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Mechanical and Physical Performance Evaluation of Laboratory-Scale LDPE–Sand Composites Modified with Rice Husk, Rice Husk Ash, and Biochar.

by

Shreeyash Acharya

A THESIS

SUBMITTED TO THE DEPARTMENT OF APPLIED SCIENCES AND CHEMICAL
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DEGREE OF MASTER IN MATERIAL SCIENCE AND ENGINEERING

DEPARTMENT OF APPLIED SCIENCES AND CHEMICAL ENGINEERING
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DECLARATION

I hereby declare that the Thesis entitled "Mechanical and Physical Performance Evaluation of Laboratory-Scale LDPE–Sand Composites Modified with Rice Husk, Rice Husk Ash, and Biochar" submitted to the Institute of Engineering, Tribhuvan University, in partial fulfillment of the requirements for the award of the degree of Master of Science in Materials Science and Engineering, is my original work carried out under the supervision of Prof. Dr. Gokarna Bahadur Motra and Asst. Prof. Dr. Khem Raj Shrestha.

I further declare that this work has not been submitted, either in part or in full, to any other university or institution for the award of any degree, diploma, or academic qualification. All sources of information used in this Thesis have been duly acknowledged and referenced.

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LETTER OF FORWARD

On the recommendation of Prof. Dr. Gokarna Bahadur Motra and Asst. Prof. Dr. Khem Raj Shrestha, this Thesis is submitted by Shreeyash Acharya, (Roll No.: 080MSMSE018), entitled "Mechanical and Physical Performance Evaluation of Laboratory-Scale LDPE–Sand Composites Modified with Rice Husk, Rice Husk Ash, and Biochar" is forwarded by the Department of Applied Sciences and Chemical Engineering, Pulchowk Campus, for the approval to the Evaluation Committee, Institute of Engineering (IOE), Tribhuvan University (T.U.), Nepal.

He has fulfilled all the requirements laid down by the Institute of Engineering (IOE), Tribhuvan University (T.U.), Nepal for the Thesis.

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CERTIFICATION AND LETTER OF APPROVAL

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "Mechanical and Physical Performance Evaluation of Laboratory-Scale LDPE–Sand Composites Modified with Rice Husk, Rice Husk Ash, and Biochar" submitted by Mr. Shreeyash Acharya (080MSMSE018) in partial fulfilment of the requirements for the degree of Masters in Material Science and Engineering.

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ABSTRACT

Plastic waste and agricultural residues pose growing environmental challenges in developing countries such as Nepal. This study investigates low-density polyethylene (LDPE) as a binder for sustainable plastic sand composite bricks modified with rice husk derivatives. Laboratory-scale specimens (100 × 50 × 50 mm) were prepared using a control mix of 30:70 plastics to sand ratios, while modified mixes incorporated 10% additive as sand replacement. Composites were evaluated through visual inspection, hardness, soundness, water absorption, compressive strength, and FTIR analysis. Results showed that RHA modified specimens achieved the highest average compressive strength of 19.34 MPa, whereas RH specimens showed the lowest strength of 15.56 MPa. FTIR confirmed characteristic LDPE peaks and additive-related functional groups. Despite laboratory scale fabrication, the results compared favorably with reported studies. Findings indicate that rice husk ash significantly enhances composite performance and demonstrates strong potential for sustainable construction applications.

Keywords: Biochar, Compressive strength, FTIR analysis, Low-density polyethylene (LDPE), Plastic sand composites, Rice husk, Rice husk ash, Sustainable construction materials

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	**Full Form**
RHB	Rice Husk Biochar
RH	Rice Husk
RHA	Rice Husk Ash
LDPE	Low-Density Polyethylene
FTIR	Fourier Transform Infrared Spectroscopy
IS	Indian Standard
NBC	Nepal Building Code
UTM	Universal Testing Machine
CTRL	Control Sample
PE	Polyethylene

LIST OF SYMBOLS

%	Percentage
°C	Degree Celsius
g	Gram
C–H	Carbon–Hydrogen bond (stretching vibration)
C–O	Carbon–Oxygen bond
C=O	Carbonyl group
O–H	Hydroxyl group
Si–O	Silicon–Oxygen bond
Si–O–Si	Siloxane bond (Silicon–Oxygen–Silicon)

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

INTRODUCTION

1.1 Background

Plastic waste has become one of the most important environmental challenges of this century. The global production and consumption rate of plastics has increased due to their low cost, durability, and because of their use in various applications such as packaging and as a mean of transportation of goods. The different type of plastic is PET (Polyethylene terephthalate), HDPE (High density polyethylene), PVC (polyvinyl chloride), LDPE (Low – density polyethylene), PP(Polypropylene), PS(Polystyrene) and others (Patil et al., 2020).

Among the different types of plastics, Low Density Polyethylene (LDPE) is widely used in manufacturing plastic bags because of its lightweight and flexible properties. However, the non-biodegradable nature of LDPE leads to long-term environmental pollution when disposed improperly. In many developing countries, including Nepal, plastic waste management remains a significant challenge. Large quantities of plastic bags are discarded into landfills, drainage systems, and open environments. Since plastics can take hundreds of years to decompose naturally, their accumulation contributes to soil contamination, blockage of drainage systems, and harm to ecosystems (Beepala et al., 2025). Recycling rates of plastic materials are still relatively low due to technical, economic, and infrastructural limitations.

At the same time, agricultural waste materials are generated in large quantities from farming and agricultural industries. One such agricultural product is rice husk, which is produced during the milling process of rice. Rice husk accounts for approximately 20% of the weight of harvested rice and is often treated as waste in many rice producing regions. Improper disposal or open burning of rice husk can cause environmental pollution and waste valuable resources which can be utilized on various application after some processing (Alsharari, 2025).

Rice husk can also be converted into other useful materials such as rice husk ash (RHA) and biochar through combustion and pyrolysis processes, respectively. Rice husk ash is known for its high silica content, which has been utilized in various construction and material engineering applications. Similarly, biochar is a carbon-rich porous material with its potential use as a reinforcing filler in composite materials. In recent years, researchers have explored different innovative ways to use waste plastic as a binding material in construction products. One of such approach is the production of plastic–sand composite bricks or blocks, where melted plastic acts as a binder and sand functions as an aggregate. These composite materials have shown advantages such as reduced water absorption, improved durability, and resistance to environmental degradation compared to conventional clay bricks (Tiwari, 2025).

Using agricultural waste materials into plastic-based composites could further enhance sustainability by simultaneously addressing two major waste streams: plastic waste and agricultural residues. Rice husk, rice husk ash, and biochar may influence the mechanical and physical properties of plastic–sand composites due to their distinct chemical compositions and structural characteristics.

However, research on the incorporation of rice husk-based materials into plastic–sand composites is still limited, particularly in the context of controlled laboratory-scale experimental studies. Understanding the effects of these additives on composite performance is essential before considering large-scale applications in construction materials. Proper knowledge about the materials to be used while preparing the composite samples will make the result more consistent and we can find the properties of those kind of materials first and see the effect they will have on the composite samples.

Therefore, this study aims to investigate the mechanical and physical properties of laboratory-scale LDPE–sand composites modified with rice husk, rice husk ash, and biochar. The study evaluates parameters such as compressive strength, and water absorption, hardness and soundness as well as the physical parameters, while also analyzing the chemical characteristics of the additives using Fourier Transform Infrared Spectroscopy (FTIR). The findings of this research may contribute to the development of sustainable construction materials while promoting the reuse of plastic and agricultural waste.

1.2 Statement of the Problem

The increasing accumulation of plastic waste poses serious environmental and waste management challenges worldwide. In Nepal, plastic bags made from LDPE are widely used but are often disposed of improperly due to limited recycling infrastructure and lack of proper laws and regulation as well due to the lack of education and proper knowledge to people about the effect of plastic at Nano level that can affect us directly or indirectly through various sources like air and water or the foods that we take. These plastic wastes accumulate in landfills, waterways, and open environments, causing environmental pollution and long-term ecological damage. At the same time, agricultural residues such as rice husk are generated in significant quantities from rice milling industries. In many cases, these residues are either burned or discarded without proper utilization, which contributes to air pollution and resource wastage. Although rice husk can be converted into rice husk ash and biochar, their potential use in construction materials remains underexplored.

Traditional clay brick production also presents environmental concerns. The manufacturing process requires large quantities of clay and significant energy consumption during kiln firing, which contributes to land degradation and greenhouse gas emissions. As a result, there is a growing need for alternative construction materials that are more sustainable and environmentally friendly (Aneke & Shabangu, 2021).

Previous studies have demonstrated that plastic waste can be used as a binder to produce plastic–sand composite bricks (Tiwari, 2025). However, most existing research focuses primarily on plastic and sand mixtures without investigating the influence of agricultural waste additives. Furthermore, limited studies have conducted comparative evaluations of rice husk, rice husk ash, and biochar within the same composite system.

Additionally, many studies focus on full-scale bricks rather than controlled laboratory-scale specimens, which can provide more precise experimental evaluation of material properties. There is therefore a need to systematically investigate how rice husk-based materials affect the mechanical and physical performance of LDPE–sand composites under controlled experimental conditions.

This thesis seeks to address this gap by experimentally evaluating the effect of rice husk, rice husk ash, and biochar as partial replacements of sand in LDPE–sand composites.

1.3 Objectives of the Study

The main objective of the study is as follow:

To evaluate the mechanical and physical properties of laboratory scale LDPE–sand composite bricks modified with rice husk, rice husk ash, and rice husk Biochar.

The Specific objectives of the study are as follows:

a. To prepare the rice husk ash and rice husk bio char at lab.
b. To fabricate standardized laboratory-scale LDPE–sand composite specimens.
c. To partially replace sand (10%) with rice husk, RHA, and biochar and fabricate LDPE-sand-additives composite specimens.
d. To find physical characteristics such as hardness, soundness, and water absorption.

e. To analyze the chemical characteristics of the additives and brick samples using FTIR.
f. To compare the performance of modified bricks with the control LDPE–sand composite brick sample.

1.4 Scope and Limitations of the Study

1.4.1 Scope of the Study

The scopes of the study are as follows.

This research focuses on the laboratory-scale production and evaluation of plastic–sand composite materials modified with rice husk-based additives. The study primarily investigates the mechanical and physical properties of the composites prepared using LDPE as the binder material and sand as the aggregate.

In this thesis the materials used in the fabrication process and made in lab and the process of making rice husk biochar and rice husk ash is studied. It will be beneficial to know about the process of turning the raw rice husk to biochar, which can be used in various fields.

The scope of the research includes the preparation of four types of composite mixtures: a control mixture containing only LDPE and sand, and three modified mixtures containing rice husk, rice husk ash, and biochar as partial replacements of sand of 10 percent by weight. The composites are fabricated using laboratory molds with standardized dimensions for all samples and tested under controlled conditions.

Mechanical performance is evaluated through compressive strength testing using a Universal Testing Machine. Physical properties such as water absorption, soundness and harness is also measured to assess the structural characteristics of the composites. In addition, Fourier Transform Infrared Spectroscopy (FTIR) analysis is conducted to examine the chemical functional groups present in the rice husk-based additives.

The study aims to provide a comparative analysis of the performance of different additive materials and to identify their influence on the overall properties of LDPE–sand composites. The findings are intended to contribute to the development of sustainable construction materials using recycled plastic and agricultural waste.

1.4.2 Limitation of the Study

Despite its contributions, this study has several limitations.

First, the research is conducted using laboratory-scale specimens rather than full-scale construction bricks or blocks. Therefore, the results may not fully represent the performance of large-scale products used in real construction applications.

Second, the specimen fabrication process involves manual mixing and compaction, which may introduce some variability in the distribution of materials within the composite.

Third, the number of samples tested is limited due to time and resource constraints, which may affect the statistical reliability of the results.

Fourth, advanced microstructural characterization techniques such as Scanning Electron Microscopy (SEM) or Transmission Electron Microscopy (TEM) are not included in the study due to limited access to these facilities.

Finally, the study primarily focuses on basic mechanical and physical properties, and does not include long-term durability tests such as freeze–thaw resistance, thermal conductivity, or weathering performance.

1.5 Relevance of the Study

The increasing accumulation of plastic waste has become a major environmental concern worldwide. Low-density polyethylene (LDPE), commonly used in packaging materials such as plastic bags and films, contributes significantly to plastic pollution due to its non-biodegradable nature. Improper disposal of plastic waste leads to environmental degradation, blockage of drainage systems, and long-term ecological impacts. Therefore, developing sustainable methods for recycling plastic waste is essential.

At the same time, agricultural residues such as rice husk are generated in large quantities from rice milling industries, particularly in agricultural countries. Rice husk and its derivatives, including rice husk ash and biochar, are often disposed of or burned, which may lead to environmental pollution. However, these materials possess valuable chemical and structural properties, such as high silica content in rice husk ash and porous carbon structures in biochar, making them suitable for use as additives in composite materials.

The utilization of plastic waste together with agricultural residues in construction materials presents a promising approach for sustainable waste management. Plastic–sand composite bricks have gained attention as an alternative building material due to their durability, low water absorption, and resistance to environmental degradation. Incorporating rice husk-based materials into such composites may further enhance their mechanical and physical properties while simultaneously reducing environmental waste.

This study is therefore relevant in addressing two major environmental challenges: plastic waste management and agricultural waste utilization. By investigating the mechanical and physical performance of LDPE–sand composites modified with rice husk, rice husk ash, and biochar, the research contributes to the development of sustainable construction materials and promotes the circular use of waste resources.

Furthermore, the findings of this study may support future research on alternative building materials and provide valuable experimental data for the development of eco-friendly composite construction products.

1.6 Novelty of the Study

The novelty of this study lies in the comparative evaluation of RH, RHA, and RHB within a single LDPE–sand composite system under identical conditions. Unlike previous studies focusing on individual additives, this research integrates mechanical, physical, and FTIR characterization to identify the optimum rice husk derivative and contributes laboratory-scale insights into sustainable composite development.

1.7 Feasibility of the Study Within Scope and Time Frame

The proposed thesis is considered feasible within the available scope, laboratory facilities, and time frame. The materials required for this study, including LDPE plastic pellets, sand and rice husk are readily available and economically feasible. Recycled LDPE pellets were obtained from plastic packaging manufacture company, while rice husk were sourced from rice mills and rice husk derivatives like biochar and ash, required for this study can be easily produced in material lab within a short duration. The fabrication process of the composite specimens is relatively simple and can be carried out using basic laboratory equipment. The production of the composite samples involves melting the LDPE plastic and mixing it with sand and additive materials, followed by molding and cooling. This process does not require complex manufacturing techniques and can be conducted using conventional heating equipment and molds available in the laboratory. The experimental testing required for this study is also achievable with the available laboratory facilities. Mechanical testing such as compressive strength measurement can be conducted using a Universal Testing Machine (UTM). Physical properties including scratch test, ringing test and water absorption test can be determined using standard laboratory procedures. In addition, FTIR analysis can be performed to characterize the functional groups present in the raw materials and composite samples.

The total number of specimens required for the study is manageable, as only a limited number of sample groups are prepared and tested. This ensures that the experiments can be completed within the available time period. Furthermore, the experimental procedures are straightforward and do not require highly specialized equipment or extended testing durations.

Therefore, considering the availability of materials, laboratory equipment, and the manageable scope of the experimental work, the proposed thesis can be successfully completed within the designated time frame and resources.

1.8 Organization of the Thesis

This thesis is organized into seven chapters. Chapter One introduces the background, problem statement, objectives, scope, relevance, and feasibility of the research. Chapter Two presents a review of previous studies related to plastic waste utilization, plastic–sand composites, and rice husk-based materials. Chapter Three describes the research methodology, including materials, specimen preparation, and experimental procedures. Chapter Four presents the experimental results and discussion of the findings. Chapter Five discusses the challenges encountered and limitations of the study. Chapter Six presents the conclusions drawn from the research. Finally, Chapter Seven provides recommendations for future research and practical applications

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Plastic waste generation has become one of the most serious environmental concerns worldwide. Rapid industrialization and increased consumption of plastic products have significantly increased the amount of plastic waste generated each year. Due to their durability and resistance to degradation, plastics persist in the environment for long periods, causing serious ecological problems (Aneke & Shabangu, 2021).

Researchers have increasingly explored ways to reuse plastic waste in engineering applications, particularly in construction materials. One promising approach is the development of plastic-based composite materials where molten plastic acts as a binding agent for aggregates such as sand (Barman et al., 2022). In addition, agricultural waste materials such as rice husk, rice husk ash, and biochar have also attracted attention for their potential use as fillers or reinforcing materials in composite systems.

This chapter reviews previous research related to plastic waste utilization in construction materials, plastic–sand composite bricks, rice husk-based materials, and the application of biochar in composite materials.

2.2 Plastic Waste and Environmental Concerns

The rapid growth of plastic production and consumption has resulted in significant environmental challenges worldwide. Plastics are widely used in packaging, construction, automotive components, electronics, and household products due to their durability, lightweight nature, and low manufacturing cost. However, the same properties that make plastics useful also make them environmentally problematic, as most conventional plastics are non-biodegradable and can persist in the environment for hundreds of years (Rouch, 2021).

Global plastic production has increased dramatically over the past few decades. According to several studies, million tons of plastic are produced annually, and a large portion of this material eventually becomes waste after short periods of use. Improper disposal of plastic waste contributes to environmental pollution in both terrestrial and aquatic ecosystems. Large quantities of plastic waste accumulate in landfills, open dumping sites, rivers, and oceans, posing serious environmental and ecological risks. Low-density polyethylene (LDPE) is one of the most widely used plastic materials due to its flexibility and resistance to moisture. It is commonly used in plastic bags, and containers. Despite its usefulness, LDPE waste is a major contributor to plastic pollution because it is difficult to degrade naturally. When disposed of improperly, LDPE can remain in the environment for extremely long periods without significant decomposition.

The accumulation of plastic waste in landfills presents several environmental concerns. Plastics occupy large volumes of landfill space and do not easily degrade, which limits the capacity of waste disposal sites. In addition, certain plastic materials may release harmful substances during degradation or when exposed to environmental conditions. The long-term presence of plastic waste in soil can negatively affect soil quality and microbial activity (Patil et al., 2020).

Another major environmental issue associated with plastic waste is marine pollution. Large amounts of plastic debris enter oceans and waterways each year through improper waste management practices. Plastic materials in aquatic environments can harm marine organisms through ingestion and entanglement. Over time, plastics may break down into smaller particles known as micro plastics, which can accumulate in aquatic ecosystems and enter the food chain (Beepala et al., 2025).

Burning plastic waste is sometimes used as a method of waste disposal in regions with limited waste management infrastructure. However, uncontrolled burning of plastics can release toxic gases such as carbon monoxide, dioxins, and other hazardous compounds into the atmosphere. These emissions contribute to air pollution and may pose risks to human health and the environment.

In response to these environmental concerns, researchers and policymakers have been exploring alternative strategies for managing plastic waste. Recycling and reuse of plastic materials are considered effective approaches to reduce the volume of plastic waste entering the environment. Mechanical recycling processes allow plastic waste to be converted into new products, while other approaches involve incorporating plastic waste into construction materials such as asphalt mixtures, concrete composites, and plastic–sand bricks.

The utilization of plastic waste in construction materials has gained significant attention in recent years. Plastic materials can act as binding agents when heated and mixed with aggregates, forming durable composite materials. Plastic–sand composite bricks have been reported to exhibit good mechanical strength, resistance to moisture, and improved durability compared to conventional clay bricks. These properties make plastic–sand composites a promising alternative construction material while simultaneously addressing the issue of plastic waste disposal.

Furthermore, the use of plastic waste in construction applications contributes to sustainable waste management by diverting plastic from landfills and reducing the demand for conventional construction materials. By converting waste plastics into useful construction products, it is possible to promote resource efficiency and support the development of environmentally sustainable building practices (Nayak et al., 2025).

Therefore, the recycling and utilization of plastic waste in construction materials represent a promising solution for addressing the environmental challenges associated with plastic pollution. Continued research in this field is essential to develop innovative materials and technologies that can effectively transform plastic waste into valuable resources for sustainable development.

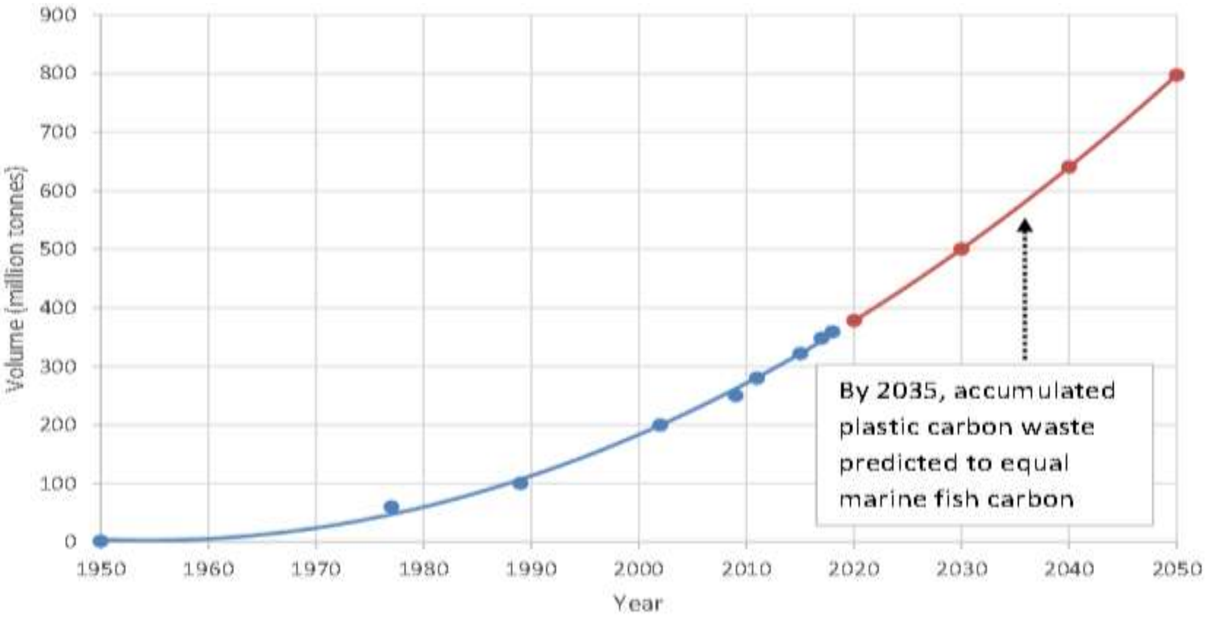
According to Beepala et al., (2025) 420 million tons of plastic is assumed to be globally produced for the year 2025.Which is way more than the plastic produced globally on the year 2015 and 2020 respectively. As shown in Table 1 the production of plastic has been increasing year by year. This trend is concerning due to its environmental implication. The data indicates a continuous increase in global plastic production over the years. This trend highlights the growing dependence on plastic materials and the resulting increase in plastic waste generation, which poses significant environmental challenges.

Table 1: Global plastic production data (1950–2025)

Year	Global Production (Million Tons)
1950	2
1970	35
1990	100
2000	200
2010	300
2020	370
2025*	420 (projected)

Source: (Beepala et al., 2025)

According to Rouch (2021), by 2035 accumulated plastic carbon waste will be equal to marine fish carbon. Figure 1 shows the quantity of plastic carbon waste that is going to impact us in the upcoming years. If the consumption keeps on growing in the same speed as of now, then by the year 2035 the waste plastic that would be accumulated is going to be equal to the marine fish carbon. So we should focus on recycling the waste plastic from today onwards so that we can contribute little from our side to prevent the upcoming accumulation of waste plastic.



Source: (Rouch, 2021)

Figure 1: Prediction of plastic waste accumulation by 2035.

As shown in Table 2, the pollution is categorized together with the effect that they have on environment, economy, biology and human health.

Table 2: Classification of pollution and its effects

Category	Type of Effect
Environmental	Soil Contamination, Air pollution ,Water pollution
Biological	Marine Life Impact
Human Health	Carcinogenicity(linked to cancer)
Economic	Waste Management Cost

Source: (Beepala et al.,2025)

This highlights the multi-dimensional impact of plastic pollution, emphasizing the need for sustainable waste management strategies such as material recycling and reuse.

2.3 Plastic as Binder in Construction Materials

2.3.1 Types of Plastics Used in Construction Applications

Plastics used in construction applications can generally be classified into two main categories: thermoplastics and thermosetting plastics. Thermoplastics soften and melt when heated and solidify upon cooling, allowing them to be reshaped multiple times. In contrast, thermosetting plastics undergo irreversible chemical reactions during curing and cannot be remelted once hardened.

Due to their ability to melt and reform, thermoplastics are commonly used in plastic recycling applications and plastic-based composite materials. Several thermoplastic polymers have been investigated for use in construction materials, including polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), and polyvinyl chloride (PVC). These materials differ in terms of their physical properties, melting temperature, chemical structure, and suitability for composite fabrication (unionfab, 2026).

Polyethylene is one of the most widely used thermoplastic materials and exists in several forms, including low-density polyethylene (LDPE) and high-density polyethylene (HDPE). Polypropylene is another commonly used plastic with good mechanical strength and thermal resistance. Polyethylene terephthalate is widely used in beverage bottles and packaging materials, while polyvinyl chloride is commonly used in pipes and construction products. Among these materials, polyethylene-based plastics have been frequently studied for plastic–sand composite production due to their relatively low melting temperatures and ease of processing.

2.3.2 Melting Temperature of Common Thermoplastics

The melting temperature of plastic materials plays an important role in determining their suitability for use as binders in composite construction materials. Plastics with very high melting temperatures require advanced processing equipment and higher energy consumption, while plastics with moderate melting temperatures can be processed using simple heating methods. The typical melting temperature ranges of commonly used thermoplastics are shown in Table 3.

Table 3: Melting temperature of different types of plastics

Plastic Type	Abbreviation	Melting Temperature Range (°C)	Common Uses
Low Density Polyethylene	LDPE	110 – 130	Plastic bags, films
High Density Polyethylene	HDPE	120 – 180	Containers, pipes
Polypropylene	PP	160 – 170	Automotive parts, packaging
Polyethylene Terephthalate	PET	250 – 260	Bottles, fibers
Polyvinyl Chloride	PVC	160 – 210	Pipes, fittings

Source: Adapted from (unionfab, 2026)

Among these materials, LDPE has one of the lowest melting temperatures, which makes it easier to process in laboratory conditions. Plastics such as PET require significantly higher temperatures and specialized equipment for melting and processing (unionfab, 2026).

2.3.3 Selection of LDPE as Binder Material

In this study, low-density polyethylene (LDPE) was selected as the binder material for the production of plastic–sand composite specimens. The selection of LDPE was based on several practical and material-related considerations.

First, LDPE has a relatively low melting temperature ranging between 110°C and 130°C, which allows it to be easily melted using conventional heating equipment. This property makes LDPE suitable for laboratory-scale fabrication processes without the need for specialized industrial machinery (unionfab, 2026).

Second, LDPE exhibits good flexibility and ductility, which helps improve the bonding between plastic and aggregate particles in composite materials. When molten LDPE is mixed with sand and other filler materials, it can effectively coat the particles and form a continuous binding matrix upon cooling. Third, LDPE is widely available in the form of plastic bags and packaging materials, which are among the most common sources of plastic waste. Utilizing LDPE waste in composite construction materials provides an effective approach for recycling plastic waste and reducing environmental pollution.

Additionally, compared to plastics such as PET and PVC, LDPE requires lower processing temperatures and energy consumption, making it more suitable for small-scale experimental studies.

For these reasons, LDPE was selected as the primary binder material for the fabrication of plastic–sand composite specimens in this research. Yusuf et al., (2024) used LDPE waste plastic as binders in composites for sustainable construction application and demonstrated its effectiveness in producing construction materials.

2.4 Plastic–Sand Composite Bricks

Plastic–sand composite bricks are an innovative construction material developed as a sustainable alternative to conventional clay bricks and cement-based masonry units. These composite bricks are produced by melting plastic materials and mixing them with sand or other aggregates to form a solid structure. The molten plastic acts as a binder that holds the aggregate particles together, creating a composite material with desirable mechanical and physical properties.

The concept of plastic–sand composite bricks has gained significant attention in recent years due to the increasing need for sustainable waste management solutions. Large quantities of plastic waste are generated globally, and traditional disposal methods such as landfilling and incineration pose serious environmental concerns. Converting plastic waste into construction materials offers an effective approach for reducing plastic pollution while simultaneously producing useful building products.

The manufacturing process of plastic–sand composite bricks typically involves heating plastic waste until it reaches its melting temperature. The molten plastic is then mixed with sand in predetermined proportions to form a homogeneous mixture. This mixture is subsequently placed into molds and compacted to remove air voids. Once the material cools and solidifies, it forms a rigid composite brick.

One of the key advantages of plastic–sand composite bricks is their low water absorption capacity. Since plastics are hydrophobic in nature, the resulting composite material exhibits improved resistance to moisture penetration compared to traditional clay bricks. This characteristic can enhance durability and reduce deterioration caused by water exposure. In addition to moisture resistance, plastic–sand composite bricks have been reported to possess good compressive strength and durability. The mechanical performance of these composites depends on several factors, including the type of plastic used, the plastic-to-sand ratio, particle size distribution of the sand, and the manufacturing process. Studies have shown that appropriate proportions of plastic and sand can produce bricks with compressive strength comparable to or higher than conventional masonry units (Chauhan et al., 2019).

Another advantage of plastic–sand composite bricks is their potential to reduce environmental impacts associated with conventional brick production. Traditional clay brick manufacturing requires high-temperature kiln firing, which consumes significant amounts of energy and releases greenhouse gases. In contrast, plastic–sand composite bricks can be manufactured at relatively lower temperatures through the melting of thermoplastic materials, thereby reducing energy consumption and carbon emissions (Frank et al., 2021).

Furthermore, plastic–sand composite bricks can be produced using a variety of waste plastics, including polyethylene, polypropylene, and polyethylene terephthalate. Among these materials, polyethylene-based plastics such as LDPE are commonly used due to their lower melting temperatures and ease of processing. The use of plastic waste as a binder also helps divert large quantities of plastic from landfills and open dumping sites (Tiwari, 2025).

Researchers have also explored the incorporation of additional materials such as natural fibers, agricultural residues, and mineral fillers into plastic–sand composites to improve their mechanical properties and sustainability. These additives can influence characteristics such as strength, density, and thermal performance of the composite material.

Despite the advantages, certain challenges remain in the production of plastic–sand composite bricks. Proper control of the mixing temperature and uniform distribution of plastic within the aggregate matrix are essential to ensure consistent quality. Inadequate mixing or improper temperature control may lead to weak bonding between plastic and sand particles.

Nevertheless, plastic–sand composite bricks represent a promising construction material that combines waste recycling with sustainable building practices. Continued research in this field can contribute to the development of environmentally friendly construction materials while addressing the growing issue of plastic waste management.

According to the plastic sand brick data from Chauhan et al. (2019), compressive strength for plastic: sand ratio is greater for 1:2(33.33% :66.67%) ratio followed by 1:3 (25%:75%) ratio and lowest strength is of 1:4(20%:80%) ratio.

The structural integrity of plastic-sand bricks varies significantly based on the binder-to-filler ratio. Research by Frank et al. (2021), indicates that a 30:70 mix can achieve a maximum strength of 38.14 MPa. However, as the proportion of filler increases, strength typically declines, for instance, Chauhan et al. (2019), found that 1:2 and 1:4 ratios produced 18.63–19.96 MPa and 5.7–6.27 MPa, respectively. This downward trend is further supported by Suriyaa et al. (2020), who recorded a low of 3.50 MPa for a 1:4 (20%:80%) ratio, highlighting the sensitivity of the composite to high aggregate volumes.

2.5 Agricultural Waste in Construction Materials

The growing demand for sustainable construction materials has led researchers to explore the potential use of agricultural waste in engineering applications. Agricultural residues are generated in large quantities worldwide as by-products of farming and food processing industries. These materials are often considered waste and are commonly disposed of through open burning, landfilling, or uncontrolled dumping. Such disposal methods not only waste valuable resources but also contribute to environmental pollution and greenhouse gas emissions. In recent years, the concept of utilizing agricultural waste in construction materials has gained significant attention as a strategy to promote sustainable development. Agricultural residues such as rice husk, wheat straw, coconut fiber, sugarcane bagasse, and palm kernel shells possess unique physical and chemical properties that can be beneficial in composite material production. These materials can be used as fillers, reinforcement agents, or additives in construction composites.

One of the primary advantages of using agricultural waste in construction materials is the reduction of environmental impact. By incorporating waste materials into construction products, the amount of waste sent to landfills can be significantly reduced. At the same time, the demand for natural raw materials such as sand, gravel, and clay can be minimized, contributing to the conservation of natural resources (Alsharari, 2025).

Agricultural waste materials also offer certain engineering benefits. Many plant-based residues contain fibrous structures that can enhance the internal bonding and structural integrity of composite materials. These fibers may improve crack resistance, toughness, and overall mechanical performance when properly incorporated into the composite matrix. Additionally, the relatively low density of many agricultural residues can help produce lightweight construction materials. Among various agricultural wastes, rice husk has attracted considerable research interest due to its abundance and high silica content. Rice husk derivatives such as rice husk ash and biochar have been widely studied for their potential applications in construction materials, including concrete, bricks, and polymer composites. These materials can influence properties such as strength, porosity, and durability of the final product.

Despite the potential benefits, the incorporation of agricultural waste in construction materials must be carefully controlled. The organic nature of many agricultural residues can influence moisture absorption, degradation behavior, and bonding characteristics within composite systems. Therefore, understanding the physical and chemical properties of these materials is essential for optimizing their use in construction applications (Barbhuiya et al., 2024).

Overall, the utilization of agricultural waste in construction materials provides an effective approach for waste management, resource conservation, and sustainable material development. Continued research in this field is necessary to fully understand the behavior of these materials and to develop reliable construction products that incorporate agricultural residues.

Alsharari (2025), reported that agricultural by-products, specifically Rice Husk Ash, Palm Oil Fuel Ash, and Corn Cob Ash, serve as viable, pozzolanic partial cement replacements in cementitious composites. These materials, with optimal replacement levels of 10–20%, improve workability, compressive strength, and durability.

2.6 Rice Husk and its Derivatives in Construction Materials

Agricultural residues have gained increasing attention in recent years as sustainable materials for construction applications. Among these residues, rice husk is one of the most abundant agricultural by-products generated during the rice milling process. Rice is one of the most widely cultivated crops worldwide, particularly in Asia, which results in the generation of large quantities of rice husk waste each year.

Rice husk typically accounts for approximately 20% of the total weight of harvested rice. Due to its low nutritional value and limited industrial applications, large amounts of rice husk are often disposed of through open burning or dumping. Such disposal methods contribute to environmental pollution and inefficient resource utilization. As a result, researchers have been investigating alternative ways to utilize rice husk and its derivatives in engineering and construction materials.

Rice husk is primarily composed of organic and inorganic components, including cellulose, hemicellulose, lignin, and silica. The silica content in rice husk is particularly significant, typically ranging between 15% and 20% by weight. This high silica content makes rice husk an attractive material for use in construction-related applications, especially when processed into forms such as rice husk ash or biochar.

In construction materials research, rice husk and its derivatives have been studied as fillers, reinforcing agents, and additives in composite materials. These materials can influence properties such as density, strength, porosity, and thermal performance. Incorporating agricultural waste materials into construction composites also contributes to sustainable development by reducing environmental waste and conserving natural resources.

2.6.1 Rice Husk in Construction Materials

Raw rice husk is the outer protective layer of rice grains that is removed during the milling process. It is a lightweight, fibrous material composed mainly of organic compounds such as cellulose and lignin, along with a significant amount of silica embedded within its structure.

The fibrous structure of rice husk makes it useful as a filler material in certain composite applications. When incorporated into construction materials, rice husk can help reduce the density of the composite due to its lightweight nature. This characteristic can be beneficial in producing lightweight building materials that are easier to handle and transport. However, the presence of organic components in raw rice husk can also introduce certain limitations. Rice husk tends to have a relatively high porosity and water absorption capacity, which may influence the durability and moisture resistance of composite materials. Additionally, the organic nature of rice husk may affect the bonding behavior within the composite matrix depending on the type of binder used.

Despite these limitations, raw rice husk has been investigated as an additive in various construction materials, including cement composites, polymer composites, and building panels. Its availability, low cost, and renewable nature make it an attractive option for sustainable material development.

Many research has been done on raw rice husk for preparing carbon or in energy efficient materials, but there has been no significant use of rice husk in its raw form on plastic sand composite brick or for construction uses. It has wide application after being converted to its biochar or ash form but the raw form of rice husk has many space left to be worked on.

2.6.2 Rice Husk Ash (RHA)

Rice husk ash is produced when rice husk is burned under controlled conditions. The ash typically contains a high percentage of silica, which can range from 80% to 95%.

Tiwari (2025), used rice husk along with plastic and sand and fabricated the brick of different ratio, showing that the plastic sand bricks can be made of composite materials with enhancement in strength and other properties.

In composite materials, rice husk ash can act as a fine filler that improves particle packing and enhances mechanical performance. The presence of silica particles may contribute to improved bonding between components within the composite structure.

2.6.3 Biochar in Composite Materials

Biochar is a carbon-rich material produced through the pyrolysis of biomass under limited oxygen conditions. Rice husk biochar has gained attention in recent years due to its porous structure and high carbon content.

Barbhuiya et al. (2024), investigated the use of biochar in concrete and reported that Biochar, as a carbon-rich material derived from biomass, offers several potential benefits such as reduced environmental impact, improved material properties and the opportunity to contribute to the circular economy.

Javed et al. (2025), investigated the use of biochar in construction material and reported that incorporating rice husk biochar (RHB) into blocks can balance environmental sustainability with functional performance when dosage levels are appropriately tailored to the intended application.

The porous structure of biochar may enhance interaction between filler particles and polymer matrices, potentially improving the mechanical performance of composite materials. However, the effectiveness of biochar as a reinforcing material strongly depends on its dosage, particle size, and compatibility with the matrix. Excessive incorporation of biochar may increase internal porosity and reduce the effective bonding area, leading to a reduction in mechanical strength. Therefore, optimizing the content of biochar is critical to achieving balanced composite properties.

2.7 Mechanical Properties of Plastic Based Composites

Plastic-based composite materials have gained increasing attention in construction and engineering applications due to their durability, lightweight characteristics, and resistance to environmental degradation. These materials are typically produced by combining a polymer matrix with reinforcing fillers or aggregates such as sand, fibers, or mineral particles. The mechanical performance of plastic composites depends on the interaction between the polymer matrix and the reinforcing materials.

One of the most important mechanical properties evaluated in construction materials is compressive strength. Compressive strength represents the ability of a material to resist compressive loads without failure. In plastic–sand composite materials, the compressive strength is influenced by several factors, including the type of plastic used, the ratio of plastic to aggregate, particle size distribution of the aggregate, and the uniformity of mixing during fabrication. Proper bonding between the plastic matrix and aggregate particles is essential to ensure effective load transfer within the composite structure (Chauhan et al., 2019).

The proportion of plastic binder plays a significant role in determining the strength of plastic composites. When the plastic content is too low, the bonding between aggregate particles may be insufficient, leading to weak composite structures. On the other hand, excessive plastic content may reduce stiffness and increase material cost. Therefore, an optimal plastic-to-aggregate ratio is required to achieve balanced mechanical performance.

Another important property of plastic composites is density. Density affects the weight, handling, and structural performance of construction materials. Plastic-based composites often exhibit lower density compared to conventional cement-based materials because plastic has a lower specific gravity than most mineral aggregates. The incorporation of lightweight fillers such as agricultural residues can further reduce the density of composite materials, producing lightweight construction units.

Water absorption is another important property that influences the durability of construction materials. Traditional clay bricks and cement-based materials often absorb significant amounts of water, which can lead to deterioration over time. In contrast, plastic materials are naturally hydrophobic, meaning they repel water. As a result, plastic–sand composites generally exhibit lower water absorption compared to conventional bricks, improving their resistance to moisture-related damage (Ikechukwu & Naghizadeh, 2022).

In addition to these properties, plastic composites are known for their high resistance to chemical corrosion and environmental degradation. Unlike cement-based materials, plastic composites do not undergo hydration reactions or chemical deterioration when exposed to certain environmental conditions. This property makes plastic-based composites suitable for use in environments where moisture or chemical exposure may be present. However, the mechanical behavior of plastic composites can be affected by factors such as temperature, manufacturing conditions, and the distribution of filler materials within the matrix. Uniform mixing and proper molding techniques are essential to achieve consistent mechanical performance. Inadequate mixing may lead to voids or weak bonding regions within the composite, reducing its strength and durability.

Therefore, evaluating the mechanical and physical properties of plastic-based composites is essential to determine their suitability for construction applications. Understanding how different additives and filler materials influence these properties can help optimize composite formulations and improve the overall performance of plastic-based construction materials.

2.8 FTIR Characterization

Chemical characterization techniques are essential for understanding the composition and structure of materials used in composite systems.

Fourier Transform Infrared Spectroscopy (FTIR) is a widely used analytical technique for identifying functional groups and chemical bonds in materials. The technique works by measuring the absorption of infrared radiation at different wavelengths.

According to Stuart (2004), FTIR analysis can identify functional groups such as hydroxyl (O–H), carbonyl (C=O), and silicon–oxygen (Si–O) bonds in organic and inorganic materials. In biomass materials such as rice husk and biochar, FTIR analysis can provide information about chemical composition and structural characteristics.

In this study, FTIR analysis is used to examine the chemical characteristics of rice husk, rice husk ash, and biochar used as additives in LDPE–sand composites.

2.9 Summary of Previous Studies

The literature review indicates that plastic waste can be effectively utilized in construction materials, particularly in plastic–sand composite bricks where plastic acts as a binding agent. These composites demonstrate promising properties such as good compressive strength, low water absorption, improved durability, and resistance to environmental degradation. In addition, the use of waste plastic contributes to sustainable waste management. Agricultural waste materials such as rice husk and rice husk ash have also been widely studied due to their potential use in composite materials. Rice husk ash, in particular, contains a high amount of amorphous silica, which can enhance mechanical properties and improve bonding within the composite matrix. These materials are also advantageous due to their low cost, availability, and environmentally friendly nature.

Biochar has recently emerged as a potential filler material in polymer composites due to its porous structure, high surface area, and carbon-rich composition. It is reported to influence properties such as density, thermal stability, and microstructural characteristics of composites, although its effect on mechanical strength varies depending on processing conditions and composition.

However, limited research has been conducted to comparatively evaluate the effects of rice husk, rice husk ash, and biochar in LDPE–sand composite materials under controlled laboratory conditions. Furthermore, there is a lack of comprehensive studies examining their combined influence on both physical and mechanical performance, highlighting the need for systematic investigation in this area. The Mix ratio used on previous studies along with their strength is shown in Table 4, which helps to analyze the most suitable mix ratio.

Table 4: Summary of previous study

Author	Material Used	Mix Ratio	Mold Size(mm)	Strength Result (MPa)
Frank et al., (2021)	Plastic + Sand	30:70 60:40 80:20	222×106×73	38.14 33.25 29.45
Chauhan et al., (2019)	Plastic + sand	1:2(33.33% :66.67%) 1:3 (25%:75%) 1:4(20%:80%) ratio	230×100×75	18.63-19.96 12-13.3 5.7-6.27
Suriyaa et al., (2020)	Plastic + sand	1:2(33.33% :66.67%) 1:3 (25%:75%) 1:4(20%:80%) ratio	230×100×80	9.17 6.40 3.50

Source: Adapted from (Frank et al., 2021; Chauhan et al., 2019; Suriyaa et al. ,2020)

2.10 Research Gap

Although significant research has been conducted on plastic–sand composite materials and the utilization of agricultural waste in construction, several important gaps remain that justify the present study.

Most studies have focused primarily on plastic–sand composites with single agricultural additives. While materials such as rice husk ash and biochar have been individually studied, limited research is available that systematically compares raw rice husk (RH), rice husk ash (RHA), and biochar (RHB) within the same plastic–sand composite system under identical conditions. As a result, the relative influence of these additives on composite performance is not well established.

Furthermore, existing studies have largely concentrated on standard brick sizes and industrial-scale production, whereas laboratory-scale experimental investigations using controlled specimen sizes are limited. There is a lack of studies that explore material behavior at reduced scale for controlled parametric comparison, especially in academic research environments.

In addition, existing research emphasizes mechanical properties such as compressive strength, but limited attention has been given to simple field-level performance. Another key gap lies in material characterization. While FTIR analysis has been widely used for individual materials, the relationship between additive chemistry and composite performance through functional group characterization in final composites remains insufficiently understood.

Moreover, the use of raw rice husk in plastic-based composites remains underexplored, as most studies focus on processed derivatives such as ash or biochar. This creates an opportunity to investigate its direct applicability and performance.

Therefore, this study aims to address these gaps by:

a. Conducting a comparative analysis of RH, RHA, and RHB in LDPE–sand composites
b. Evaluating Mechanical, physical and field level performance.
c. Incorporating FTIR-based chemical characterization
d. Using a controlled laboratory-scale approach for consistency and repeatability

This research contributes to the development of sustainable composite materials while expanding the understanding of agricultural waste utilization in plastic-based construction applications.

Chapter 3

METHODOLOGY

3.1 Research Methodology Overview

The methodology of this study involves the fabrication of LDPE–sand composite specimens at a base ratio of 30:70 and the partial replacement of sand with rice husk and its derivatives. The prepared specimens are then tested to evaluate their mechanical and physical properties.

3.2 Research Methodology Flowchart

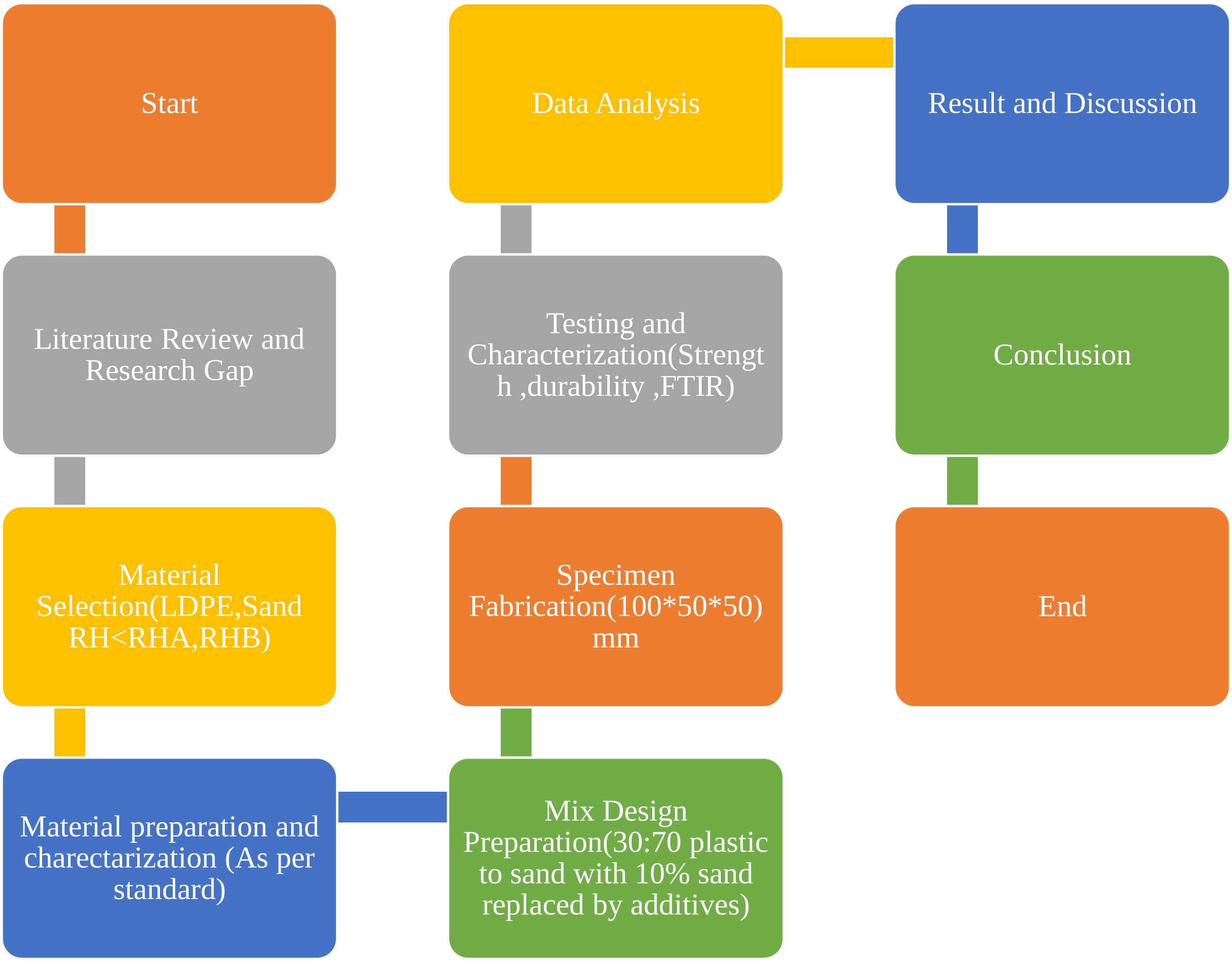


Figure 2: Methodological framework of the study

Figure 2 illustrates the overall methodological framework adopted in this study. The process begins with a comprehensive literature review to identify the research gap and establish the objectives of the study. Based on this, appropriate materials including LDPE waste plastic, sand, rice husk (RH), rice husk ash (RHA), and biochar (RHB) were selected.

The selected materials were then prepared, where sand was washed, dried, and sieved, and characterized according to IS 383 standards. Following this, mix design was carried out using a base ratio of 30:70 (plastic: sand), with 10% additive replacement for modified mixes. The next stage involved specimen fabrication, where LDPE was melted and thoroughly mixed with sand and additives, followed by molding into standard cube size (100 × 50 × 50 mm), compaction, and cooling.

After fabrication, the specimens were subjected to testing and characterization, including compressive strength, water absorption, and FTIR analysis. The obtained results were then compiled and analyzed through comparative evaluation with the control mix. Finally, the results were interpreted and discussed to assess the performance of different additives and draw conclusions

3.3 Materials and Chemicals Used

3.3.1 Low Density Polyethylene (LDPE)

Recycled Low Density Polyethylene (LDPE) pellets were collected from local recycling sources in Kathmandu, primarily derived from post-consumer plastic waste such as plastic bags and packaging materials. The material was cleaned to remove impurities before use.

LDPE is a thermoplastic polymer with a low melting temperature range of 105–115°C. Due to its low melting point and better flow characteristics, it can be easily melted and mixed with sand, making it suitable as a binding material in composite production (unionfab, 2026).

In this study, LDPE acts as the primary binder, holding the sand and additives together to form a solid composite upon cooling. The use of recycled LDPE also promotes sustainable waste management and reduces environmental impact

3.3.2 Fine Sand (Aggregate Phase)

Locally available river sand was used as the aggregate phase in this study. The sand was collected from nearby sources and was selected due to its wide availability and suitability for construction applications. The maximum particle size of the sand was limited to less than 4.75 mm, conforming to fine aggregate classification as per IS 383.

Prior to use, the sand was thoroughly washed to remove dust and organic impurities. It was then oven-dried at approximately 105°C to eliminate moisture content and ensure proper bonding with the molten LDPE. The dried sand was sieved to obtain a uniform particle size distribution.

In the composite, sand acts as the primary load-bearing phase, providing strength and stiffness, while the LDPE functions as the binding matrix.

3.3.3 Rice Husk, Rice Husk Ash and Biochar

Rice husk and its derivatives, namely rice husk ash (RHA) and rice husk biochar (RHB), were used as additive materials in this study. Rice husk was collected from a local rice mill, while RHA was obtained through controlled combustion of rice husk, and biochar was produced under limited oxygen conditions (pyrolysis).

These materials were selected due to their availability as agricultural waste and their potential to influence the properties of plastic–sand composites. RHA is known for its high silica content, whereas rice husk and biochar possess porous and carbon-rich structures. Their effects on the composite performance are evaluated in subsequent sections.

3.3.4 Chemicals

A small amount of Limaplex HTX 3 grease was used during specimen fabrication. The grease was applied to the inner surfaces of the molds to act as a release agent, preventing adhesion of the molten composite to the mold and facilitating easy demolding of the specimens without damage. The use of grease ensured proper surface finish and maintained the shape and integrity of the molded samples.

Figure 3 shows the materials used for the preparation of composite sample.

Figure 3: Raw materials used in the study

3.4 Material Preparation

The material used as an additive in the composite sample were prepared inside the laboratory following standard guidelines and rules. Figure 4 illustrates the preparation stages of the materials, including cleaning, drying, grinding and sieving. These steps were necessary to ensure uniformity and proper interaction between the materials during composite fabrication

Figure 4: Material preparation process

3.4.1 Preparation of Rice Husk

a. Source of Husk

Raw rice husk was collected from a local rice mill from Bhaktapur. The husk was obtained as an agricultural by-product generated during the milling of rice. The collected husk was ensured to be free from contaminants such as soil, stones, and organic debris.

b. Cleaning Process

The collected rice husk was manually cleaned to remove unwanted impurities such as dust, soil particles, and other foreign materials. Hand sorting and sieving were performed to ensure that only clean husk was used for further processing.

c. Drying Method

The cleaned rice husk was dried to remove moisture content. Drying was carried out under sunlight for 24–48 hours, followed by oven drying at approximately 80–105°C for 24 hours to ensure complete removal of moisture. Proper drying is essential to avoid steam formation during mixing with molten plastic.

d. Grinding Process

The dried rice husk was lightly ground using a mechanical grinder to reduce particle size and improve uniformity. Grinding helps in better dispersion of husk within the plastic matrix.

e. Sieving Process

After grinding, the rice husk was passed through a fine sieve to obtain a uniform particle size distribution. Oversized particles were removed to ensure consistency in composite preparation.

f. Final Properties

RH is lightweight fibrous material which contains cellulose, hemicellulose, lignin, and silica with high porosity and water absorption capacity and low density compared to sand.

g. Function in Composite

Rice husk acts as a lightweight filler material, influencing density and internal structure of the composite.

3.4.2 Preparation of Rice Husk Ash (RHA)

Rice husk ash (RHA) was prepared from raw rice husk through a controlled combustion process to obtain a silica-rich material suitable for use as a filler in LDPE–sand composite specimens.

a. Source of Rice Husk

The raw rice husk used in this study was collected from a local rice mill. Rice husk is an agricultural by-product obtained during the milling of rice and typically constitutes approximately 20% of the total weight of harvested rice. The collected husk was stored in dry conditions prior to processing.

b. Cleaning Process

The collected rice husk was manually cleaned to remove impurities such as dust, soil particles, and foreign organic matter. This step was essential to ensure uniform combustion and to avoid contamination in the resulting ash.

c. Drying Method

The cleaned rice husk was dried under ambient conditions followed by oven drying at approximately 105°C for 24 hours to eliminate moisture content. Proper drying is necessary to achieve efficient and uniform burning during the combustion process.

d. Burning Conditions (Temperature and Time)

The dried rice husk was subjected to controlled combustion in a muffle furnace at a temperature range of 600°C to 700°C. The burning process was maintained for a duration of approximately 2 hours to ensure complete removal of organic components. At this temperature range, the combustion process converts the organic constituents (cellulose, hemicellulose, and lignin) into gaseous products, leaving behind a residue rich in silica. Controlled burning is critical, as temperatures above 700°C may lead to the formation of crystalline silica, which is less reactive compared to amorphous silica.

e. Cooling Method

After combustion, the furnace was allowed to cool gradually to room temperature to avoid thermal shock and preserve the amorphous structure of silica. Controlled cooling prevents thermal shock and helps preserve the amorphous nature of silica in the ash.

f. Grinding and Sieving

The obtained ash was lightly ground using a mortar and pestle to break down agglomerated particles. The ground ash was then sieved through a fine sieve to obtain uniform particle size distribution. This step improves the dispersion of RHA within the composite matrix and enhances particle packing.

g. Final Properties of RHA

The prepared rice husk ash exhibited fine particle size with high silica (SiO_2) content (predominantly amorphous) and low density with grey to off-white color.The high silica content and fine particle size of RHA contribute to improved packing density and interfacial bonding within the LDPE–sand composite, thereby enhancing mechanical properties such as compressive strength.

3.4.3 Preparation of Biochar

Biochar was prepared from rice husk through a controlled thermal decomposition process under limited oxygen conditions, known as pyrolysis. The resulting material is a carbon-rich, porous substance used as a filler in composite specimens.

a. Raw Material Preparation

Rice husk was used as the precursor material for biochar production. The husk was first cleaned to remove impurities and then dried to eliminate moisture content. The dried husk was lightly ground to ensure uniform heating during the pyrolysis process.

b. Pyrolysis Concept

Pyrolysis is a thermochemical process in which organic material is decomposed at elevated temperatures in the absence or limited presence of oxygen. Unlike combustion, pyrolysis does not completely oxidize the material but instead converts it into solid carbon (biochar), along with gaseous and liquid by-products. This process preserves the carbon content of the biomass and results in a stable, carbon-rich material with a porous structure.

c. Temperature Range

The pyrolysis process for biochar production was carried out at a temperature of approximately 350°C. This temperature range is sufficient to decompose organic compounds while retaining a significant portion of carbon within the solid structure.

d. Oxygen Limitation Explanation

To achieve pyrolysis conditions, the rice husk was placed in a covered container (crucible) to restrict the supply of oxygen. Limited oxygen availability prevents complete combustion and ensures that the material undergoes carbonization instead of burning into ash. If sufficient oxygen were present, the husk would undergo complete combustion, resulting in ash rather than biochar.

e. Carbonization Mechanism

During pyrolysis, the primary components of rice husk—cellulose, hemicellulose, and lignin undergo thermal decomposition. Volatile compounds are released in the form of gases and vapors, while the remaining solid material becomes enriched in carbon. This process results in the formation of a porous carbon structure with increased surface area. The presence of micro-pores and macro-pores in biochar can influence the mechanical and physical properties of composite materials.

f. Post-Processing

After pyrolysis, the biochar was allowed to cool naturally to room temperature. The cooled biochar was then:

I. Ground to break large particles

II. Sieved to obtain uniform particle size

No chemical activation or washing was performed, as the biochar was intended to function solely as a filler material in the composite specimens.

g. Final Properties of Biochar

The prepared biochar exhibited black color with high carbon content and having a porous structure with low density. The porous nature of biochar can enhance mechanical interlocking within the composite matrix. However, excessive porosity may also introduce voids, which can reduce compressive strength if not properly controlled.

3.4.4 Preparation of Fine Sand

a. Source of Sand

Fine aggregate (sand) was collected from a local river source. The sand was selected based on availability and suitability for construction applications.

b. Cleaning Process

The collected sand was washed thoroughly with clean water to remove silt, clay, and organic impurities. After washing, it was allowed to settle and excess water was drained.

c. Drying Method

The sand was oven-dried at 105°C for 24 hours to remove all moisture content. Dry sand ensures proper bonding with molten plastic and prevents void formation.

d. Sieving Process

The dried sand was sieved using a 4.75 mm sieve to remove oversized particles. Further sieve analysis was conducted to determine particle size distribution as per IS 383 standards.

e. Final Properties

Well-graded fine aggregate (Zone II) having specific gravity of 2.5 and bulk density around 1.5 to 1.7 g/cm^3 and having angular to sub-angular particles.

f. Function in Composite

Sand acts as the primary load-bearing aggregate providing strength and structural stability to the composite.

3.4.5 Preparation of LDPE Plastic Pellets

a. Source of Plastic

Low-Density Polyethylene (LDPE) pellets were procured from local suppliers. LDPE was selected due to its low melting temperature and suitability for laboratory-scale processing.

b. Cleaning Process

The plastic pellets were manually inspected and cleaned to remove dust, dirt, or foreign particles that could affect melting and bonding.

c. **Drying Method**

The pellets were dried at room temperature for 24 hours to eliminate surface moisture. In some cases, mild oven drying at 60°C was performed to ensure complete dryness.

d. **Size Reduction**

Since pellets were already small and uniform, no additional cutting or shredding was required. However, if larger plastic pieces are used, they should be cut into smaller sizes to ensure uniform melting.

e. Melting Characteristics

Heating at the range of 110–130°C, LDPE softens gradually and becomes viscous before complete melting.

3.5 Material Characterization

3.5.1 Sieve Analysis of Sand

Sieve analysis was performed to determine the particle size distribution of the sand used as fine aggregate in the composite specimens. The gradation of sand plays an important role in the performance of composite materials because it affects packing density, void content, and bonding between aggregate particles and the plastic binder.

The sieve analysis was carried out in accordance with the procedures specified in IS 383 for fine aggregates. A representative sample of sand was first dried to remove moisture and then weighed accurately. The dried sand sample was passed through a series of standard sieves arranged in descending order of size. The sieves used in the analysis included 4.75 mm, 2.36 mm, 1.18 mm, 0.60 mm, 0.30 mm, and 0.15 mm, along with a pan to collect the particles passing through the smallest sieve. The sand sample was placed at the top sieve and subjected to mechanical shaking for a specified duration to allow proper separation of particles according to their sizes. After the sieving process, the amount of sand retained on each sieve was carefully collected and weighed. The cumulative weight retained and the percentage passing were then calculated for each sieve size. These values were used to construct the gradation curve of the fine aggregate.

The results obtained from the sieve analysis were compared with the grading limits specified in IS 383 to determine the grading zone of the sand. The sand used in this study was found to fall within the Zone II grading range, which is commonly suitable for construction applications and composite material preparation. The detailed results of the sieve analysis are shown in Table 5.

Table 5: Data for gradation of sand

S.N.	Sieve Size (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Cumulative % Retained	% Passing	IS Limits (Zone II) (%)
1	10.00	–	–	–	100	100
2	4.75	89.1	89.1	8.91	91.09	90–100
3	2.36	116.5	205.6	20.56	79.44	75–100
4	1.18	109.0	314.6	31.46	68.54	55–90
5	0.60	130.6	445.2	44.52	55.48	15–59
6	0.30	266.5	711.7	71.17	28.83	8–30
7	0.15	202.2	913.9	91.39	8.61	0–10
8	Pan	86.1	1000	100	0	–

Figure 5 shows the grading curve of sand obtained from sieve analysis, which indicates the particle size distribution.

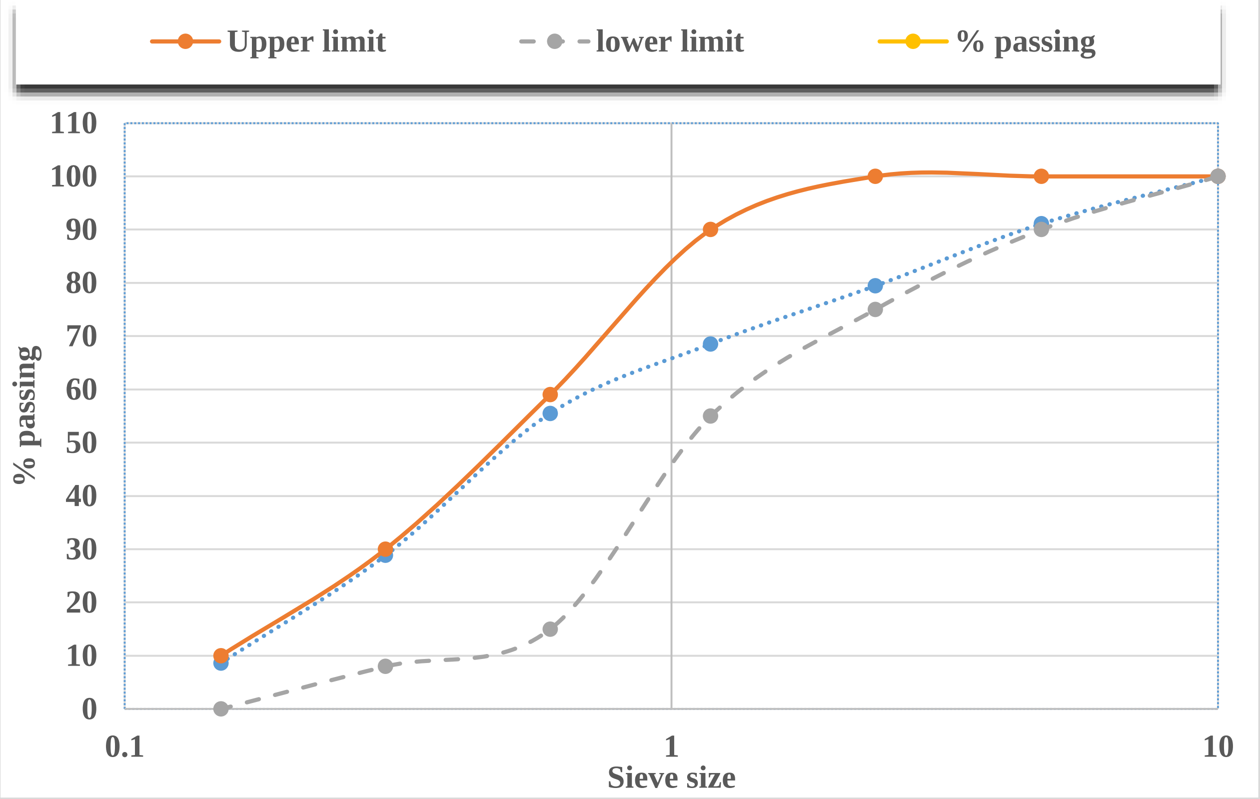


Figure 5: Grading curve of sand

Figure 6 shows the equipment used for conducting the sieve analysis.

Figure 6: Equipment for sieve analysis of sand

3.5.2 Specific Gravity Test of Water

The pycnometer method was used to determine the specific gravity of sand.
While doing the test, the following data was recorded

Mass of empty container (w1) = 630 g

Mass of container + dry sand (w2) = 830 g

Mass of container + sand + water (w3) = 1605 g

Mass of container + water (w4) = 1485 g

Specific gravity is calculated using

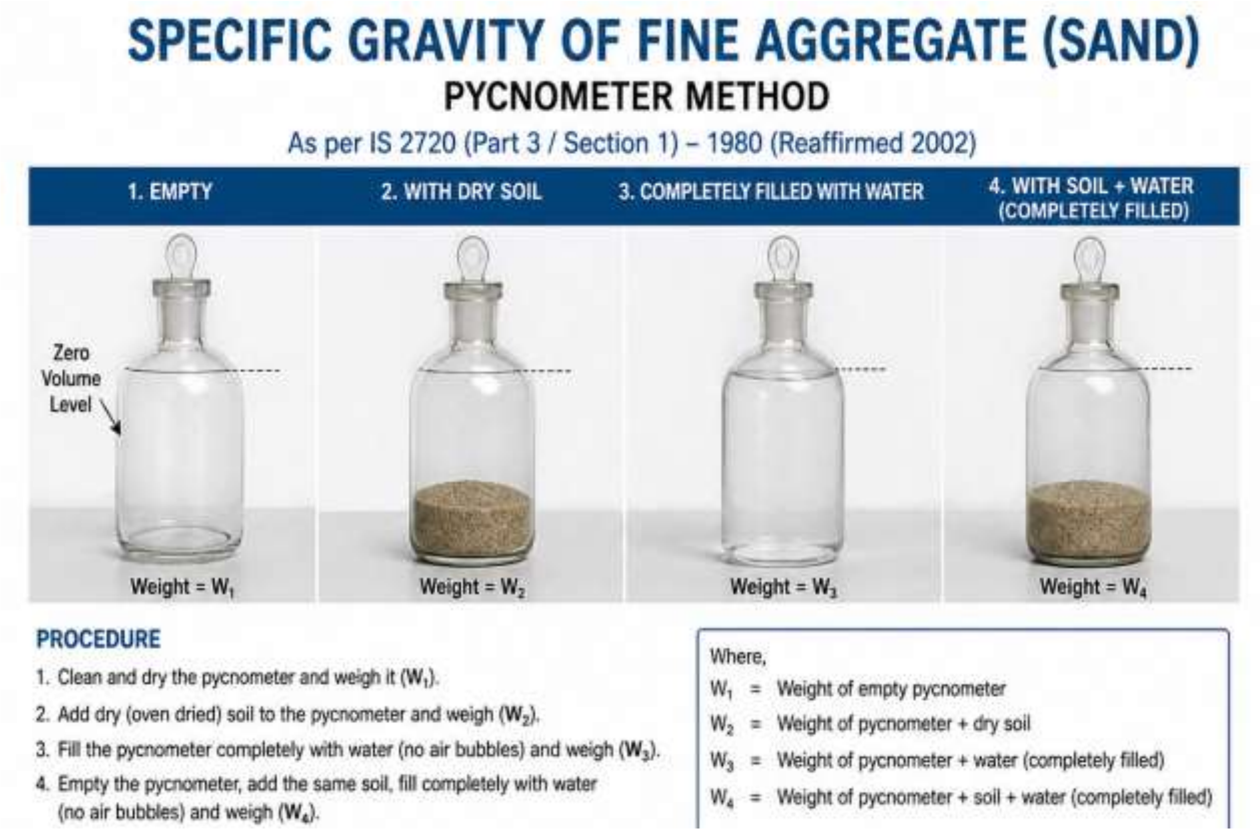
$$G=\frac{\boldsymbol{w2-w1}}{(\boldsymbol{w2-w1})-(\boldsymbol{w3-w4})}$$

$$=\frac{\mathbf{830-630}}{(\mathbf{830-630})-(\mathbf{1605-1485})}$$

$$=2.5$$

The specific gravity of sand was found to be 2.5.

Figure 7 shows the setup used for determining the specific gravity of sand using a pycnometer. The setup ensures accurate determination of sand properties, which is essential for proper mix design and material consistency.



1. Clean and dry the pycnometer and weigh it (W_1).
2. Add dry (oven dried) soil to the pycnometer and weigh (W_2).
3. Fill the pycnometer completely with water (no air bubbles) and weigh (W_3).
4. Empty the pycnometer, add the same soil, fill completely with water (no air bubbles) and weigh (W_4).

Where,
W_1 = Weight of empty pycnometer
W_2 = Weight of pycnometer + dry soil
W_3 = Weight of pycnometer + water (completely filled)
W_4 = Weight of pycnometer + soil + water (completely filled)

Figure 7: Testing procedure of specific gravity of sand using pycnometer

3.5.3 FTIR Analysis

Fourier Transform Infrared Spectroscopy (FTIR) analysis was conducted to investigate the chemical composition and functional groups present in the materials used in this study. FTIR is a widely used analytical technique that allows identification of chemical bonds and molecular structures based on the absorption of infrared radiation at specific wavelengths.

In this study, FTIR analysis was carried out on the raw agricultural materials and the prepared composite specimens in order to evaluate their chemical characteristics. The samples for FTIR analysis were prepared and submitted to the Department of chemistry, Amrit Campus, lainchaur, Kathmandu, Nepal. Where there is a laboratory equipped with an FTIR spectrometer. The analysis was performed by the laboratory personnel, and the obtained spectra were provided for further interpretation and discussion.

The FTIR spectra were recorded over a typical wavenumber range of 4000 cm⁻¹ to 400 cm⁻¹, which covers most functional groups commonly present in organic and inorganic materials. During the FTIR analysis, infrared radiation was passed through the sample, and the absorption of radiation at different wavelengths was measured. Different chemical bonds absorb infrared radiation at characteristic frequencies, allowing identification of functional groups present in the material.

3.4.3.1 FTIR Analysis of Rice Husk

Figure 8 presents the FTIR spectrum of rice husk, showing the presence of organic functional groups and exhibits absorption peaks associated with cellulose, hemicellulose and lignin. The FTIR analysis of rice husk reveals the presence of key functional groups associated with its lignocellulosic structure. Broad absorption around 3200–3500 cm⁻¹ indicates O–H stretching (hydroxyl groups), while peaks near 2900 cm⁻¹ correspond to C–H stretching of organic compounds. The band around 1700 cm⁻¹ represents C=O stretching (carbonyl groups), and peaks between 1000–1100 cm⁻¹ are attributed to Si–O–Si stretching, confirming the presence of silica. These results show that rice husk contains cellulose, hemicellulose, lignin, and significant silica content, which influence its bonding behavior and suitability as a reinforcing material in composites.

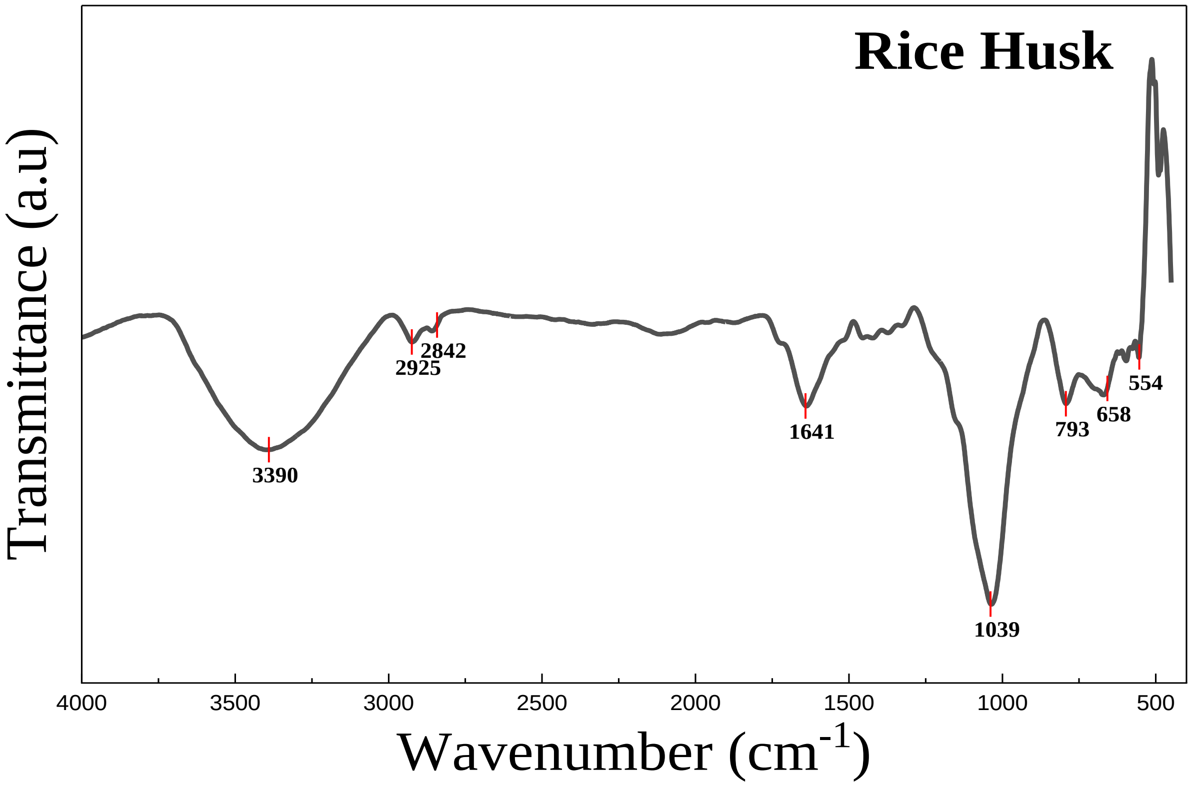


Figure 8: FTIR graph of raw rice husk sample

3.4.3.2 FTIR Analysis of rice husk ash

Figure 9 illustrates the FTIR spectrum of rice husk ash, indicating strong silica-related peaks. FTIR analysis of rice husk ash (RHA) primarily indicates a high silica content with reduced organic components due to combustion. A strong peak around 1000–1100 cm^{-1} corresponds to Si–O–Si stretching, confirming the presence of amorphous silica. Weak or diminished bands near 3400 cm^{-1} (O–H stretching) may appear due to absorbed moisture, while the absence of peaks related to C–H and C=O groups shows the removal of organic matter during burning. This confirms that RHA is predominantly inorganic and silica-rich, making it suitable for enhancing strength and durability in composite materials.

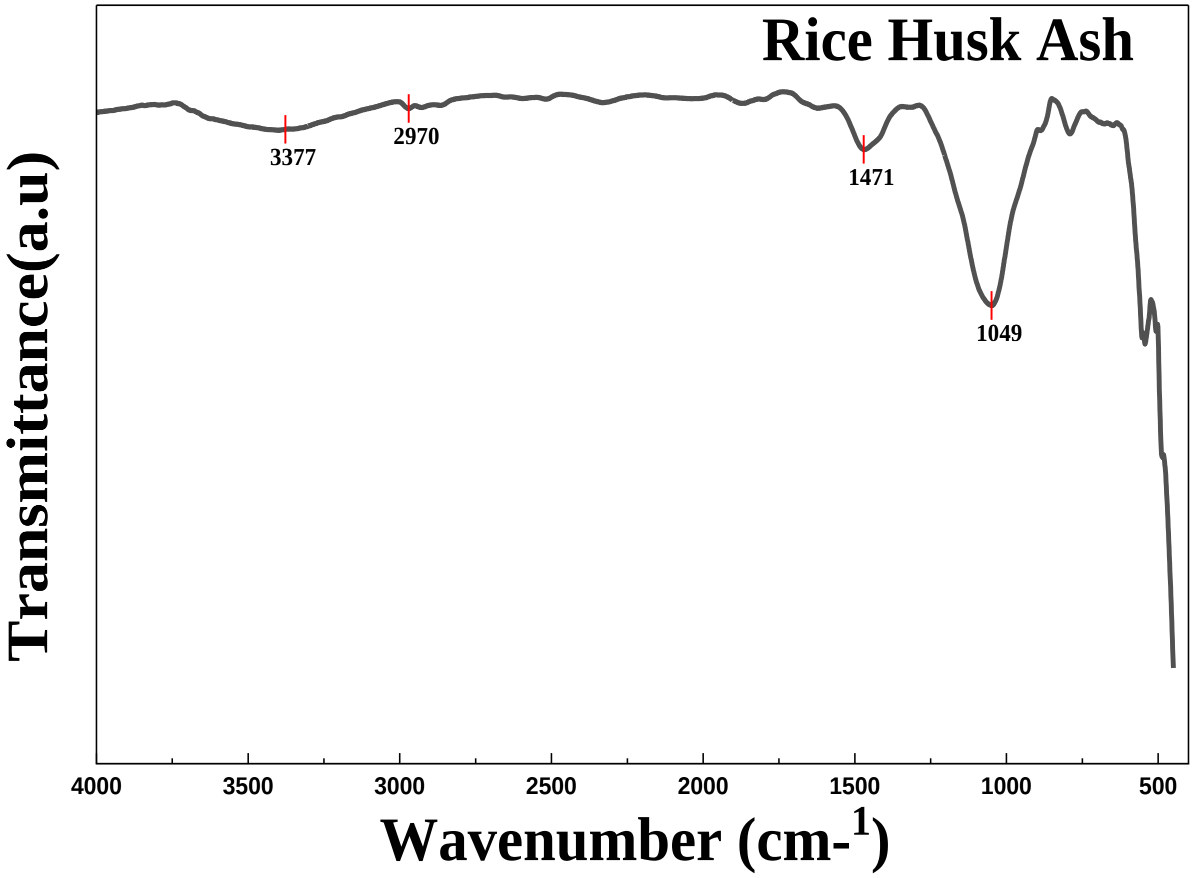


Figure 9: FTIR graph of rice husk ash sample

3.4.3.3 FTIR Analysis of Rice Husk Biochar

Figure 10 shows the FTIR spectrum of rice husk biochar, highlighting carbon-rich functional structures. FTIR analysis of rice husk biochar (RHB) shows a carbon-rich structure with residual functional groups formed during pyrolysis. A broad peak around 3200–3400 cm^{-1} indicates O–H stretching from hydroxyl groups, while peaks near 1600 cm⁻¹ correspond to aromatic C=C bonds, reflecting the development of stable carbon structures. Weak bands around 1700 cm⁻¹ (C=O) and 1000–1100 cm⁻¹ (Si–O–Si) may still appear, indicating remaining oxygen-containing groups and silica from the original husk. Compared to raw rice husk, the reduction in aliphatic C–H peaks confirms thermal decomposition, resulting in a more stable, porous, and carbon-dominated material suitable for composite applications.

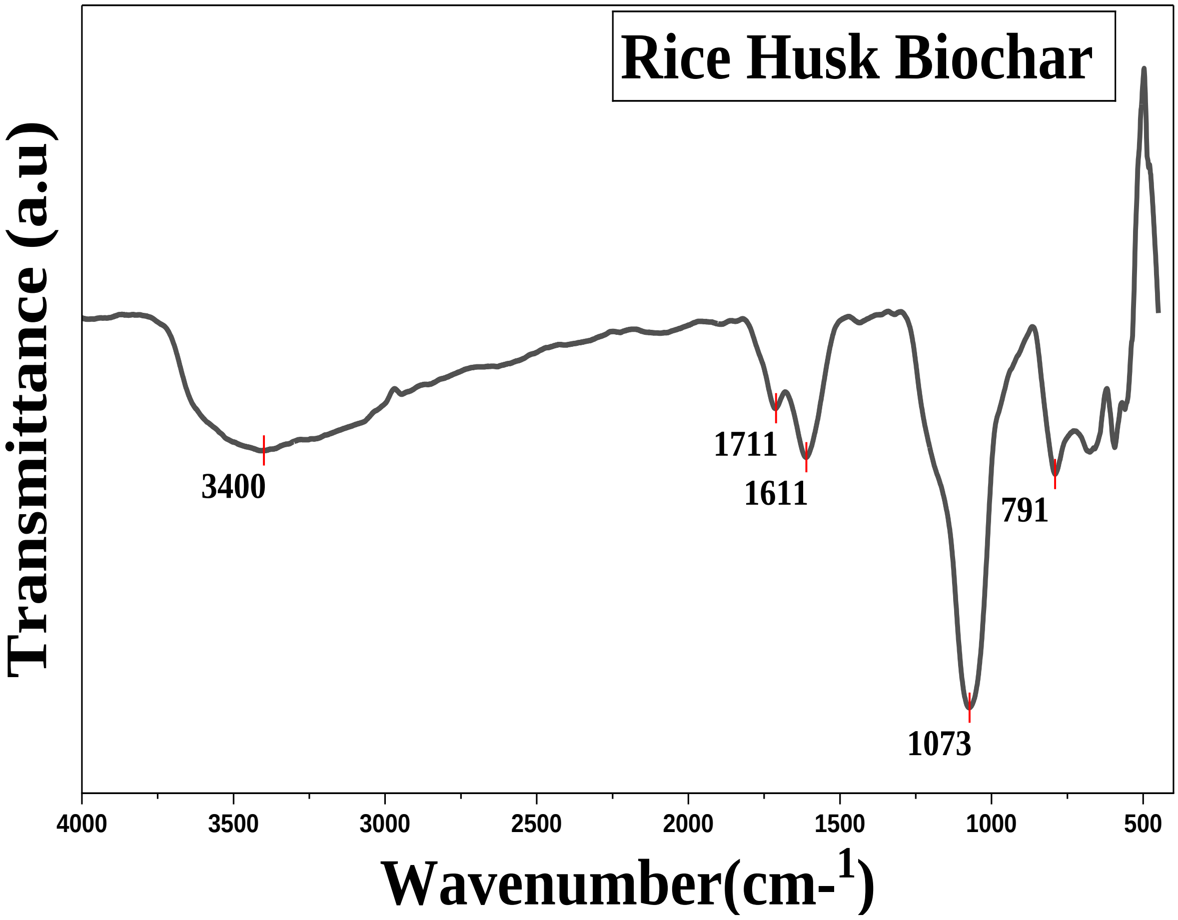


Figure 10: FTIR graph of rice husk biochar sample

3.4.3.4 FTIR Analysis of Final Composite Sample

The FTIR analysis of the composite brick samples was performed to determine whether the characteristic peaks of the additives and the plastic matrix could be detected within the final composite material. This analysis helps in understanding the chemical characteristics of the composite and the presence of different functional groups originating from the plastic binder and agricultural additives. The FTIR spectra obtained from the composite samples and the detailed comparison of graph of raw samples are presented in Chapter 4 (Results and Discussion), where the peak positions and their corresponding functional group assignments are discussed in detail.

3.6 Mix proportion

The mix proportions for the preparation of the plastic–sand composite specimens were determined based on previous studies related to plastic-based construction materials and preliminary experimental considerations. In this study, low-density polyethylene (LDPE) plastic was used as the binding material, while sand was used as the primary aggregate. Rice husk, rice husk ash, and biochar were incorporated as additive materials to evaluate their influence on the mechanical and physical properties of the composite bricks.

The base mix proportion selected for the control composite was 30% LDPE plastic and 70% sand by weight. This proportion was chosen because previous studies have shown that plastic–sand composites within this range provide adequate bonding and mechanical strength. For the modified composite samples, 10% of the sand content was replaced with the respective agricultural additives. The purpose of replacing a portion of sand with these materials was to investigate their effect on the structural performance of the composite specimens. A replacement level of 10% (by weight of sand) was selected for incorporating rice husk, rice husk ash, and biochar. This percentage was chosen as a moderate value to ensure observable changes in material properties without significantly compromising structural integrity. The study focuses on comparative evaluation of different additives; therefore, a single replacement level was maintained across all samples to ensure consistency and controlled experimental conditions.

Investigation of multiple replacement levels such as 5%, 15%, or higher percentages was beyond the scope of the present study and is recommended for future research. Four types of composite mixtures were prepared for experimental investigation:

Control sample (CTRL): LDPE + Sand

Rice husk sample (RH): LDPE + Sand + Rice Husk

Rice husk ash sample (RHA): LDPE + Sand + Rice Husk Ash

Biochar sample (RHB): LDPE + Sand + Biochar

For the modified samples, the sand content was reduced from 70% to 60%, while the remaining 10% was replaced by the additive material. The LDPE plastic content remained constant at 30%.

The mix proportions used in this study are summarized in Table 6.

Table 6: Mix proportion of composite specimens

Sample Type	LDPE Plastic % (By Weight)	Sand %	Additive %
CTRL	30	70	0
RH	30	60	10
RHA	30	60	10
RHB	30	60	10

Each composite type was prepared with Four replicate specimens in order to ensure reliable experimental results and reduce variability during testing.

3.7 Material Quantity Calculation

The material quantity calculations were carried out based on volume and density relationships commonly used in composite material design. The required volume of each specimen was determined from mold dimensions, and the corresponding mass was estimated using the density of constituent materials.

The composite density was approximated using the rule of mixtures, which is widely applied in polymer composite systems to estimate overall material behavior.Since no standard mix design procedure exists for plastic–sand composite materials, the proportions were adopted based on previous research studies and experimental considerations. Similar approaches have been reported in studies by Chauhan et al. (2019), Suriyaa et al. (2020), and Frank et al. (2021), where mix ratios were selected based on performance evaluation rather than standard codes. General principles from IS 10262:2019 related to volume-based material estimation were considered as a guiding reference for calculation methodology.

3.7.1 Basis of Design

The mix design was developed based on the volume of the mold and the estimated density of the composite materials. The mold size used for specimen preparation was 100 mm × 50 mm × 50 mm, corresponding to a volume of 250 cm^3.

To account for practical variations during fabrication such as overfilling, trimming, and compaction, a 5% extra volume was considered. Additionally, a density correction factor of 1.05 was applied to account for reduced voids due to manual compaction. Further 10% extra material allowance was included to compensate for material losses during heating, mixing, and handling.

3.7.2 Adjusted Volume Calculation

Volume of One Specimen

$V = L \times W \times H$

$V = 100 \times 50 \times 50$

$V = 250000\ \text{mm}^3$

$= 250\ \text{cm}^3$

Considering 5% Extra volume

$V = 1.05 \times 250$

$= 262.5\ \text{cm}^3$

3.7.3 Composite Density Calculation

The density of the control mix was calculated using weighted average density:

$\text{Density} = (0.30 \times 0.92) + (0.70 \times 1.60) = 1.396\ \text{g/cm}^3$

Applying correction factor:

$\text{Density} = 1.396 \times 1.05$

$= 1.466\ \text{g/cm}^3$

3.7.4 Estimated Weight of Specimen

Weight= Density × Volume Weight

$= 1.466 \times 262.5 = 384.8\ \text{g}$

Including 10% extra allowance:

Final Weight= 384.8 × 1.10

=423.5 g ≈ 425 g

Therefore, the adopted weight per specimen was taken as approximately 425 g.

3.7.5 Estimated Weight of Samples

Control mix

Table 7 shows the material and their estimated weight required for the fabrication of single composite sample of plastic and sand only.

Table 7: Weight of materials for control mix

Material	Weight (g)
LDPE	128
Sand	297
Total	425

Modified mix (10 % replacement)

Plastic = 128g (constant)

Sand = 297

Replacement = 10 percent × 297 = 29.7 = 30 gm

Sand = 297 - 30 = 267 gm

Additives = 30 gm (By weight)

Additive mix

Table 8 shows the material and their estimated weight in gram required for the fabrication of single composite sample mixed with agricultural residue.

Table 8: Weight of materials for additive mix

Material	Weight (g)
LDPE	128
Sand	267
Additive (10 percent of sand)	30
Total	425

3.7.6 Total Material required for 16 samples

Table 9 shows the material and their total estimated weight required for the fabrication of 16 composite sample.

Table 9: Total materials required for 16 samples

Material	Weight (Kg)
LDPE	2.048
Sand	3.324
RH	0.120
RHA	0.120
RHB	0.120
Total	5.732

The mix design incorporated practical adjustments to account for material losses, compaction effects, and variability during specimen preparation.

3.8 Specimen Preparation

The specimen size of 100 mm × 50 mm × 50 mm was selected for this study to facilitate controlled laboratory-scale experimentation and efficient use of materials. Due to equipment limitations and the exploratory nature of the study, full-scale brick dimensions were not adopted. The reduced specimen size allowed uniform heating, mixing, and compaction of the LDPE-based composite. Similar laboratory-scale dimensions have been used in previous experimental studies to evaluate material behavior under controlled conditions. The results obtained are therefore intended for comparative analysis rather than direct compliance with standard brick specifications.

The preparation of plastic–sand composite specimens was carried out through a heating and mixing process in which LDPE plastic acted as the binding material. The fabrication process involved melting the plastic and mixing it with sand and additive materials to produce a homogeneous composite mixture.

Prior to specimen fabrication, all materials were properly prepared. The sand and additive materials (rice husk, rice husk ash, and biochar) were dried to remove moisture and ensure proper mixing .

3.8.1 Sample Identification

In total, sixteen composite specimens were prepared, consisting of Four specimens for each mixture type (CTRL, RH, RHA, and RHB). The fabricated specimens were subsequently subjected to mechanical and physical testing to evaluate their performance characteristics.

Each mix produced 4 specimens.

Total specimens = 16.

3.9 Specimen Fabrication Procedure

The specimen size of 100 mm × 50 mm × 50 mm was selected based on considerations of geometric stability, testing feasibility, and laboratory constraints. The chosen dimensions provide an adequate loading area for compressive testing while maintaining a manageable specimen size for uniform heating and mixing of LDPE.

The aspect ratio of the specimen was selected to ensure stable load distribution during compression testing and to minimize edge effects or premature failure. Additionally, the selected size allowed efficient utilization of materials and ensured repeatability across multiple specimens.

Larger specimen sizes were not adopted due to limitations in heating control, mixing uniformity, and equipment capacity. Therefore, the selected dimensions are considered suitable for laboratory-scale evaluation and comparative analysis of composite performance. The preparation of composite specimens was carried out using the following procedure.

Step 1: Melting of Plastic

a. First, the LDPE pellets were placed in a steel container and heated gradually until it reached its melting temperature. LDPE typically melts at temperatures between 110°C and 130°C, and the plastic was heated within this range until it became fully molten.

b. LDPE pieces were placed in a steel container.
c. Heated gradually to 110–140°C.
d. Plastic allowed to fully melt.
e. Continuous stirring to prevent localized burning.

Step 2: Mixing

a. Once the plastic was completely melted, the required amount of sand and additive material was gradually added to the molten plastic according to the predetermined mix proportions. The mixture was continuously stirred using a metal rod to ensure uniform distribution of sand and additive particles within the plastic matrix.
b. Pre-weighed sand (and additive for modified samples) added slowly.
c. Manual mixing performed for 5–7 minutes.
d. Uniform distribution ensured visually.

Step 3: Molding

a. After achieving a homogeneous mixture, the hot composite material was transferred into pre-Lubed steel molds. The molds used for specimen preparation had internal dimensions of 100 mm × 50 mm × 50 mm, which represent laboratory-scale brick specimens.
b. Manual compaction was applied to the mixture inside the molds to remove entrapped air and improve the internal packing of the composite material. Proper compaction ensures better bonding between the plastic binder and the aggregate particles.
c. Steel molds were cleaned and were lubed with Grease for easy removal.
d. Hot composite mixture poured into mold.
e. Manual compaction applied using a crafted sheet with rod attached to it .
f. Surface leveled.

Step 4: Cooling and Demolding

After casting, the molds were allowed to cool at room temperature. During cooling, the molten plastic solidified and formed a rigid composite structure binding the sand and additive particles together.

Once the specimens had completely cooled, they were carefully removed from the molds and labeled according to their respective sample types. The prepared specimens were then stored under laboratory conditions until further testing was conducted.

a. Specimens cooled at room temperature (25–30°C).

b. Cooling duration: More than 2 hours.

c. Specimens removed carefully.

d. Stored in dry condition for 24 hours before testing.

3.10 Experimental Testing

The testing procedures followed general laboratory practices. Due to limitations in specimen size and equipment availability, strict adherence to standard codes (IS/ASTM) was not possible. However, consistent procedures were maintained across all samples to ensure reliable comparative analysis. The fabricated plastic–sand composite specimens were subjected to several experimental tests in order to evaluate their mechanical and physical properties. These tests were conducted to assess the performance of the composite materials and to determine the effect of incorporating rice husk, rice husk ash, and biochar into the plastic–sand matrix.

The experimental testing program included the following tests:

a. Compressive strength test

b. Water absorption test

c. Efflorescence test

d. Visual examination of bricks (shape, size, color and structure)

e. Scratch test

f. Ringing test

These tests were performed on the prepared composite specimens after they had completely cooled and stabilized under laboratory conditions.

3.10.1 Compressive Strength Test

Compressive strength testing was conducted with reference to IS 3495 (Part 1):1992. Due to the non-standard specimen size, the procedure was adapted while maintaining uniform loading conditions across all samples.

Objective

The compressive strength test was conducted to determine the load-bearing capacity of the plastic–sand composite specimens. Compressive strength is an important mechanical property that indicates the ability of a material to resist compressive forces without failure.

Test Equipment

The compressive strength test was carried out using a Universal Testing Machine (UTM) available in the laboratory. The UTM applies controlled compressive loads to the specimen until failure occurs.

Specimen Size

The composite specimens used for testing had dimensions of:

100 mm × 50 mm × 50 mm

During testing, the specimen was placed horizontally so that the loading area was:

100 mm × 50 mm

Therefore, the cross-sectional area (A) used for calculation was:

A = Length × Width
A = 100 × 50
A = 5000 mm2

Test Procedure

The compressive strength test was performed according to the following steps:

a. The specimen was placed between the loading plates of the Universal Testing Machine.

b. The specimen was positioned carefully to ensure proper alignment and uniform load distribution.

c. A compressive load was applied gradually to the specimen.

d. The load was increased continuously until the specimen failed.

e. The maximum load at failure was recorded in kilo Newton’s (kN).

f. The compressive strength was calculated using the recorded load and specimen area.

Calculation of Compressive Strength

The compressive strength was calculated using the following formula:

$$F_c = \frac{P}{A}$$

F_c = Compressive strength (MPa)
P = Maximum load applied (N)
A = Cross-sectional area (mm^2)

Since 1 MPa = 1 N/mm^2, the calculated value directly represents the compressive strength in MPa. Figure 11 shows the compression testing setup and recorded data. The figure demonstrates the testing procedure used to evaluate compressive strength, ensuring consistency in load application.

Figure 11: Compression test and data of the composite sample

The figure demonstrates the testing procedure used to evaluate compressive strength, ensuring consistency in load application.

3.10.2 Water Absorption Test

Objective

The water absorption test was conducted to evaluate the porosity and moisture resistance of the composite specimens. Water absorption is an important indicator of the durability of construction materials, as excessive water absorption may lead to deterioration over time.

Test Procedure

The water absorption test was carried out according to the following steps:

a. The specimens were first dried under laboratory conditions to remove any surface moisture.

b. The dry weight of each specimen was measured using a digital weighing balance.

c. The specimens were then completely immersed in water for a period of 24 hours.

d. After 24 hours, the specimens were removed from the water and their surfaces were wiped with a dry cloth to remove excess water.

e. The saturated weight of the specimens was then recorded.

Calculation of Water Absorption

The test was done following the test procedure mentioned in IS 3495 (Part 1): 1992. Blocks are weighted dried and are weighted again after submerging inside water for 24 hrs., then they are submerged at the temp of 27 ± 2 ℃ , and water absorption was calculated using the following equation:

Water Absorption(%)= $\frac{Ws-Wd}{Wd}\times 100$

Where: W_s= Saturated weight of specimen, W_d= Dry weight of specimen

Figure 12 illustrates the water absorption test setup. The setup ensures controlled conditions for evaluating water absorption behavior of composite samples.


Figure 12: Composite samples placed inside water tank for water absorption test

3.10.3 Efflorescence Test

Objective

The efflorescence test was conducted to evaluate the presence of soluble salts in the plastic–sand composite specimens. Efflorescence is identified by the appearance of white crystalline deposits on the surface of materials due to the migration of soluble salts.

The test procedure was carried out with reference to IS 3495 (Part 3): 1992, with necessary adaptations for polymer-based composite specimens.

Test Procedure

The test was performed using one specimen from each mix category (CTRL, RH, RHA, and BC) as follows after testing the above sample for water absorption for 24 hrs. The specimens were subjected to two cycles of water absorption and drying over a total duration of approximately 7 days. The specimens were placed in a clean, non-reactive container containing distilled water. A laboratory-grade container was not mandatory for this test, as the procedure primarily involves visual observation of salt deposits. The specimen was placed in a shallow container, and distilled water was added to a depth of approximately 25 mm from the base of the specimen. The specimen was not fully immersed; instead, water was allowed to rise through capillary action.

a. Each specimen was placed in a shallow dish containing distilled water.

b. The depth of water was maintained at approximately 25 mm.

c. The specimens were allowed to absorb water through capillary action.
d. The setup was kept undisturbed at room temperature until the water was completely evaporated.
e. After drying, the surface of the specimens was visually examined for the presence of white salt deposits.
f. It was done in 2 cycle within 7 days (Immersion then evaporation followed by re-immersion)

Observation Criteria

The degree of efflorescence was classified qualitatively as:

a. **Nil:** No visible deposits
b. **Slight:** Thin layer of deposits covering less than 10% of the surface
c. **Moderate:** Deposits covering 10–50% of the surface
d. **Heavy:** Deposits covering more than 50% of the surface

Since the specimens are plastic–sand composites and do not contain conventional cementitious materials, the procedure was used primarily for comparative observation rather than standard compliance. Figure 13 shows the efflorescence test conducted on composite samples. The results indicate minimal or no visible salt deposition, suggesting good durability of the composite material.

Figure 13: Efflorescence test of composite sample

3.10.4 Visual Examination of Bricks

Visual examination was carried out to assess the general quality and appearance of the fabricated composite bricks. The specimens were inspected carefully to observe their shape, dimensions, color, and internal structure.

3.10.4.1 Shape and Size

The shape and dimensions of the fabricated bricks were examined to ensure uniformity and proper mold filling. The bricks were observed to verify that they maintained their shape after demolding and cooling. Figure 14 presents the dimensions of the fabricated specimen. The uniform dimensions confirm standardized specimen preparation, ensuring consistency in experimental results.

Figure 14: Dimension of fabricated sample

3.10.4.2 Color Test

The color of the prepared composite bricks was visually examined. The color of plastic–sand composite bricks generally depend on the type of plastic used and the additives incorporated into the mixture. Figure 15 shows color variation among composite samples.

The variation in color reflects the influence of different additives on the visual characteristics of the composite. In this study, the bricks exhibited a dark grey to blackish appearance due to the presence of molten plastic and carbon-based additives such as biochar.

Figure 15: Color inspection of composite samples

The variation in color reflects the influence of different additives on the visual characteristics of the composite. In this study, the bricks exhibited a dark grey to blackish appearance due to the presence of molten plastic and carbon-based additives such as biochar.

3.10.4.3 Structure of Brick

The internal structure of the bricks was examined by breaking a specimen to observe the distribution of sand and additive particles within the plastic matrix. A uniform distribution of materials indicates proper mixing during the fabrication process and contributes to improved mechanical performance.

3.10.5 Scratch Test

A qualitative hardness assessment was performed to evaluate the surface resistance of the composite specimens. The test involved scratching the surface of the specimen using a sharp steel object (knife), and the resistance to surface damage was visually observed. This method is not based on any specific IS code and was used as a simple field-level assessment to understand the relative surface hardness and abrasion resistance of the composite materials.

Objective

The hardness test was conducted to evaluate the surface resistance of the composite bricks against scratching or abrasion.

Procedure

The hardness test was performed by scratching the surface of the brick using a sharp steel object such as a nail or knife. The surface of the brick was carefully observed to determine whether the scratching action produced visible marks or grooves.

Observation

A good quality brick should resist surface scratching and should not show deep visible marks when scratched with a sharp object. The resistance to scratching indicates the hardness and durability.

3.10.6 Ringing Test

A qualitative soundness assessment was carried out as a field-based evaluation method to examine the internal integrity of the composite specimens. In this method, two specimens were lightly struck against each other, and the nature of the sound produced was observed. This test is not a standardized procedure under IS codes and was used only for preliminary assessment of structural integrity and detection of internal defects such as cracks or weak bonding.

Objective

The ringing test was conducted to evaluate the structural integrity of the composite bricks.

Procedure

Two bricks were held in each hand and struck gently against each other. The sound produced during the impact was carefully observed.

Observation

A good quality brick produces a clear ringing sound when struck against another brick. The absence of a dull sound indicates that the brick does not contain internal cracks or defects. Figure 16 illustrates the ringing test used to assess internal soundness.

Figure 16: Ringing test of composite samples

The dull but firm sound indicates good internal bonding and absence of major cracks within the composite samples.

3.11 Statistical Analysis

Statistical analysis was carried out to evaluate the consistency, reliability, and comparative performance of the compressive strength results obtained from the plastic–sand composite brick specimens. Since three specimens were tested for each sample type, the individual compressive strength values were used to calculate the mean compressive strength and standard deviation.

The tested sample groups included the control sample (LDPE + Sand) and modified samples containing rice husk (RH), rice husk ash (RHA), and biochar (RHB). The purpose of statistical analysis was to determine the representative strength value of each mix and to assess the variation among the tested specimens.

3.11.1 Mean Compressive Strength

The mean compressive strength represents the average strength of the three tested specimens for each sample type. It provides the most representative value for comparing the performance of different mixes.

The mean compressive strength was calculated using the following equation:

$$\text{Mean} = \frac{x1+x2+x3}{n}$$

Where:

Mean = mean compressive strength (MPa)
x1,x2,x3 = individual compressive strength values of the specimens
n = total number of specimens tested (n = 3)

The mean value helps in identifying the overall strength behavior of each composite and reduces the effect of minor variations in individual test results.

3.11.2 Standard Deviation

The standard deviation (SD) was calculated to determine the dispersion of the compressive strength values from the mean value. It indicates the uniformity and consistency of specimen preparation, mixing, and testing conditions.

A lower standard deviation indicates that the test results are closely grouped and more reliable, while a higher standard deviation indicates greater variation among the specimens.

The standard deviation was calculated using the following equation:

$$\text{SD} = \sqrt{\frac{\sum(\boldsymbol{X}\boldsymbol{i}-\bar{\boldsymbol{X}})^{2}}{\boldsymbol{n}-\mathbf{1}}}$$

Where:

SD = standard deviation
xi = individual compressive strength value
$\bar{X}$= mean compressive strength
n = number of observations

The standard deviation was used to evaluate the stability of each sample group and to compare the consistency of the control and modified composite bricks.

3.11.3 Error Bar Diagram

An error bar diagram was prepared using the mean compressive strength values with standard deviation as the error bars. The error bars visually represent the variation in the test results and help in comparing the reliability of different sample groups. Smaller error bars indicate better consistency and uniformity among the tested specimens, while larger error bars indicate greater variation in material behavior or specimen preparation. The error bar diagram was used to compare the control sample and modified samples containing rice husk, rice husk ash, and biochar. This graphical representation provided a clearer understanding of the effect of additives on compressive strength and helped identify the most effective additive for improving the performance of plastic–sand composite bricks. Thus, statistical analysis through mean value calculation, standard deviation, and error bar representation improved the interpretation of the experimental results and provided stronger support for the discussion and conclusion of the study.

3.12 Safety Measures

The composite sample were fabricated following all the safety measures. Heat resistant glovers were used to handle the hot utensils and to protect the hand. Proper clothes covering the body was used. Face mask was used along with a fire extinguisher in case of emergency. The room was well ventilated with proper passing of air.

a. Heat-resistant gloves used during melting.

b. Face mask during ash handling.

c. Laboratory ventilation ensured.

d. Fire extinguisher kept nearby.

Chapter 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained from the experimental investigation conducted on the fabricated plastic–sand composite bricks. The results obtained from various tests including visual examination, scratch test, ringing test, water absorption test, compressive strength test, efflorescence test, and FTIR analysis are presented and discussed in this chapter.

The purpose of these tests was to evaluate the mechanical and physical performance of the composite bricks prepared using LDPE plastic, sand, rice husk, rice husk ash, and biochar and to assess the influence of these additives on composite behavior.

4.2 Compressive Strength Results

4.2.1 Introduction

The compressive strength test was conducted to evaluate the load-bearing capacity of the fabricated plastic sand composite specimens. Compressive strength is one of the most important mechanical properties of construction materials as it indicates the ability of the material to resist compressive loads without failure. The test was performed using a Universal Testing Machine (UTM).

The specimens were prepared with dimensions of 100 mm × 50 mm × 50 mm. During the test, the samples were placed horizontally so that the loading area was 100 mm × 50 mm, giving a cross-sectional area of 5000 mm². The load was gradually applied until failure occurred, and the maximum load at failure was recorded.

4.2.2 Calculation of Compressive Strength

The compressive strength of each specimen was calculated using the following equation:

Where:

$F_c = P/A$

F_c = Compressive strength (MPa)

P = Maximum load applied (N)

A = Cross-sectional area (mm^2)

Sample Calculation (Control Specimen C1)

Area of specimen:

A = Length × Width

A = 100 × 50

A = 5000 mm^2

Maximum load recorded:

P = 95 kN

P = 95 × 1000

P = 95000 N

Compressive strength:

$F_c = P/A$

$F_c = \frac{95000}{5000}$

F_c = 19 MPa

Sample Calculation (Additive Specimen RHA1)

Area of specimen:

A = Length × Width = 5000 mm^2

Maximum load recorded:

P = 99 kN

= 99000 N

Compressive strength: $F_c = P/A$

= 19.8 MPa

Similar procedure was followed for all other sample.

4.2.3 Experimental Results

Table 10 shows the Maximum load(KN) and Compressive strength(MPa) of all the samples. The result indicates that compressive strength varies significantly with the type of additive used. Among all samples, RHA Samples exhibited the highest strength, While RH specimen showed the lowest value. RHB showed strength greater than RH but the strength was lower than the control sample.

Table 10: Compressive strength test results

Sample	Composition	Specimen	Maximum load (KN)	Compressive strength (MPa)
CTRL	LDPE + Sand	C1	95	19
CTRL	LDPE + Sand	C2	94	18.8
CTRL	LDPE + Sand	C3	92	18.4
RH	LDPE + Sand + RH	RH1	78.1	15.62
RH	LDPE + Sand + RH	RH2	77.4	15.48
RH	LDPE + Sand + RH	RH3	77.9	15.58
RHA	LDPE + Sand + RHA	RHA1	99	19.8
RHA	LDPE + Sand + RHA	RHA2	95	19
RHA	LDPE + Sand + RHA	RHA3	96.1	19.22
RHB	LDPE + Sand + RHB	RHB1	85	17
RHB	LDPE + Sand + RHB	RHB2	84	16.8
RHB	LDPE + Sand + RHB	RHB3	87	17.4

Figure 17 illustrates the variation in compressive strength among all specimens, highlighting the influence of different additives on mechanical performance. The different additive resulted in different strength, showing clear variation between the strength obtained.

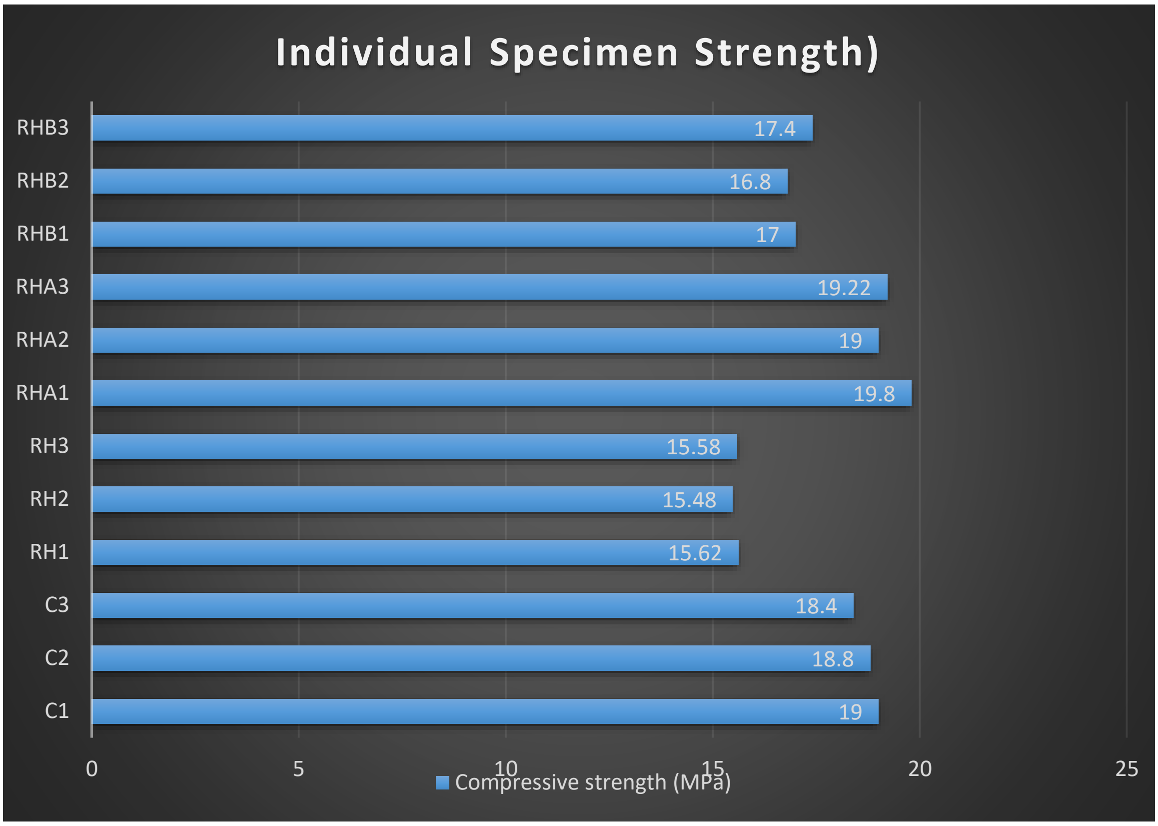


Figure 17: Individual compressive strength of 12 samples

4.2.4 Average Compressive Strength

Table 11 shows the Average Compressive strength in MPa of the composite sample.

Table 11: Average compressive strength of composite samples

Sample Type	Composition	Average Compressive Strength (MPa)
CTRL	LDPE + Sand	18.73
RH	LDPE + Sand + RH	15.56
RHA	LDPE + Sand + RHA	19.34
RHB	LDPE + Sand + RHB	17.07

The average values confirm that RHA provides the best improvement in compressive strength among all additives. Figure 18 demonstrates that RHA-modified specimens achieved the highest average compressive strength due to improved particle packing and bonding.

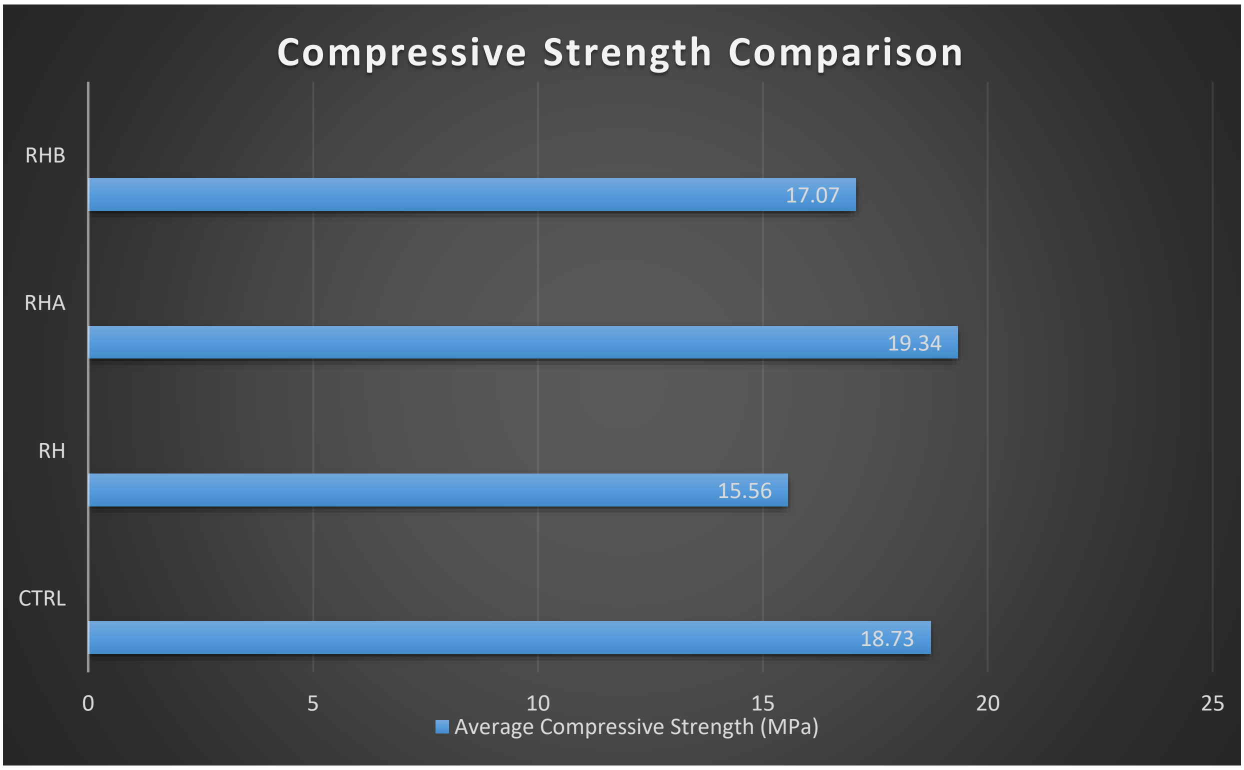


Figure 18: Comparison of average compressive strength of composite samples

4.2.5 Maximum Load Capacity of Composite Specimens

Table 12 shows the maximum load(KN) obtained of the composite sample.

Table 12: Maximum load capacity of composite specimens

Sample Type	Composition	Maximum Load (KN)
CTRL	LDPE + Sand	93.7
RH	LDPE + Sand + RH	77.8
RHA	LDPE + Sand + RHA	96.7
RHB	LDPE + Sand + RHB	85.3

Figure 19 shows the maximum load capacity of composite specimens. The maximum load capacity follows a trend similar to compressive strength, confirming the direct relationship between load-bearing capacity and material strength.

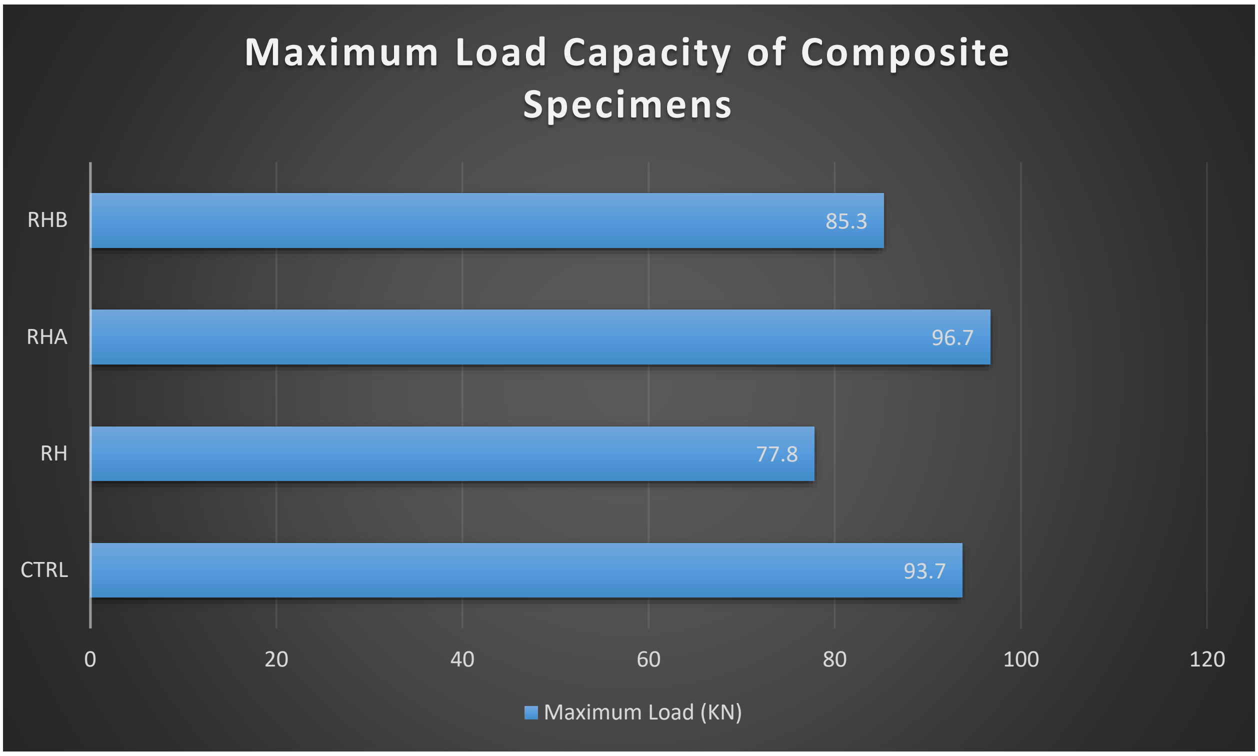


Figure 19: Maximum load capacity of composite specimens

4.2.6 Mean, Standard Deviation and Error Bar Diagram

To evaluate the consistency and reliability of the compressive strength results, statistical analysis was carried out using the mean compressive strength and standard deviation of each sample group. Three specimens were tested for each sample, and the individual compressive strength values were used for the calculation.

The mean compressive strength represents the average performance of the specimens, while the standard deviation indicates the variation among the test results. Lower standard deviation values indicate better consistency and uniformity of specimen preparation and testing.

Table 13: Compressive strength ,mean and standard deviation

Sample	Compressive Strength Values (MPa)	Mean (MPa)	Standard Deviation
CTRL	19.00, 18.80, 18.40	18.73	0.31
RH	15.62, 15.48, 15.58	15.56	0.07
RHA	19.80, 19.00, 19.22	19.34	0.41
RHB	17.00, 16.80, 17.40	17.07	0.31

The standard deviation values indicate that RH samples exhibit the highest consistency, while RHA samples show slightly higher variability due to differences in particle distribution. Figure 20 illustrates the error bar diagram representing variability in compressive strength results. The error bars represent the variability in compressive strength values, where smaller error bars indicate more consistent specimen performance.

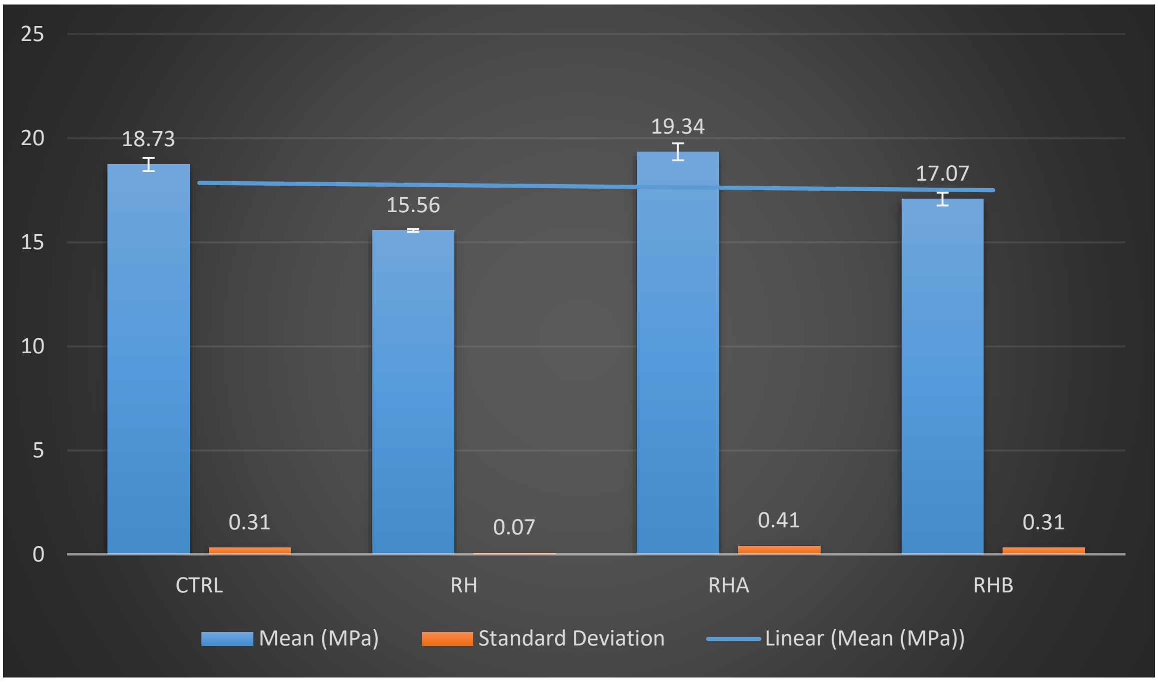


Figure 20: Error bar diagram

4.2.7 Comparative Analysis

To better understand the effect of different additives on compressive strength, the percentage change in strength of modified composites relative to the control specimen was calculated using Equation:

$$\%\Delta = \frac{Fm - Fc}{Fc} \times 100$$

where F_m is the compressive strength of the modified specimen and F_c is the compressive strength of the control specimen.

Table 14 presents the percentage change in compressive strength.

Table 14: Percentage change with respect to compressive strength

Mix	Compressive strength(MPa)	Percentage change
RH	15.56	-16.9%
RHA	19.34	+3.3%
RHB	17.07	-8.9%

The comparative analysis indicates that the incorporation of rice husk ash (RHA) resulted in an approximate 3.3% increase in compressive strength compared to the control specimen. This improvement can be attributed to the high silica content of RHA, which enhances particle packing and improves interfacial bonding within the composite matrix.

In contrast, the addition of raw rice husk (RH) led to a significant reduction of approximately 16.9%, primarily due to its fibrous and porous structure, which increases void content and weakens the bonding between LDPE and aggregate particles.

Similarly, biochar (RHB) incorporation resulted in a strength reduction of approximately 8.9% compared to the control specimen. Although biochar possesses a carbon-rich structure, its porous morphology and relatively weak interfacial adhesion with the polymer matrix contribute to reduced load transfer efficiency.

4.3 Visual Examination of Composite Bricks

Visual inspection of the prepared composite bricks was carried out to evaluate their general appearance and structural quality. The bricks were examined for their shape, size, color, and internal structure. These observations indicate that the fabrication process was effective in producing structurally stable composite specimens.

4.3.1 Shape and Size

The fabricated composite bricks were observed to have a regular rectangular shape corresponding to the mold dimensions of 100 mm × 50 mm × 50 mm. The specimens maintained their shape after demolding and cooling. No visible deformation or distortion was observed in the prepared specimens. This indicates that the molten plastic successfully bound the sand and additive particles during the fabrication process, resulting in properly formed composite bricks.

4.3.2 Color

The color of the composite bricks was visually examined after cooling and demolding. The control plastic–sand bricks exhibited a dark grey color, which is typical for plastic-based composite materials.

The bricks containing rice husk showed a slightly lighter grey color, while the bricks containing rice husk ash and biochar appeared darker due to the presence of carbon-rich materials. The variation in color among the different specimens reflects the influence of the additive materials incorporated into the composite mixture.

4.3.3 Structure of Brick

The internal structure of the bricks was examined by breaking one specimen to observe the distribution of materials within the composite. The sand and additive particles were found to be embedded within the plastic matrix.

The plastic acted as a binding agent that held the aggregate particles together. The internal structure appeared relatively dense and compact, indicating proper mixing and compaction during specimen preparation.

4.4 Water Absorption Results

The water absorption test was conducted by immersing the composite bricks in water for a period of 24 hours. The dry weight and saturated weight of the specimens were recorded, and the percentage of water absorption was calculated.

The results indicate that the plastic–sand composite bricks exhibited relatively low water absorption compared to conventional clay bricks. This is mainly due to the hydrophobic nature of LDPE plastic, which reduces water penetration into the composite structure.

Among the tested samples, the rice husk sample showed slightly higher water absorption due to the porous nature of the rice husk particles and the lower water absorption observed in RHA specimens is attributed to improved packing density and reduced pore connectivity. Table 15 presents the water absorption results of composite samples

Table 15: Water absorption result

Sample ID	Dry Weight (g)	Wet Weight (g)	Water Absorption (%)
CTRL	400	410	2.50
RH	390	404	3.59
RHA	410	419	2.20
RHB	395	406	2.78

The results confirm that all composite samples exhibit low water absorption, with RHA showing the lowest value, indicating improved durability.

4.5 Efflorescence Test Results

Table 16 shows the efflorescence test results indicating negligible salt formation.

Table 16: Efflorescence test result

Sample ID	Observation	Efflorescence Level
CTRL	No visible white deposits	Nil
RH	No visible deposits	Nil
RHA	Very slight traces observed	Nil
RHB	No visible deposits	Nil

The efflorescence test results indicate that no visible white deposits were observed on the surface of any of the specimens after completion of the test cycles. All samples, including control and modified composites, were classified under the “Nil” category as per IS 3495 (Part 3): 1992. The absence of significant efflorescence indicates good durability and resistance to salt formation.

4.6 **Scratch Test**

The hardness assessment showed that all composite specimens exhibited noticeable resistance to surface scratching. When subjected to scratching using a steel object, only minor surface marks were observed, and no deep grooves or material disintegration occurred.

The control and RHA specimens showed relatively higher resistance to scratching, indicating better surface hardness, which can be attributed to denser particle packing and improved bonding. In contrast, the rice husk specimens exhibited slightly more surface marking due to their more porous and fibrous nature. Biochar-based specimens showed moderate resistance to scratching.

Although the test is qualitative in nature, the observations suggest that the developed composite materials possess adequate surface hardness suitable for non-structural construction applications.

4.7 Ringing Test

The acoustic (Ringing) Observation was conducted by striking two bricks together and observing the sound produced during impact.

The soundness assessment indicated that all composite specimens produced a **dull but firm sound** when struck against each other. Unlike conventional fired clay bricks, which typically produce a clear metallic ringing sound due to their dense and brittle nature, the developed plastic–sand composites did not exhibit such behavior.

This difference can be attributed to the presence of LDPE as the binding matrix. Being a polymeric material, LDPE has inherent energy-absorbing characteristics, which dampens vibrations and reduces the sharpness of the sound produced upon impact. Despite the absence of a metallic ringing sound, none of the specimens showed visible cracking, breakage, or disintegration during the test. This indicates that the composite specimens possess adequate internal bonding and structural integrity.

Therefore, the test results suggest that while the acoustic response differs from conventional bricks due to material composition, the overall integrity of the developed composites remains satisfactory.

4.8 FTIR Analysis

4.8.1 FTIR Analysis of Rice Husk, Rice Husk Ash and Biochar

4.8.1.1 Introduction

FTIR analysis was conducted to evaluate the chemical composition of rice husk, rice husk ash, and rice husk biochar in the range of 4000–400 cm⁻¹. Figure 21 compares the FTIR spectra of RH, RHA, and RHB.

4.8.1.2 FTIR Spectra Interpretation

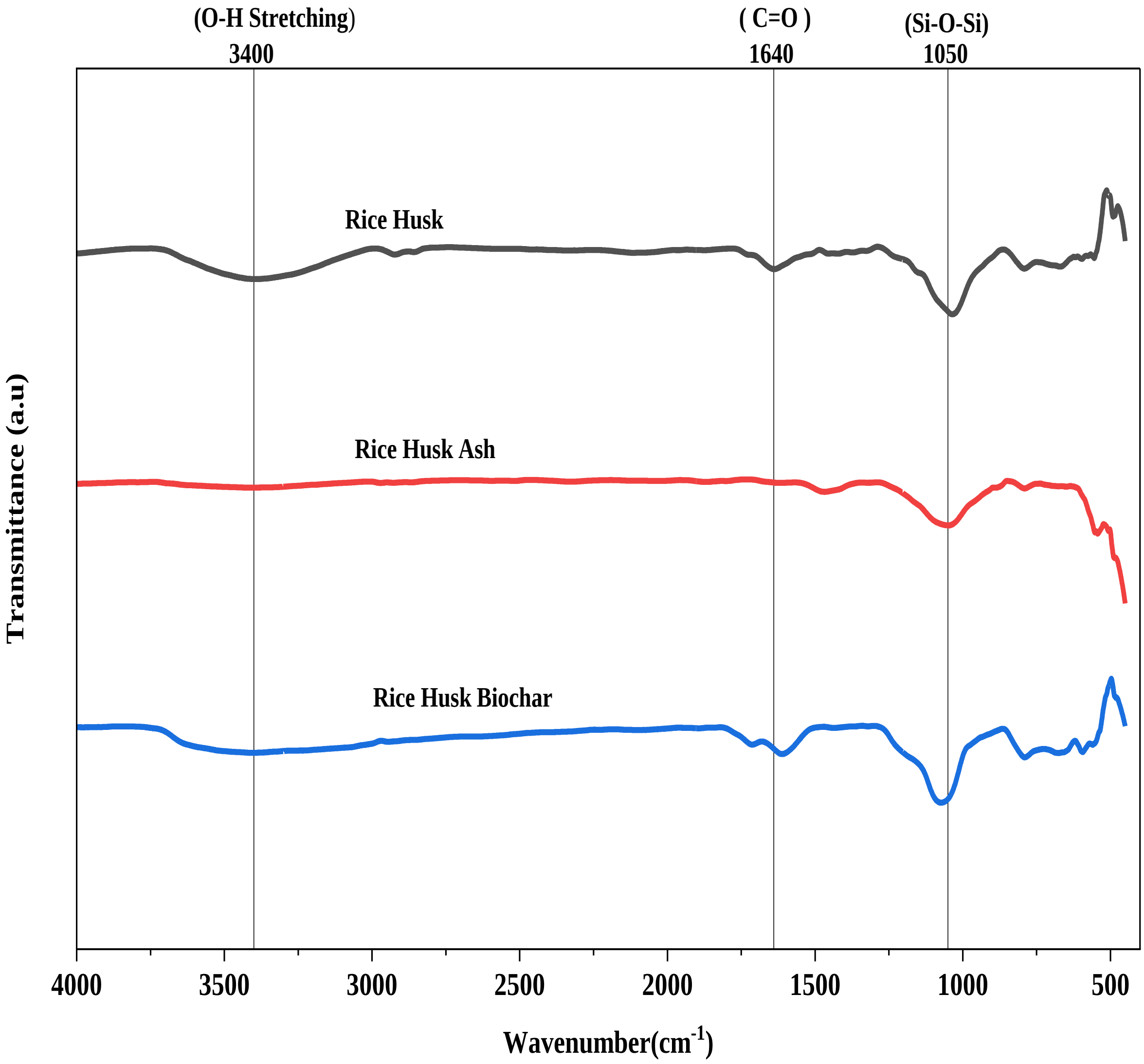


Figure 21: Comparison of FTIR data of rice husk ,rice husk ash and rice husk biochar

The comparison highlights distinct chemical compositions of RH, RHA, and RHB, which influence composite performance.

a. **Rice Husk**

The rice husk sample exhibited a broad peak around 3400 cm^{-1}, corresponding to O–H stretching vibrations, indicating the presence of hydroxyl groups from cellulose and absorbed moisture. A peak near 1640 cm^{-1} was observed due to H–O–H bending vibrations. A strong peak around 1050 cm^{-1} corresponds to Si–O–Si stretching, confirming the presence of silica. These results indicate that rice husk contains both organic components and silica.

b. **Rice Husk Ash**

The FTIR spectrum of rice husk ash showed a significant reduction in the O–H peak, indicating the removal of organic components during combustion. A dominant peak at approximately 1050 cm^{-1} was observed, corresponding to Si–O–Si stretching vibrations. This confirms that rice husk ash is primarily composed of silica and other inorganic oxides.

c. **Rice Husk Biochar**

The biochar sample exhibited relatively weaker peaks, indicating a reduction in functional groups. A minor peak near 1640 cm^{-1} corresponds to aromatic C=C bonds, suggesting the presence of carbonaceous structures. The reduced intensity of O–H peaks indicates partial decomposition of organic material during pyrolysis.

4.8.1.3 Overall Interpretation

The FTIR analysis demonstrates that thermal treatment of rice husk significantly alters its chemical composition. Rice husk contains organic material and silica, whereas rice husk ash is predominantly inorganic and silica-rich. In contrast, biochar is mainly composed of stable carbon structures with limited functional groups.

4.8.1.4 Conclusion

The transformation of rice husk into ash and biochar results in the removal of organic functional groups and the formation of silica-rich and carbon-rich materials, respectively. This variation in chemical composition influences their behavior when used as partial replacements in plastic–sand composite bricks.

4.8.2 FTIR Analysis of Plastic–Sand Composite Bricks

4.8.2.1 Introduction

Fourier Transform Infrared (FTIR) spectroscopy was conducted to identify the functional groups present in plastic–sand composite bricks and to evaluate the interaction between polyethylene (PE) and the replacement materials (rice husk, ash, and biochar). The analysis was performed in the range of 4000–400 cm^{-1}.

4.8.2.2 FTIR Spectra Interpretation

Figure 22 presents the FTIR spectra of composite samples, showing interaction between LDPE and additives.

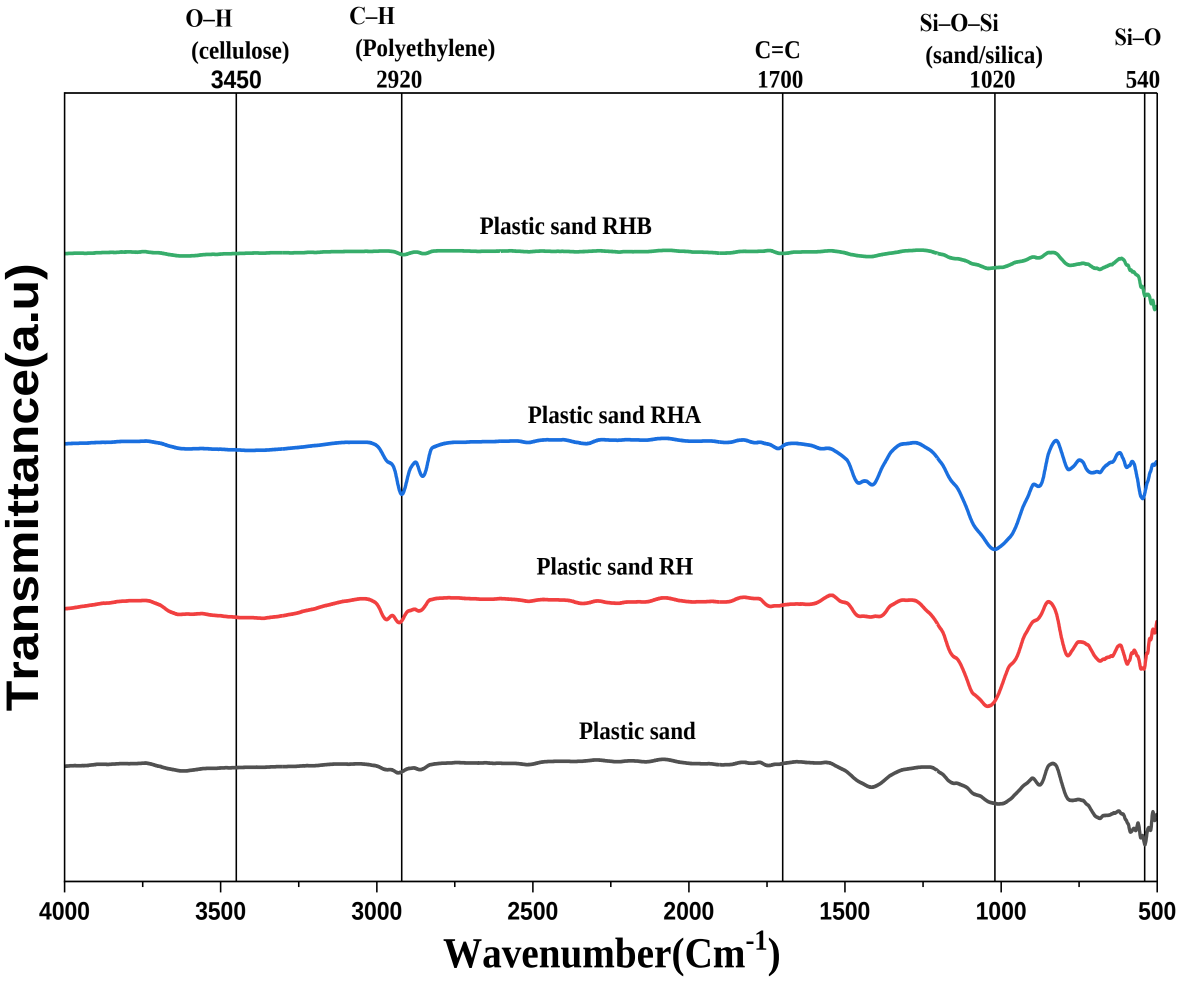


Figure 22: Comparison of FTIR result of four composite samples

The spectra confirm the interaction between LDPE and additives, indicating successful composite formation. Common Features in All Samples are that all spectra exhibited characteristic peaks associated with polyethylene and silica. A prominent peak at approximately 2920 cm^{-1} corresponds to C–H stretching vibrations, confirming the presence of polyethylene in all samples. A strong peak around 1000–1100 cm^{-1} is attributed to Si–O–Si stretching vibrations, indicating the presence of silica from sand. Peaks observed in the region of 400–600 cm^{-1} correspond to Si–O bending vibrations, further confirming the mineral (sand) component. These common peaks confirm that the base composition of plastic and sand is retained across all brick types.

a. Plastic Sand Brick (Control Sample)

The control sample shows clear peaks corresponding to polyethylene and silica without any additional functional groups. This indicates that the brick is composed primarily of physically combined plastic and sand, with no evidence of additional chemical components.

b. Plastic Sand Rice Husk Brick

The Plastic sand rice husk sample exhibits a broad peak around 3400 cm^{-1}, corresponding to O–H stretching vibrations, indicating the presence of hydroxyl groups from cellulose and hemicellulose in rice husk. Increased intensity in the 1000–1100 cm^{-1} region, suggesting additional silica content contributed by rice husk ash. These features confirm the successful incorporation of rice husk into the composite matrix.

c. Plastic Sand Ash Brick

The Plastic sand ash composite sample shows a pronounced peak in the 1000–1100 cm^{-1} region, indicating a high concentration of silica and inorganic oxides. Additional minor peaks in the 600–800 cm^{-1} range, which may be attributed to metal oxides (e.g., Al–O, Fe–O bonds) present in ash. This confirms the presence of mineral-rich ash within the composite.

d. Plastic Sand Biochar Brick

The Plastic sand biochar sample exhibits a relatively weaker and flatter peaks, indicating fewer functional groups. A minor peak around 1600 cm^{-1}, which can be associated with aromatic C=C bonds, characteristic of carbon-rich biochar. This suggests that biochar is primarily composed of stable carbon structures with limited functional groups.

4.8.2.3 Interaction Between Components

A comparison of all spectra shows that:

The characteristic peaks of polyethylene (around 2920 cm^{-1}) remain unchanged in all samples and no significant peak shifts or new peaks were observed and only variations in peak intensity were noted with the addition of different materials.

These observations indicate that:

a. The interaction between polyethylene and the added materials (rice husk, ash, and biochar) is predominantly physical rather than chemical.

b. There is no evidence of strong chemical bonding or formation of new functional groups. The composite structure is therefore formed through physical mixing and encapsulation of particles within the plastic matrix.

4.8.2.4 Overall Interpretation

The FTIR analysis confirms that:

a. Polyethylene retains its chemical structure in all composite bricks.

b. Sand and replacement materials are successfully incorporated into the matrix.

c. Rice husk contributes hydroxyl and silica groups.

d. Ash contributes inorganic oxides and enhances mineral content.

e. Biochar contributes stable carbon structures with minimal functional groups.

f. No chemical degradation or reaction occurs between plastic and additives.

4.8.2.5 Conclusion from FTIR Analysis

FTIR results demonstrate that plastic sand composite bricks with partial replacement of sand by rice husk, ash, and biochar are chemically stable systems. The absence of peak shifts or new functional groups confirms that the interaction between components is primarily physical. This indicates that the incorporation of waste materials does not alter the fundamental chemical structure of polyethylene, making the composite suitable for sustainable construction applications.

4.9 Discussion

4.9.1 Compressive Strength Discussion

The compressive strength results demonstrated that the incorporation of rice husk derivatives significantly influenced the mechanical behavior of LDPE–sand composite bricks. The control specimen exhibited stable compressive strength, indicating that molten LDPE effectively functioned as a binding matrix, providing cohesion among sand particles and facilitating stress transfer under compressive loading.

Among the modified specimens, rice husk ash (RHA) exhibited the highest compressive strength. This improvement may be attributed to the micro-filler effect of the fine RHA particles, which enhanced particle packing, reduced internal voids, and promoted matrix densification. The silica-rich nature of RHA likely contributed to improved interfacial adhesion between the plastic matrix and filler particles, resulting in more efficient load transfer and higher strength. These findings suggest that RHA improved the structural compactness of the composite and acted as an effective reinforcing additive.

In contrast, specimens containing raw rice husk (RH) showed the lowest compressive strength. This reduction may be attributed to the fibrous and porous nature of rice husk, which can introduce discontinuities and weak zones within the composite matrix. In addition, limited wetting and bonding between molten LDPE and fibrous husk particles may have reduced interfacial strength, creating stress concentration points under compression. These factors collectively contributed to lower load-bearing capacity.

The reduction in compressive strength observed in biochar-modified specimens compared to the control mix can be attributed to the inherent porous structure of biochar. While biochar was initially selected for its potential to improve interfacial interaction due to its high surface area and carbon-rich composition, the experimental results suggest that at the selected replacement level (10%), the increased porosity dominated the behavior.

The presence of micro-voids within biochar particles reduces the effective load-bearing area and weakens stress transfer between the LDPE matrix and aggregate particles. As a result, instead of acting as a reinforcing filler, biochar behaves as a defect-inducing phase in the composite. This indicates that although biochar has potential benefits, its performance is highly dependent on optimized dosage and particle characteristics.

Overall, the results indicate that particle size distribution, porosity, filler morphology, and interfacial bonding strongly influence the compressive behavior of plastic–sand composites. The findings are consistent with previous studies reporting that finer silica-rich fillers tend to enhance strength through improved packing and reduced void content, whereas highly porous lignocellulosic fillers often reduce mechanical performance (Chauhan et al. (2019), Frank et al. (2021)).

4.9.2 Water Absorption Discussion

Water absorption results showed generally low absorption values for all specimens, which can primarily be attributed to the hydrophobic nature of LDPE. Unlike cementitious materials, the plastic matrix restricts water ingress and limits interconnected pore pathways, contributing to improved moisture resistance.

The control specimen showed low water absorption due to the dense plastic–sand matrix. The RH-modified specimen exhibited comparatively higher absorption, likely because the fibrous and porous structure of rice husk increased internal void content and created pathways for moisture penetration.

The RHA specimen demonstrated lower water absorption than RH and comparable behavior to the control specimen. This may be attributed to improved packing density caused by fine ash particles, which reduced pore connectivity and enhanced matrix compactness.

Biochar specimens exhibited moderate water absorption behavior. Although biochar possesses internal porosity that can promote moisture uptake, the surrounding plastic matrix likely restricted extensive water penetration.

These findings indicate that moisture resistance in the developed composites is governed by the interaction between additive morphology and composite pore structure. In particular, the use of fine mineral-rich ash appears beneficial for maintaining both strength and reduced water absorption.

4.9.3 Efflorescence Test Discussion

The absence of efflorescence in all specimens can be attributed to the non-cementitious nature of the composite materials. Unlike conventional clay or cement-based bricks, the plastic–sand composites do not contain soluble salts such as calcium hydroxide, which are primarily responsible for efflorescence formation.

Additionally, the hydrophobic nature of LDPE plastic limits water absorption and prevents the movement of dissolved salts to the surface. This significantly reduces the possibility of efflorescence formation.

Therefore, the developed composite materials demonstrate excellent resistance to efflorescence, making them suitable for applications where moisture exposure is a concern

4.9.4 Visual Examination and Hardness Discussion

Visual examination indicated that all specimens maintained dimensional stability and satisfactory surface quality after demolding, suggesting adequate processing, mold filling, and compaction.

Minor differences in surface texture and internal appearance were observed among additive types. Specimens containing RH and biochar showed minor internal voids, which aligns with their comparatively lower compressive performance. This suggests a relationship between observed microstructural uniformity and mechanical behavior.

Hardness test observations further supported the compressive strength trends. Control and RHA specimens exhibited greater resistance to scratching, likely due to denser packing and improved matrix integrity. RH specimens showed relatively lower hardness due to the softer fibrous nature of the filler, while biochar showed intermediate performance.

Together, these observations suggest that additive characteristics influence not only bulk mechanical strength but also surface durability and material integrity.

4.9.5 Ringing Test Discussion

The ringing test provided preliminary qualitative evidence of internal integrity and bonding quality in the developed composites. The relatively clear and firm sound produced by the control and RHA specimens suggests better compactness and internal cohesion.

The comparatively duller sound observed in RH specimens may be associated with greater internal porosity or reduced bonding efficiency, which is consistent with compressive strength observations.

Although this test is qualitative in nature, its results support the overall trend observed in mechanical testing and suggest acceptable soundness of the developed composites

4.9.6 FTIR Discussion

FTIR analysis provides important insights into the chemical structure and bonding characteristics of the composite materials. The spectra of RHA show prominent peaks corresponding to Si–O–Si and Si–O functional groups, indicating the presence of silica-rich phases. These silica components contribute to improved particle packing and stronger interfacial bonding within the composite, which is consistent with the observed increase in compressive strength.

In contrast, the FTIR spectra of RHB are dominated by C=C, C–H, and O–H functional groups, representing its carbon-rich and organic nature. Unlike RHA, biochar lacks significant inorganic bonding phases such as silica, which limits its ability to enhance structural rigidity. Furthermore, the absence of strong interfacial chemical bonding between biochar and LDPE results in weaker stress transfer, contributing to reduced compressive strength. Similarly, raw rice husk (RH) exhibits FTIR peaks associated with cellulose and lignin structures, which are inherently less compatible with the polymer matrix and contribute to higher moisture absorption and weaker bonding.

Therefore, the FTIR results support the findings by demonstrating that materials with higher silica content enhance composite strength, whereas materials with higher organic and porous characteristics tend to reduce strength. This correlation between FTIR results and mechanical performance validates the role of chemical composition in determining composite strength.

4.9.7 Overall Comparative Discussion

Comparative evaluation of all specimens indicates that rice husk ash is the most effective additive among those investigated, as it improved compressive strength while maintaining low water absorption, good hardness, sound structural integrity, and favorable chemical characteristics.

Raw rice husk, although sustainable and lightweight, reduced mechanical performance due to porosity, fibrous discontinuity, and weaker matrix interaction. Biochar provided balanced performance, offering moderate strength and potential lightweight benefits, though optimization may be required to minimize porosity effects. The study demonstrates that composite performance is strongly dependent on additive morphology, porosity, particle size, and chemical composition. In particular, silica-rich fine fillers appear beneficial for matrix densification and reinforcement, while highly porous biomass fillers may adversely affect strength.

These findings highlight the importance of optimizing additive characteristics for improved composite performance.

Chapter 5

CHALLENGES AND LIMITATIONS

5.1 Challenges Faced During the Study

During the course of this research, several practical and experimental challenges were encountered:

a. **Temperature control during plastic melting**

   Maintaining a uniform temperature during the melting of LDPE was difficult using conventional laboratory heating methods. Overheating could lead to degradation of plastic, while insufficient heating affected proper mixing and bonding.

b. **Uniform Mixing of Materials**

   Achieving homogeneous mixing of molten plastic with sand and additives (rice husk, rice husk ash, and biochar) was challenging due to differences in density and particle size. Manual mixing sometimes resulted in uneven distribution.

c. **Handling of Molten Plastic**

   Working with molten plastic posed difficulties in terms of safety and workability. Rapid cooling of LDPE required quick handling during casting and compaction.

d. **Mold Preparation and Compaction**

   Ensuring proper compaction and removal of air voids was challenging due to the viscous nature of molten plastic. Manual compaction may have introduced variability between specimens.

e. **Limited Access to Advanced Equipment**

   Advanced characterization tools such as SEM and XRD were not readily accessible, which limited detailed microstructural analysis of the composites.

f. **Material preparation Variability**

   Preparation of rice husk ash and biochar involved manual processes (burning and pyrolysis), which may have introduced inconsistencies in material properties.

5.2 Limitations of the Study

Despite achieving the objectives, the study has the following limitations:

a. **Non-Standard Specimen Size**

The specimens used in this study (100 × 50 × 50 mm) were laboratory-scale and do not conform to standard brick dimensions. Therefore, the results are primarily suitable for comparative analysis rather than direct field application.

b. **Limited Range of Mix Proportions**

Only one plastic-to-sand ratio (30:70) and a single additive replacement level (10%) were investigated. The effect of other proportions was not studied.

c. **Limited Mechanical Testing**

The study focused mainly on compressive strength and basic physical tests. Other important mechanical properties such as flexural strength and impact resistance were not evaluated.

d. **Absence of Long-Term Durability Analysis**

Long-term performance characteristics such as weathering, chemical resistance, and aging behavior were not assessed.

e. **Simplified Testing Conditions**

Some tests were conducted using adapted procedures rather than strict adherence to IS or ASTM standards due to equipment and specimen constraints.

f. **Environmental Impact Not Quantified**

Although the study promotes plastic recycling, detailed analysis of emissions during plastic melting and overall environmental impact (e.g., life cycle assessment) was not performed.

g. **Limited Sample Size**

A relatively small number of specimens were tested for each mix type, which may affect the statistical reliability of the results.

h. **Manual Fabrication Process**

The use of manual mixing and compaction methods may have introduced human error and variability in specimen quality.

i. Lack of Field Validation

The study was conducted entirely under laboratory conditions, and real-world performance in construction applications was not evaluated.

Despite these limitations, the study provides valuable insights into the feasibility of utilizing plastic waste and agricultural residues in composite construction materials and establishes a foundation for future research.

Chapter 6

CONCLUSION

6.1 Summary of Findings

This study investigated the development of plastic sand composite specimens using low density polyethylene (LDPE) as a binding material and sand as the primary aggregate. Agricultural waste materials, namely rice husk (RH), rice husk ash (RHA), and rice husk biochar (RHB), were incorporated as partial replacements of sand at 10% by weight.

The experimental results indicated that plastic sand composites can be successfully fabricated using a simple heating and molding process under laboratory conditions. The control mix (LDPE + sand) exhibited stable and consistent compressive strength, confirming the effectiveness of LDPE as a binder.

Among the modified mixes, the rice husk ash (RHA) composite showed the highest compressive strength, slightly exceeding that of the control specimen. The rice husk biochar based composite demonstrated moderate strength, while the raw rice husk composite showed the lowest compressive strength among all samples.

6.2 Key Outcomes

a. LDPE plastic effectively functions as a binding matrix, providing adequate bonding between aggregate particles.

b. The addition of rice husk reduces compressive strength due to its fibrous, porous, and low-density nature.

c. Rice husk ash improves strength performance, likely due to its fine particle size and high silica content, which enhances packing density.

d. Rice husk biochar acts as a reinforcing filler with moderate performance, though its porous structure may introduce internal voids.

e. Plastic based composites exhibit low water absorption due to the hydrophobic nature of LDPE.

f. FTIR analysis confirmed the presence of characteristic functional groups of the raw materials within the composite, indicating successful incorporation without significant chemical degradation.

6.3 Practical Implications

The findings of this study highlight the potential of plastic sand composites as an alternative construction material, particularly for non-structural and low-load applications. The use of waste plastic and agricultural residues contributes to sustainable material development and effective waste management.

The incorporation of rice husk ash appears particularly promising for enhancing mechanical performance, making it a suitable additive for improving composite properties.

Additionally, the use of simple fabrication techniques makes this approach feasible for small-scale and low-cost production, especially in regions with limited access to conventional construction materials.

6.4 Final Remarks

Overall, the study demonstrates that plastic waste, when combined with sand and appropriate additives, can be transformed into functional composite materials with acceptable mechanical and physical properties. While the results are limited to laboratory-scale specimens, the research provides a strong foundation for future investigations aimed at optimizing material composition, improving performance, and scaling up for practical construction applications.

Chapter 7

RECOMMENDATION

Based on the experimental findings and observations of this study, the developed plastic–sand composite materials demonstrated potential for use in various non-structural and low-load construction applications due to their acceptable mechanical performance, low water absorption, and lightweight nature. These composites may be utilized in applications such as partition walls, paving blocks, footpaths, landscaping elements, boundary walls, and low-cost housing components. Furthermore, the incorporation of waste plastic and agricultural by-products contributes to sustainable construction practices and waste management. However, further investigations and improvements are necessary to enhance material performance, durability, safety, and large-scale applicability. Therefore, the following recommendations are proposed for future research and practical implementation of plastic–sand composite materials.

a. **Optimization of Mix Proportions**

   The present study was limited to a single plastic to sand ratio (30:70) and a fixed additive replacement level (10%). Future studies should investigate a wider range of mix proportions, including different plastic contents (e.g., 20%, 40%) and additive replacement levels (e.g., 5%, 15%, 20%) to determine the optimum composition for maximum strength and durability.

b. **Use of standard sample size**

   The current research utilized laboratory-scale specimens (100 × 50 × 50 mm) for small laboratory level experimentation. Future work should focus on producing full scale bricks or blocks as per relevant standards (IS or ASTM) to validate the applicability of results for real construction practices.

c. **Advanced Mechanical and Durability Testing**

   Further investigations should include additional tests such as:

I. Flexural strength

II. Impact resistance

III. Abrasion resistance

IV. Long-term durability tests (freeze-thaw, chemical resistance)

These tests will provide a more comprehensive understanding of the material performance.

d. Thermal and Fire Performance Analysis

Since plastic is a polymeric material, evaluation of thermal stability and fire resistance is essential and Future studies should assess:

I. Thermal conductivity

II. Heat resistance

III. Fire behavior and flammability characteristics

This is critical for assessing safety in construction applications.

e. Environmental and Emission Analysis

Although this study promotes recycling of plastic waste, further research should evaluate:

I. Emissions during plastic melting

II. Potential release of harmful gases

III. Life cycle assessment (LCA) of plastic–sand composites

This will help in ensuring environmental sustainability and safety.

f. Microstructural Characterization

Advanced characterization techniques such as:

I. Scanning Electron Microscopy (SEM)

II. X-ray Diffraction (XRD)

Should be used in future studies to better understand the bonding mechanism and internal structure of the composite materials.

g. Exploration of Other Waste Materials

Future research may incorporate other waste materials such as:

I. Fly ash
II. Waste glass powder
III. Coconut fiber or other natural fibers

to further enhance mechanical properties and sustainability.

h. Scale-Up and Industrial Application

I. Pilot-scale production and field trials should be conducted to evaluate:
II. Workability in real construction conditions
III. Cost-effectiveness
IV. Feasibility of mass production

This will bridge the gap between laboratory research and practical application.

i. Improvement in Manufacturing Process

Automation of mixing, heating, and compaction processes should be explored to:

I. Ensure uniform quality
II. Reduce human error
III. Improve production efficiency

j. Standardization and Code Development

Since plastic–sand composites are emerging materials, there is a need for:

I. Development of standard guidelines
II. Establishment of testing protocols
III. Inclusion in building codes

to promote wider acceptance in the construction industry.

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APPENDIX A: EXPERIMENTAL PICTURES

Figure 23: Making biochar and ash inside muffle furnace

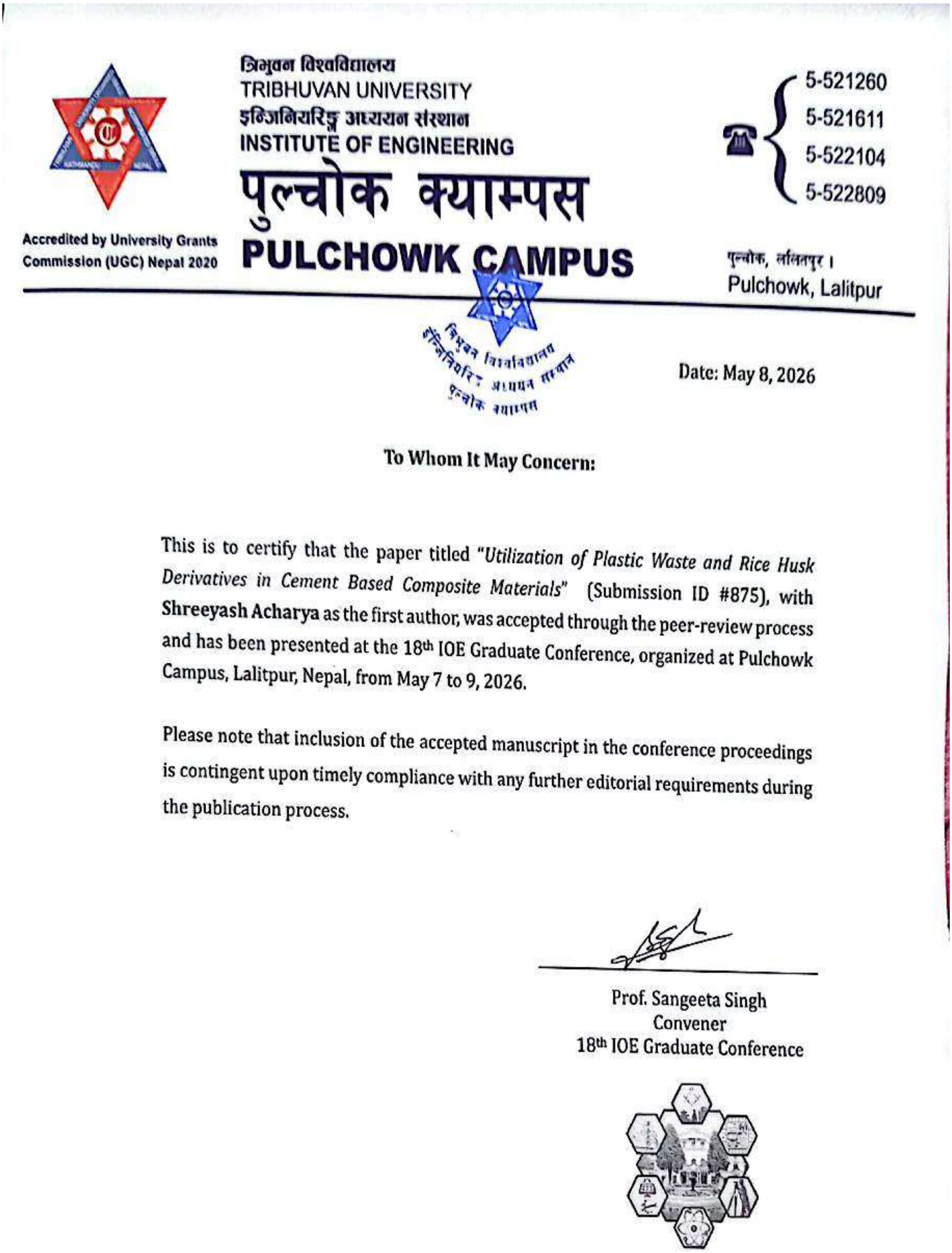
Figure 24:Grinding and sieving the biochar and ash

Figure 25: Brick molds and composite samples

Figure 26: Test of sand and composite

Figure 27: Melting of plastic

APPENDIX B: SUPPORTING DOCUMENTS



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पुल्चोक क्याम्पस
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पुल्चोक, ललितपुर।
Pulchowk, Lalitpur

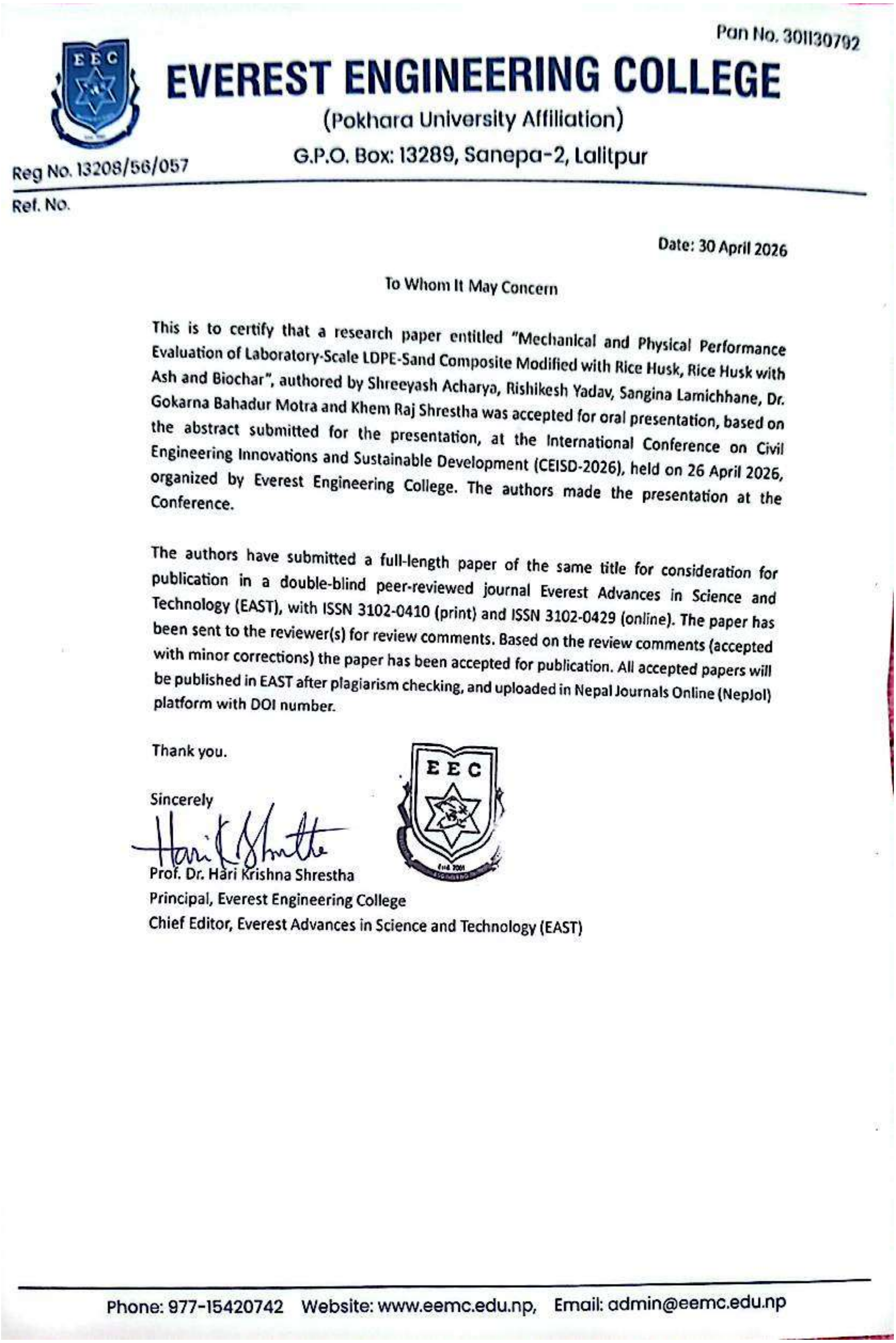
Date: May 8, 2026

To Whom It May Concern:

This is to certify that the paper titled "*Utilization of Plastic Waste and Rice Husk Derivatives in Cement Based Composite Materials*" (Submission ID #875), with **Shreeyash Acharya** as the first author, was accepted through the peer-review process and has been presented at the 18th IOE Graduate Conference, organized at Pulchowk Campus, Lalitpur, Nepal, from May 7 to 9, 2026.

Please note that inclusion of the accepted manuscript in the conference proceedings is contingent upon timely compliance with any further editorial requirements during the publication process.

Prof. Sangeeta Singh
Convener
18th IOE Graduate Conference



Pan No. 301130792

EVEREST ENGINEERING COLLEGE

(Pokhara University Affiliation)

Reg No. 13208/56/057

G.P.O. Box: 13289, Sanepa-2, Lalitpur

Ref. No.

Date: 30 April 2026

To Whom It May Concern

This is to certify that a research paper entitled "Mechanical and Physical Performance Evaluation of Laboratory-Scale LDPE-Sand Composite Modified with Rice Husk, Rice Husk with Ash and Biochar", authored by Shreeyash Acharya, Rishikesh Yadav, Sangina Lamichhane, Dr. Gokarna Bahadur Motra and Khem Raj Shrestha was accepted for oral presentation, based on the abstract submitted for the presentation, at the International Conference on Civil Engineering Innovations and Sustainable Development (CEISD-2026), held on 26 April 2026, organized by Everest Engineering College. The authors made the presentation at the Conference.

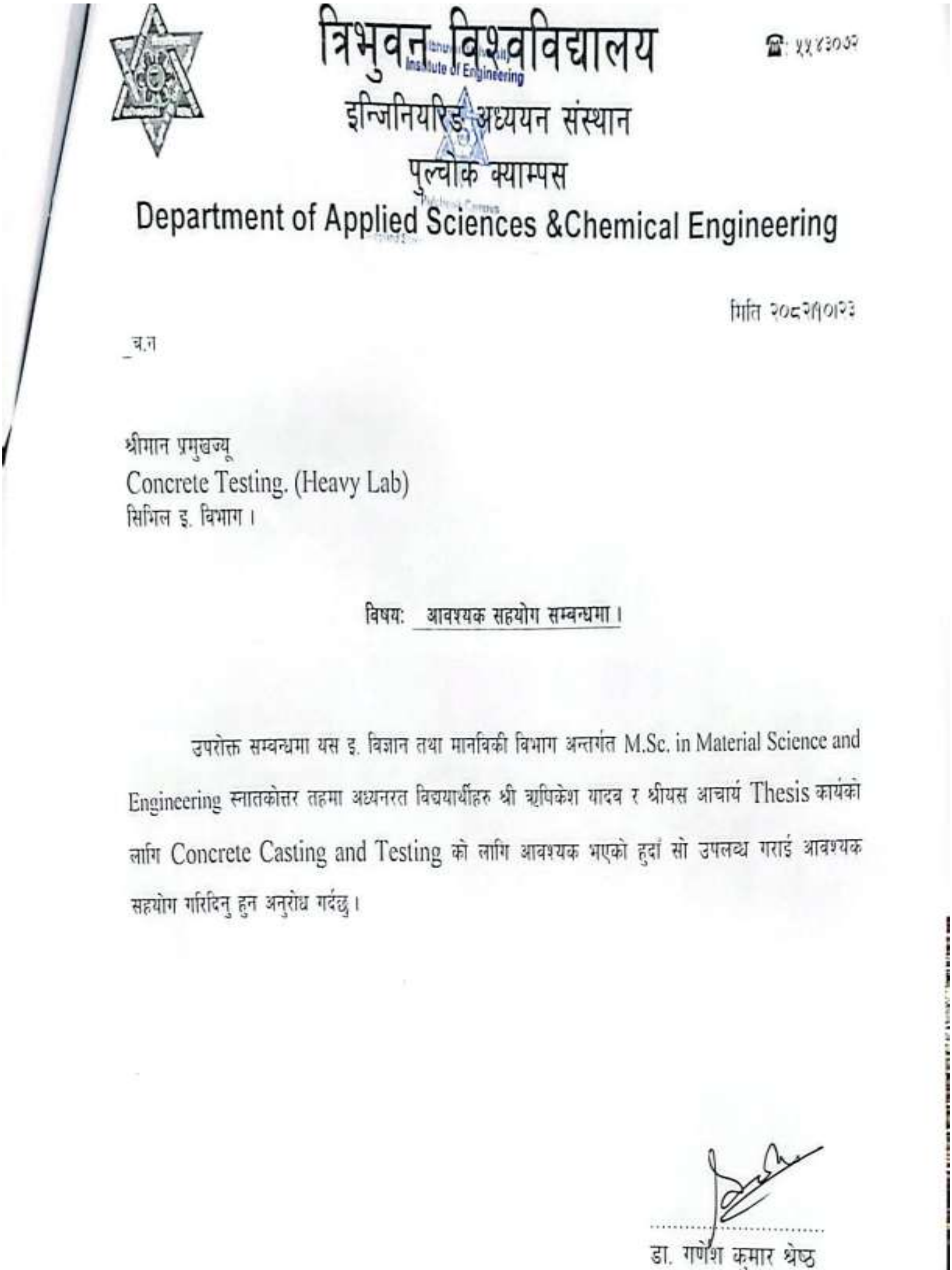
The authors have submitted a full-length paper of the same title for consideration for publication in a double-blind peer-reviewed journal Everest Advances in Science and Technology (EAST), with ISSN 3102-0410 (print) and ISSN 3102-0429 (online). The paper has been sent to the reviewer(s) for review comments. Based on the review comments (accepted with minor corrections) the paper has been accepted for publication. All accepted papers will be published in EAST after plagiarism checking, and uploaded in Nepal Journals Online (NepJol) platform with DOI number.

Thank you.

Sincerely

Prof. Dr. Hari Krishna Shrestha
Principal, Everest Engineering College
Chief Editor, Everest Advances in Science and Technology (EAST)

Phone: 977-15420742 Website: www.eemc.edu.np, Email: admin@eemc.edu.np



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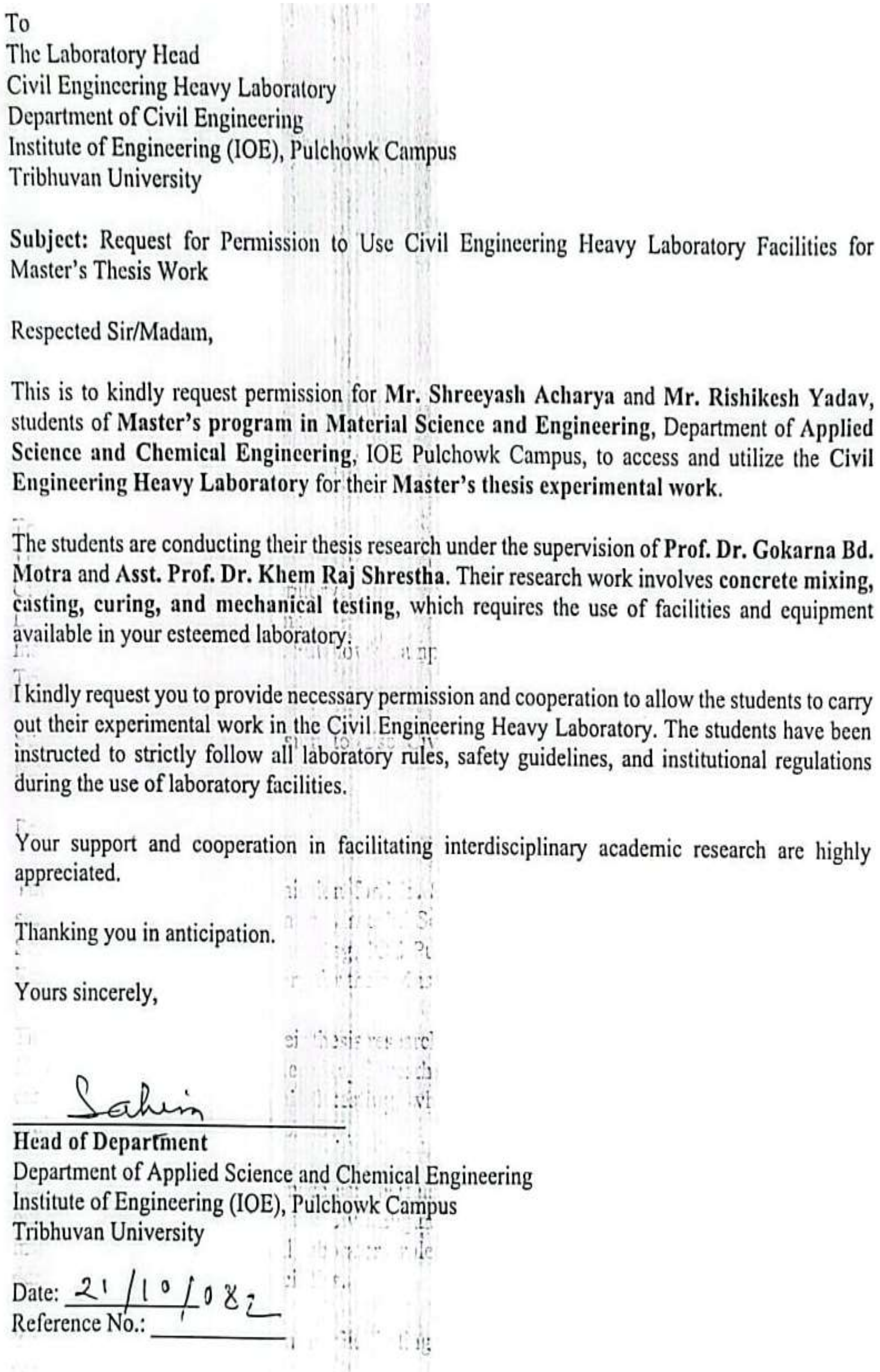
च.न

श्रीमान प्रमुखज्यू
Concrete Testing. (Heavy Lab)
सिभिल इ. विभाग ।

विषय: आवश्यक सहयोग सम्बन्धमा ।

उपरोक्त सम्वन्धमा यस इ. विज्ञान तथा मानविकी विभाग अन्तर्गत M.Sc. in Material Science and Engineering स्नातकोत्तर तहमा अध्यनरत विद्यार्थीहरु श्री ऋषिकेश यादव र श्रीयस आचार्य Thesis कार्यको लागि Concrete Casting and Testing को लागि आवश्यक भएको हुदाँ सो उपलब्ध गराई आवश्यक सहयोग गरिदिनु हुन अनुरोध गर्दछु ।

डा. गणेश कुमार श्रेष्ठ
प्रोग्राम को-अर्डिनेटर



To
The Laboratory Head
Civil Engineering Heavy Laboratory
Department of Civil Engineering
Institute of Engineering (IOE), Pulchowk Campus
Tribhuvan University

Subject: Request for Permission to Use Civil Engineering Heavy Laboratory Facilities for Master's Thesis Work

Respected Sir/Madam,

This is to kindly request permission for **Mr. Shreeyash Acharya** and **Mr. Rishikesh Yadav**, students of **Master's program in Material Science and Engineering**, Department of Applied **Science and Chemical Engineering**, IOE Pulchowk Campus, to access and utilize the **Civil Engineering Heavy Laboratory** for their **Master's thesis experimental work.**

The students are conducting their thesis research under the supervision of **Prof. Dr. Gokarna Bd. Motra** and **Asst. Prof. Dr. Khem Raj Shrestha**. Their research work involves **concrete mixing, casting, curing, and mechanical testing**, which requires the use of facilities and equipment available in your esteemed laboratory.

I kindly request you to provide necessary permission and cooperation to allow the students to carry out their experimental work in the Civil Engineering Heavy Laboratory. The students have been instructed to strictly follow all laboratory rules, safety guidelines, and institutional regulations during the use of laboratory facilities.

Your support and cooperation in facilitating interdisciplinary academic research are highly appreciated.

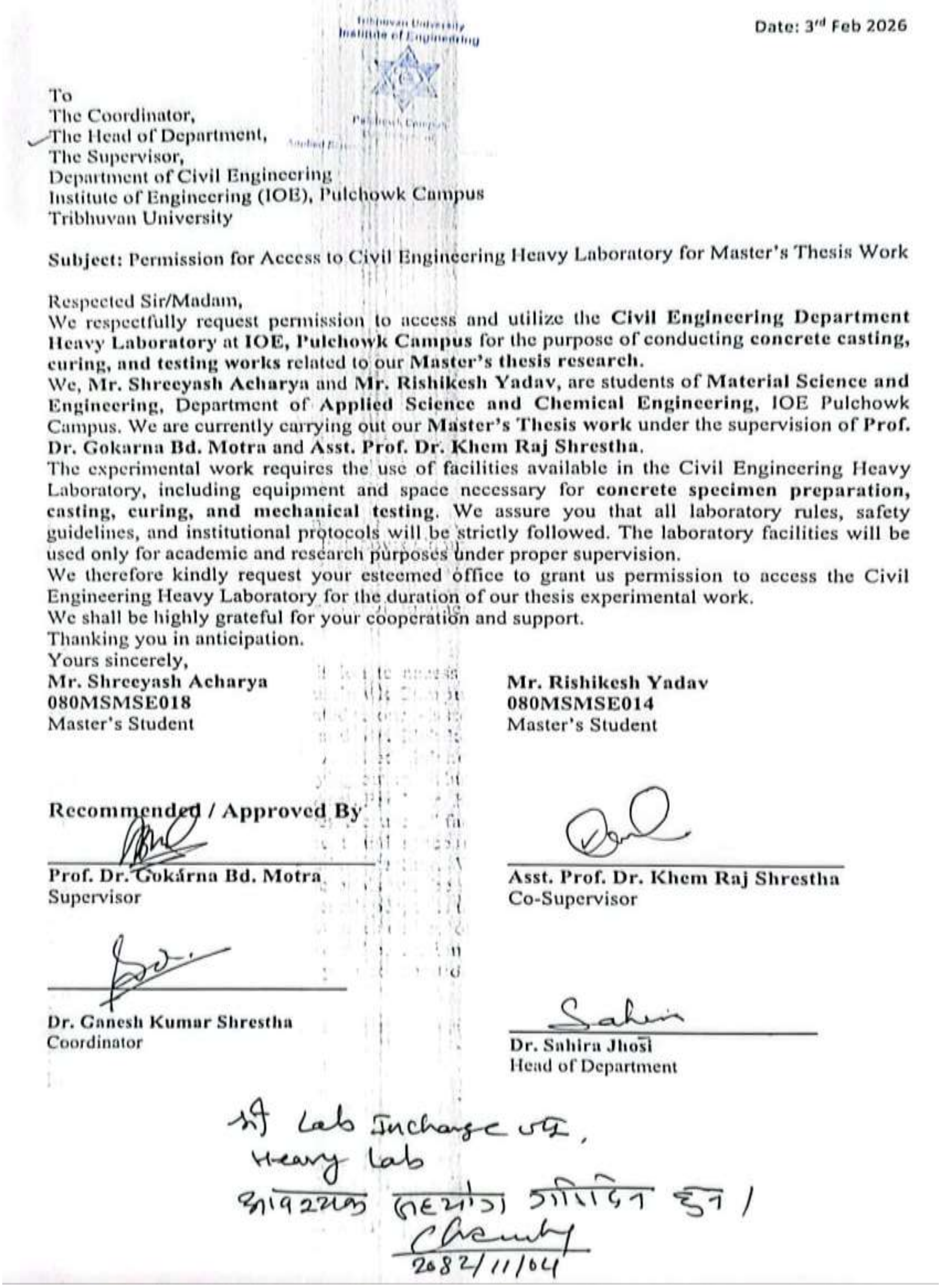
Thanking you in anticipation.

Yours sincerely,

Sahin

Head of Department
Department of Applied Science and Chemical Engineering
Institute of Engineering (IOE), Pulchowk Campus
Tribhuvan University

Date: 21/10/082
Reference No.: ____________



Date: 3rd Feb 2026

To
The Coordinator,
The Head of Department,
The Supervisor,
Department of Civil Engineering
Institute of Engineering (IOE), Pulchowk Campus
Tribhuvan University

Subject: Permission for Access to Civil Engineering Heavy Laboratory for Master's Thesis Work

Respected Sir/Madam,
We respectfully request permission to access and utilize the **Civil Engineering Department Heavy Laboratory** at **IOE, Pulchowk Campus** for the purpose of conducting **concrete casting, curing, and testing works** related to our **Master's thesis research.**
We, **Mr. Shreeyash Acharya** and **Mr. Rishikesh Yadav**, are students of **Material Science and Engineering**, Department of **Applied Science and Chemical Engineering**, IOE Pulchowk Campus. We are currently carrying out our **Master's Thesis work** under the supervision of **Prof. Dr. Gokarna Bd. Motra** and **Asst. Prof. Dr. Khem Raj Shrestha.**
The experimental work requires the use of facilities available in the Civil Engineering Heavy Laboratory, including equipment and space necessary for **concrete specimen preparation, casting, curing, and mechanical testing.** We assure you that all laboratory rules, safety guidelines, and institutional protocols will be strictly followed. The laboratory facilities will be used only for academic and research purposes under proper supervision.
We therefore kindly request your esteemed office to grant us permission to access the Civil Engineering Heavy Laboratory for the duration of our thesis experimental work.
We shall be highly grateful for your cooperation and support.
Thanking you in anticipation.
Yours sincerely,

Mr. Shreeyash Acharya	**Mr. Rishikesh Yadav**
080MSMSE018	**080MSMSE014**
Master's Student	Master's Student

Recommended / Approved By

Prof. Dr. Gokarna Bd. Motra	**Asst. Prof. Dr. Khem Raj Shrestha**
Supervisor	Co-Supervisor
Dr. Ganesh Kumar Shrestha	Sahira
Coordinator	**Dr. Sahira Jhosi**
	Head of Department

श्री Lab Incharge ज्यू,
Heavy lab
आवश्यक ([illegible]) गरिदिनु हुन /
2082/11/04

APPENDIX C: BIBLIOGRAPHY OF CANDIDATES AND SUPERVISORS

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PAPER NAME

Mechanical and Physical Performance Evaluation of Laboratory-Scale LDPE–Sand Composites Modified with Rice Husk, Rice Husk Ash, and Biochar

AUTHOR

Shreeyash Acharya

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