Design and Development of Interlocking Paver Blocks, Employing Plastic Waste

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By

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Declaration

We, Musaffa Shahid, Shayan Khan, Noman Bacha and Ifrah Sarfaraz hereby declare that we have produced the work presented in this thesis, during the scheduled period of study. Where material has been used from other sources, it has been properly referenced. If violation of HEC rules on research has occurred in this thesis, we shall be liable to punishable action under the plagiarism rules of the HEC.

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ABSTRACT

The global challenge in plastic waste pollution has necessitated innovative approaches to reduce plastic accumulation in the environment while concurrently advancing sustainable construction practices. From the research it is known that the incorporation of recycled plastics into paver block formulations not only significantly decreases plastic waste but also enhances the mechanical strength of the blocks. This study explores the development of sustainable plastic based paver blocks as an alternative of conventional paver blocks, with a focus on utilizing recycled low density polyethene (LDPE), high density polyethene (HDPE), the polypropylene (PP) plastics, these plastics wastes shredded into grains will be melted, mixed with preheated sand and the samples are prepared using 25%, 30%, 35%, plastic by weight of sand respectively. Fly ash (FA) along with glass fibers (GF) are incorporated to enhance the mechanical properties. Fly ash is added in different proportions ranging from (25-35)% by weight of plastic, glass fibers is added in proportion starting from(0.4-0.5)% by weight of plastic. Five samples of each combination are prepared. Compressive and durability tests are performed on these samples.

The Life Cycle Assessment (LCA) is performed using Open LCA software in order to analyze the effects of production of these PSPBs on the environment and to perform the comparative analysis of these PSPBs with conventional cement sand pavers. The results from LCA have shown a significant decrease in carbon dioxide emissions as a results of production of different mixes of PSPBs, as compared to those of cement sand pavers. Additionally, the PSPBs have shown impressive increased strength and overall resistance to environmental factors, including water absorption and chemical corrosion.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS (Acronyms)

HDPE: High-Density Polyethylene

LDPE: Low-Density Polyethylene

PVC: Polyvinyl chloride

PW: Plastic waste

LCA: Life Cycle Assessment

PP: Polypropylene

PC: Poly carbonate

GF: Glass Fibers

FA: Fly Ash

PSPBs: Plastic-Sand Paver Blocks

CF: Coconut fibers

LCC: Life-cycle costs

ESI: Environmental Sustainability Index

RCA: Recycled Concrete Aggregate

GWP: Global Warming Potential

CHAPTER 01

INTRODUCTION

CHAPTER I

INTRODUCTION

I.1 Environmental Challenges in Construction

Cement production is considered a major source of carbon dioxide (CO_2)emissions, a longside deforestation and burning of fossil fuels [1].These emissions have fueled ong oing debates about climate change in construction and industry[2].The main cause of global warming is the release of carbon dioxide, which is the largest contributor acco unting for 65% of global warming. Worldwide, the cement industry is responsible for approximately 7% of carbon monoxide emissions into the atmosphere [1].

Fig.1 carbon dioxide emissions

Furthermore, the excessive extraction of raw materials for cement production causes the depletion of non-renewable mineral resources such as limestone. Extracting these mineral resources not only depletes these valuable resources but also inflicts harm upon the green landscapes that serve as habitats for various flora and fauna, posing a risk of ecological imbalance[3].

I.2 Plastic – Its Types, Uses and Environmental Concerns

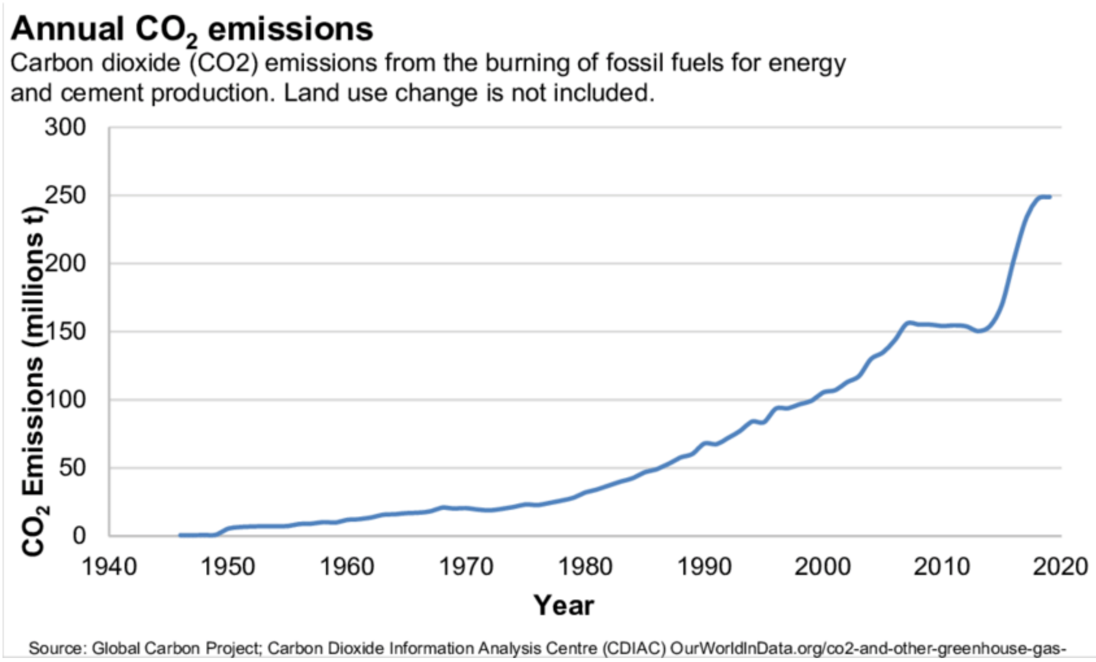

Fig. 1 Pakistan CO2 emission from cement production

Plastics, a major innovation of the 20th century, have gained widespread popularity due to the fitting properties , including low density, high strength to weight ratio, durability, the ease of designing and manufacturing along with the cost effectiveness [4]. Polyolefin such as LDPE, HDPE, and PP are prominent thermoplastics used globally in a wide array of applications, spanning from bags, containers, and toys to pipes (LDPE), industrial wrappings, housewares, and films, as well as automotive parts and electrical components (PP) [5]. However, plastic's non-biodegradable nature results in its persistence in the environment for decades, causing substantial harm. Some commonly known plastics such as polyvinyl chloride (PVC) and many others have the tendency to release harmful compounds in the environment leading to ultimate degradation of environment [4]. The massive accumulation of plastic wastes (PW) is a threat to aquatic lives and sustainability of the environment [6]. Annually, world generates approximately 300 million tons of plastic waste, with an alarming 8 million tons ending up in our oceans[7] .

I.3 Innovations and Application of Paver Blocks

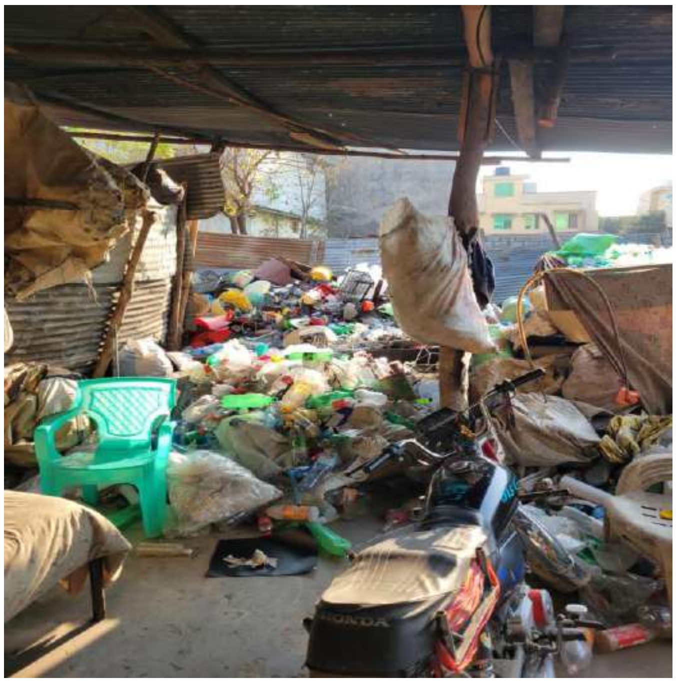

Fig.2 Plastic Waste

The rapid increase in plastic production and its use and waste has impelled the researchers and scientists to seek innovative and sustainable ways to reduce, reuse and recycle PW, mitigating its adverse impact on the environment [8]. The construction industry, as a substantial contributor to the economy, holds promise for the innovative and sustainable employment of PW in construction works, thus significantly reducing heaps of PW ultimately meeting the demands of the construction sector [5]. Previously, plastic waste has found use and implication in the making of construction related materials , such as in the creation of plastic bricks [9], as an aggregate in concrete preparation [10], and as aggregates in asphalt mixtures and construction blocks [11].

The PSPB, composed solely of sand and plastic, represent one solution to the PW problems and reduction of cement consumption in the construction industry [12]. Paver blocks are a common choice for flexible surface treatment application [6, 13]. Among various plastic types, LDPE stands out for its resistance to chemical substances and its versatility in applications. LDPE exhibits excellent binding properties, making it conducive to the formation of durable plastic blocks [14]. Paver blocks made from LDPE or other types of plastic waste offer comfort and durability, making them suitable for pedestrian walkways and areas with low traffic. These blocks are highly adaptable, easy to install, require minimal maintenance, and demand no specialized equipment for installation [6, 13]. Further the joint addition of glass fiber and fly ash can enhance the mechanical properties and durability performance. FA tends to improve the binding properties, therefore the glass fiber reinforced mixes with the additional FA exhibit the increased mechanical strength[15].

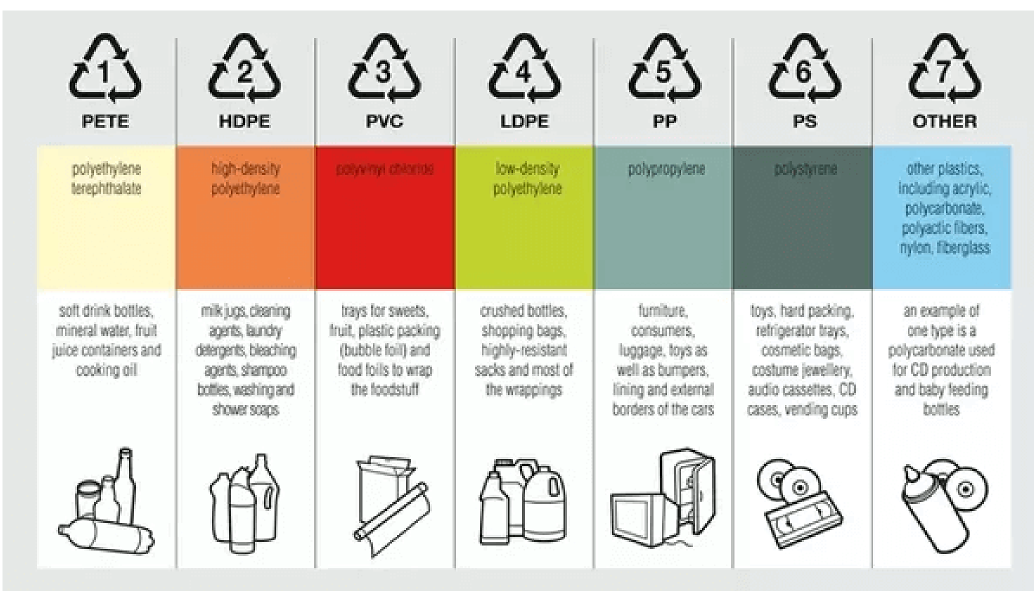

Fig. 3 Different types of plastic waste

I.4 Construction of Pavers and Its Interlocking Design

This study aims at developing and designing different PSPBs for pedestrians and low traffic use; employing different plastics wastes (HDPE, LDPE, and PP) in combination with sand, incorporating GF reinforcement to improve the mechanical properties and FA, the industrial waste as a filler material to ensure the enhanced durability. The optimal interlocking design of these PSPB will eliminate the need of any additional binder requirements making these PSPBs cost effective and sustainable. Performing Life Cycle Analysis (LCA) on PSPBs allows the analysis and evaluation of environmental effects compared to conventional materials, helping in promoting sustainable construction techniques and works. Through comparative analysis and identification of environmental hotspots, LCA informs policy, facilitates continuous improvement, and guides efforts towards reducing the environmental footprint of plastic sand paver block production.

I.5 Paver Block

Paver blocks are sturdy, customizable paving materials made up of concrete, clay, stone, marble, and plastic used to create durable and visually appealing outdoor surfaces like driveways, walkways, and patios.

I.6 The Life Cycle Assessment (LCA) Framework

1. **Evaluation of Environmental Impacts:** LCA provides a comprehensive framework for assessing the environmental impacts associated with the entire life cycle of plastic sand paver blocks, production of the product, its transportation, use and disposal at the end of life. The evaluation allows researchers to quantify the environmental burdens, including overall consumption of energies, release of

greenhouse gases and depletion of resources, linked with the stages of the life cycle of the product.

2. **Comparative Analysis:** Life cycle analysis enables researchers to compare the environmental performance of PSPBs with alternative materials or products, such as conventional cement-based paver blocks. By conducting a comparative analysis, researchers can identify the potential environmental benefits or drawbacks of using plastic sand paver blocks, thereby informing decision-making processes and promoting sustainable choices.

3. **Identifying Hotspots***:* LCA helps identify environmental "hotspots" or areas within the life cycle of plastic sand paver blocks where significant environmental impacts occur. This information allows researchers to target specific stages or processes for improvement, leading to more sustainable product design and manufacturing practices.

4. **Informing Policy and Practice:** The results of LCA provides commendable insights for the governmental policymakers, consumers and stakeholders of construction industry regarding the environmental implications of using plastic sand paver blocks. This information can lead to regulation of standards and incentives to inspire the implementation of sustainable construction materials and practices.

5. **Continuous Improvement***:* LCA facilitates the environmental performance's evaluation of PSPBs through a very systematic approach, allowing for ongoing monitoring and continuous improvement. By periodically reassessing the life cycle impacts and implementing measures to reduce environmental burdens, researchers can enhance the sustainability of plastic sand paver block production over time.

Overall, performing LCA on plastic sand paver blocks plays a pivotal role in advancing research efforts towards developing sustainable construction materials by providing a holistic understanding of their environmental implications and guiding efforts towards minimizing their environmental footprint.

I.7 Objectives

- To develop the different PSPBs by utilizing plastic waste(HDPE and HDPE) and incorporating FA and GF.
- To perform mechanical and durability tests.
- To determine the optimal shape and interlocking design for PSPBs
- To perform life cycle assessment.

I.8 Significance

- This research has the potential to drastically alter current building methods by introducing a super quick method of producing paver blocks. Gaining full strength in just one day can cut down construction timelines and expenses considerably.
- The study addresses the critical issue of waste management by repurposing both plastic and fly ash waste into a valuable construction material. This contributes to waste reduction, alleviates environmental concerns, and promotes recycling.
- Conducting research on innovative construction practices can raise awareness among the public and construction industry professionals about the benefits of recycling and reusing waste materials.
- Conducting the comparative analysis through LCA, the study demonstrates the environmental advantages of plastic-based paver blocks over traditional concrete counterparts, while also highlighting the need for further research and development to address technical, economic, and regulatory barriers.

CHAPTER 02

LITERATURE REVIEW

CHAPTER II

LITERATURE REVIEW

II.1 Utilizing Waste Plastic in Construction Industry

Salman Ahmed [18]: Paver blocks, crucial for pavement applications in construction, were manufactured using LDPE plastic waste as a complete replacement of cement in paver blocks . The authors conducted experimental analyses to assess the impact of varying proportions of coconut fiber on the physical and mechanical characteristics of the paver blocks. Parameters such as compressive strength, flexural strength, and water absorption were examined to evaluate the composite material's performance. LDPE waste was melted in the open air and mixed with sand of different particle sizes in various proportions, with percentages of coconut fibers (CF) added. Specimens were tested for compression strength, water absorption, and density. No additional water was added, and the pavers were ready after 24 hours, proving suitable for waterlogged areas. The experiments were conducted in three phases: the first phase varied the LDPE to sand ratio, the second phase incorporated coconut fibers in proportions from 1 to 5% by weight of the total mix, and the third phase focused on varying sand grain sizes using the CF proportion that yielded the best results. Results showed that adding 3% CF along with the finest sand grains in a 30:70 LDPE to sand ratio improved compressive strength by 18.4% and reduced water absorption by 54.1%. Incorporating LDPE waste up to 30% with 3% CF provided optimal results, beyond which there was a decline in paver block properties. The LDPE to sand ratio of 30:70% yielded the best results with a compressive strength of 19.62 MPa, 72-hour water absorption of 2.16%, and a density of 1.45 g/cm3. The study suggests that adding coconut fiber positively impacts the properties of LDPE plastic-sand paver blocks, enhancing both mechanical strength and environmental sustainability. It offers insights into using natural fibers in composite materials, providing a sustainable alternative to conventional construction materials. The research holds implications for the construction industry, presenting a potential solution to improve paver block performance while addressing environmental concerns associated with traditional materials. These findings contribute to sustainable engineering efforts and the development of eco-friendly construction practices.[18].

Bawar Iftikhar [19]: The authors investigated the development of eco-friendly plastic-sand paver blocks by incorporating plastic waste and basalt fibers. LDPE waste was used to create cement-free PSPBs. Eco-friendly basalt fibers (BF) were added to meet the ASTM C902-15 standard of 20 N/mm² for light traffic. LDPE plastic waste was melted outdoors and combined with sand to form the paver blocks. Variations were made in the LDPE-to-sand ratio, basalt fiber proportion, and sand grain sizes. Key mechanical and environmental parameters, including compressive strength, flexural strength, water absorption, and abrasion resistance, were thoroughly examined to evaluate the composite material's performance. Adding 0.5% of 4 mm-long BF resulted in a 20.5% increase in compressive strength and a nearly 50.5% decrease in water absorption. Optimal results were achieved with a 30:70 LDPE to sand ratio, with finer sand contributing to the highest compressive strength. Temperature effects were assessed from 0 to 60°C, revealing only a 20% decrease in compressive strength at 60°C for basalt fiber-incorporated plastic paver blocks. The inclusion of plastic waste and basalt fibers positively impacted the paver blocks' mechanical properties, enhancing compressive and flexural strengths and suggesting improved durability and structural integrity. The use of basalt fibers reinforced the composite material and promoted environmentally conscious practices by replacing traditional synthetic materials with natural reinforcements.

Gill, Y.Q and Ubaid [20]: The unregulated disposal of non-biodegradable plastic waste, encompassing items like beverage containers, bags, cups, and plates, significantly contributes to environmental deterioration. Misuse of plastic products as luxury items exacerbates this problem. Conventional plastic waste disposal methods, such as incineration and dumping, are globally unpopular due to their inherent environmental hazards. An alternative and preferable approach involves utilizing plastic waste in constructing durable and flexible pavements using plastic-modified bitumen. This method not only helps manage a significant amount of plastic waste but also yields longer-lasting, eco-friendly roads compared to standard bitumen roads. Various tests confirm the cost-effectiveness and durability of these "green roads," highlighting properties such as improved water resistance, higher flash point, and elevated softening point. This study explores the efficient integration of plastic waste into the construction of environmentally sustainable roads, commonly known as "green roads." It investigates the incorporation of plastic waste alongside traditional construction materials to enhance the environmental performance of road infrastructure while addressing the escalating global plastic waste issue. By examining various construction techniques, material ratios, and types of plastic waste suitable for road construction, the research aims to optimize the use of plastic in road infrastructure. It emphasizes environmental benefits, including potential reductions in traditional material demand and the carbon footprint associated with road construction. The study also evaluates overall sustainability impacts, considering factors such as durability, longevity, and performance of roads constructed with plastic-infused materials. By addressing challenges and opportunities, the research provides valuable insights into the technical aspects and potential benefits of incorporating plastic waste into road construction practices, with the goal of promoting greener and more sustainable infrastructure development.

Pratiksha Singh Rajput, R.K.Y [21]: Utilizing plastic waste in bituminous mixes has demonstrated significant enhancements in mix properties and has offered a solution to the disposal of large amounts of plastic waste. The present study explores the feasibility and effectiveness of incorporating plastic waste into bituminous mixes for road paving. The plastic waste underwent cleaning, shredding, and size reduction to pass through a 2.36mm sieve. The resulting aggregate was heated to ensure effective coating with plastic. The plastic-coated aggregates were then thoroughly mixed with hot bitumen to create the job mix. The shredded plastic waste was combined with the hot aggregate, and the plastic-modified mix was prepared with varying proportions of 6%, 8%, 10%, 12%, and 14% plastic by weight of bitumen. Key properties such as Marshall stability flow, density, and indirect tensile strength were systematically evaluated. The study found that the Marshall Stability value was highest when 12% plastic was added to the mix. Adding plastic waste to bituminous mixes has significantly improved the engineering properties of the resulting asphalt. The modified mixes exhibited enhanced stability, reduced rutting potential, and increased resistance to fatigue and thermal cracking. Additionally, the study highlights the environmental benefits of incorporating plastic waste into road construction. By diverting plastic waste from landfills and utilizing it in road infrastructure, the study advocates for a sustainable and eco-friendly approach to waste management.

Senthil Kumar [22]: Electronic plastic (E-plastic) waste has become a significant global environmental concern due to the rapid proliferation of electronic devices and the subsequent increase in discarded electronic components. Urgency is emphasized for adopting sustainable practices to repurpose E-plastic waste. This study presents an experimental investigation on structural concrete with partial replacement of coarse aggregate using electronic plastic waste (E-plastic). To utilize non-degradable waste in the construction industry, E-plastic from computer plastics was considered as coarse aggregate. Different percentages (10, 20, 30, 40, and 50%) of E-plastic by volume replaced coarse aggregate. Tests were conducted for properties of fresh and hardened concrete at different ages, such as 7 and 28 days. It was observed that the workability of the mix decreased with an increase in the percentage of E-plastic. Compressive strength, split tensile strength, and flexural strength of partially replaced concrete were lower compared to control concrete. The addition of E-plastic reduced the dry density of the concrete and exhibited high deformability behavior before failure. The lower dry density may offer advantages in reducing self-weight in structural applications. This study explores the current understanding of recycling E-plastic waste as a construction material, particularly focusing on its suitability in developing countries. The aim is to assess existing methodologies, challenges, and potential benefits associated with integrating recycled E-plastic waste into construction materials.

Alexander Kumi-Larbi Jnr [14]: In many developing nations, the disposal of low-density polyethylene (LDPE) items such as sheets, bags, and water sachets presents a significant waste challenge due to the lack of local collection and recycling systems. As a result, LDPE often ends up being discarded without value, leading to aesthetic, environmental, and public health issues. This study investigates the recycling of waste plastics in developing countries, focusing specifically on using low-density polyethylene water sachets to create plastic-bonded sand blocks. The research addresses the prevalent problem of plastic waste in regions with limited waste management infrastructure. By adopting a sustainable approach, the study explores the conversion of LDPE water sachets into a construction material known as plastic-bonded sand blocks. The LDPE water sachets are melted and mixed with sand to produce these blocks, which are then tested for particle size density, mechanical properties such as compressive strength and water absorption, as well as flexural strength and thermal conductivity. The results indicate that under optimal conditions, these blocks can exhibit strengths of up to 27MPa, particularly with decreased sand particle size. The study discusses the potential of this simple technology and the materials it generates to revolutionize LDPE plastic waste management in developing countries.

K. Gowtham [23]: Utilizing plastic waste (PW) recycling emerges as a viable strategy to mitigate environmental impacts, aligning with global pollution control efforts. This study introduces an innovative approach by incorporating various PW types as a substitute for cement, aiming to create cement-less paver blocks. The paver block composition blends different PW types in varying proportions with natural fine aggregate. PW replaces cement at proportions of 40%, 50%, 60%, and 70%, and its impact on achieving satisfactory physical and mechanical properties, particularly under temperature variations, is examined. Results indicate that compressive strength increases with higher plastic content, but exposure to very high temperatures reduces strength by 31.17%. However, the plastic paver block shows low water absorption potential. The binder exhibits an average initial and final setting time of 19 and 24 minutes, respectively. Abrasion tests reveal minimal surface wear, indicating high durability with a maximum wear of 2.56%. A trial footpath pavement constructed using cement-less paver blocks is evaluated for performance, with each block consuming 1.8 kg of PW. Economic assessment shows that the average unit cost of cement-less blocks is 35.39% lower than concrete paver blocks, resulting in a cost benefit ranging from 29.39% to 32.15% when PW is used. To evaluate sustainability, an "Environmental Suitability Index" (ESI) is developed based on embodied energy; life-cycle costs (LCC), and re-usability, supplemented by three additional parameters—fire resistance, social impact, and labor efficiency. These collectively contribute to a comprehensive evaluation of the environmental sustainability of the proposed cement-less paver blocks.

Babar Ali [15]: The authors were motivated by the high environmental impacts and low tensile strengths of plain cement concrete to explore the use of recycled materials and fiber reinforcement. In their innovative research, they proposed a method to improve the mechanical properties and durability performance of Recycled Concrete Aggregate (RCA) by incorporating glass fibers (GF) and fly ash (FA). This approach aimed to enhance the durability, ductility, and sustainability of concrete. They prepared various samples with different proportions of RCA and tested them for flexural, split tensile, and compressive strengths, as well as water absorption. GF and FA were added at volumes of 0.5% and 20%, respectively, replacing ordinary Portland cement. The study concluded that the addition of FA and GF improved both the mechanical properties and durability of RCA, providing increased resistance to acid attacks.

Karma Tempa [24]: The paper explores the consumption of waste plastic as a binding material for production paver blocks, aiming to provide a sustainable and economically viable substitute conventional cement-sand pavers. It highlights the urgency for sustainable construction materials due to environmental concerns related to cement production and plastic waste accumulation. Through laboratory experiments and sustainability assessments, the study evaluates the mechanical properties, durability, and environmental impacts of plastic-sand pavers, compared to cement-sand paver blocks. The researchers focus on factors such as energy consumption, carbon dioxide emissions and overall waste demonstrate the potential environmental benefits of utilizing plastic waste in paver block production. Moreover, the paper discusses existing research on incorporating plastic waste into construction materials, showcasing the versatility and potential of plastic waste as a sustainable additive or binder. It emphasizes the importance of innovative approaches in addressing environmental challenges and promoting sustainability in the construction sector. The study contributes valuable insights to the discourse on sustainable construction practices, highlighting the feasibility and environmental implications of plastic-based alternatives for paver block production. It calls for further research and development to scale up and optimize these solutions for widespread adoption in the construction industry.

Oscar Ortiz [16]: This study offers critical insights into advancing sustainability practices within the construction sector. Highlighting the pressing need for environmentally conscious approaches due to the industry's significant environmental impact, the paper emphasizes the adoption of LCA as a fundamental tool for evaluating and enhancing sustainability in construction works. Significant findings include the growing incorporation of LCA into building design and decision-making processes, aiding in the identification of environmentally preferable materials and methods. Moreover, the study emphasizes the importance of data accuracy and transparency in LCA analyses, alongside emerging trends such as evaluating embodied carbon and integrating principles of circular economy. It underscores LCA's essential role in promoting sustainability within construction, advocating for interdisciplinary cooperation and ongoing innovation to effectively address intricate sustainability challenges. This summary encapsulates the paper's significant contributions to advancing sustainable practices and driving positive environmental outcomes in construction.

CHAPTER 03

METHODOLOGY

CHAPTER III

METHEDOLOGY

This chapter is dedicated to elaborating the methodologies employed for material selection and testing to achieve the desired anticipated outcomes. It encompasses various studies including the utilization of diverse materials, experimentation with different proportions within a mix, the meticulous preparation of test samples, determination of sample numbers per proportion, and the detailed procedures encompassing sample preparation and testing protocols.

Materials in major that were used for preparing samples of plastic sand paver blocks for testing were following:

- Low Density Polyethylene (LDPE)
- High Density Polyethylene (HDPE)
- Sand
- Fly Ash
- Glass fibers

III.1 Sample Enumeration:

Several samples of plastic paver blocks were prepared making the use of specific Plastic-sand proportion with varying sand grain sizes. Based on the sand particle sizes, 3 ranges of grain sizes were selected against a single mix proportion. These 3 ranges of grain sizes are:

- Grain size < Sieve #40 (0.42 mm)
- Sieve#60 < Grain size < Sieve#40
- Sieve#200 < Grain size < Sieve#60

Fig. 4 Sieving of Sand

III.2 Material Used

III.2.1 LDPE

Low-Density Polyethylene (LDPE) is a thermoplastic polymer with a relatively high degree of flexibility. It has density in the range of from 0.910–0.940 g/cm3 with highly inflammable property. Its various applications are packaging materials, plastic bags, and containers etc. LDPE is typically characterized by its softness, transparency, and ability to withstand impact, making it suitable for products that require a certain level of flexibility and durability. The plastic bags were used for the testing purposes which were collected and were shredded in plastic manufacturing facility.

III.2.2 HDPE

High-Density Polyethylene (HDPE), on the other hand, is a thermoplastic polymer having good chemical resistance and high strength-to density ratio. It is widely used in industries such as construction, agriculture, and packaging. HDPE exhibits properties such as rigidity, toughness, and good impact strength, making it ideal for applications such as pipes, bottles, and geo membranes.

III.2.3 Glass Fibers

Glass fibers are synthetic fibers made from glass materials, commonly used as reinforcements in composite materials to enhance their strength and durability. Glass fibers are known for their high tensile strength and resistance to heat and corrosion. They are extensively used in industries like automotive, aerospace, and construction for applications such as structural components, insulation, and reinforcement in composite materials.

III.2.4 Fly Ash

Fly ash is a residual material from coal combustion in power plants. It is commonly used as a supplementary cementitious material in concrete production due to its pozzolanic properties. Fly ash enhances the strength and durability of concrete while also contributing to environmental sustainability by reducing the need for cement, thus lowering carbon emissions associated with concrete production.

Additionally, the use of fly ash in plastics promotes sustainability by recycling waste material and reducing the environmental impact associated with disposal.

Fig.5 a) Fly Ash b) HDPE c) LDPE d) Glass Fibers e) Sand

III.3 Experimental Procedure

The process of preparing samples involved blending LDPE and sand after melting them in a controlled environment. Initially, samples were created using a specific ratio of plastic to sand, incorporating different sizes of sand grains. Subsequently, in the second stage, the sand grain size that provided maximum strength was utilized in varying proportions with the plastic. Throughout these sample preparation pr0cesses, the precise amounts of plastics and sands were placed in separate containers. The plastic was then heated outdoors to a temperature range of 120-150°C to achieve the desired consistency and uniformity of the mixture. The preheated sand will be added to the molten plastics followed by the incorporation of GF and FA, the specimen will then be thoroughly mixed to get uniform and homogenous mixture. This mix will then be molded in the cubic molds of (150mm*150mm*150mm) and the molds prepared. Heating the molds to about 100 degrees of centigrade, facilitated easy placement and compaction of the sand-plastic mixture, preventing the plastic from losing its plasticity prematurely. Additionally, the heated molds were lubricated with a suitable lubricating oil to aid in the easy demolding of the samples. Once lubricated, the homogeneous mixture of sand and plastic was carefully transferred into the molds where it was left at room temperature for 24 hours to cool and set properly.

After 24 hours of molding, 3 samples of each mix were tested to get the average value. This process was repeated every time the samples would have to be made, whether for the purpose of finding a proper sand size to be used or for finding proper plastic sand ratio throughout the progress of the project. The stepwise process of preparing samples is given below:

1) In this step samples of plastic and sand of required grain sizes were collected in pan and weighed so that desired proportions could be achieved.
2) In this step LDPE and HDPE was heated to a desired heat to gain a consistent plastic.

Fig. 6 Melting of Plastic

3) In this step sand, fly ash and glass fibers was added to plastic when it was heated to make it consistent.

4) In this step the molds were preheated for compaction and placement of the plastic in molds.

Fig. 7 Preheating of molds

5) Homogenous mix of sand-plastic was put in molds, and then it was compacted.

6) After molding samples were placed at room temperature for about 24 hours.

Fig.14 Molds placement at room temperature

7) Cooled samples were tested for compression strength using loading rate of 0.3MPa/sec, and/or finding the water absorption.

Fig. 15 Compressive strength Test

III.4 Tests

III.4.1 Compressive Strength Test

III.4.1.1 Non-Destructive Testing

III.4.1.1.1 Rebound Hammer Test

The apparatus used for this test is called is called rebound hammer or also called Schmidt hammer. It is a quick and non-destructive method of finding the compressive strength of the specimen. The test will be performed according to ASTM C805.

Fig. 16 Rebound Hammer Test

III.4.1.1.2 Ultrasonic Pulse Velocity

This test is used to access the quality and integrity of the specimen. Testing procedure of ASTM C597 will be followed. Testing will be done on both concrete and mortar specimen.

Fig. 17 Ultrasonic Pulse Velocity Test

III.4.1.2 Destructive Testing

III.4.1.2.1 Compressive Strength

The Compression testing machine will be used for the testing the compressive strength of the specimen according to ASTM C109.

III.4.2 Durability Tests

III.4.2.1 Water Absorption Test

This test measures the moisture absorbed by the PSPB when submerged under the water for approximately 24 hours. This test directly indicates the durability of the sample and shows the water tightness of the mortar specimen. Testing procedure of ASTM D570 will be followed.

III.5 Life Cycle Assessment Using Open LCA

The Life Cycle Assessment (LCA) conducted in this study aimed to evaluate the environmental impact, particularly carbon emissions, associated with the production, use, and disposal of one cubic meter of plastic sand paver blocks. The assessment was performed using Open LCA software, following a systematic approach to ensure robustness and accuracy in the results.

III.5.1 Scope Definition

The scope of the LCA encompassed all pertinent life cycle stages ranging from raw material extraction and production to transportation, utilization, and end-of-life disposal or recycling. The functional unit chosen for comparison was one cubic meter of plastic sand paver blocks, providing a standardized basis for assessment.

III.5.2 Inventory Analysis

Data collection involved gathering information on inputs (e.g., LDPE, sand, energy, water) and outputs (e.g., emissions to air, water, soil, waste generation) across the entire life cycle of the paver blocks. This included detailed data on quantities of material, energy usage, transportation distances, and emissions factors.

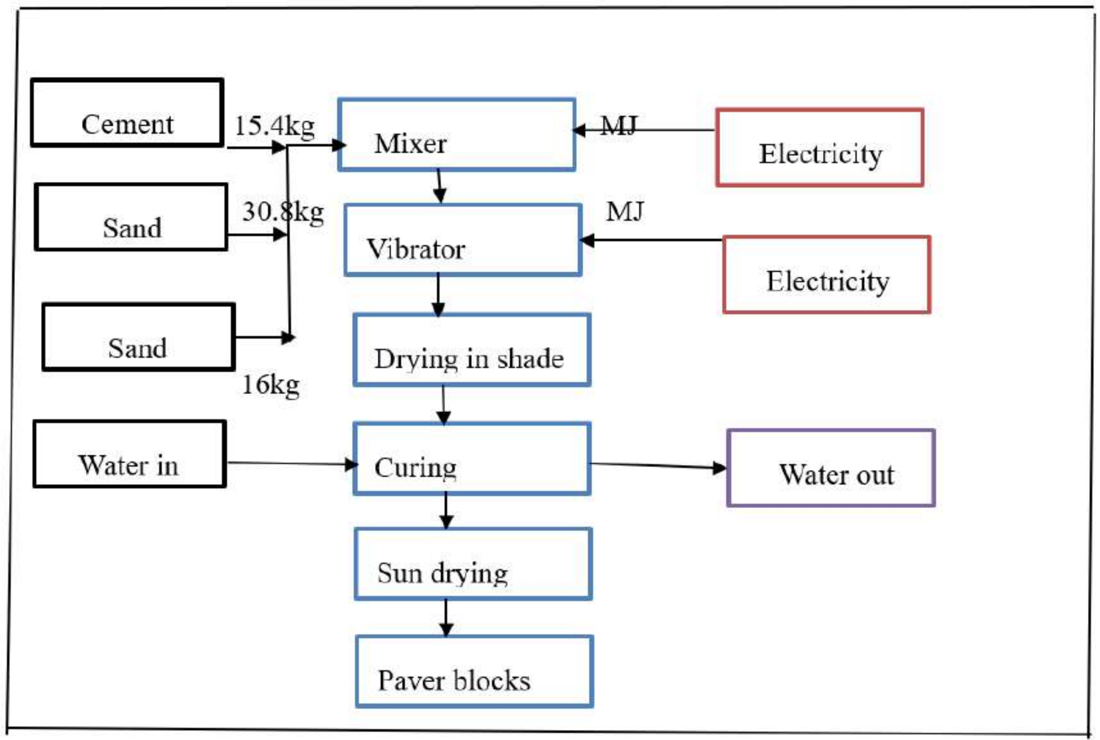

Fig. 18 System boundary for manufacturing of cement-sand pavers

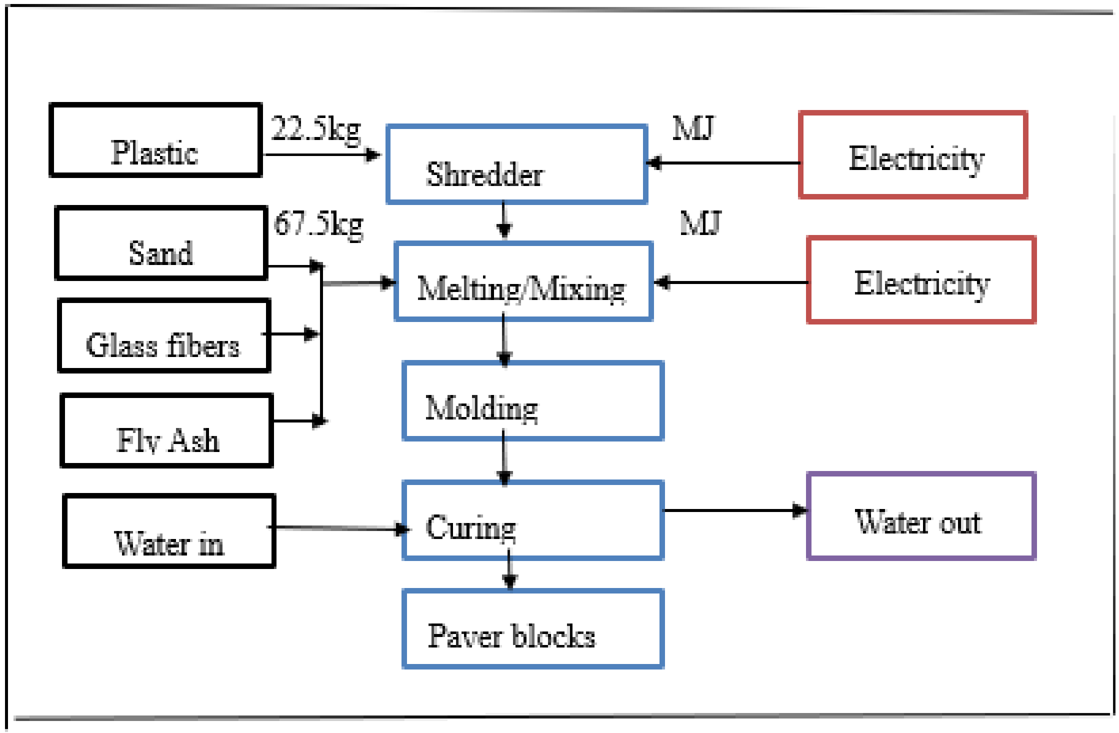

Fig. 19 System boundary for manufacturing PSPBs with GF and FA

III.5.3 Impact Assessment

Using Open LCA, impact assessment methods were applied to quantify environmental impacts, with a specific focus on global warming potential (GWP) and carbon footprint. Emissions of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) etc. were calculated and analyzed.

III.5.4 Interpretation

This process allows one to interpret the results and to estimate the uncertainties.

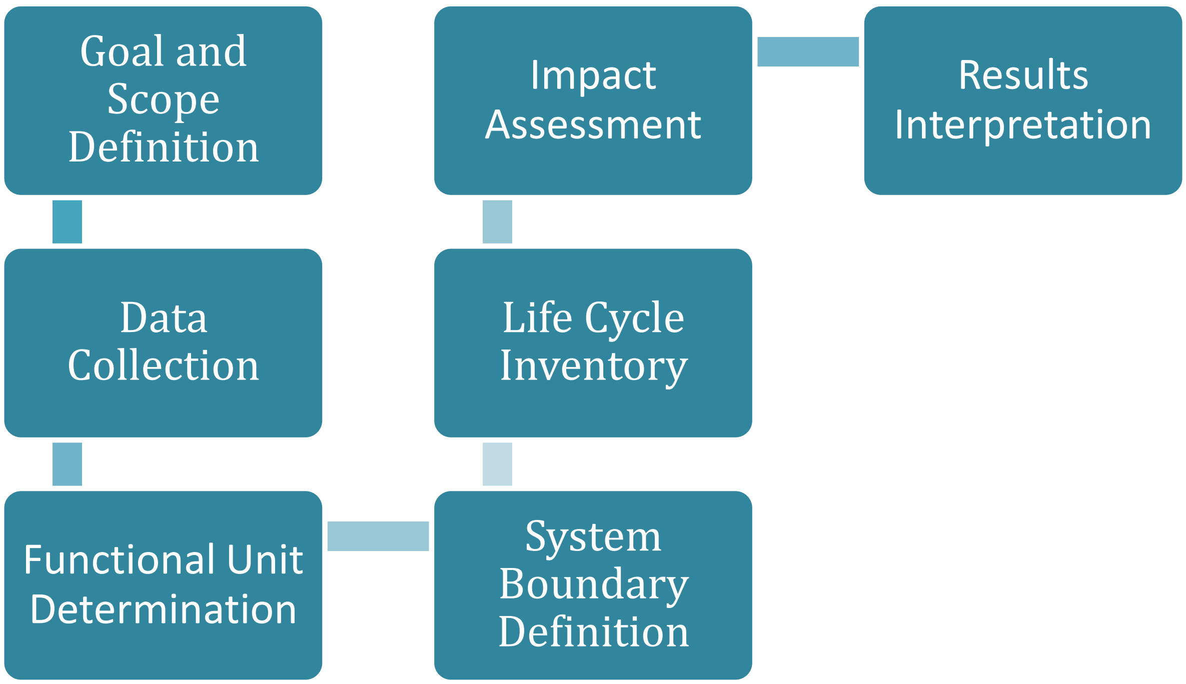

Fig. 20 flow diagram of LCA methodology

CHAPTER 04

RESULTS

CHAPTER IV

RESULTS

The research involved a comprehensive collection of data derived from the various tests conducted on different types of samples. Utilizing statistical tools such as MS Excel, the gathered data underwent meticulous analysis. Visual representations in the form of graphs were employed to enhance the interpretation of results, facilitating a deeper understanding of the observed trends and relationships among different variables.

First the Compressive strength test was performed on varying proportions of plastic, sand, GF and FA to obtain the strength of the prepared samples. Some samples were also made for performing the Rebound Hammer Test and Ultrasonic Pulse Velocity Test to find the compressive strength and also to check the quality of the samples.

IV.1 Compressive Strength Results

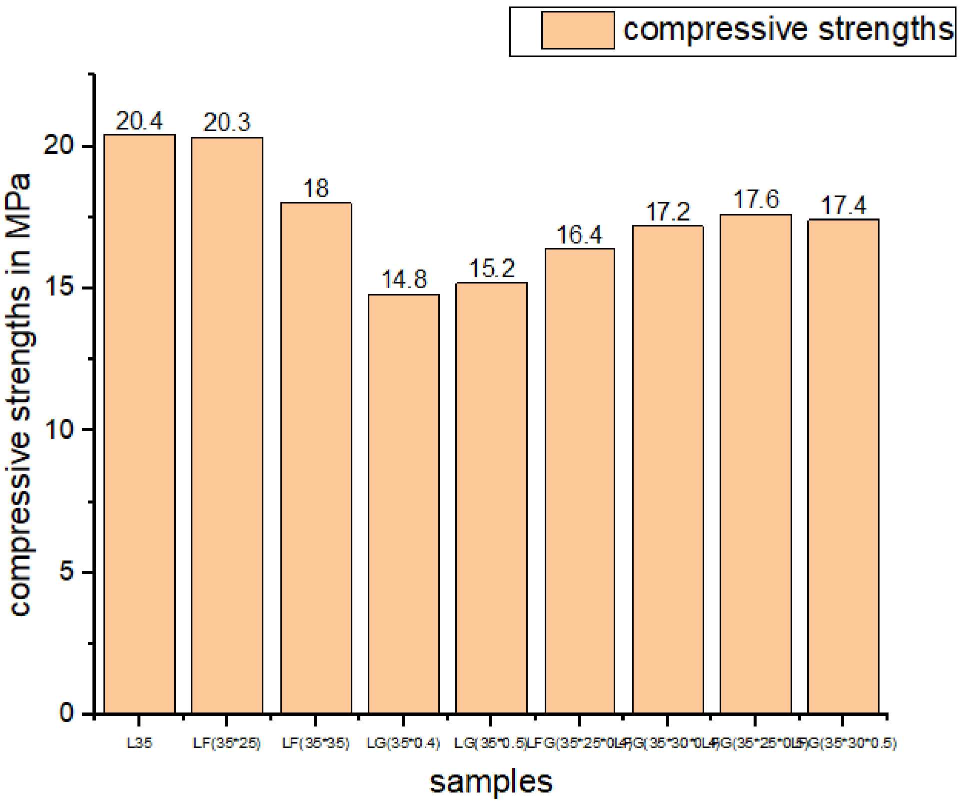

Fig. 21 compressive strength results

IV.1.1 Compressive Strength Of Varying Plastic-Sand Ratios

Different Plastic-sand ration was chosen and the sizes of sand and the proportions of GF and FA were varied to determine the proportion which would give higher strength.

IV.2 Rebound Hammer Results

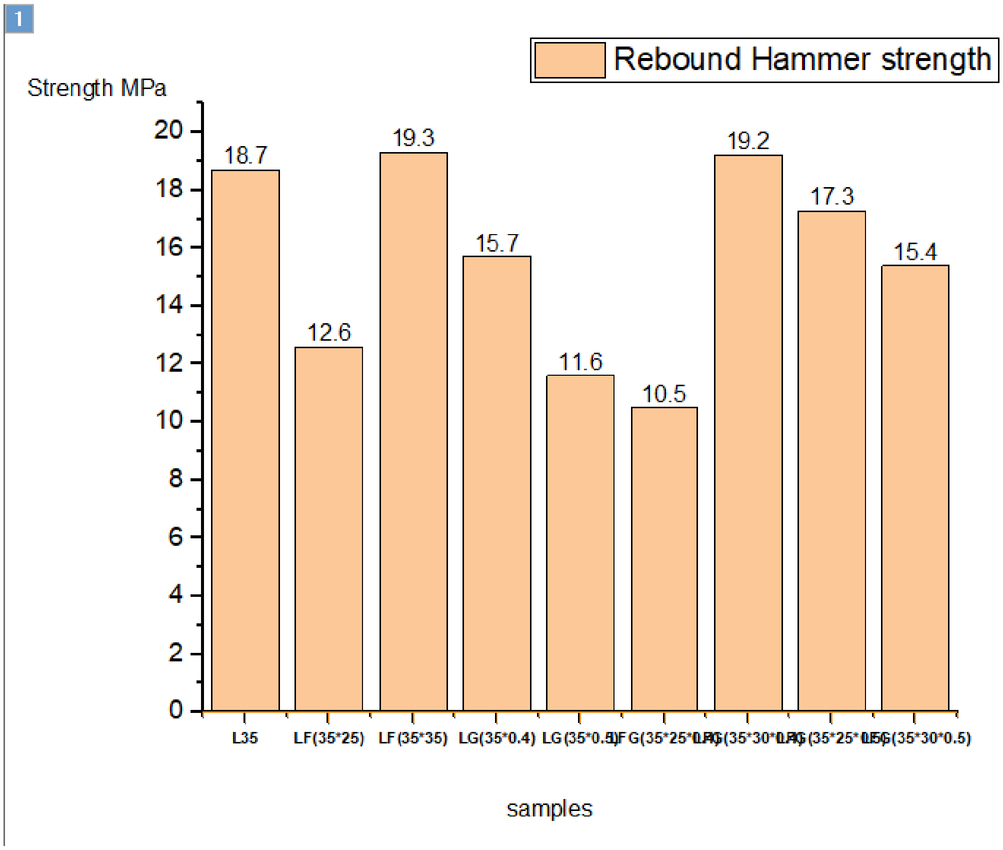

Fig. 22 compressive strength results

IV.3 LCA Results

Table 1 life cycle impact assessment of different type of plastic waste

Sr.No	Impact categories	Unit	C30	H25	H30	H35	L25	L30	L35
1	climate change	kg CO2-Eq	619.5	585.221	571.1	557.07	581.5	566	551
2	fossil depletion	kg oil-Eq	63.17641	103.852	101.4	99.073	103.2	101	97.9
3	freshwater ecotoxicity	kg 1,4-DCB-Eq	0.47478	1.91735	1.874	1.8268	1.905	1.86	1.81
4	human toxicity	kg 1,4-DCB-Eq	85.93554	197.293	192.6	187.4	196	191	186
5	marine ecotoxicity	kg 1,4-DCB-Eq	0.78816	1.77784	1.736	1.6887	1.766	1.72	1.67
6	terrestrial acidification	kg SO2-Eq	1.70274	2.52881	2.464	2.3945	2.513	2.44	2.37
7	urban land occupation	m2a	8.08503	6.30702	6.117	5.9283	6.272	6.07	5.87

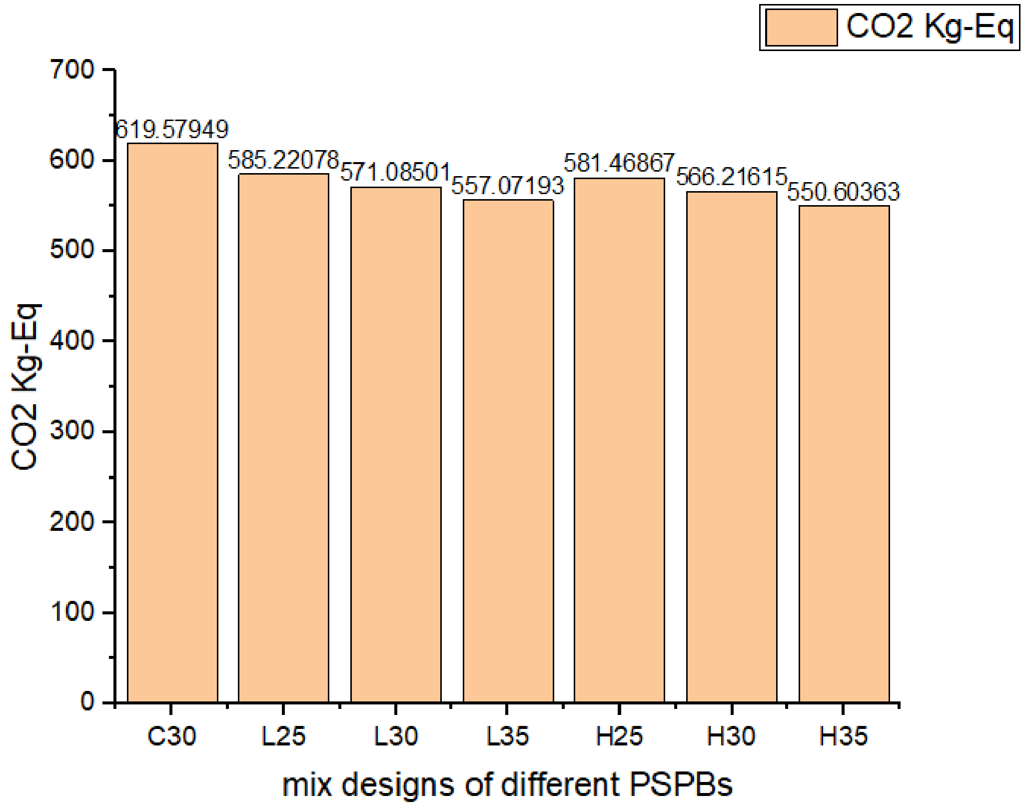

Fig. 23 comparisons of C02 emissions

IV.4 CONCLUSION AND FUTURE WORK

- From the results of LCA it can be seen that manufacturing of PSPBs results in less Carbon dioxide Kg-Eq emissions as compared as Cement-sand pavers.
- PSPBs having 35% of plastic gives highest strength.
- Addition of glass fibers has increased overall strength of PSPBs.

IV.5 Summary

This study focuses on developing sustainable plastic-based paver blocks (PSPBs) as an alternative to conventional cement sand pavers, aiming to reduce plastic waste while improving mechanical strength. Recycled LDPE, HDPE, and PP plastics are shredded and mixed with preheated sand in varying proportions (25-35% by weight). Fly ash and glass fibers are added to enhance mechanical properties. Compressive and durability tests are conducted on samples, showing increased strength and resistance to environmental factors. Life Cycle Assessment (LCA) using Open LCA software reveals significant reductions in carbon dioxide emissions compared to cement sand pavers. PSPBs offer promising solutions for plastic waste reduction and sustainable construction practices.

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