A COMPARATIVE ANALYSIS OF CONCRETE COMPRESSIVE STRENGTH WITH COARSE AGGREGATE REPLACEMENT BY EXPANDED POLYSTYRENE BEADS AND COCONUT FIBER ADDITION

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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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To

"OUR PARENTS & TEACHERS"

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ABSTRACT

The thesis "A Comparative Analysis of Concrete Compressive Strength with Coarse Aggregate Replacement by Expanded Polystyrene Beads and Coconut Fiber Addition" explores the use of EPS beads and coconut fibers as partial replacements for conventional aggregates in concrete. The objective is to assess the effects of these eco-friendly materials on compressive strength, particularly in lightweight concrete applications.

The study involves mixing different proportions of EPS beads (5%, 10%, 15%) and coconut fibers into concrete and testing their performance after curing for 7, 14, and 28 days. The results show that incorporating 5-10% coconut fiber significantly enhances compressive strength, while EPS beads reduce the overall weight of the concrete. However, higher EPS content slightly affects workability.

This research demonstrates the potential of EPS and coconut fiber in producing lightweight, strong, and sustainable concrete, suitable for applications like roofing and flooring. It highlights the environmental benefits of using alternative materials in construction, aligning with global sustainability trends. The work is done using M20 grade concrete.

Keywords: Lightweight concrete, Compressive strength, EPS Beads, Coconut Fiber, Universal Testing Machine.

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CHAPTER 1
INTRODUCTION

1.1 Background

Concrete is a flexible and frequently used building material. One of its most crucial characteristics is its compressive strength, which governs how much weight concrete structures can support. The type of cement used, the amount of water to cement, the amount of aggregate, and the curing conditions are some of the variables that might impact the compressive strength of concrete.

We will go over the elements that impact the compressive strength of typical concrete in this brief article. The significance of compressive strength in concrete design and construction will also be covered. The results of current studies on the compressive strength of typical concrete will be shown before we conclude.

1.2 The definition of compressive strength and its importance in concrete design and construction.

A material's capacity to withstand compression is known as compressive strength. Megapascals (MPa) are used to measure it. Concrete has compressive strengths that typically range from 20 to 40 MPa, making it a powerful material. Importance in the design and construction of concrete o Compressive strength is one of the most crucial characteristics of concrete since it determines the ability of concrete structures to support loads.

Concrete constructions are made to resist the loads they are expected to sustain. The maximum load that a structure can support before failing is calculated using the concrete's compressive strength. Concrete’s compressive strength is crucial in building. The concrete needs to be strong enough to handle the loads and the weight of the construction.

1.3 Organization of the Thesis

The layout of the thesis is written through five chapters in the following sequence. Chapter one deals with the background and the definition of compressive strength and its importance in concrete design and construction. Chapter Two is a literature review which includes the definition of the compressive strength of EPS beads & coconut fiber. Chapter Three contains the Methodology and Experimental Program which Material, the Procedure of Making the cylinder, the methodology Overview and a Summary. Chapter Four contains the experimental results along with the data, figures and graphs obtained from the laboratory tests, discussions on the test results, specific aim and summary. Chapter Five describes the conclusion of the research work and recommendations for further research.

1.4 Objective

- To find out maximum compressive strength of concrete using EPS beads and coconut fibers at varying contents and to compare it with that of conventional concrete.

CHAPTER 2

Literature Review

2.1 General

A number of studies have been conducted on the compressive strength of coconut fiber and EPS beads concrete. These studies have shown that the compressive strength of concrete can be significantly improved by adding coconut fiber or EPS beads. The compressive strength of coconut fiber and EPS beads concrete is affected by a number of factors, including the type of fiber, the length of the fiber, the amount of fiber, the size of the EPS beads, and the curing conditions. In general, the compressive strength of coconut fiber and EPS beads concrete increases with the amount of fiber or EPS beads added to the mix. However, the compressive strength of concrete can also decrease if too much fiber or EPS beads are added.

2.2 Materials

2.2.1 Cement: Ordinary Portland Cement (OPC) is the most widely used and fundamental type of cement in construction. It serves as the foundation for various concrete applications due to its versatility, availability, and consistent performance. OPC is manufactured by grinding clinker (a material produced through the heating of limestone and other components to high temperatures) with a small amount of gypsum to control its setting time. Type I: This is general-purpose cement suitable for most construction applications, offering good strength and durability. It's commonly used in building foundations, walls, pavements, and more. Type II: Type II OPC produces less heat during hydration, making it suitable for projects where heat generation can cause issues like thermal cracking. It's commonly used in large-scale concrete projects and structures. Type III: Type III OPC is known for its rapid setting and high early strength development. It's often used in situations where quick construction or early load-bearing capacity is essential. Type IV: Type IV OPC generates less heat during hydration than Type I and Type II cements, making it suitable for massive concrete structures with low heat tolerance. Type V: Type V OPC has high sulfate resistance, making it ideal for environments with high sulfate content in soil or water. It's commonly used in marine structures and environments with exposure to sulfates. All specimens were cast using Ordinary Portland Cement (OPC) Type I throughout the experiment. This kind of cement complies with the Iraqi specification 5/2019 [16].



Figure: 2.1 Cement

2.2.2 Fine Aggregates: Fine aggregates are an essential component in the construction industry, forming a significant portion of concrete, mortar, and other building materials. They are granular materials, typically smaller than 5mm in diameter,



Figure: 2.2 **Fine Aggregates**

that play a crucial role in enhancing the workability, strength, and durability of construction mixes. Here's an in-depth overview of fine aggregates. Sylhet sand was used for producing lightweight cylinder for performing compressive strength test.

2.2.3 Coarse Aggregates: Coarse aggregates are an integral component in construction, constituting a substantial portion of concrete, asphalt, and other building materials. These granular materials, typically larger than 4.75mm in diameter, play a crucial role in providing structural strength, stability, and durability to construction mixes. Here's an in-depth exploration of coarse aggregates. Natural gravel from the West Bengal region with a nominal aggregate size of 9.5-37.5mm, shown in Figure 3.3, was used as coarse aggregates in all mixes. The physical and chemical parameters of the coarse aggregates comply with the Indian standard [17].



Figure: 2.3 **Coarse Aggregates**

2.2.4 Water: According to IS 456 : 2000, water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete. The pH value of water shall be not less than 6.Water is a fundamental and essential element in the construction industry, playing a critical role in various construction processes and materials. It serves as a mixing and curing agent, a component of construction materials, and a medium for cleaning and hydration. Here's an exploration of the significance and functions of water in construction.



Figure: 2.4 **Water**

2.2.5 EPS : Concrete is an artificial material used to construct various civil engineering structures [1]. Concrete is the most commonly used substance in construction and can be used as standalone mass concrete, reinforced concrete, or prestressed concrete when combined with steel [2]. For every ton of cement produced, one ton of carbon dioxide (CO2) is emitted into the atmosphere. Cement manufacturing is responsible for 5% of anthropogenic CO2 emissions [3]. Cement production produces a significant amount of CO2 and requires a large amount of energy during the manufacturing process. Given that Pakistan is already facing an energy crisis, the high energy consumption in cement production puts additional pressure on its energy sector. As a result, the price of cement is rising daily. Furthermore, waste disposal and the restoration of concrete components after demolition have negative environmental consequences. As a result, the use of this waste reduces cement manufacturing and energy consumption while also helping protect the environment [4]. One of the drawbacks of traditional concrete is its high self-weight. The density of regular concrete ranges between 2200 kg/m3 and 2600 kg/m3 making its an uneconomical structural material. Several attempts have been made in the past to reduce the self-weight of concrete to increase its efficiency. Lightweight Concrete (LWC) is a type of concrete with a density ranging from 300 to 1850kg/m3 [5]. Since LWC was first used approximately two thousand years ago, several lighter structures were built, particularly in the Mediterranean region. The three

most important structures built during the Roman Empire are the Coliseum, the Port of Coosa, and the Pantheon Dome [6]. The use of LWC in buildings, structural and non-structural, as construction material must have specific characteristics that meet the requirements of strength and performance for the application. Before using any material in construction, there is a need to study its mechanical properties to determine its suitability [7].



Figure: 2.5 EPS BEADS

2.2.6 COCONUT FIBER: Coconut fiber used in a reinforced concrete mixture to increase its strength is widely researched. In this study, we used coconut fiber for a mixture of paving blocks. Nowadays the technology development in the field of construction has increased, especially for highway pavement. Paving block pavements start to be widely used for pavement construction on roads [8].This can be seen from the use of paving blocks which are increasingly used as asphalt replacement because they are easy to install, do not require heavy equipment, can be mass-produced, and are easy to maintain and reinstall. The quality of paving blocks can be measured by their strength in compressive loads and resistance [9]. Paving can withstand small earthquakes, freeze and melt [10]. The contribution of this research is the utilization of coconut fiber as a substitute for steel to paving blocks, making it cheaper. For this reason, the research of sustainable composite concrete is necessary [11]. 2) Effect of Coconut Coir Fiber Traditionally coconut fiber is used for household products. Coconut

fiber is used in mixes with construction materials to increase their strength [12]. Coconut fiber is divided into two types of colors, namely white from young coconut and brown from old coconut, both with low thermal conductivity [13]. The stress and strain produced by coconut coir fibers have a higher value than other natural fibers [14, 15].



Figure: 2.6 COCONUT FIBERS

2.3 Summery

The literature highlights the potential of expanded polystyrene (EPS) beads and coconut fiber to enhance concrete properties. EPS beads reduce concrete density, making it lightweight while maintaining adequate strength, and are effective for improving thermal insulation. Coconut fiber, known for its durability and toughness, reinforces concrete, increasing compressive strength. However, excessive fiber can reduce workability.

Overall, the combination of EPS beads and coconut fiber offers promise for producing lightweight, strong concrete, with optimal proportions being key to balancing strength and workability. This study further explores their combined effects on concrete performance.

CHAPTER 3

Methodology

3.1 Introduction

The methodology employed in this study focuses on analyzing the compressive strength of concrete through the partial replacement of coarse aggregate with expanded polystyrene (EPS) beads and the addition of coconut fiber. The experimental process is designed to evaluate the potential of these materials to enhance the properties of lightweight concrete, specifically its compressive strength.

The study involves the preparation of concrete cylinders using different proportions of EPS beads and coconut fiber, ranging from 0% to 15% by volume of coarse aggregate. The concrete mix is prepared with standard materials such as cement, fine and coarse aggregates, and water. After casting the specimens, they are cured for specified periods (7, 14, and 28 days), followed by compressive strength testing using a Universal Testing Machine. This methodology aims to provide a comparative analysis of how these eco-friendly materials affect the structural performance of concrete, offering potential applications in lightweight and sustainable construction practices.

3.1.1 Procedure of the Making the Cylinder: The mixture composition paving cylinder used the ratio of 1:1.5:3 which is 1kg cement, 1.5kg sand, and 3kg Coarse Aggregates, Expanded Polystyrene Beads (EPS) & Coconut Fiber with the addition of 450ml of water (not too much water should be added in order to get maximum water-cement ratio). Coconut fibers and EPS Beads by 0%, 5%, 10% and 15% of all Aggregates weight were added. The mixture compositions were mould. The mould was hit 9 times in order to even up the mixture so there were no air voids. The finished mixture was taken out from the mould into plywood.



Figure: 3.1 Concrete mixed with Expanded Polystyrene Beads (EPS)



Figure: 3.2 Concrete mixed with Coconut Fiber

3.2 Methodology Overview

The methodology employed for investigating the compressive strength of concrete using EPS beads and coconut fiber involves a systematic approach that encompasses various experimental and analytical steps. This section provides a concise overview of the key methodologies utilized in the research process

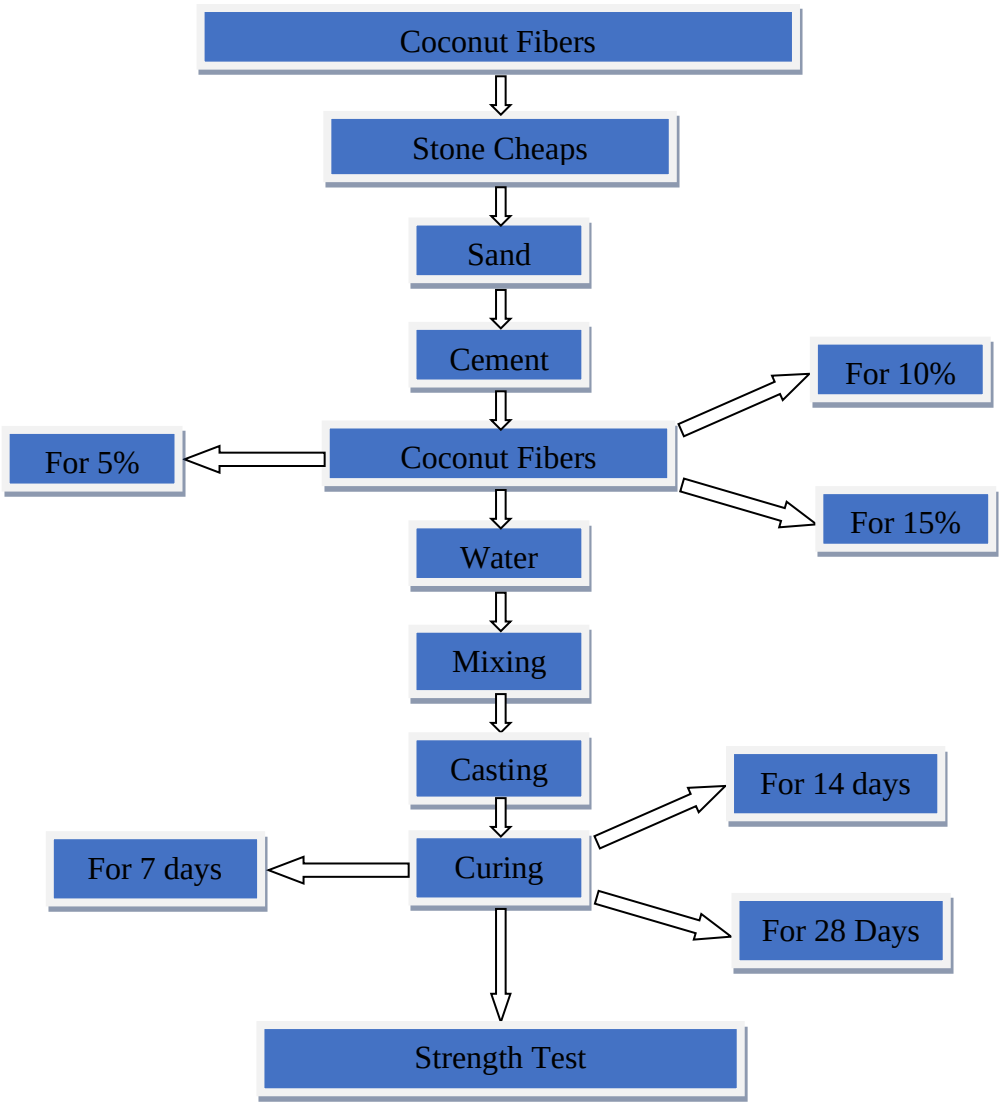


Figure 3.3 Overview of the coconut fibers methodology.

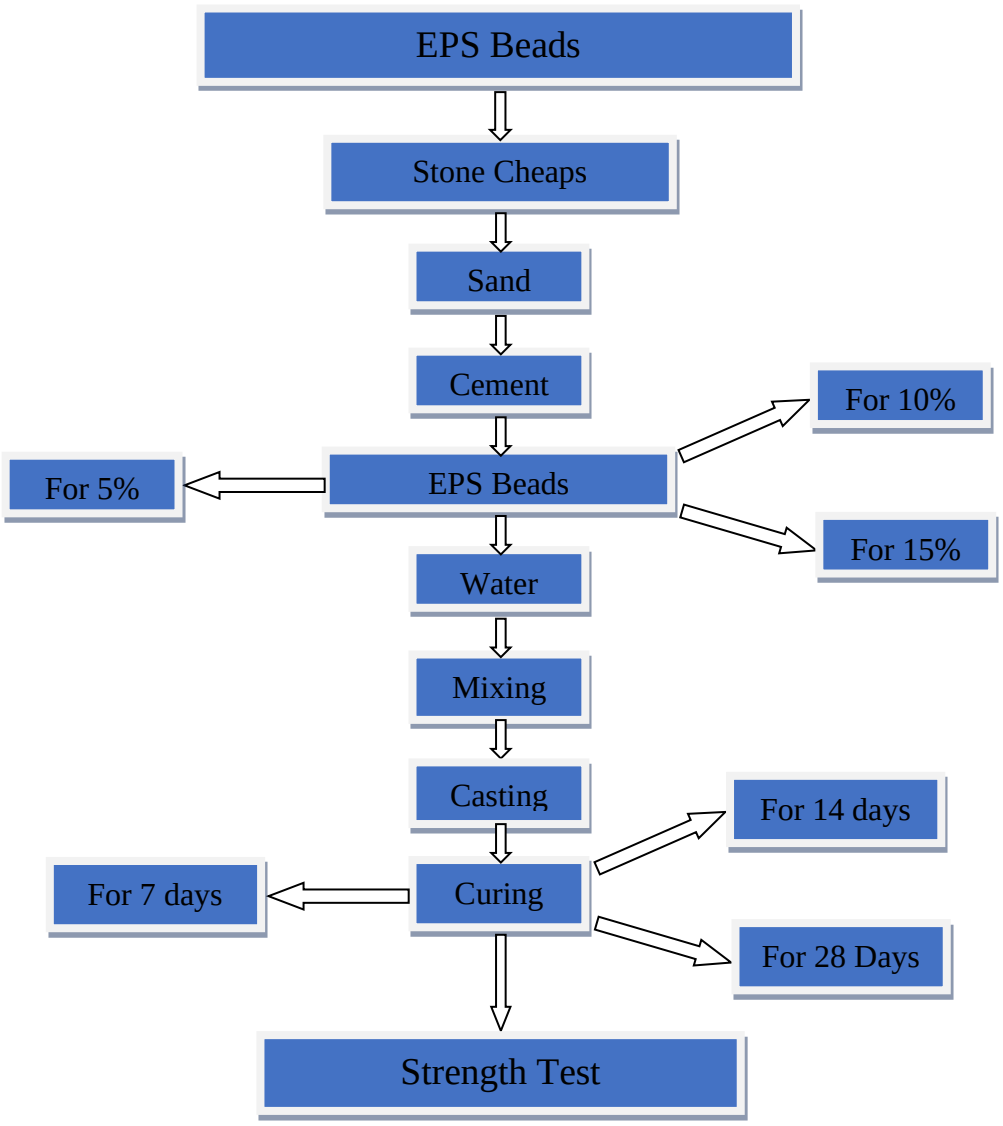


Figure 3.4 Overview of the Expanded Polystyrene Beads (EPS) methodology**.**

3.2.1 Materials Selection and Preparation:

The materials for the concrete mixture will include Portland cement, fine and coarse aggregates, water, EPS beads, and coconut fiber. High-quality materials will be selected to ensure accurate and repeatable results. The EPS beads will be of uniform size, and the coconut fiber will be properly processed to remove impurities.

3.2.2 Mix Proportioning: A series of concrete mixtures will be designed with varying proportions of EPS beads and coconut fiber. The mix design will be based on established guidelines for achieving the desired compressive strength. The control mixtures without any additives will also be prepared for comparison.



Figure: 3.5 **Mix Proportioning**

3.2.3 Concrete Mixing: The concrete mixtures will be batched using a concrete mixer, following standard mixing procedures.



Figure: 3.6 **Concrete Mixing**

The sequence of adding materials, mixing duration, and water-cement ratio will be consistent for all batches to ensure consistency.

3.2.4 Specimen Casting:

The freshly mixed concrete will be cast into standard cylindrical or cubic molds, adhering to relevant testing standards. Special care will be taken to prevent segregation during casting. The molds will be properly vibrated to eliminate air void



Figure: 3.7 Specimens Casting

3.2.5 Curing Regime:

The cast specimens will undergo a controlled curing process to simulate real-world conditions. This process will involve both moist curing and air curing, as per established concrete curing practices. The curing duration will be chosen to ensure proper hydration and development of strength



Figure: 3.8 Curing Regime

3.2.6 Compressive Strength Testing: After the curing period, the specimens will be carefully demoded and tested for compressive strength using a universal testing machine.



Figure: 3.9 Compressive Strength Testing

The load will be applied gradually and uniformly until failure occurs. The maximum load at failure and the corresponding stress will be recorded to calculate the compressive strength.

3.2.7 Data Collection and Analysis:

The obtained compressive strength values from different mixtures will be compiled and analyzed statistically. The effects of varying proportions of EPS beads and coconut fiber on the compressive strength will be studied. Comparative analysis will be conducted between the modified concrete mixes and the control mixes.

3.3 Summary

The methodology of this study focuses on evaluating the compressive strength of concrete with partial replacement of coarse aggregate using expanded polystyrene (EPS) beads and the addition of coconut fiber. Ordinary Portland Cement (OPC), fine aggregates, and natural coarse aggregates were used alongside varying percentages of EPS beads (5%, 10%, 15%) and coconut fiber (5%, 10%, 15%).

Concrete cylinders were cast following a standard mix ratio and water-cement ratio. The specimens were cured in controlled environments for 7, 14, and 28 days. Compressive strength tests were conducted using a Universal Testing Machine to assess the performance of the different concrete mixes. The methodology also included data analysis to compare the performance of modified concrete mixes with normal concrete. This experimental approach aims to provide insights into the viability of EPS beads and coconut fiber as sustainable alternatives to traditional coarse aggregates in concrete.

CHAPTER 4

Results and Discussion

4.1 Introduction

This pivotal section delves into the empirical outcomes and insightful interpretations derived from the experimental investigation on the utilization of EPS beads and coconut fiber as additives in concrete. The primary focus centers on the compressive strength characteristics of the modified concrete mixes.

4.2 Results

4.2.1 Density

The quantity and density of lightweight aggregates are two of the most crucial elements in regulating a variety of physical properties in LWC. Due to the low density of polystyrene, the density of LWC falls as polystyrene volume increases [18-19]. Table VII shows the densities of the samples and their density variation with age.

4.2.2 Compressive Strength

This rise is the result of the cement hydration process becoming more advanced with time. and both provide a comparison of the compressive strengths of several specimens at 7 days, 14 days and 28 days of age.

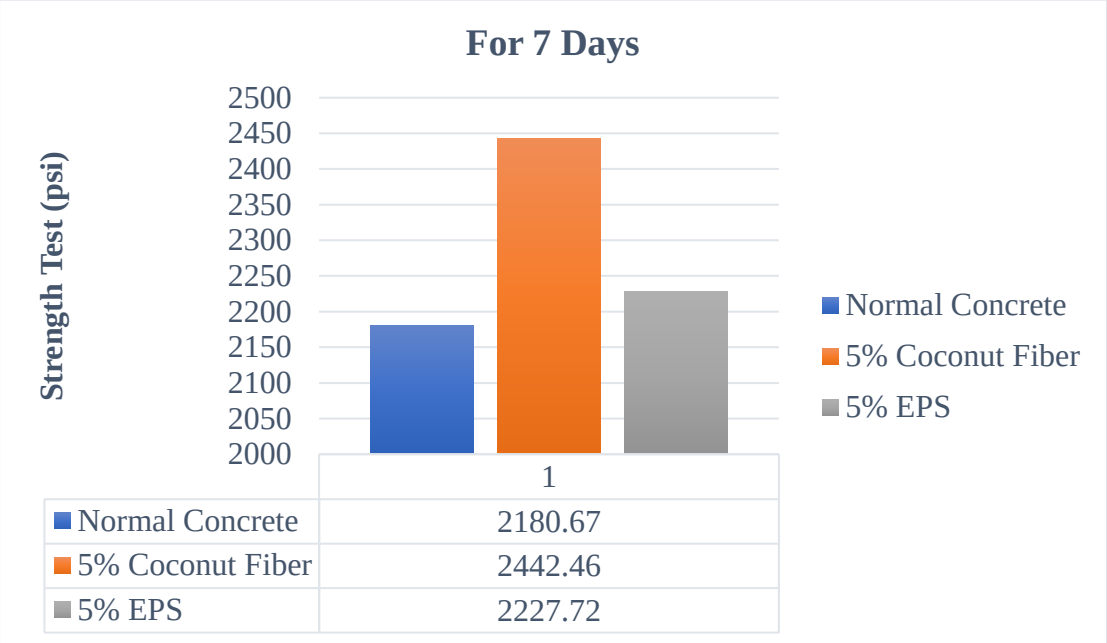


Figure 4.1 Compare Compressive Strength with Normal Concrete, 5% Coconut Fiber , and 5% EPS

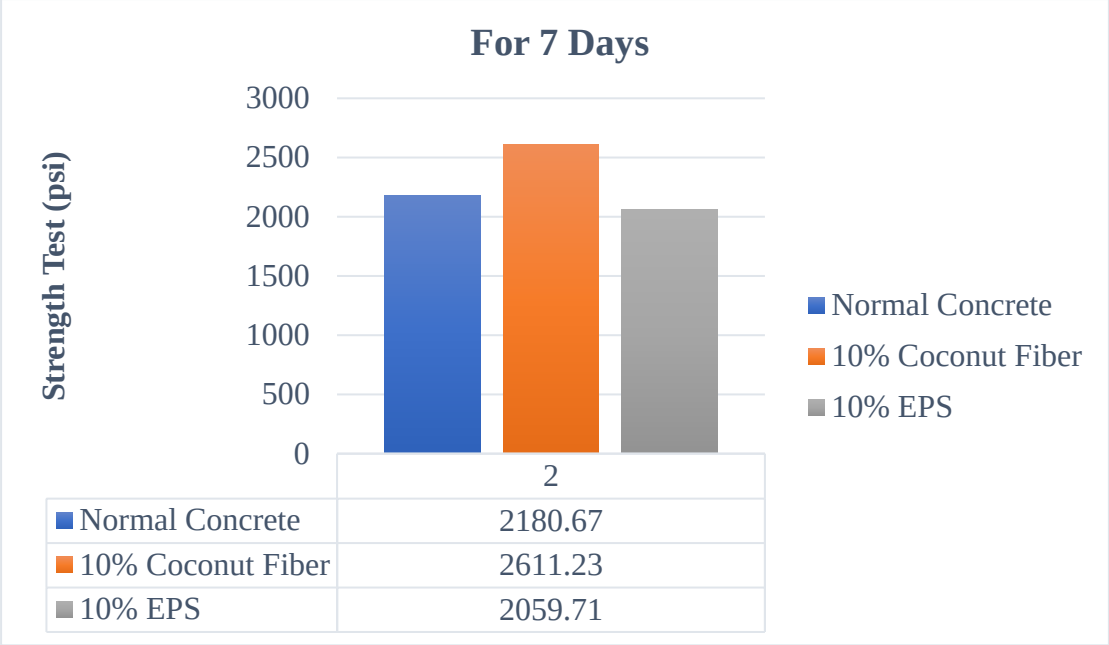


Figure 4.2 Compare Compressive Strength with Normal Concrete, 10% Coconut Fiber , and 10% EPS

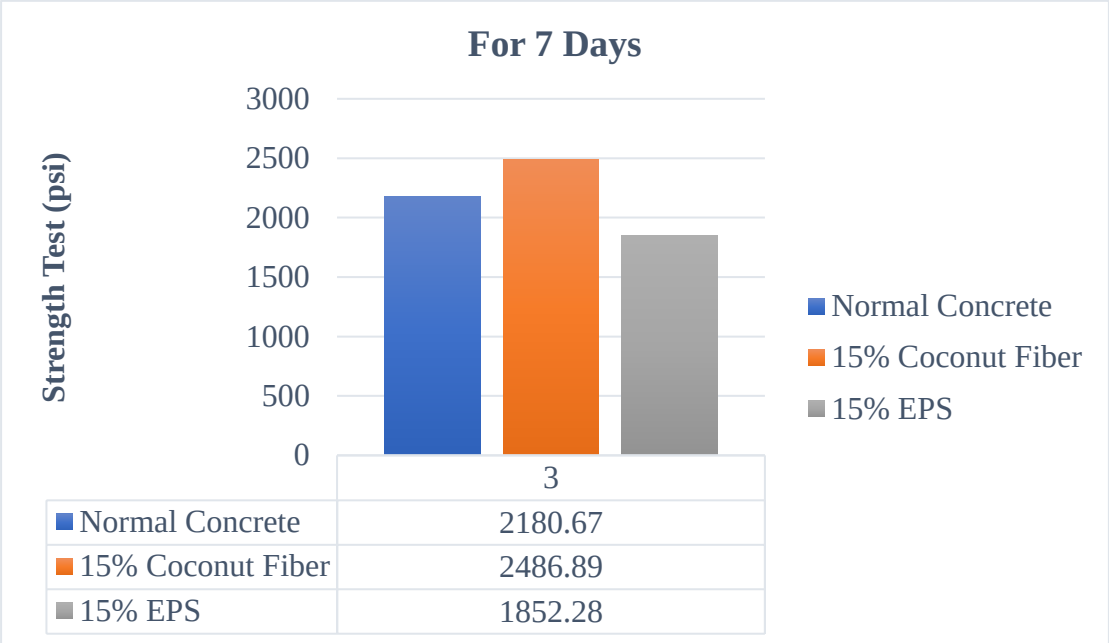


Figure 4.3 Compare Compressive Strength with Normal Concrete, 15% Coconut Fiber , and 15% EPS

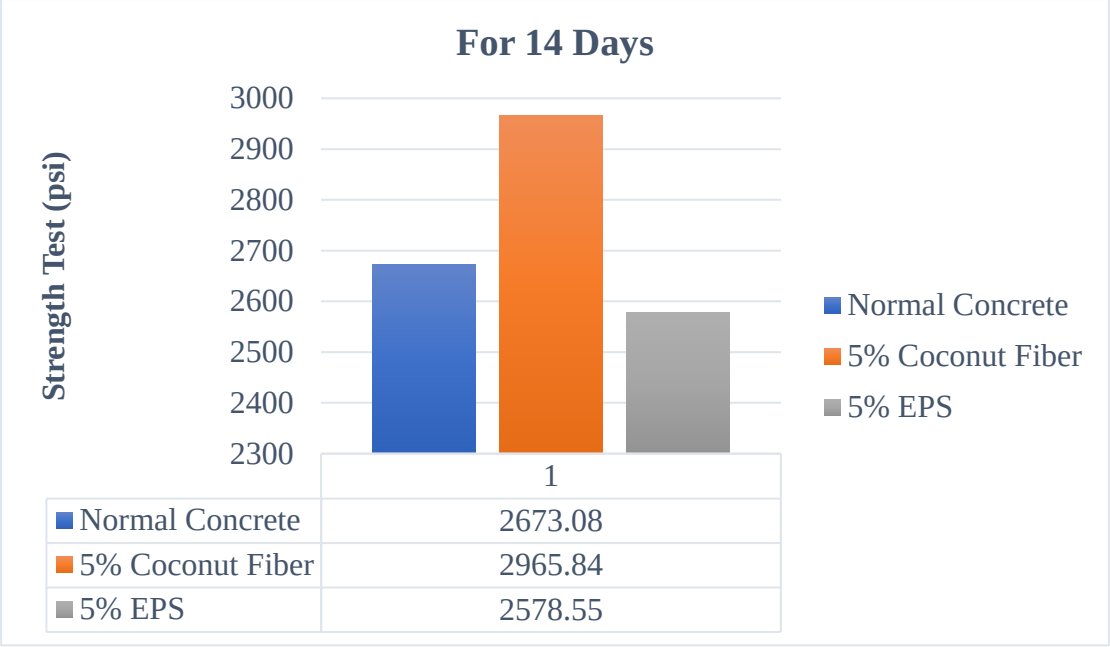


Figure 4.4 Compare Compressive Strength with Normal Concrete, 5% Coconut Fiber , and 5% EPS

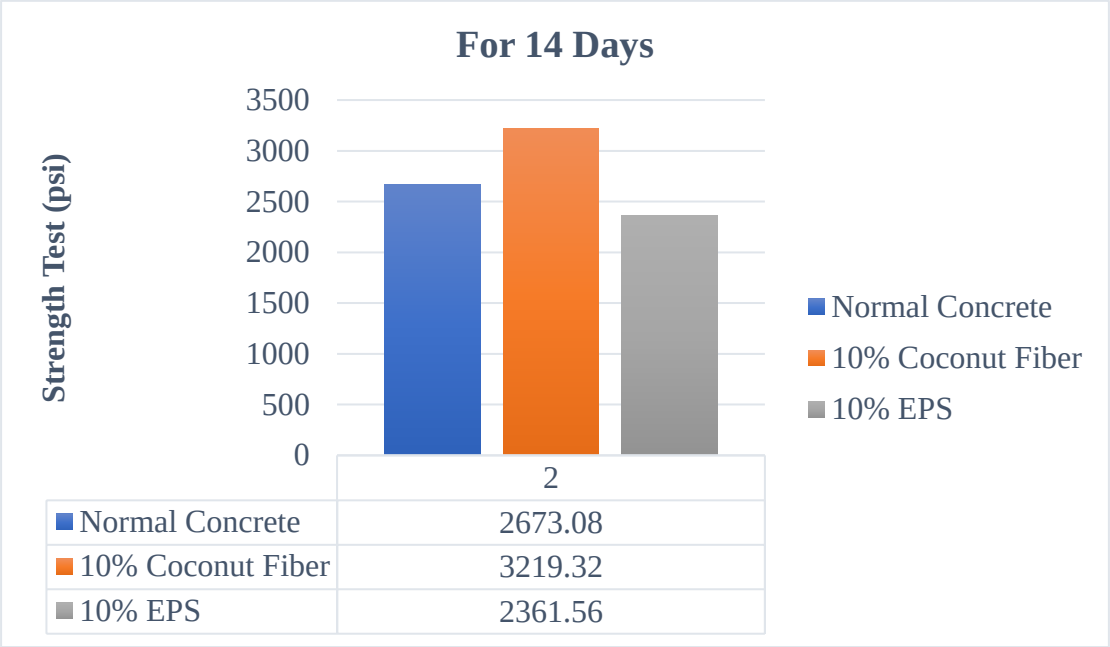


Figure 4.5 Compare Compressive Strength with Normal Concrete, 10% Coconut Fiber , and 10% EPS

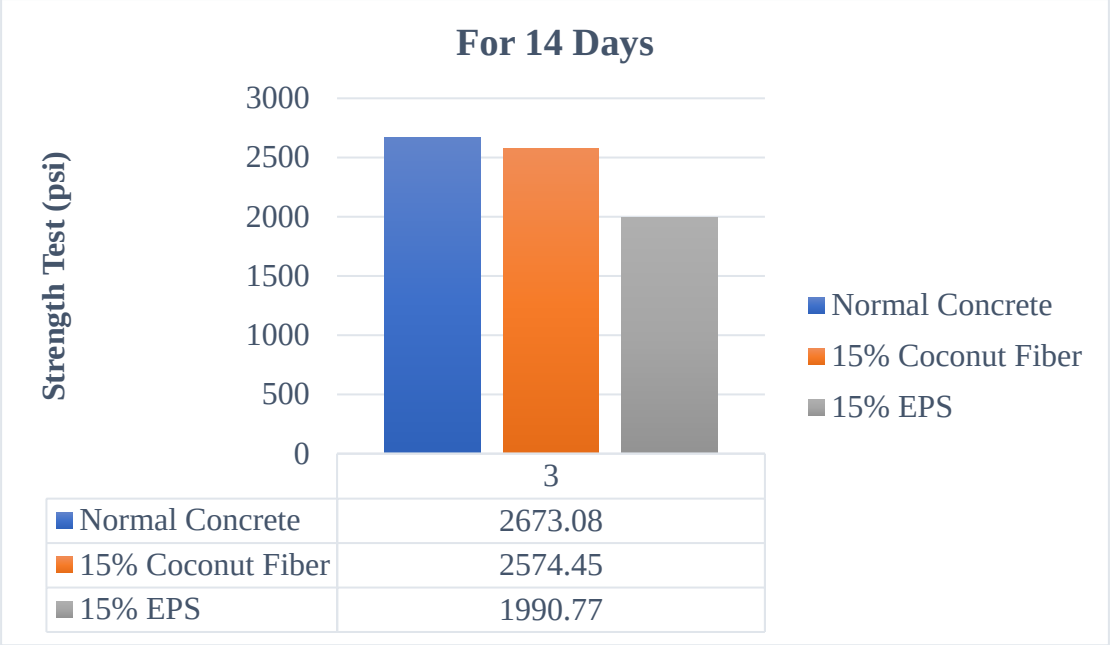


Figure 4.6 Compare Compressive Strength with Normal Concrete, 15% Coconut Fiber , and 15% EPS

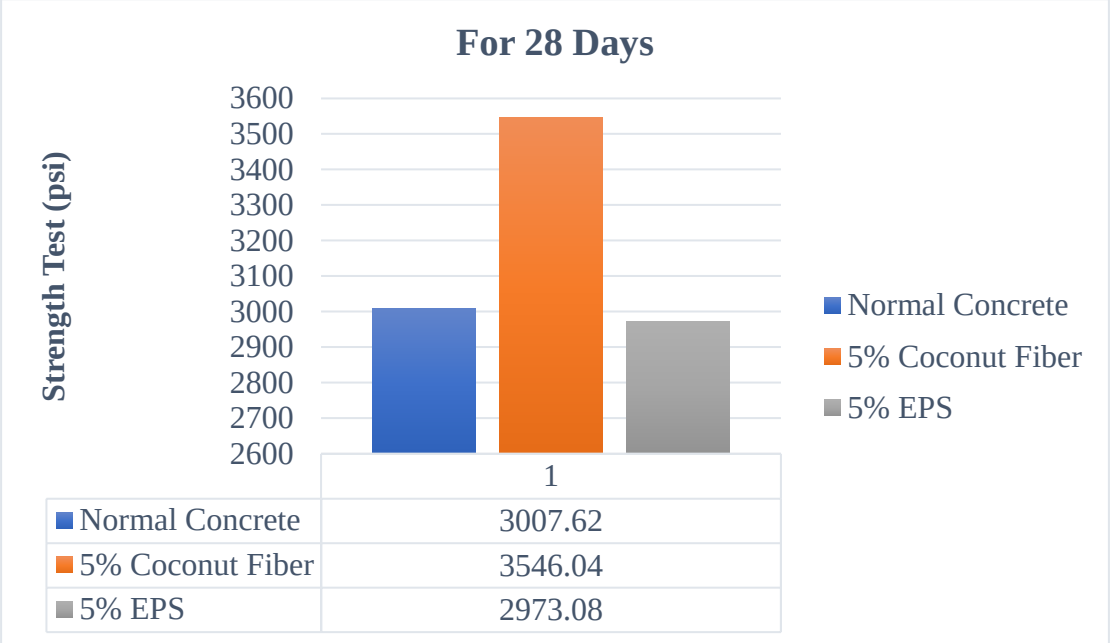


Figure 4.7 Compare Compressive Strength with Normal Concrete, 5% Coconut Fiber , and 5% EPS

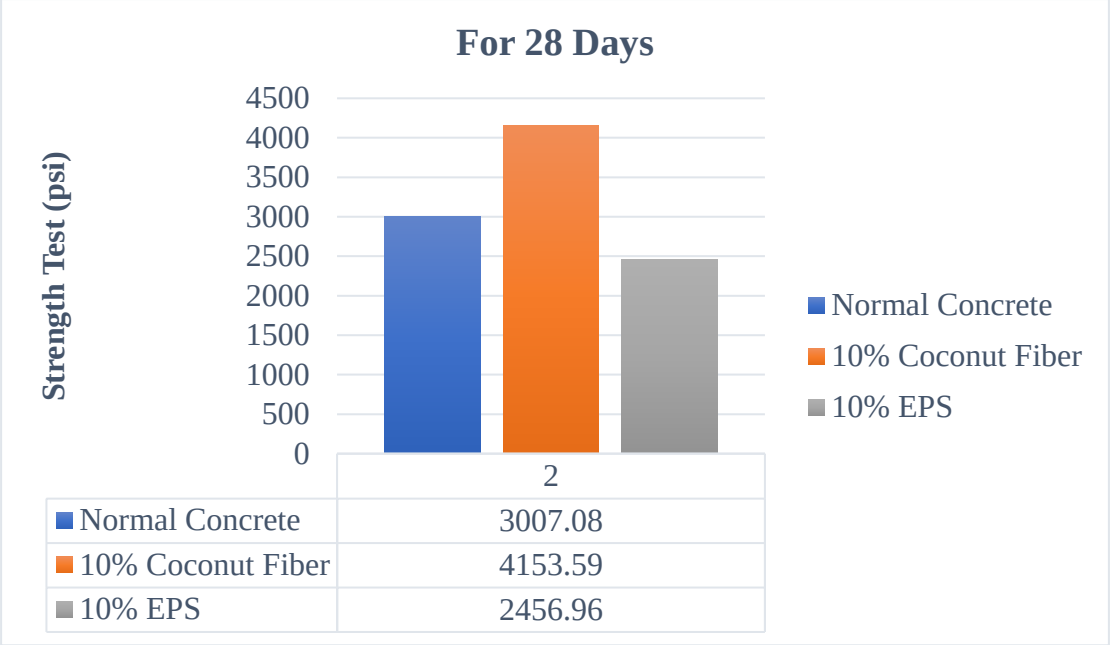


Figure 4.8 Compare Compressive Strength with Normal Concrete, 10% Coconut Fiber , and 10% EPS

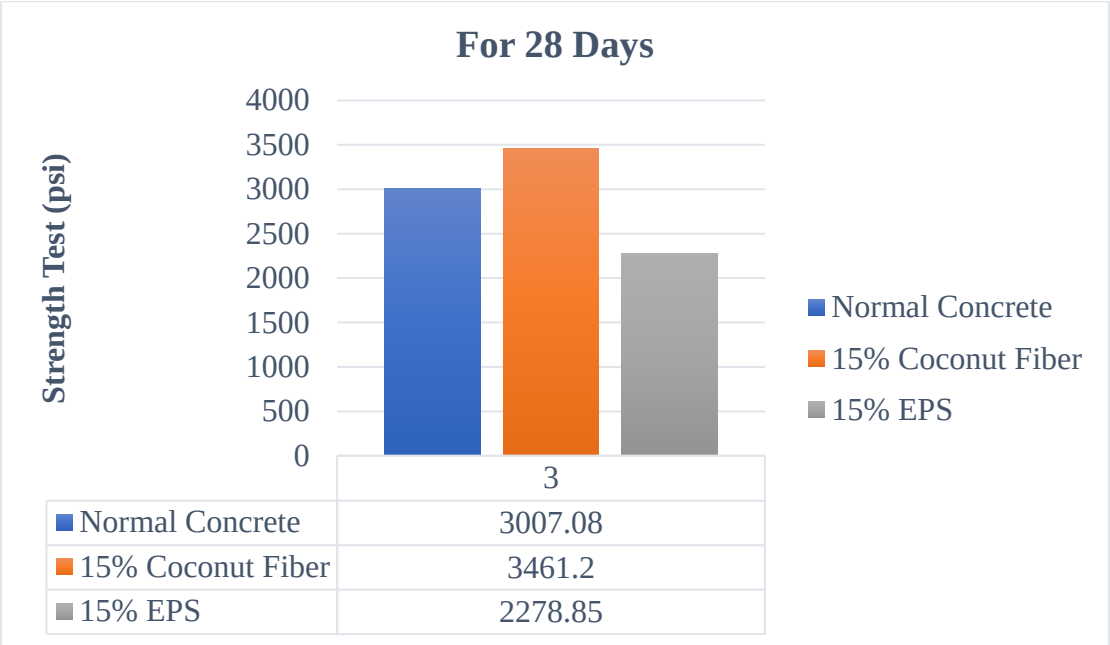


Figure 4.9 Compare Compressive Strength with Normal Concrete, 15% Coconut Fiber , and 15% EPS

Table 4-1. Summary of the goodness-of-fit of the prediction models.

For 7 Days							
SL No.	Dia (Inch)	Height (Inch)	Weight (Kg)	Load (KN)	Crushing Strength (KN/inch2)	Average Crushing Strength (KN/inch2)	PSI
Normal Concrete							
1	4.04	8.15	4.15	134	9.689	9.700	2180.67
2	4.00	8.13	4.02	122	9.862		
3	4.07	8.03	4.17	124	9.549		
5% Coconut Fiber							
1	4.03	8.09	3.96	118	10.974	10.865	2442.46
2	4.05	8.13	4.07	133	10.884		
3	4.07	8.15	4.10	140	10.736		
10% Coconut Fiber							
1	4.01	8.07	3.95	144	11.589	11.615	2611.23
2	4.00	8.11	3.95	146	11.591		
3	3.99	8.11	3.95	146	11.666		
15% Coconut Fiber							
1	4.08	8.11	4.10	142	10.857	11.062	2486.89
2	4.05	8.09	4.15	126	11.025		
3	4.00	8.15	4.02	122	11.304		
5% EPS							
1	4.05	8.11	4.05	120	9.864	9.909	2227.72
2	4.06	8.13	4.08	127	9.792		
3	4.01	8.05	3.99	119	10.073		
10% EPS							
1	4.07	8.07	4.00	116	8.912	9.162	2059.71
2	4.03	8.07	3.80	105	9.094		
3	3.95	8.11	3.82	108	9.479		
15% EPS							
1	4.09	8.07	3.95	104	8.151	8.239	1852.28
2	4.06	8.15	3.94	107	8.256		
3	4.05	8.07	3.84	100	8.311		

Table 4-2. Summary of the goodness-of-fit of the prediction models.

For 14 Days							
SL No.	Dia (Inch)	Height (Inch)	Weight (Kg)	Load (KN)	Crushing Strength (KN/inch2)	Average Crushing Strength (KN/inch2)	PSI
Normal Concrete							
1	4.04	8.15	4.15	147	11.877	11.890	2673.08
2	4.00	8.13	4.02	152	12.089		
3	4.07	8.03	4.17	143	11.705		
5% Coconut Fiber							
1	4.03	8.09	3.96	164	13.325	13.193	2965.84
2	4.05	8.13	4.07	160	13.217		
3	4.07	8.15	4.10	170	13.036		
10% Coconut Fiber							
1	4.01	8.07	3.95	180	14.287	14.320	3219.32
2	4.00	8.11	3.95	177	14.290		
3	3.99	8.11	3.95	175	14.383		
15% Coconut Fiber							
1	4.08	8.11	4.10	145	11.240	11.452	2574.45
2	4.05	8.09	4.15	147	11.413		
3	4.00	8.15	4.02	140	11.702		
5% EPS							
1	4.05	8.11	4.05	140	11.417	11.470	2578.55
2	4.06	8.13	4.08	140	11.334		
3	4.01	8.05	3.99	147	11.659		
10% EPS							
1	4.07	8.07	4.00	133	10.218	10.505	2361.56
2	4.03	8.07	3.80	127	10.427		
3	3.95	8.11	3.82	125	10.869		
15% EPS							
1	4.09	8.07	3.95	108	8.761	8.855	1990.77
2	4.06	8.15	3.94	115	8.873		
3	4.05	8.07	3.84	115	8.932		

Table 4-3. Summary of the goodness-of-fit of the prediction models.

For 28 Days							
SL No.	Dia (Inch)	Height (Inch)	Weight (Kg)	Load (KN)	Crushing Strength (KN/inch2)	Average Crushing Strength (KN/inch2)	PSI
Normal Concrete							
1	4.03	8.11	4.04	162	13.359	13.379	3007.62
2	4.03	8.09	4.09	167	13.346		
3	4.01	8.07	4.07	170	13.430		
5% Coconut Fiber							
1	4.06	8.05	4.09	202	15.631	15.774	3546.04
2	4.02	8.07	4.02	195	15.883		
3	4.03	8.07	3.91	187	15.806		
10% Coconut Fiber							
1	4.04	8.11	4.01	235	18.349	18.476	4153.59
2	4.01	8.07	4.04	227	18.580		
3	4.02	8.07	4.06	232	18.500		
15% Coconut Fiber							
1	4.01	8.11	4.11	173	15.448	15.396	3461.20
2	4.02	8.09	4.07	181	15.345		
3	4.02	8.15	4.07	195	15.396		
5% EPS							
1	4.05	8.11	4.08	166	13.171	13.225	2973.08
2	4.06	8.13	3.97	155	13.150		
3	4.03	8.05	4.05	170	13.354		
10% EPS							
1	4.04	8.07	3.91	144	10.910	10.929	2456.96
2	4.03	8.07	3.94	140	10.989		
3	4.05	8.11	4.01	140	10.889		
15% EPS							
1	4.06	8.07	3.90	127	10.066	10.137	2278.85
2	4.02	8.09	3.97	124	10.228		
3	4.04	8.07	3.92	130	10.117		

4.3 Summary

The "Results and Discussion" section stands as the culmination of empirical data and interpretative insights, driving the narrative towards a more profound understanding of the application of EPS beads and coconut fiber in enhancing concrete's compressive strength and broader performance attributes...

CHAPTER 5
Conclusions

5.1 Conclusions

The research successfully demonstrates that integrating **expanded polystyrene (EPS) beads and coconut fiber** into concrete mixtures enhances lightweight properties while offering improved compressive strength under optimal conditions. Specifically, concrete with **5-10% coconut fiber** significantly increases compressive strength, particularly at 28 days of curing, while **low EPS content (≤ 5%)** aids in achieving a balance between the reduced weight and adequate strength. These modifications make the concrete suitable for lightweight and sustainable building applications, aligning with modern needs for green construction practices.

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