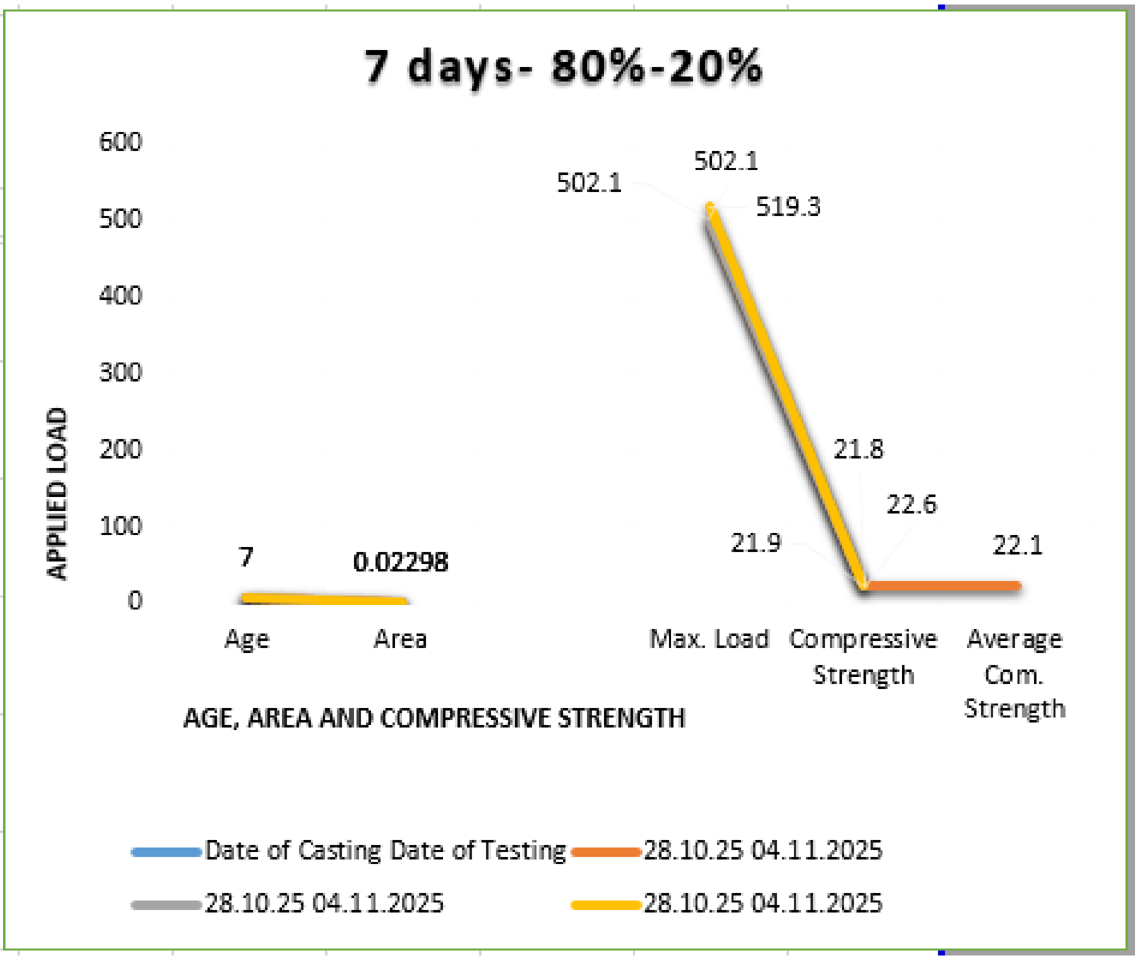


4.4.1 Result for 7 days (Coarse Sand 80%+ Steel Slag 20%) – Data Table:04

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	04.11.2025	7	0.02298	502.1	21.9	22.1	
2	Cylinder	2	28.10.25	04.11.2025	7	0.02298	502.1	21.8		
3	Cylinder	3	28.10.25	04.11.2025	7	0.02298	519.3	22.6		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.
For Diameter / Area determination: refer to ASTM-C-39



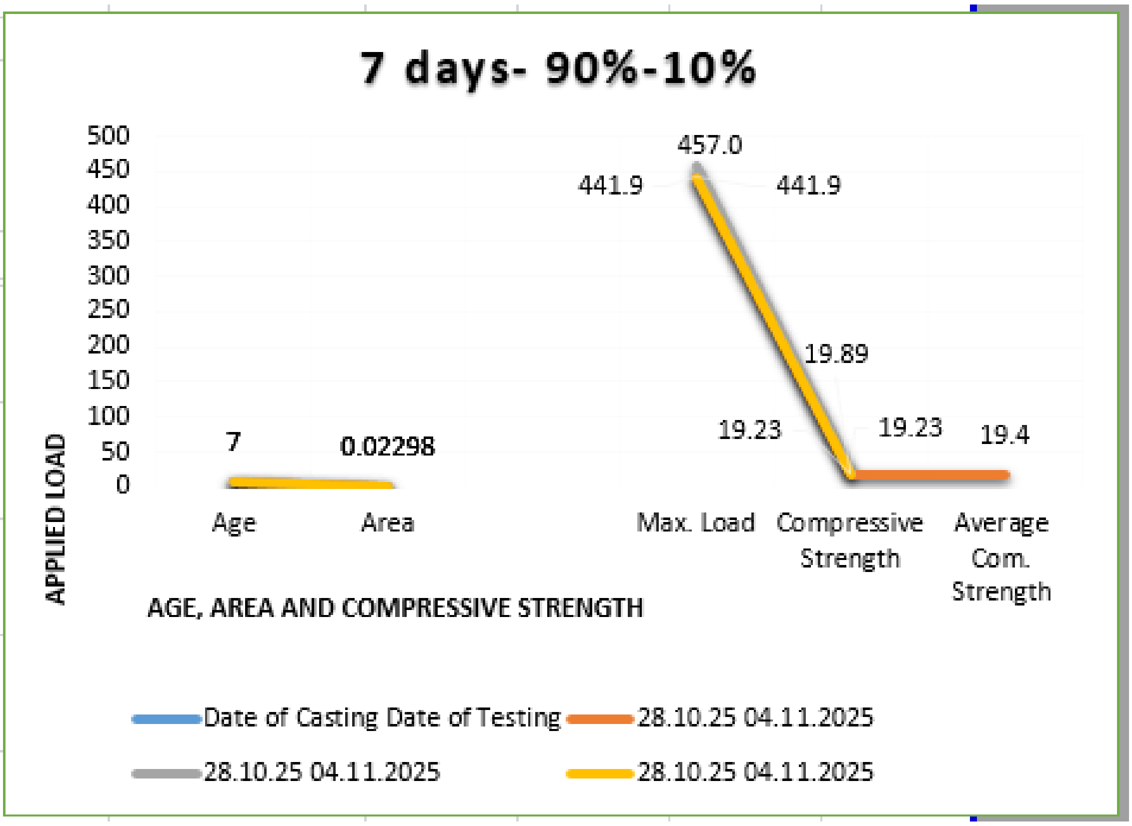
4.5.1 Result for 7 days (Coarse Sand 90%+ Steel Slag 10%) – Data Table: 05

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	04.11.2025	7	0.02298	441.9	19.23		
2	Cylinder	2	28.10.25	04.11.2025	7	0.02298	457.0	19.89	19.4	
3	Cylinder	3	28.10.25	04.11.2025	7	0.02298	441.9	19.23		

NOTE: -1 MN/m^2 = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



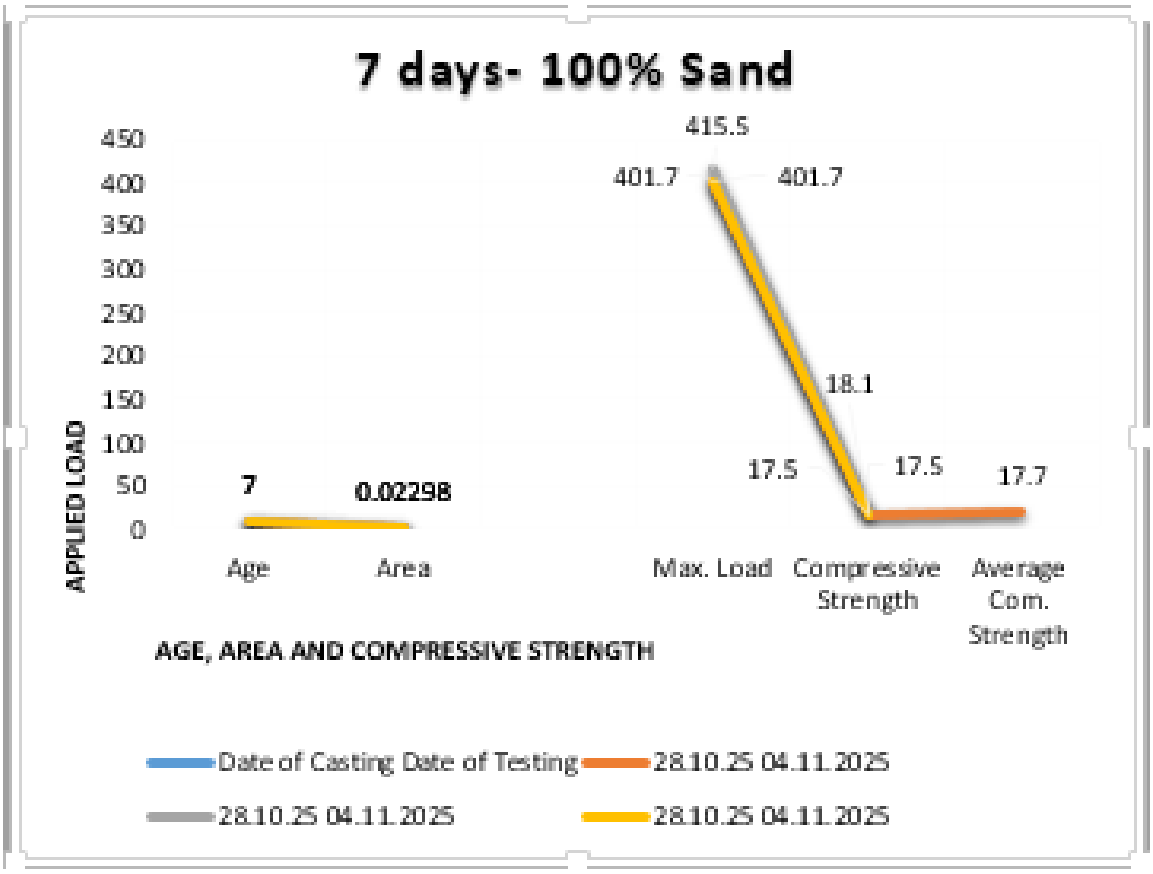
4.6.1 Result for 7 days (Coarse Sand 100%) -Data Table: 06

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	04.11.2025	7	0.02298	401.7	17.5	17.7	
2	Cylinder	2	28.10.25	04.11.2025	7	0.02298	415.5	18.1		
3	Cylinder	3	28.10.25	04.11.2025	7	0.02298	401.7	17.5		

NOTE: -1 MN/m^2 = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



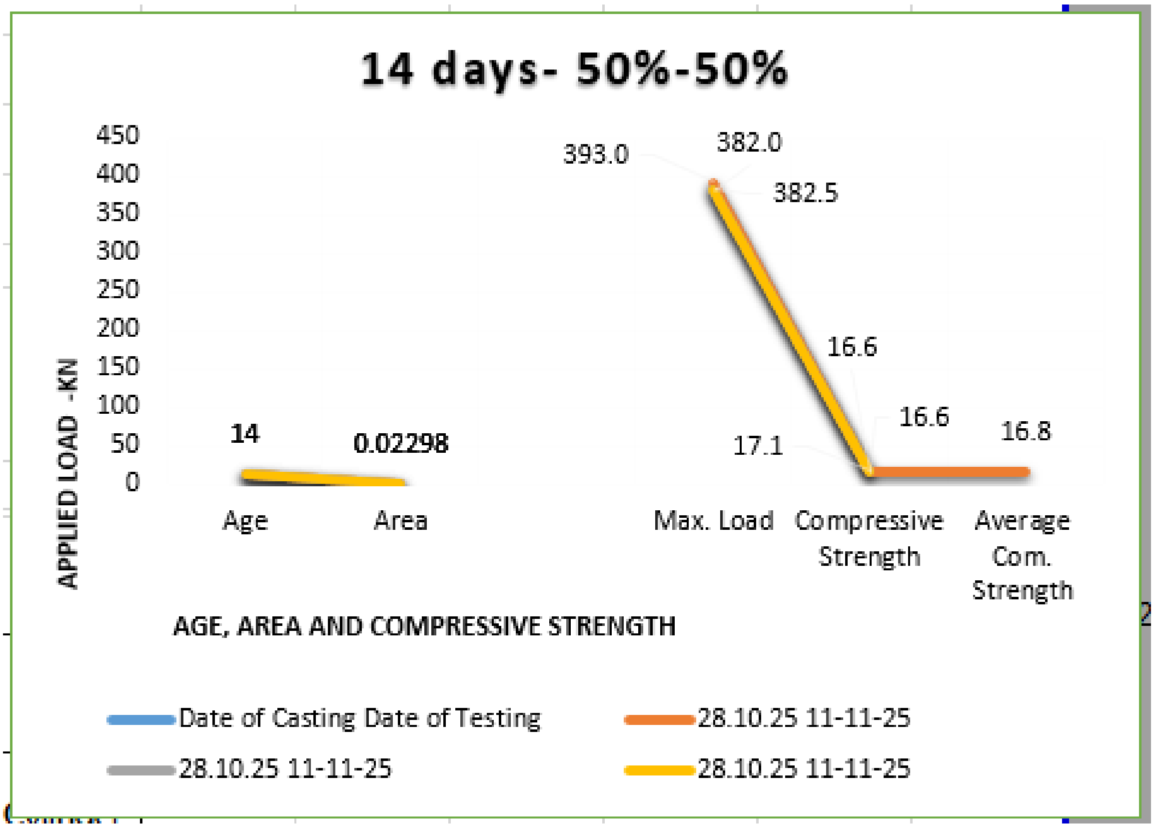
4.1.2 Result for 14 days (Coarse Sand 50%+ Steel Slag 50%) – Data Table:07

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/11/2025	14	0.02298	393.0	17.1	**16.8**	
2	Cylinder	2	28.10.25	11/11/2025	14	0.02298	382.0	16.6		
3	Cylinder	3	28.10.25	11/11/2025	14	0.02298	382.5	16.6		

NOTE: -1 MN/m^2 = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39

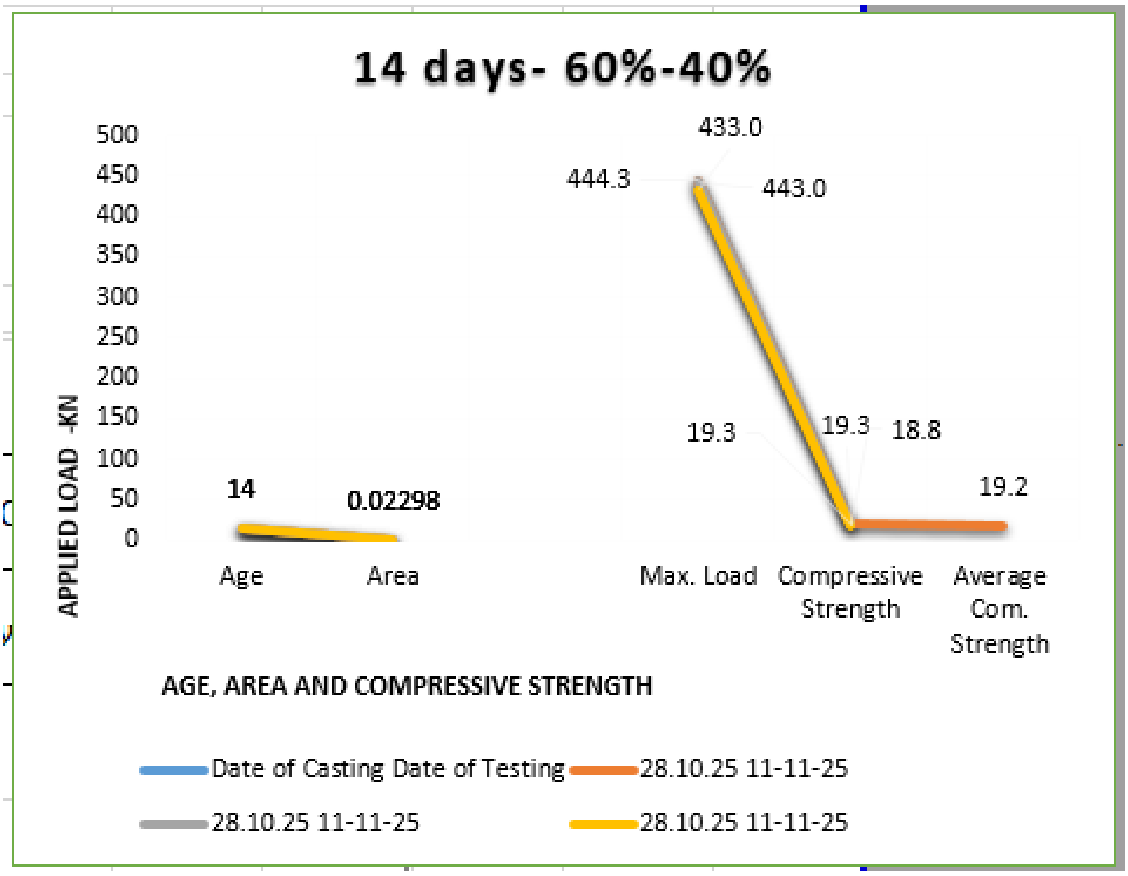


4.2.2 Result for 14 days (Coarse Sand 60%+ Steel Slag 40%) – Data Table:08

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m²)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/11/2025	14	0.02298	444.3	19.3	19.2	
2	Cylinder	2	28.10.25	11/11/2025	14	0.02298	443.0	19.3		
3	Cylinder	3	28.10.25	11/11/2025	14	0.02298	433.0	18.8		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.
For Diameter / Area determination: refer to ASTM-C-39



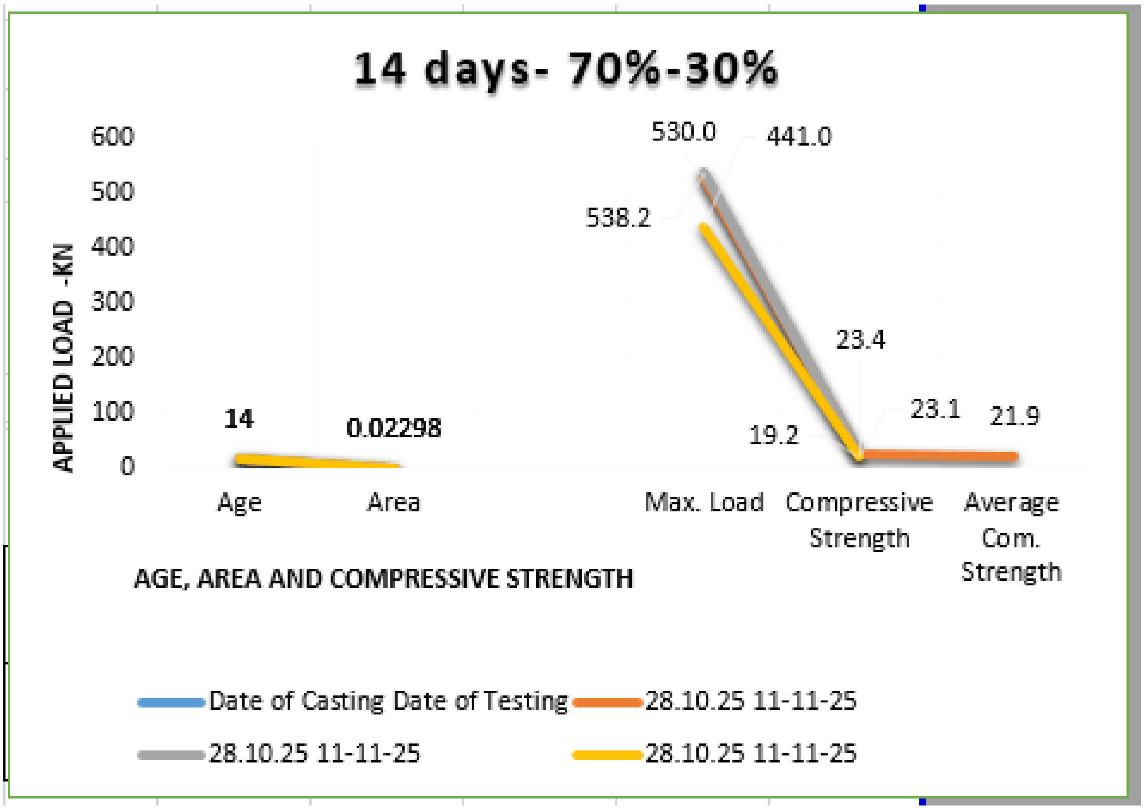
4.3.2 Result for 14 days (Coarse Sand 70%+ Steel Slag 30%) – Data Table: 09

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m²)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/11/2025	14	0.02298	530.0	23.1	21.9	
2	Cylinder	2	28.10.25	11/11/2025	14	0.02298	538.2	23.4		
3	Cylinder	3	28.10.25	11/11/2025	14	0.02298	441.0	19.2		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



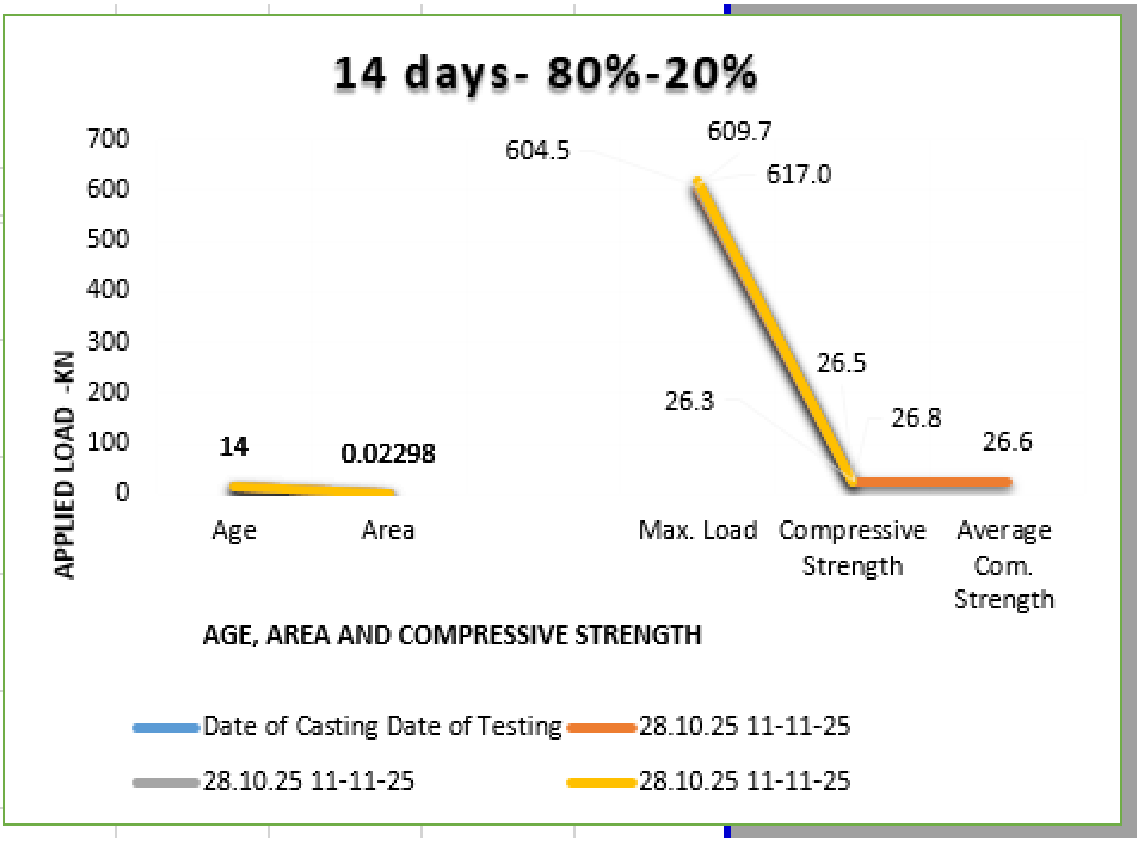
4.4.2 Result for 14 days (Coarse Sand 80%+ Steel Slag 20%) – Data Table: 10

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/11/2025	14	0.02298	604.5	26.3	26.6	
2	Cylinder	2	28.10.25	11/11/2025	14	0.02298	609.7	26.5		
3	Cylinder	3	28.10.25	11/11/2025	14	0.02298	617.0	26.8		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



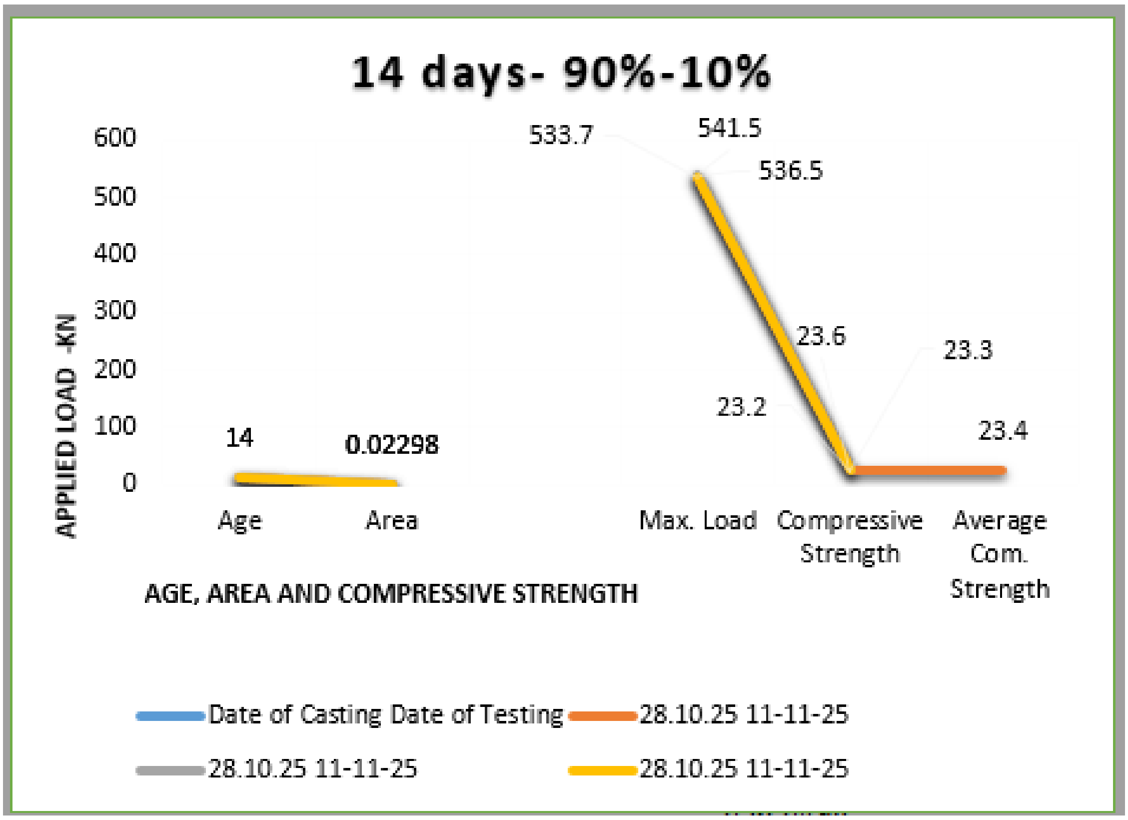
4.5.2 Result for 14 days (Coarse Sand 90%+ Steel Slag 10%) -Data Table: 11

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/11/2025	14	0.02298	533.7	23.2	23.4	
2	Cylinder	2	28.10.25	11/11/2025	14	0.02298	541.5	23.6		
3	Cylinder	3	28.10.25	11/11/2025	14	0.02298	536.5	23.3		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39

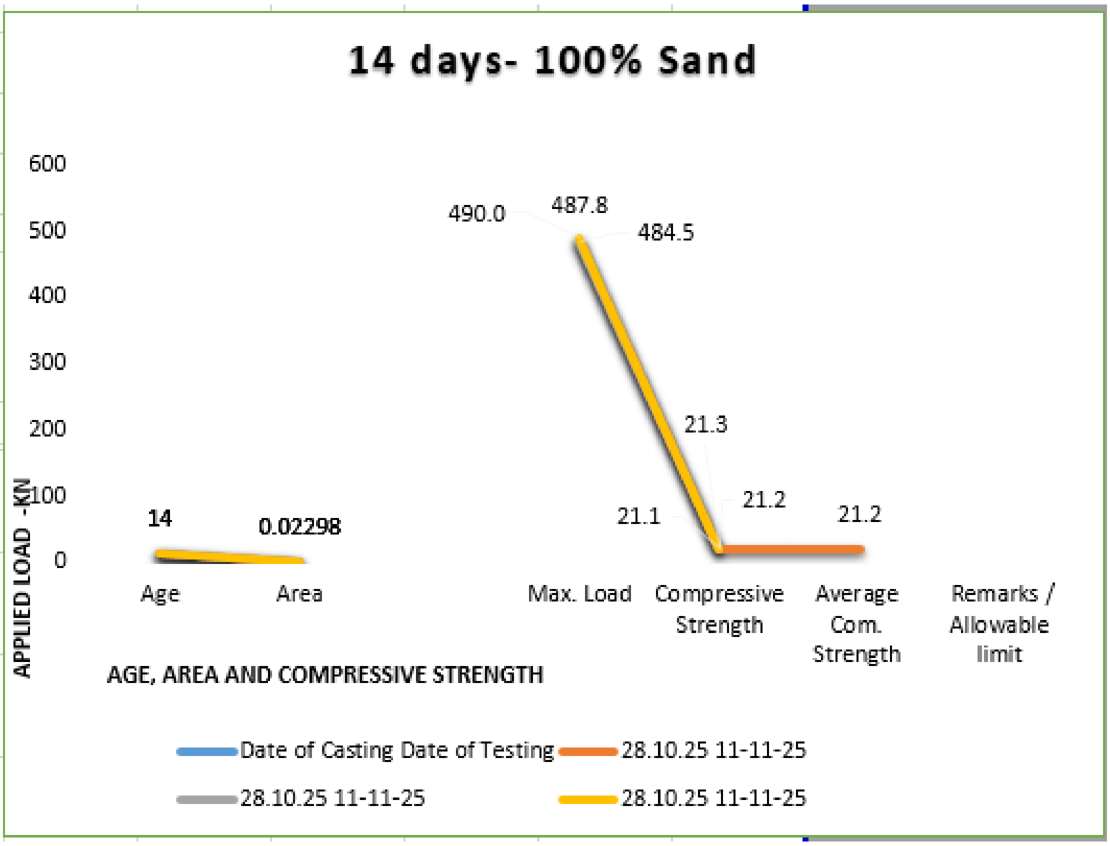


4.6.2 Result for 14 days (Coarse Sand 100%)- Data Table:12

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m²)	(KN)	Mpa	Mpa	
1	Cube	1	28.10.25	11/11/2025	14	0.02298	487.8	21.2	21.2	
2	Cube	2	28.10.25	11/11/2025	14	0.02298	484.5	21.1		
3	Cube	3	28.10.25	11/11/2025	14	0.02298	490.0	21.3		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.
For Diameter / Area determination: refer to ASTM-C-39



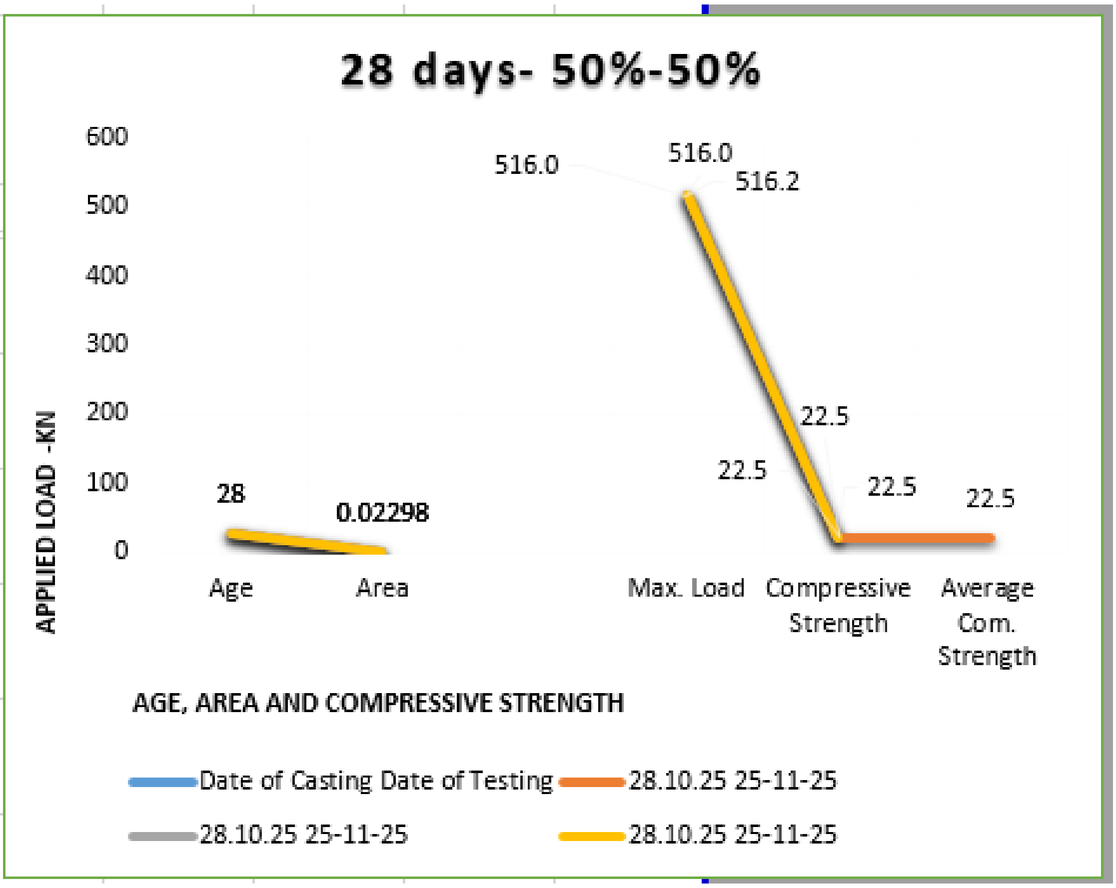
4.1.3 Result for 28 days (Coarse Sand 50%+ Steel Slag 50%) – Data Table:13

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m²)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/25/2025	28	0.02298	516.0	22.5	22.5	
2	Cylinder	2	28.10.25	11/25/2025	28	0.02298	516.0	22.5		
3	Cylinder	3	28.10.25	11/25/2025	28	0.02298	516.2	22.5		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



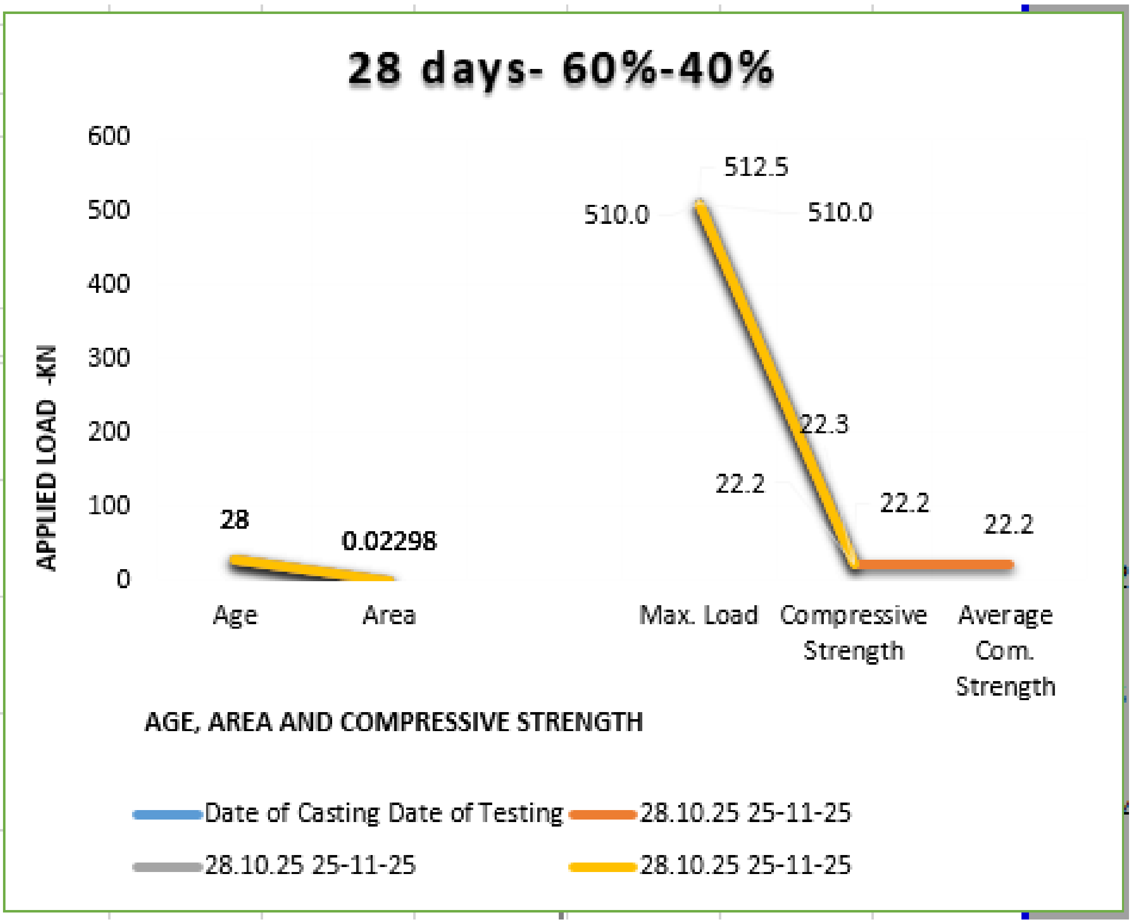
4.2.3 Result for 28 days (Coarse Sand 60%+ Steel Slag 40%) – Data Table:14

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/25/2025	28	0.02298	510.0	22.2	22.2	
2	Cylinder	2	28.10.25	11/25/2025	28	0.02298	512.5	22.3		
3	Cylinder	3	28.10.25	11/25/2025	28	0.02298	510.0	22.2		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



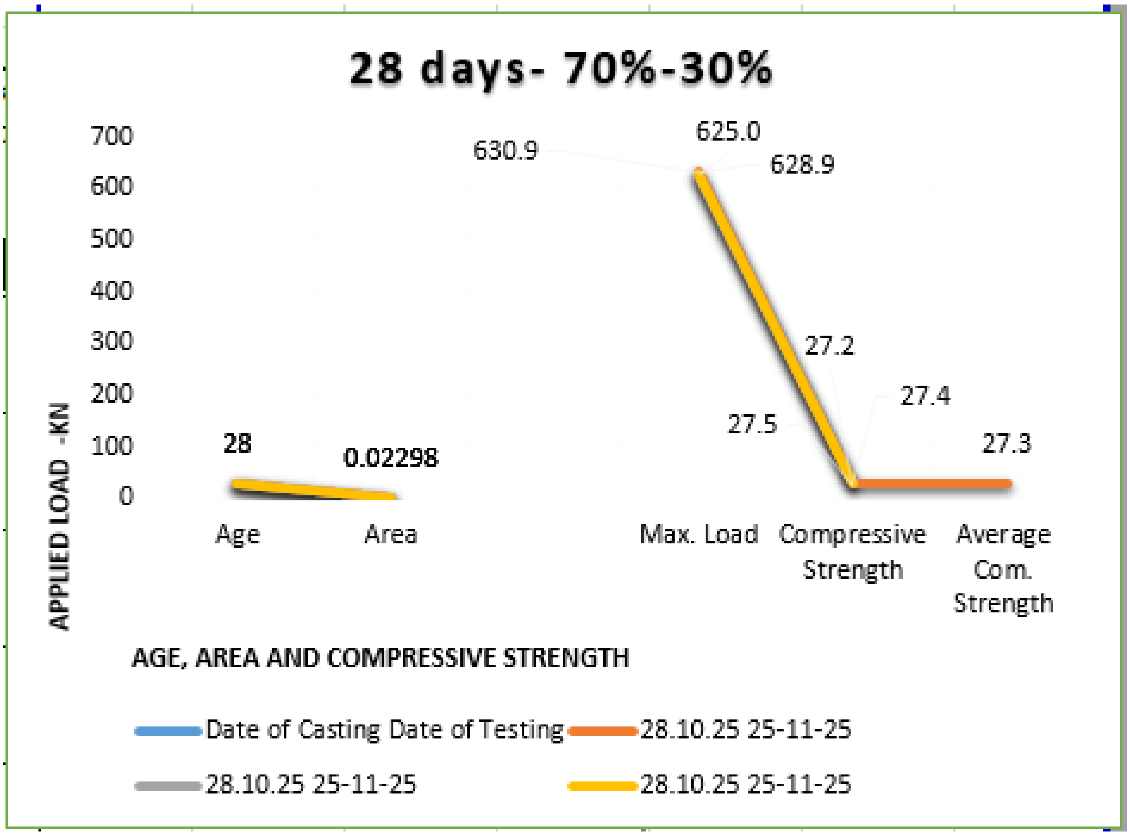
4.3.3 Result for 28 days (Coarse Sand 70%+ Steel Slag 30%) – Data Table:15

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m²)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/25/2025	28	0.02298	630.9	27.5	27.3	
2	Cylinder	2	28.10.25	11/25/2025	28	0.02298	625.0	27.2		
3	Cylinder	3	28.10.25	11/25/2025	28	0.02298	628.9	27.4		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



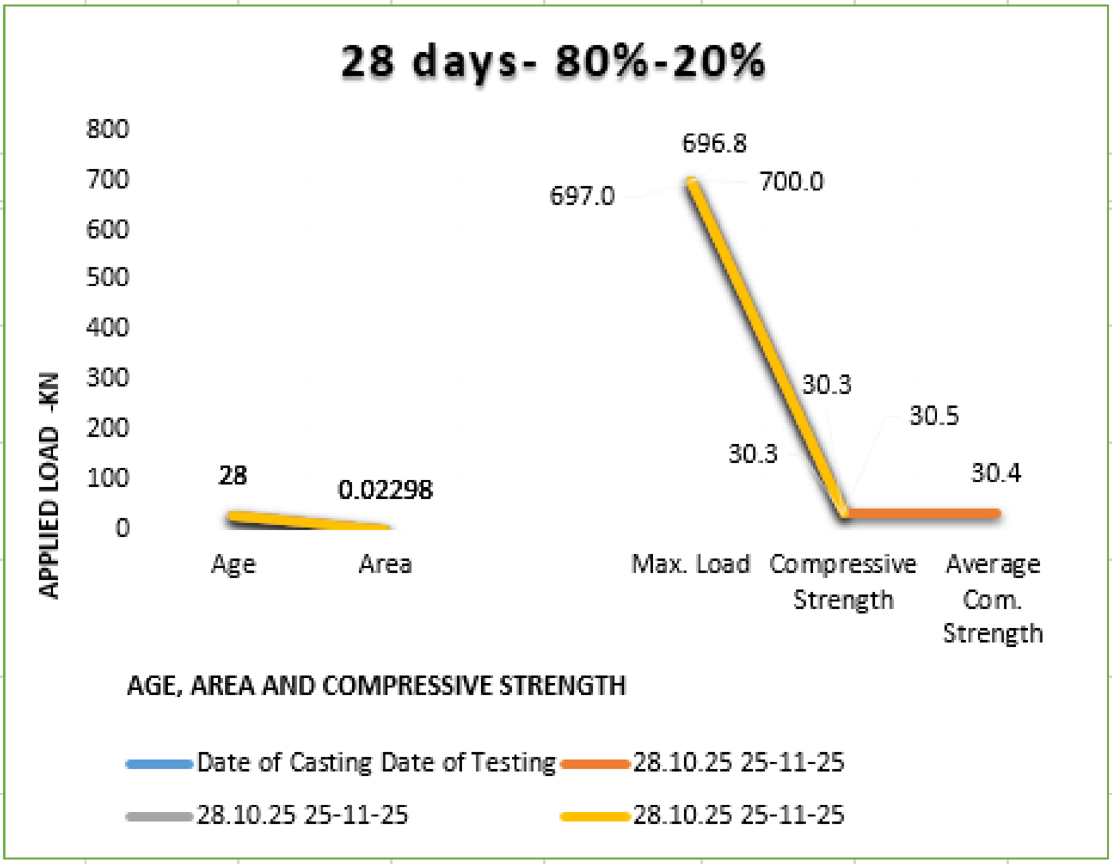
4.4.3 Result for 28 days (Coarse Sand 80%+ Steel Slag 20%) – Data Table:16

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/25/2025	28	0.02298	697.0	30.3	30.4	
2	Cylinder	2	28.10.25	11/25/2025	28	0.02298	696.8	30.3		
3	Cylinder	3	28.10.25	11/25/2025	28	0.02298	700.0	30.5		

NOTE: -1 MN/m² = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



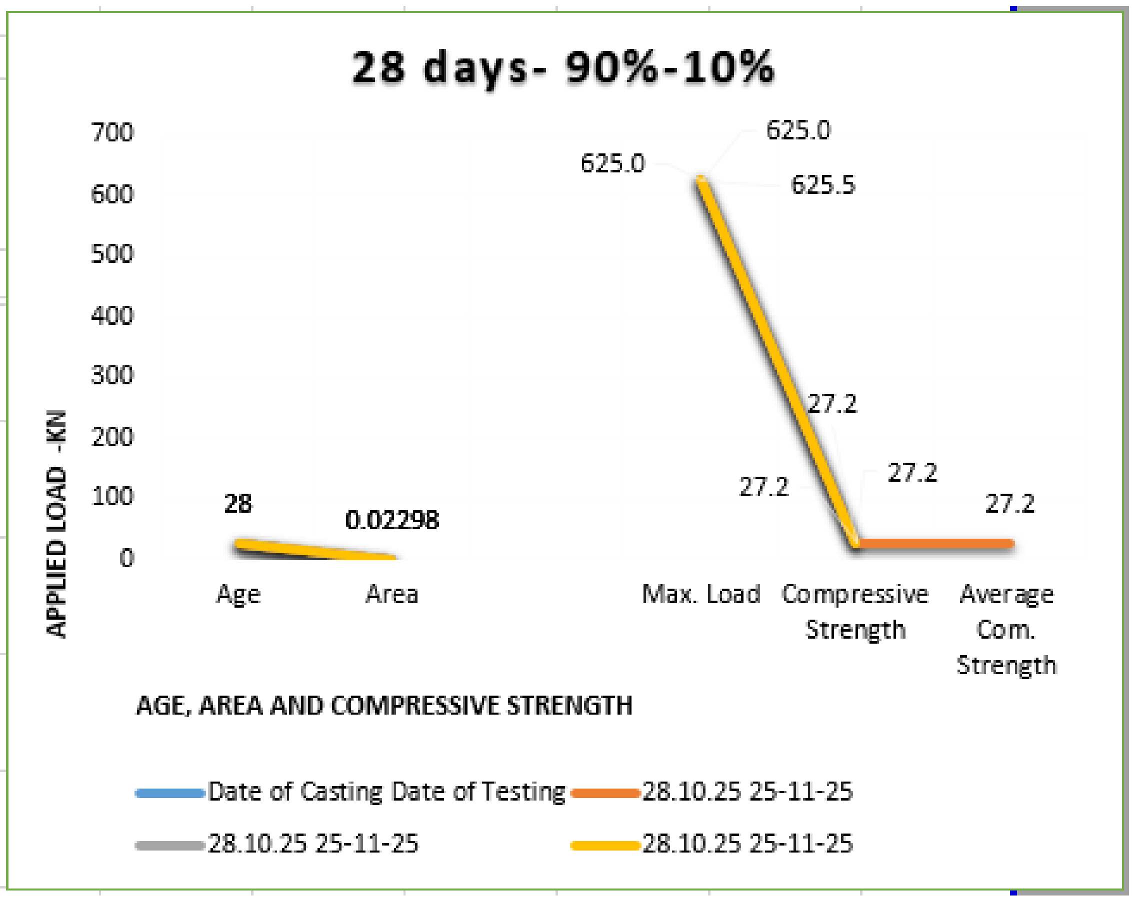
4.5.3 Result for 28 days (Coarse Sand 90%+ Steel Slag 10%) – Data Table:17

COMPRESSIVE STRENGTH TEST OF CONCRETE

Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/25/2025	28	0.02298	625.0	27.2	27.2	
2	Cylinder	2	28.10.25	11/25/2025	28	0.02298	625.0	27.2		
3	Cylinder	3	28.10.25	11/25/2025	28	0.02298	625.5	27.2		

NOTE: -1 MN/m^2 = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39



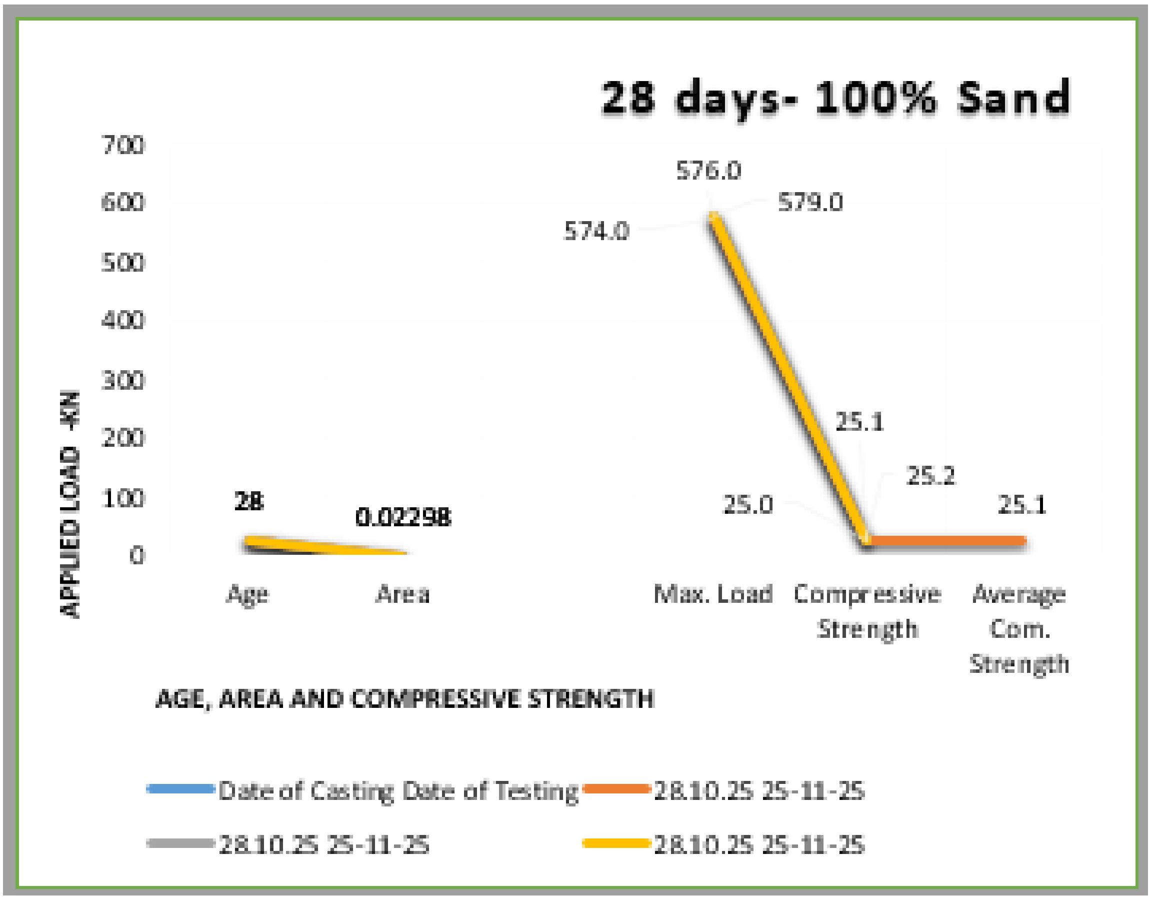
4.6.3 Result for 28 days (Coarse Sand 100%) – Data Table:18

COMPRESSIVE STRENGTH TEST OF CONCRETE

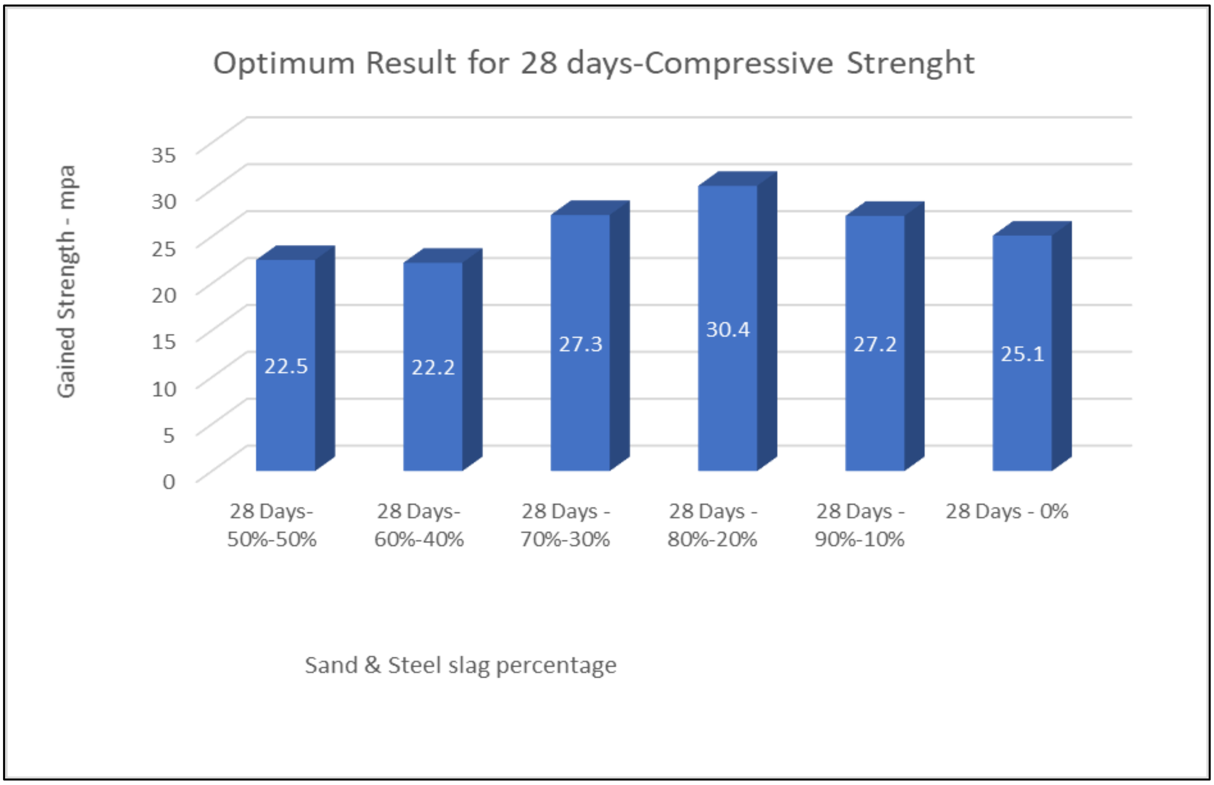
Specimen no.	Type of Specimen	component	Date of Casting	Date of Testing	Age	Area	Max. Load	Compressive Strength	Average Com. Strength	Remarks / Allowable limit
					days	(m^2)	(KN)	Mpa	Mpa	
1	Cylinder	1	28.10.25	11/25/2025	28	0.02298	574.0	25.0	25.1	
2	Cylinder	2	28.10.25	11/25/2025	28	0.02298	576.0	25.1		
3	Cylinder	3	28.10.25	11/25/2025	28	0.02298	579.0	25.2		

NOTE: -1 MN/m^2 = 145.038 psi and 1KN = 224.809 lb.

For Diameter / Area determination: refer to ASTM-C-39

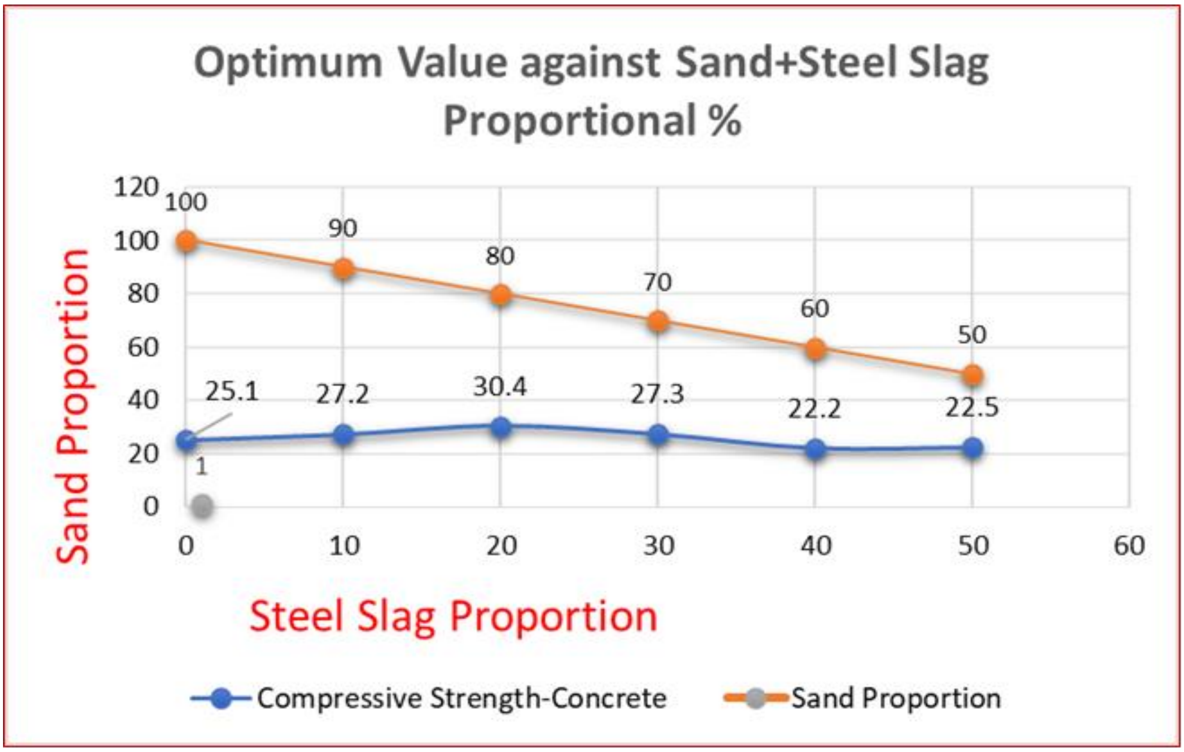


4.7.1 Optimum Result for 28 days – Chart



4.7.2 Optimum Result Chart – Steel slag and Sand Proportion

CHAPTER 5: CONCLUSION



5.1 Determined Results

The optimization study shows different type of compressive strength result when steel slag ratio is changed. We got as per below for 7 days, 14 days and 28 days

7 days lowest result value when steel slag with sand proportion 50% -50% is 14.1 Mpa and highest result is 22.1 Mpa with 80% -20% proportion. And also, 0% proportion result shows 17.7 Mpa.

14 days lowest result value when steel slag with sand proportion 50% -50% is 16.8 Mpa and highest value is 26.6 Mpa with 80% -20% proportion. And also, 0% proportion result shows 21.2 Mpa.

28 days lowest result value when steel slag with sand proportion 50% -50% is 22.2 Mpa and highest result is 30.4 Mpa with 80% -20% proportion. And also, 0% proportion result shows 25.1 Mpa.

In a summary overview, the characteristics of steel slag as replaced proportional particle with coarse sand ratio grade concrete shows use of steel slag decrease the compressive strength when proportion is half of the sand volume, and increase gradually while mixing proportion is reduced, the examination has shown acceptable proportion is 80% sand with 20% steel slag gives the highest result than the conventional normal concrete.

- Steel slag can be effectively used in concrete as an aggregate replacement
- Suitable for structural concrete within optimal replacement limits
- Encourages sustainable and eco-friendly concrete production

5.2 Recommendations

- Long-term durability studies (shrinkage, creep, sulfate resistance)
- Performance under aggressive environmental conditions
- Use of steel slag in high-strength or self-compacting concrete
- Life-cycle cost and environmental impact analysis

5.3 Limitations 0f The Study:

- Volume Instability Due to Free Lime and MgO
- High Water Absorption and Workability Issues
- Variability in Chemical and Physical Properties
- Increased Density and Self-Weight

REFERENCES

Acknowledged and grateful to the following article for their tremendous effort and inspire us to study on the thesis to "Investigation on Compressive Strength Characteristics of Steel Slag Concrete"

Thi-Thuy-Hang Nguyen, Duc-Hung Phan, Hong-Ha Mai, and Duy-Liem Nguyen "Investigation on Compressive Strength Characteristics of Steel Slag Concrete"
Faculty of Civil Engineering, Ho Chi Minh City University of Technology and Education, 01 Vo Van Ngan St,Thu Duc District, Ho Chi Minh City 700000, Vietnam; hangntt@hcmute.edu.vn (T.-T.-H.N.);
https://www.mdpi.com/1996-1944/13/8/1928?utm_source=chatgpt.com

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