Experimental Investigation of Physical and Mechanical Properties of Plastic Tuff Pavers

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DEPARTMENT OF CIVIL ENGINEERING

NFC INSTITUTE OF ENGINEERING AND FERTILIZER RESEARCH
FAISALABAD

Experimental Investigation of Physical and Mechanical Properties of Plastic tuff pavers

The entire project has been put together by the students of Civil Engineering of session 2019-2023 who have been designated the given project by civil engineering department in order to fulfill the requirements of

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In

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We certify project titled

“Experimental Investigation of Physical and Mechanical Properties of Plastic tuff pavers”

We proclaim that this project titled as “Experimental Investigation of Physical and Mechanical Properties of Plastic tuff pavers” is our own work. Use of the work of others has been properly acknowledged by reference list

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ABSTRACT

Plastic waste and cement production are the major environmental concerns around the globe. Plastic waste creates a significant environmental problem due to its non-biodegradable nature and vast quantities. The cement industry is responsible for 8% of global CO_2 emissions. These challenges can be addressed by replacing cement with plastic in the construction industry. The use of waste plastic can reduce waste management costs and make the construction industry more sustainable. Pavers are commonly used construction materials for outdoor surfaces, and this research investigates the feasibility of using waste plastic as a substitute for cement in pavers. In this research study, the mechanical, and weather impacts of pavers made entirely from waste plastic are investigated and further, the feasibility and cost-effectiveness of plastic waste pavers were assessed. Past research on the potential use of waste plastic as a partial replacement for cement in pavers is presented in the literature review. The methodology for the preparation of paver samples using waste (PET) plastic, fine aggregate, and coarse aggregate is detailed. Material characterization techniques are employed to investigate the properties of the samples. The results show that waste PET plastic can replace cement without severely affecting the material's strength, and the use of waste plastic as a replacement for cement in construction has the potential to address the environmental and economic challenges facing the construction industry. Plastic replacement with cement shows that, at specific ratio, pavers shows high strength which is more than a load bearing conventional pavers. If the ratio of plastic with sand and aggregate increases, the strength reduces due to the less amount of plastic as compared to the other materials, as if the amount of plastic increases, the strength reduces with a very much. This is due to the amount of plastic increases and the amount of sand and aggregates decreases which results segregation and improper mixing. More amount of plastic is used for lower strength pavers, optimum amount of plastic is used for highest strength and less plastic for the middle strength of both of them. This research concludes with a suggestion of directions for future research pertaining to the effects of these studies.

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INTRODUCTION

1.1 GENERAL

Cement is a fundamental component of construction, widely used for creating buildings, roads, bridges, and other infrastructure. However, the manufacturing of cement is linked to considerable negative effects on the surrounding ecosystem., including carbon dioxide emissions, energy consumption, and depletion of natural resources. According to the International Energy Agency, from 2015 to 2021, the direct CO_2 intensity of cement production increased by about 1.5 percent annually on average over the past few years. **(International Energy Agency, 2022)** In comparison, annual decrease of 3% is required until 2030 to stay on pace with the scenario of reaching net zero emissions by 2050 **(International Energy Agency, 2022).**

Meanwhile, the issue of plastic waste has emerged as a growing environmental concern. It was expected that the global production of plastics will reach 390.7 million metric tons in 2021, representing an annual increase of 4 % **(Statista Research Department, 2023).** Since 1950s, plastic production has exploded, and only a small portion is recycled. Much of the plastic waste ends up in landfills or pollutes oceans and other natural environments, causing harm to wildlife and ecosystems. According to the World Economic Forum, the ocean is expected to contain more plastic than fish by weight if current trends continue, by 2050 **(World Economic Forum, 2023).** As a result, there has been increasing interest in exploring alternative materials that can replace cement in construction while also addressing the problem of plastic waste. One of these alternatives is to use waste plastic in place of some or all of the cement in concrete mixes. This can be done either partially or entirely. This strategy has the potential to not only cut down the amount of waste plastic that is disposed of in landfills or that causes pollution to the environment, but it also has the potential to cut down the environmental impact that is caused by the production of cement by making use of recycled materials. Recent researches have demonstrated that waste plastic can be used in place of cement in concrete without severely affecting the material's strength. By diverting plastic waste from landfills and repurposing it for construction, the cost of waste management can be reduced. The construction industry can become more sustainable. Plastic waste can be used in different forms, such as shredded or granulated, and can replace varying percentages of cement in the concrete mix. However, it is essential to note that the replacement percentage must be carefully considered to ensure that the resulting material meets the required strength and durability standards for the intended application. A study published that using recycled plastic as a partial replacement for cement in concrete can lead to a 15% reduction in the material's carbon footprint **(Kognole et al., 2019a).** Another study published in Construction and Building Materials found that replacing 10% of the cement with plastic waste improved the material's insulation properties, making it more energy-efficient **(Hassanien et al., 2017.).**

Despite the promising results of these studies, several challenges must be addressed to integrate plastic waste into the construction industry successfully. These include issues related to material consistency, structural integrity, and the environmental impact of plastic additives. Additionally, the cost-effectiveness and scalability of using plastic waste as a replacement for cement in large-scale construction projects are still under investigation. Overall, the use of plastic waste as a replacement for cement in construction has the potential to address the environmental and economic challenges facing the construction industry. By providing an overview of the current use of cement in construction, its environmental impact, and the magnitude of the plastic waste problem, this research aims to contribute to a growing body of knowledge on sustainable and eco-friendly construction materials.

1.2 PROBLEM STATEMENT

The replacement of cement with plastic waste has gained considerable attention as a sustainable solution for the construction industry. There needs to be more research on the feasibility and potential of using 100% plastic waste as a replacement for cement in pavers. Based on a report published by the United Nations Development Program (UNDP), Pakistan produces an estimated annual quantity of 20 million tons of solid waste, with plastic waste constituting approximately 5 to 10 percent of this total **(Fayyaz Salih**

Hussain, 2023). In Pakistan, the predominant composition of the 250 million tons of waste is comprised of plastic bags, pet bottles, and food scraps **(World Wide Fund, 2023).** The Pacific Garbage Patch, which encompasses approximately 1.8 trillion plastic pieces, has now expanded to a size three times that of France. The escalating plastic pollution in Pakistan is presenting a significant environmental hazard **(Saba Rana & Dr. Azfar Nisar, 2023).** The production of cement-based pavers contributes to CO_2 emissions and the depletion of natural resources, making using plastic waste as a replacement material an attractive option. However, the mechanical, weather properties of pavers made entirely from plastic waste have yet to be thoroughly evaluated. In addition, the cost-effectiveness and feasibility of using 100% plastic waste as a replacement material in large-scale paving projects still need to be discovered.

1.3 AIMS AND OBJECTIVES

The purpose of this study includes:

- To investigate the mechanical characteristics and weather properties of pavers constructed from waste plastic.
- To compare cost analysis of plastic and conventional pavers.

1.4 SCOPE OF PROJECT

This research explores the feasibility of using plastic waste as a substitute for cement in paving materials. The project aims to conduct a comprehensive experimental investigation of plastic waste paver and compare them with those of traditional cement-based pavers. The study will focus on evaluating the compressive strength, tensile strength, water absorption, environmental affect, temperature effect and acid dip test of recycled plastic made pavers. The research aims to determine the performance of plastic waste pavers in various construction applications, such as pavements, walkways, and bike paths, and assess their potential as a sustainable construction material. The project outcomes will provide valuable insights into the advantages and limitations of using plastic waste in construction and contribute to developing sustainable construction practices.

1.5 THESIS OVERVIEW

The thesis, titled the “Experimental investigation of physical and mechanical properties of plastic tuff paver”, is divided into five chapters, each containing information on the project’s progress.

1.5.1 Chapter 1

The first chapter of the research study provides an explanation of the introduction, the problem statement, the research objectives, and scope of project.

1.5.2 Chapter 2

The "Literature Review" section of Chapter 2 provides an overview of the previously published literature on the effect of using plastic in the construction industry and the use of plastic as a replacement for cement.

1.5.3 Chapter 3

This chapter covers the technique for testing materials in accordance with the ASTM standards, as well as the casting of pavers made out of plastic. It comprises the specifics of the experiments that were conducted, the various raw materials that were utilized, and the procedure that was taken for testing the raw materials, the casting process, and the methodology of the various tests on pavers.

1.5.4 Chapter 4

This chapter is comprised of all of the findings that were obtained from testing performed on pavers. This chapter also includes a discussion on various ratios as well as a comparison and discussion of the results of using different ratios.

1.5.5 Chapter 5

This chapter presents the conclusions that were arrived at as a result of the preceding four chapters' worth of experimentation. This chapter offers some suggestions for the direction of future research pertaining to the effects of studies like these.

LITERATURE REVIEW

2.1 PREVIOUS STUDIES

The work done in the past regarding the potential use of waste plastic as a partial or complete replacement with cement in pavers or the construction industry has been reviewed and presented below:

This study investigates the feasibility of using several waste paving block types as raw materials to create new concrete paver blocks and building bricks**.** In Korea, waste paving blocks represent a significant social and environmental issue, with the recycling rate remaining low at around 11%. The study focuses on recycled clay, granite, and concrete blocks and assesses the feasibility of using them to partially replace sand in a concrete mixture. Replacement ratios of 10%, 20%, and 30% were tested and evaluated. To determine the suitability of the recycled materials, the researchers conducted compressive strength, flexural strength, and water absorption tests in line with Korean standards for concrete pavers and building bricks. UPV and unit weight tests were performed. The study found that waste clay and concrete blocks decreased the performance of concrete mixtures compared to the reference mixture, while waste granite blocks improved properties. The results suggest that waste paving blocks could be used for particular applications, but the characteristics of the recycled materials and the need for a centralized waste disposal solution must be considered. Further research is necessary to determine the long-term durability of concrete incorporating waste materials. Overall, this study highlights the need for more sustainable practices and the potential for waste management strategies that conserve natural resources and reduce landfill usage. **(Kim & Kim, 2022)**

The use of plastic trash as a binding substance for paver blocks devoid of cement is the subject of an experimental investigation in this article. Through the use of plastic as a building material, this study hopes to lessen the growing amount of plastic trash in the environment. The trials used different ratios of natural fine aggregate blended with plastic. The possibility of recycled plastic trash as a green building material is examined in the article. Plastic trash has accumulated as a result of the exponential increase in plastic manufacture, which is harmful to the environment. Potential management and mitigation strategies for these environmental problems include the use of plastic waste in construction materials. The research examines the numerous applications of plastic waste in bricks, tiles, concrete, highways, and other materials. Plastic trash has been utilized as a binder, aggregate, fine aggregate, modifier, or replacement for cement and sand in the production of building materials. The review concludes that waste plastic has the ability to complement and partially replace traditional building materials in a sustainable way. **(Lamba *et al.,* 2022).**

This article gives a useful study on the prospective uses of goods made from waste plastic films (WPFs) for infrastructure development, particularly in the construction of road pavement. WPF is a huge post-consumer plastic waste, and because of the problems with waste treatment, recycling and utilizing it are an urgent global issue. The mechanical characteristics, weathering stability, and environmental factors of WPF-recycled products (WPF-RPs), such as the presence of hazardous compounds, are evaluated in this study. Results show that WPF-RPs can be used in low-speed driving sections because they have a moderate strength, high weathering stability against sun irradiation, and superior road pavement vehicle load. Additionally, the backfilling and compaction flaws can be improved by installing attachment devices between the WPF-RP temporary pavement blocks. The potential use of WPF-RPs in infrastructure development, such as filler materials for buried pipes or tubes, is highlighted by this empirical investigation; nevertheless, these prospective elements need to be further investigated **(Ki *et al.*, 2021).**

This paper discusses the disposal of plastic waste and the possibility of using recycled plastic as a component of paver block fabrication for pedestrian walkways. Two methods, heating, and compression, were used in the production of paver blocks. Of the two, the compression method proved to be more efficient while exhibiting higher compressive strength, better adhesion, and skid resistance than the heating method. Results show that up to 30% of recycled plastic content can be utilized for economic consideration to produce paver blocks **(Gungat *et al.*, 2021)**.

This study investigates the impact of recycling PET on the mechanical and workability characteristics of cement-based mortar. In cement mortar compositions with a constant cement content and water-cement ratio of 525 kg/m3 and 0.48, respectively, the researchers substituted five different weight fractions of PET for river sand, namely 0%, 5%, 15%, 25%, and 50%. With the exception of the mixture containing 5% waste PET, the compressive and flexural strengths of the mixtures decreased as waste PET inclusion rose. According to the study, a combination that contains 25% waste PET is regarded as a light mortar that can be used for structural purposes. While the dry density declines as the percentage of waste PET incorporation increases, the workability of mixtures is improved by increasing the level of waste PET replacement. The study's final recommendation is that substituting up to 5% of the fine aggregate in plastic waste with plastic PET waste could be a practical and efficient way to dispose of plastic waste **(Abed *et al.*, 2021)**.

The modification of C320 bitumen for asphalt mixtures using waste polyethylene terephthalate (PET) plastic is examined in this research. In two phases, modified bitumen binders and modified asphalt mixtures were examined for their effects on various PET-modified bitumen contents. The engineering characteristics and viscos-elastic behavior of plastic-modified bitumen binders were examined using the dynamic shear rheometer (DSR) and rolling thin film oven tests (RTFOT). The Marshall Stability, Marshall Flow, Marshall Quotient, and rutting tests were carried out to assess the engineering qualities of the plastic-modified asphalt mixtures. The findings showed that adding a suitable amount of waste PET—ideally between 6 and 8 percent—can improve the stiffness and elasticity of asphalt binders. Furthermore, as evidenced by improved Marshal Stability, improved Marshall Quotient, and reduced rut depth, the asphalt mixture amended with 8% waste PET demonstrated the greatest improvement in stability and rutting resistance. According to the study, additional research on the mechanical properties of asphalt mixtures treated with waste plastic will be required in the form of fatigue and modulus stiffness testing **(N. Mashaan *et al.*, 2021)**.

The research examines the viability of modifying binder class C320, a typical bitumen type used for local road covering in Australia, utilizing locally discarded polyethylene terephthalate (PET) plastic. In order to examine rutting, fatigue, and ageing of bitumen binder, the research assesses various components of waste plastic modified bitumen using the Dynamic Shear Rheometer (DSR), Rolling Thin Film Oven (RTFOT), and Pressure Aging Vessel (PAV) tests. According to the findings, 6 to 8 percent of waste plastic should be present in order to improve rutting and ageing resistances. Additionally, PET with an 8% content increases resistance to fatigue cracking. According to the study's findings, using plastic obtained locally for pavements not only lowers costs but also increases the sustainability of the environment and natural resources **(N. S. Mashaan *et al.*, 2021)**.

The paper explores the increasing issue of plastic waste on land and in the oceans. The paper highlights the importance of recycling plastic waste and reducing the amount of plastic used, with the ultimate goal of having a circular economy. The authors also discuss the challenges of recycling plastic due to the difficulty in separating different types of plastics, mixed/multi-layered plastic products, and the low rate of plastic recycling globally (less than 20%). The book is divided into several sections, each tackling various aspects of the plastic waste problem and its impact on the environment. Chapters cover subjects such as the production, uses, and fate of all synthetic plastic; bio based and biodegradable plastics; recycling technologies; the treatment of plastic waste; and issues related to society and the environment. The book emphasizes the importance of educating people to reduce plastic waste along with developing a proper infrastructure for recycling plastic. The authors also discussed the need for adequate waste management facilities in underdeveloped countries. Overall, the paper highlights the paramount need to address the increasing volume of plastic waste and to develop new technologies and management systems for sustainable waste management practices **(Letcher, 2020)**.

This paper investigates using crushed glass and plastic aggregates to replace traditional components in concrete. Crushed glass trash can be used in place of cement and sand in concrete, which helps to lower the price of the finished product by lowering the number of aggregates used and, in turn, lowering aggregate manufacture and demand. On the other hand, using plastic waste in concrete weakened its compressive strength. The researchers conducted several tests to determine the optimum ratios of glass and plastic waste in the concrete mix and report their findings. The paper summarizes previous research on recycling waste materials in the concrete industry, and it provides a general overview of the significance and properties of concrete components **(Salah Al-kizwini, 2020)**.In order to address the housing shortage in developing nations and lessen the amount of plastic waste in the environment, this article investigates the use of used plastic bottles in construction as a sustainable solution. The research focuses on using the plastic bottles as a substitute for masonry units by filling them with soil, sand, or solid waste items. The results of different experiments indicate that walls made of plastic bottles help to conserve energy and maintain room temperatures. Leftover plastic bottles are less expensive to buy than the majority of common building supplies like sand and crushed rock. Any quantity of plastic bottle can be added to concrete or brick to minimize the overall amount of conventional materials needed, which also lowers the cost. The research concludes that recycling plastic waste through the use of used PET bottles in construction improves the energy efficiency and environmental friendliness of buildings **(Dadzie *et al.*, 2020)**.

In this study, the effects of adding PET to clay for usage in burnt bricks were investigated. At ratios of 0 %, 5 %, 10 %, 15 %, and 20 %, PET was added to lateritic clay. Following a 48-hour kiln firing at a temperature of about 900°C, the bricks' characteristics were examined for water absorption, firing shrinkage, density, compressive strength, rupture modulus, bending stress, and shear stress. In contrast to the addition of 0%, 5%, and 10% PET, which caused bricks to be distorted at their edges, the study discovered that adding 15% and 20% PET caused the bricks to disintegrate during the firing process. The bricks' compressive strength decreased as the percentage of PET increased; the results for the 0%, 5%, and 10% PET mixtures were 5.15 N/mm^2, 2.30 N/mm^2, and 0.85 N/mm^2, while the corresponding values for modulus of rupture were 13.20 N/mm^2, 11.96 N/mm^2, and 8.53 N/mm^2, respectively. The findings imply that PET can be used as a replacement in burnt bricks, but if the amount is less than 5% and temperature during burning is closely regulated **(Akinyele *et al.*, 2020)**.

In order to address the issue of disposing of plastic waste and increase the sustainability of the building sector, this article explores the potential use of plastic waste as a construction material. The study discusses numerous strategies for turning waste plastic into new products while drawing attention to the environmental problems caused by plastic disposal, such as the danger plastics provide to the marine ecosystem and human health and the restrictions on using plastic waste in construction. The study concludes that the best environmentally friendly way to make cementitious composites is to employ recycled plastic waste in place of all of the solid components. The results will be used to guide future research into the possibility of employing plastic trash in building to increase environmental sustainability **(Awoyera & Adesina, 2020)**.

This paper discusses the problem of plastic waste and identifies it as hazardous to the environment and humanity. The research proposes using plastic waste to produce bricks for the construction industry, which they believe will be eco-friendlier and more economical without compromising on quality. The study goes on to outline a methodology to create these bricks and details the composition of various types of plastic wastes used in the process. The testing results reveal that the bricks made from plastic have zero water absorption, have higher compressive strength, and lower soundness compared to conventional bricks. **(Kognole *et al.*, 2019b)**.

This review article discusses the usage of plastic bricks made from waste PET plastic bottles as a building material in Rohingya refugee camps. It is argued that the use of plastic bricks can be a sustainable and low-cost solution to the shelter issues faced by the Rohingya people. The article also mentions other examples of utilizing plastic bottles as a building material, such as for wall structures for greenhouses. The paper highlights the increasing percentage of plastic waste in urban areas of Bangladesh and the poor ambient air quality in the country, emphasizing the need for sustainable solutions. Overall, this article suggests that utilizing plastic waste in construction can provide opportunities for cost-efficient housing and environmental protection **(Haque, 2019)**.

The use of chemically treated plastic wastes, notably polyethylene terephthalate (PET) wastes, in place of natural coarse aggregates in concrete is examined in this article. The study investigates the effects of processing PET trash with calcium hypochlorite ($Ca\ (CO)_2$) and hydrogen peroxide (H_2O_2) before adding it to concrete at three different percentages 10%, 20%, and 30% substitution of natural aggregates. Analyzed and contrasted with control samples are the PACs' physical and mechanical characteristics. According to the findings, chemically treated plastic aggregates strengthen the link between the aggregates and cement paste, increasing the compressive strength by up to 30%. PET aggregates that have been chemically treated outperform untreated aggregates in terms of compressive strength, with $Ca(CO)_2$ treatment being the most efficient. The rough surfaces of the treated plastic aggregates are shown in the study to have an adverse effect on workability. However, the study contends that these PACs have the potential to lessen the adverse effects of disposing of plastic waste while enhancing the qualities of concrete and can be employed in both structural and nonstructural applications **(Lee *et al.*, 2019)**.

This paper explores using quarry dust and waste plastic in place of natural sand while making concrete, with a focus on the economic and environmental benefits. The study involves conducting an XRD analysis of the three materials, namely natural sand, quarry dust, and waste LDPE. The results indicate that the quarry dust primarily consists of Graphite and calcium oxides together, while the natural sand contains primarily quartz with the presence of calcite. The XRD test on waste LDPE revealed that the material was Structure that is partially crystalline and partially amorphous, this was caused by the presence of both broad and acute, narrow diffraction peaks. The d-spacing at $2\theta=19.8°$ was 4.479 Å. The paper concludes that the incorporation of quarry dust and waste plastic into concrete can be a potential replacement for natural sand, and the tests outlined provide insights into the potential structural characteristics of the materials. Therefore, XRD may be an appropriate analytical technique for this research and can help innovate the utilization of substitute materials in the construction sector **(Bahoria *et al.*, 2018)**.

This study explores the possibility of integrating waste plastic into concrete tiles to mitigate inadequate supply of raw materials and alleviate the problem of plastic waste disposal. The study found that cement can be replaced with plastic waste at a dosage of 10-15% without a significant reduction in strength. Concrete's compressive strength rises as the amount of waste plastic it contains rises up to 35% replacement. The study concludes that concrete tiles with plastic waste can offer a sustainable solution for the disposal of unwanted plastic waste and the shortage of natural aggregates, but workability can be a challenge for some replacement percentages **(Shankar Yaligar *et al.*, 2018)**.

The goal of the study is to employ discarded plastic fibers to improve some of the characteristics of self-compacting concrete (SCC). The purpose of the tests was to determine how adding waste plastic fibers to self-compacting concrete would affect both its fresh and hardened qualities. The wet density values of several self-compacting concrete mixtures reduced when waste plastic fibers were added, which was regarded normal for application. The use of waste plastic fibers improved the flexural and compressive strengths of self-compacting concrete. However, when the amount of waste plastic fiber content increased, the slump flow values generally fell because the fibers began to tangle and cluster in the center of the flow spread, endangering the flow of the concrete. **(Al-Hadithi & Hilal, 2016)**.

The report gives a summary of the research on the utilization of several types of waste plastic in concrete. To tackle the environmental issues caused by plastic wastes, concrete has been reinforced with a variety of plastic wastes, including crushed plastics, laminar fibers, shredded fibers, and PET aggregates. The addition of plastic has a minimal impact on how easily concrete can be worked. Concrete loses some of its workability when plastic is added, but it gains other advantages. For instance, adding modest amounts of waste plastic to concrete boosts its compressive strength substantially. Additionally, concrete reinforced with waste plastic fibers is more ductile than ordinary concrete, and as the amount of plastic in any form grows, the modulus of elasticity of concrete reinforced with plastic fibers lowers. In order to minimize degradation or unfavorable interactions between the plastic and the concrete matrix, the research advises treating the surface of plastic materials with reactive compounds, such as iron slag, silica fume, and metakaolin, before inserting them into concrete **(Sharma & Bansal, 2016)**.

By performing compression experiments on plastic water bottles with various infill materials, this study investigates the viability of employing used plastic water bottles as suitable compression members in geotechnical engineering (fly ash and stone aggregates). According to the study's findings, plastic bottles with the right infill materials can function as the optimum compression member and serve as a type of reinforcing material for geotechnical engineering. The study also demonstrates that the composite cells' load-carrying capability was improved when coarse stone aggregates were used as the infill material. The study found that plastic bottles can function as the optimum compression member when they are filled with the right substance **(Dutta *et al.*, 2016)**.

The research examines the fresh and hardened properties of concrete mixtures with varied amounts of plastic flakes as a partial replacement for sand. For testing, concrete beams and cubes were cast. The study concluded that waste plastic can be utilized in concrete without significantly changing its characteristics or strength. The study also found that utilizing waste plastic only slightly reduces compressive strength, which can be restored by adding a superplasticizer. Testing mixes containing up to 15% waste plastic revealed that as the waste plastic ratio increased, the fresh density tended to decline and the compressive strength values declined at each curing age. Superplasticizer has been found to enhance the compressive strength by 5%. **(Rai *et al.*, 2012)**.

The document provides a summary of recycled plastics' use in concrete. An affordable and environmentally responsible method of producing concrete is the use of waste products. The article explores several waste materials that could be included into concrete, including old tires, plastic, glass, steel, burned foundry sand, and coal combustion by-products (CCBs). The bulk density, air content, workability, compressive strength, splitting tensile strength, elastic modulus, impact resistance, permeability, and abrasion resistance of recycled and waste plastic were reviewed in the literature by the authors. They discovered that recovered plastic may be used to successfully and effectively replace traditional aggregates, which lowers the overall bulk density of concrete. Additionally, they discovered that the compressive strength of concrete containing aggregates made from 10–50% recycled plastic ranged between 19 and 48 MPa, and that compressive strength dropped as recycled plastic content rose **(Siddique *et al.*, 2008)**.

The study's goal was to learn more about how plastic trash is used to make paver blocks. The physical characteristics of several mixtures of plastic trash, M-sand, and quarry dust were tested. In terms of cost, water absorption, and compressive strength, paver blocks constructed from plastic waste, quarry dust, coarse aggregate, and ceramic waste performed better than concrete paver blocks. The use of discarded plastic in the creation of paver blocks is a useful approach to get rid of plastic trash. Although the plastic paver block's compressive strength was lower than that of the concrete paver block, it can still be utilized on roads with little to no traffic **(Raju *et al.*, 2008)**.

The advantages of using plastic trash to make bricks with cement and sand are covered in this paper. The study aims to lessen the environmental impact of plastic garbage by recycling it. According to the study, using plastic waste in the manufacturing of bricks had a minimal impact on water absorption but had no discernible impact on compressive strength. The study also revealed a novel method for producing porous bricks without the substantial carbon emissions caused by incineration. These bricks' main qualities are their light weight, porosity, low thermal conductivity, and significant mechanical strength. In order to forecast the compressive strength of bricks at various plastic contents, a mathematical model was also created. The authors believe that these bricks show potential as cutting-edge and environmentally friendly building materials that can improve buildings' energy efficiency and boost manufacturers' bottom lines **(Bhushaiah *et al.*, 2008)**.

The article "Recycling Waste Plastic Bags as a Replacement for Cement in Manufacture of Building Bricks and Concrete Blocks" assesses the use of recycled waste plastic bags as a cement substitute in brick and concrete block production. The research revealed that when plastic content increased in both bricks and concrete blocks, the heat conductivity of both materials dropped and that bending stress increased as plastic content increased. The authors note that waste plastic, which is a significant environmental concern, can be recycled and used in the production of construction materials, reducing the amount of plastic that ends up in the environment **(Hassanien *et al.*, n.d.)**.

The usage of Waste Polyethylene Terephthalate (PET) Bottles Lightweight Aggregate (WPLA) as an aggregate in concrete is examined in this research. On the quality of WPLA, granulated blast-furnace slag (GBFS) was employed to study the impact. According to the study, using WPLA increases concrete's workability while reducing concrete's density and compressive strength. The research also reveals that by limiting the transition zone as a result of the reaction with calcium hydroxide, the adherent GBFS on the surface of the WPLA can strengthen the aggregate's surface **(Choi *et al.*, 2005)**.

The article covers the topic of managing plastic waste in the context of building, highlighting the need of developing reprocessing technology, infrastructure for plastic waste collection, and cost-efficient markets for the use of recovered plastic components. The study discusses the creation of high-performance composite materials known as polyester concrete (PC) utilizing unsaturated polyester resins based on recycled polyethylene terephthalate (PET) plastic waste developed using recycled PET plastic waste. The paper discusses the characteristics of PC and demonstrates that the composite has strong mechanical and durability properties, making it a great source of aggregates for a variety of applications in concrete and road construction. Utilizing PCs can reduce the quantity of garbage dumped in landfills while saving money, energy, and raw petrochemical resources. **(Rebeiz & Craft, 1995)**.

2.2 PLASTIC

Plastic waste is a pressing environmental concern, with diverse types of plastics being generated from various consumer products, packaging materials, and industrial applications. Understanding the different types of plastic waste is essential for effective waste management and sustainable solutions. Below, we provide a detailed overview of some common types of plastic waste.

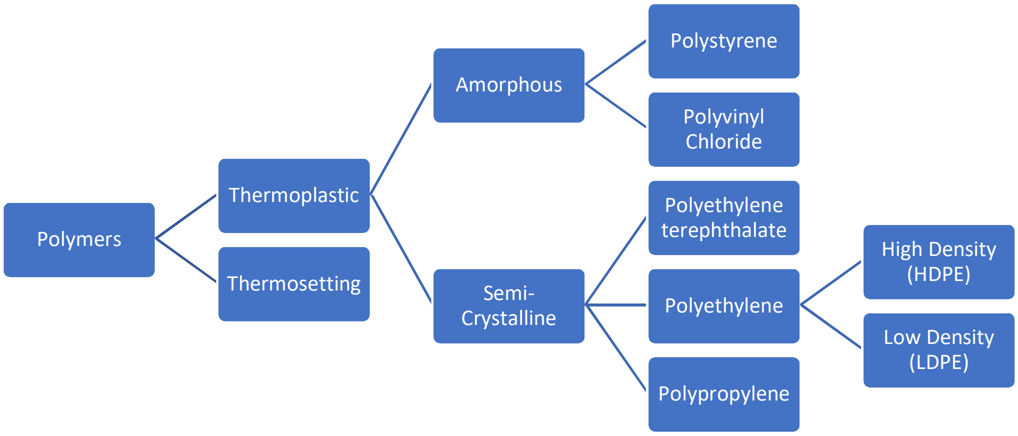


Figure 2-1 Classification of Plastic

2.2.1 Polyethylene terephthalate (PET)

Polyethylene terephthalate (PET) is commonly utilized as the predominant substance for manufacturing plastics falling under category one. Due to its extensive range of applications, it holds the top position in terms of ranking. The primary application of this material is in the packaging of food and beverages, as it effectively prevents the ingress of oxygen and subsequent contamination of the enclosed products.

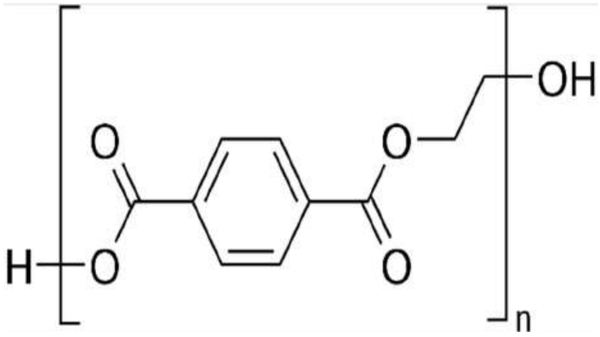


Figure 2-2 Chemical formula PET plastic

It is often collected through most curbside recycling programs and has an incredibly successful history. In actuality, PET bottles are the type of plastic that is recycled the most globally.

Figure 2-3 Polyethylene terephthalate (Welle, 2017)

2.2.2 High Density Polyethylene (HDPE)

Technically known as HDPE, this exceptionally resilient plastic is utilized in products including shopping bags, milk jugs, recycling bins, agricultural pipe, and playground equipment, caps, and shampoo bottles.

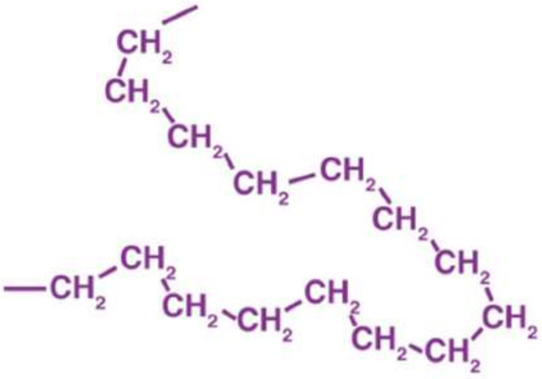


Figure 2-4 Chemical formula of HDPE

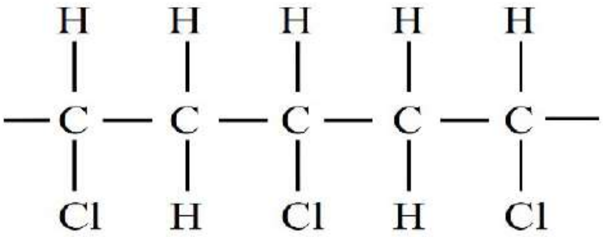
It is thicker and stronger than PET because it is formed of long, unbranched polymer chains. It is also fairly tough, impact-resistant, and resistant to temperatures up to 120 °C without suffering any negative effects. Given that HDPE is one of the most easily recycled plastic polymers, most recycling facilities across the world accept it for disposal.

Figure 2-5 High Density Polyethylene Plastic (Recycing, 2015)

2.2.3 Polyvinyl chloride (PVC)

Polyvinyl chloride, a synthetic plastic polymer, ranks as the third most widely manufactured material globally. There are two primary classifications of it, namely rigid and flexible. Polyvinyl chloride (PVC) is commonly employed within the building and construction industry for the fabrication of pipes and profiles utilized in the construction of doors and windows, serving both potable water and wastewater applications. When combined with other materials, it has the ability to enhance its softness and flexibility, making it suitable for various applications such as flooring, wiring, and plumbing insulation.

Chemical Formula of PVC Plastic is:



$$\begin{array}{ccccccccccc} & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & & \mathrm{H} & \\ & | & & | & & | & & | & & | & \\ - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - & \mathrm{C} & - \\ & | & & | & & | & & | & & | & \\ & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & & \mathrm{H} & & \mathrm{Cl} & \end{array}$$

Figure 2-6 Chemical formula of PVC

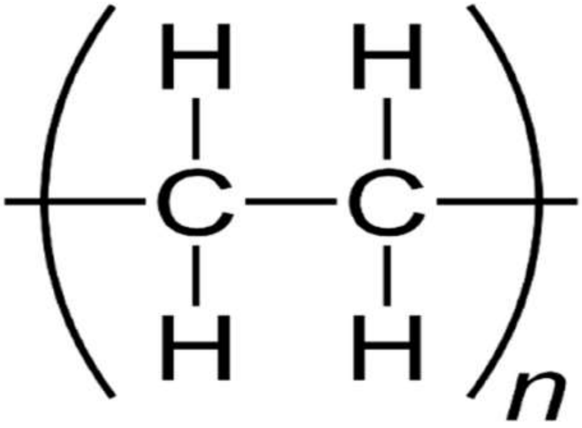
Figure 2-7 Polyvinyl chloride Plastic (Johnson, 2020)

2.2.4 Low density polyethylene (LDPE)

The distinguishing characteristic between LDPE and HDPE lies in the lower density of molecules in LDPE, leading to the production of a resin that is thinner and possesses greater flexibility. Due to its minimalistic molecular structure, this plastic can be readily and inexpensively manufactured.

It is not frequently recycled through curbside programmers, despite being used in plastic bags, six-pack rings, various containers, dispensing bottles, and most infamously for plastic wraps.

Chemical Formula of LDPE:



$$\left(-CH_2-CH_2-\right)_n$$

Figure 2-8 Chemical formula of LDPE

Figure 2-9 Low density polyethylene Plastic (CHUAN, 2018)

2.2.5 Polypropylene

The market for polypropylene, the second-most frequently produced commodity plastic, is anticipated to expand even further during the next years. Tupperware, automobile components, thermal jackets, yoghurt containers, and even disposable diapers include this tough, durable material that can tolerate extreme temperatures.

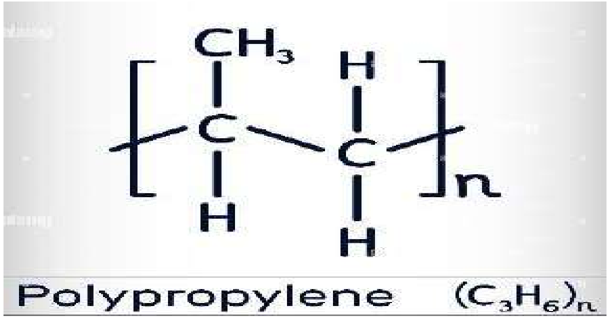


Figure 2-10 Chemical formula of Polypropylene

Figure 2-11 Polypropylene Plastic (amstockphoto)

2.2.6 Polystyrene

The second-most common commodity plastic produced is polypropylene, and market growth for this material is anticipated in the coming years. It is tough and resilient, can tolerate high temperatures, and is used in Tupperware, automobile components, thermal vests, yoghurt containers, and even disposable diapers.

Chemical Formula of Polystyrene

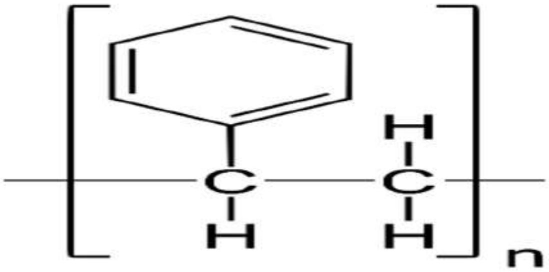


Figure 2-12 Chemical formula of Polystyrene

Figure 2-13 Polystyrene Plastic (Group, 2021)

2.3 OTHER PLASTIC

Plastic shall be classified within group 7 in the event that it lacks discernibility from the aforementioned six categories. Polycarbonates (PC) are widely recognized as the most prominent plastics within this category, renowned for their ability to produce resilient and long-lasting goods. Polycarbonate is a commonly employed material for the production of lenses in safety, sport, and sunglasses, with the primary objective of safeguarding the eyes. Nevertheless, these files can also be encountered in compact discs and, with increasing frequency, on smartphones (CD).

2.4 AGGREGATES

In order to create concrete, asphalt, and other forms of composite materials, binders such as cement and other binders must be combined with inert fillers or reinforcement known as aggregates. These granular materials are made from recycled concrete, slag, and fly ash, as well as from natural resources including sand, gravel, and crushed stone. Construction materials' overall strength, durability, and performance are greatly influenced by the aggregates they are made of. Here is a thorough explanation of aggregates and their importance in building:

Types of Aggregates

- Fine Aggregate
- Coarse Aggregate

2.4.1 Fine Aggregate

Fine aggregate, also known as sand, is an essential component in construction materials, particularly in concrete and mortar mixes. It constitutes a major portion of the total volume in these mixtures and plays a crucial role in determining the workability, strength, and durability of the final product. Here is a detailed note on fine aggregate and its significance in construction

Figure 2-14 Sand

Characteristics of Fine Aggregate

- **Particle Size:** Fine aggregate consists of small, fine particles with diameters ranging from 75 micrometers to 4.75 millimeters.
- **Shape:** Sand particles are typically angular or rounded, with a well-graded distribution of sizes to ensure optimal packing and interlocking.
- **Color:** The color of fine aggregate can vary depending on its source, ranging from white to various shades of brown, gray, or black.

Significance in Concrete Mixes

- **Workability:** Fine aggregate provides lubrication between larger particles and facilitates the ease of mixing, placing, and finishing concrete mixes.
- **Cohesion:** It improves the cohesion and plasticity of the concrete mix, enhancing its ability to be molded and shaped into desired forms.
- **Water Demand:** The presence of fine aggregate affects the water demand of the concrete mix, as it contributes to the overall surface area and porosity.

Influence on Concrete Properties

- **Compressive Strength:** Fine aggregate contributes to the strength of concrete by filling voids between larger particles and promoting better bonding with the cement paste.
- **Durability:** It improves the durability and resistance to environmental factors such as freeze-thaw cycles, chemical attacks, and abrasion.
- **Shrinkage and Creep:** The inclusion of fine aggregate helps reduce the shrinkage and creep tendencies of concrete.

Uses in Construction

- **Concrete Mixes:** Fine aggregate is an integral component in concrete production, used in various applications such as foundations, walls, columns, and slabs.
- **Mortar Mixes:** It is also a key ingredient in mortar mixes used for masonry work, providing a cohesive binding material for bricks and blocks.
- **Filler:** Fine aggregates are also used as a filler material in road construction field and other industries

Quality and Gradation

- Proper grading of fine aggregate is crucial to achieving the desired properties of concrete or mortar.
- Fine aggregate should conform to specific grading requirements to ensure a well-packed mix and reduce the risk of bleeding and segregation.

2.4.2 Coarse Aggregates

Coarse aggregate is a vital component in construction materials, particularly in concrete mixes and various structural applications. It forms a significant portion of the total volume in these materials and plays a critical role in providing strength, stability, and durability to the final product. Here is a detailed note on coarse aggregate and its significance in construction

Figure: 2-15 Coarse Aggregates

Characteristics of Coarse Aggregate

- **Particle Size:** Coarse aggregate consists of larger particles with diameters typically greater than 4.75 millimeters.
- **Shape:** These particles can have angular, rounded, or irregular shapes, depending on the source and production process.
- **Color:** Coarse aggregate comes in various colors, such as shades of brown, gray, or black, based on its geological origin.

Significance in Concrete Mixes

- **Strength and Load-Bearing Capacity:** Coarse aggregate provides the main structural strength to concrete mixes, contributing to their compressive strength and load-carrying capacity.
- **Interlocking and Cohesion:** The larger particles interlock with each other and with the cement paste, enhancing the cohesion and stability of the concrete mix.
- **Volume Stability:** Coarse aggregate helps reduce the overall volume changes in concrete due to shrinkage and temperature variations.

Influence on Concrete Properties

- **Workability:** The presence of coarse aggregate affects the workability of concrete mixes, necessitating the use of an appropriate water-cement ratio and admixtures to achieve the desired consistency.
- **Durability:** Coarse aggregate enhances the durability of concrete by providing resistance to abrasion, weathering, and chemical attacks.
- **Thermal Insulation:** The air voids between coarse aggregate particles contribute to the thermal insulation properties of concrete.

Uses in Construction

- **Concrete Mixes:** Coarse aggregate is a crucial ingredient in concrete production, commonly used in structural elements such as foundations, columns, beams, and slabs.
- **Road Construction:** It is used as a base material in road construction to provide strength and stability to pavements.

Quality and Gradation

- Proper grading of coarse aggregate is essential for achieving workable concrete with good strength and durability.

The size and shape of coarse aggregate particles influence the compactness of concrete, affecting its mechanical properties.

METHODOLOGY

3.1 INTRODUCTION

The experimental work started with the collection of coarse aggregate (Sargodha crush), fine aggregate (Lawrence-purr Sand), and PET plastic from local Industry. Different basic tests are performed on fine and coarse aggregates to find the different properties of Fine and coarse aggregates. In our research work we 100% replaced the cement with PET Plastic and we select the overall Density of our sampling as 2.9 kg/m^3. We select the three different ratios of 1:0.5:0.75, 1:0.75:1, and 1:1:1.25 that were selected based on trials and literature work. After carefully examining the results obtained, conclusions on the research project are draw in the next chapter.

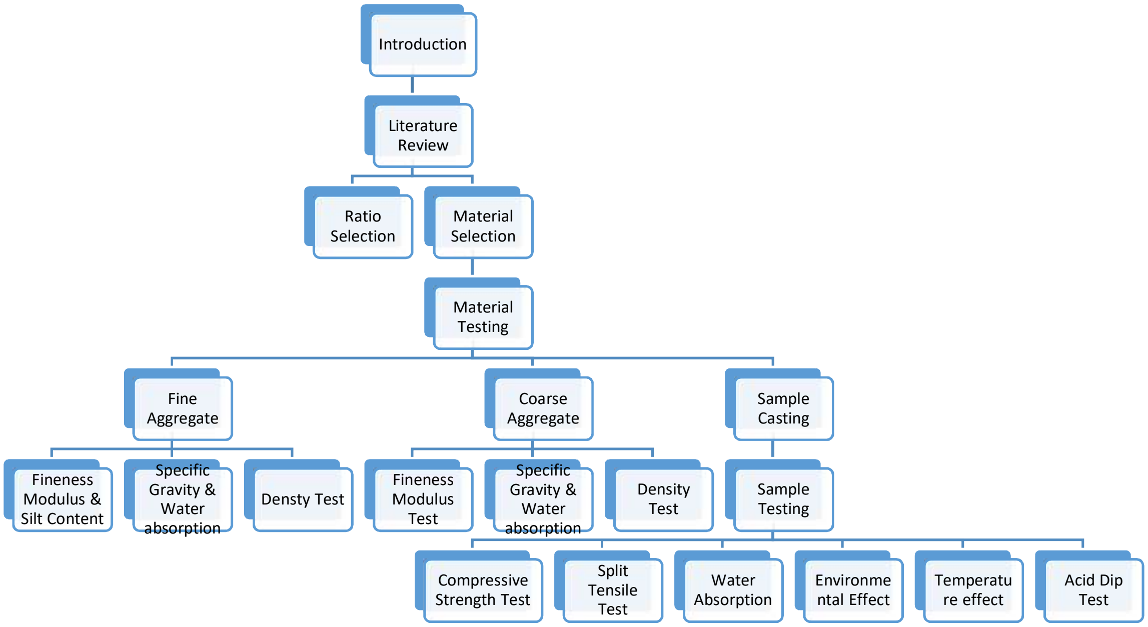


Figure 3-1 Methodology Flow Chart

A specific type of material is used in this research. Properties of material plays a vital role in every research. Material having following properties are used in this research.

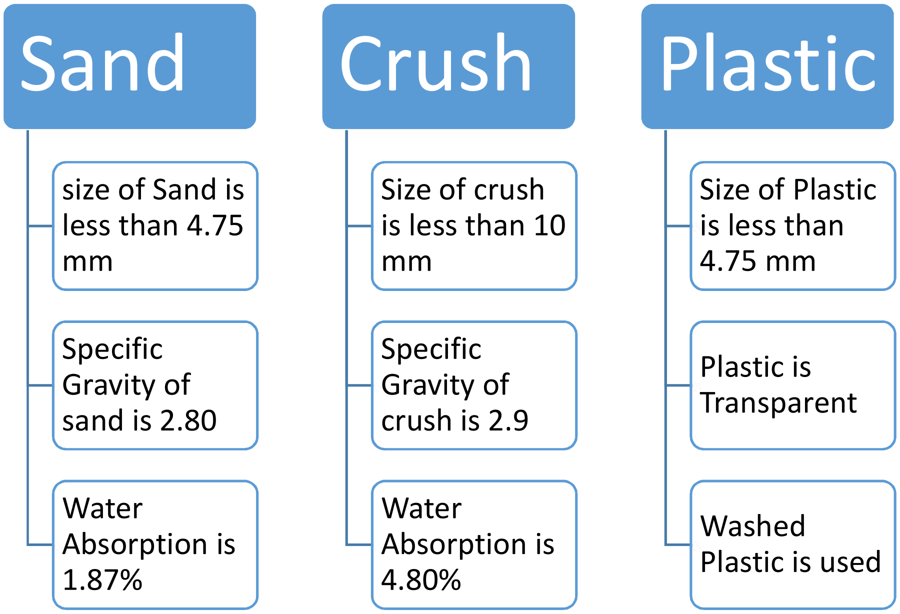


Figure 3-2 Material properties

3.1.1 Ratios

We use the following ratios for research purpose in which plastic, sand and aggregate are mention respectively.

- 1:0.5:0.75
- 1:0.75:1
- 1:1:1.25
- 1:0.25:0.5 (Conventional Concrete)

3.2 TRAIL METHOD FOR PAVER

3.2.1 Procedure

Take the weight of all the material and then put the plastic in one container and put the sand and aggregate in another container and heating all the material side by side. Plastic almost take 30 minutes for melting after complete melting of plastic put the heated aggregate in plastic paste and mix them properly. It took five to ten minutes for mixing. Then place the mixed material in the mold.

3.3 HEATING OVEN METHOD

Figure 3-3 Recycled Plastic Made Pavers

3.3.1 Procedure for sampling

First of all, take the weight of all the materials and place it in a heating container in such a way that we put the coarse aggregate first then fine aggregate (sand) and on the top is waste PET Plastic. Then we place the sample in the heating oven for melting the plastic, the average time of melting the plastic is 1.5 hours. If the sample is not ready after this time take out the sample from the oven and do possible mixing using a trowel and again shift into the oven immediately. When plastic is completely melted or converted into viscous form then take out the sample from the heating oven and mixed properly manually with a trowel within one minute. Because exactly after the one minute the melted plastic will be started to get hard. After mixing the material shift it into the mold.

Compact the material during the shifting of material in mold so that there should be no air bubbles in the material. Now using a flat plate, provide a smooth finishing from the top surface. After one hour, demold the paver and place it for cooling. After the sample cooled. It is ready for use.

This method is used for all the sampling.

Figure 3-4 Samples placed in oven for casting

3.3.2 Precaution

Precaution should be followed during making the plastic paver otherwise it has multiple risks for health and physicals damages

- Use the heat proofing gloves for handling the sample tray
- Wearing the mask and safety glasses.
- Maintain a distance from the oven and from one another.
- Oiling should be done properly to the related tools and mold.
- Oiling should be done for every single sample casting
- Mixing of sampling should be done in such a way that material cannot come out from the container which may cause physical damage.
- Mixing time should be less than 1 minute.
- Temping should be done properly with the temping plate that also helps in getting well finishing
- Finishing should be done properly.
- Don not touch the mold for 1 hour without gloves after pouring the material even after hardening the sample.

Figure 3-5 Safety Items

3.4 COMPARISON OF MANUAL AND OVEN HEATING

Table 3-1 show the comparison the method of manual and oven heating.

Table 3-1 Comparison of manual and oven heating method

Oven heating	**Manual heating**
Heating oven are used	Simple burner was used
Place the material in three layers	Separate container was used for heating the plastic and aggregate
Plastic take one and half hour for melting	Plastic take30-40 minutes for melting
Material paste more viscous	Material paste less viscous
Oven provide uniform heating to whole material	Burner provide non-uniform heating to material
Strength of this process is 3 times higher than the manual heating	Strength of this process is three times lower than oven heating
Time of mixing the material is less	Time of mixing the material is more

3.5 MATERIAL CHARACTERIZATION

Several tests were performed on the material sample to determine whether or not the gathered material met ASTM requirements.

3.5.1 Tests Performed on Fine Aggregate

- Fineness Modulus (ASTM C-117-05)
- Relative Density (Specific gravity) and Water absorption test (ASTM C-127/128)
- Bulk density (ASTM C 29/C 29M – 97)
- Silt Content in sand

3.5.2 Tests performed on course Aggregate

- Fineness Modulus (ASTM C-316-05)
- Relative Density (Specific gravity) and Water absorption test (ASTM C-127)
- Bulk density (ASTM C 29/C 29M – 97)

3.5.3 Mechanical Testing

After the preparation of pavers with selected three different ratios. Several tests were performed on the pavers sample to check the properties of whether it is workable or not in the field.

The following tests were performed on the samples

- Compression test
- Split Tensile test
- Water Absorption
- Environmental effect
- Temperature effect
- Acid Dip

3.6 TESTS PERFORMED ON FINE AGGREGATES

Test performed on fine aggregates are given below:

3.6.1 Fineness modulus of fine aggregates and Silt Content (ASTM C-117-05)

The fineness modulus of fine aggregates is an index value that represents the average particle size in fine aggregates. Sieve analysis with conventional sieves is used to calculate it. The aggregates value is calculated by adding and subtracting the cumulative percentage retained on each sieve by 100.

First, a sample of fine aggregate weighing 2 kg was collected, weighed, and placed in sieves in decreasing sieve size order. The sieves used were; No. 4 (4.75 mm), No. 8 (2.36mm), No. 16 (1.18mm), No. 30 (0.60 mm), No. 50 (0.30 mm), No. 100 (0.15 mm) and at last pan. When the first sieve was placed on the lead, the sample was then poured into it from the top. The first sieve was then shaken for five minutes in the sieve shaker. The material that was still on the sieve was weighed at the end, and the fineness modulus of the fine aggregate was computed.

FM can be calculated by using the relation:

FM= sum (cumulative % retained) / 100

The range of fine aggregates' fineness modulus is 2.0 to 3.5.

Fine aggregates with a fineness modulus more than 3.2 shouldn't be regarded as fine aggregate.

Figure 3-6 Sieve Shaker

3.6.2 Specific gravity and Water absorption test by Pycnometer (ASTM C-128)

The bulk and apparent specific gravities of fine aggregate are measured as part of the "Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine

Aggregate" in order to assess the quality of aggregates.

To start this experiment a suitable mass was used to collect 3000 grams of fine material. It was heated at a temperature between 100 and 110 °C until it reached an appropriate weight. After drying, let the sample cool at room temperature and then cover the fine aggregate sample with fresh water for about 30 minutes. Take the sample out of the water, dry any extra water off and the sample should be spread out on a flat surface and then placed to a gently moving flame until it becomes free-flowing. Alternatively, the sample can be left in the air for a short period of time. A portion of the fine aggregate sample should be placed in the mold, lightly tamped 25 times, and then lifted vertically. Take note of the sand's shape when you remove the mold. If there is still surface moisture, the fine aggregate will keep its shape in the mold. It's not acceptable to do this. If the aggregate drops slightly when the mold is removed, you need to keep drying and repeat the previous molding procedure. This denotes the aggregate's saturated surface dry (SSD) state. As soon as possible put 500 grams of the sample into the pycnometer. Remove air bubbles by shaking the pycnometer after actually filling it to capacity. Water should be added until the meniscus bottom reaches the 500-cc line on the pycnometer's exterior surfaces. Then weigh the flask containing the sample and water as a whole. Remove the fine aggregate from the flask with care, then dry it in the oven to a weight of 100 to 110°C throughout.

Figure 3-7 Pycnometer

3.6.3 Bulk density of fine Aggregate (ASTM C 29/C 29M – 97)

This test method includes calculating the voids between particles in fine, coarse, or mixed aggregates based on the calculation of the bulk density ("unit weight") of aggregate in a compacted or loose condition.

First of all note down the measuring container's dimensions and empty weight and then calculate its volume. To determine the loose bulk density, fill the container with the fine aggregate material using a shovel. Then, leveled the top surface of the container. Measure the weight of the aggregate-filled container and record the result. The relationship can then be used to calculate the loose bulk density of the aggregate material;

Loose Bulk Density = Weight of filled fine aggregate/ volume of container

The only difference in determining the compacted bulk density now is the manner in which the container is filled. The container is in this case filled in three equal layers. About a third of its height is full, use your fingers to level the top part of the container. 25 equally spaced rod strokes with the temping rod were applied to the aggregate layer. After that, fill the container two-thirds full and temping rod it once again 25 times. Finally, overfill the container to the top and rod once more using the method explained earlier. After that, level the container's top and weigh it. Calculate the compacted bulk density by using the relation

Compacted Bulk Density=Weight of filled compacted fine aggregate/volume of container

Figure 3-8 Density Apparatus

3.7 TESTS PERFORMED ON COARSE AGGREGATES

Details of test performed on coarse aggregates are given below

3.7.1 Fineness Modulus (ASTM C-316-05)

The fineness modulus of coarse aggregates uses an index number to reflect the average particle size in the coarse aggregate. Using common sieves, sieve analysis is used to calculate it. The value of fine aggregate is calculated by adding and subtracting the cumulative percentage of material retained on each filter by 100.

A sample that had been oven dried weighing about 2 kg was taken, and a set of sieves both standard and non-standard were stacked on top of one another. The sieve numbers were; 75 mm, 37.5 mm, 19 mm, 9.5 mm, No. 4 (4.75 mm), No. 8 (2.36mm), No. 16 (1.18mm), No. 30 (0.60 mm), No. 50 (0.30 mm), No. 100 (0.15 mm) and at last pan. Both manual and mechanical sieve shaker machines were used for the sieve analysis process. We use sieve shaker and shaken for five minutes in the sieve shaker. In the end, the mass retained on each sieve was measured to calculate the respective fraction going through each sieve. Weigh the mass retained on each sieve, then determine the percentage of material that passes through each sieve.

Then the FM can be calculated by using the relation:

FM= sum (cumulative % retained) / 100.

Figure 3-9 Fineness Modulus test of Coarse Aggregate

3.7.2 Relative Density (Specific gravity) and Water absorption test (ASTM C-127)

Relative Density (specific gravity) and Water Absorption are two important tests conducted on aggregates to assess their quality and suitability for various construction applications.

In order to start the experiment, about 1 kg of coarse aggregate were taken in its original state, and the sample was sieved to remove the finer particles. Calculate the proportion of material that passes through each sieve by weighing the mass retained on each sieve. Placed the sieved sample in the glass container and added water. The aggregate was saturated by immersion in water for 24 hours. The trapped air was released after the soaking period by minor agitation. Then, to make sure that no air was trapped inside the vessel, we overfilled it with water and covered it with a flat, round glass disc. The container was then dried from the outside before the entire assembly was weighed and recorded as C. At this point, the aggregate has been removed from the vessel and drained in order to be placed on a dry cloth and reach a surface-dry condition. The container was then refilled with pure water, the glass plate was positioned as before to make sure that there was no trapped air inside the container, and the entire assembly was weighed. When the aggregates appeared in surface dry condition their weight was taken and recorded as B. Placed the aggregate in an enamel plate to be kept in oven at a temperature of 100°c for 24 hours. After 24 hours the aggregates were taken out of the oven and cooled in an air tight container. The weight of the aggregate after being oven-dried was noted and noted as A on the measurement pad. The values of the specific gravity of the oven-dried sample, the specific gravity of the saturated surface-dry sample, the apparent specific gravity, the oven-dry density, and the percentage of water absorption of the coarse aggregate, were then determined using the formula, in that order.

“The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 3.0 with an average of about 2.65.”

3.7.3 Bulk density (ASTM C 29/C 29M – 97)

This test method covers the determination of bulk density (“unit weight”) of aggregate in a compacted or loose condition, and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination. This test method is applicable to aggregates not exceeding 125 mm [5 in.] in nominal maximum size.

Note down the measuring container's dimensions and empty weight and then calculate its volume. To determine the loose bulk density, fill the container with the fine aggregate material using a shovel. Then, leveled the top surface of the container. Measure the weight of the aggregate-filled container and record the result. The relationship can then be used to calculate the loose bulk density of the aggregate material;

$$\text{Loose Bulk Density} = \frac{Weight\ of\ filled\ fine\ aggregate}{volume\ of\ container}$$

The only difference in determining the compacted bulk density now is the manner in which the container is filled. The container is in this case filled in three equal layers. About a third of its height is full, use your fingers to level the top part of the container. 25 equally spaced rod strokes with the temping rod were applied to the aggregate layer. After that, fill the container two-thirds full and temping rod it once again 25 times. Finally, overfill the container to the top and rod once more using the method explained earlier. After that, level the container's top and weigh it. Calculate the compacted bulk density by using the relation;

$$\text{Compacted Bulk Density} = \frac{Weight\ of\ filled\ compacted\ course\ aggregate}{volume\ of\ container}$$

3.8 MECHANICAL TESTING FOR PAVERS

Test performed on recycled plastic made pavers are given below.

3.8.1 Compression test on pavers (C39/C39M - 18)

The ability of the concrete to hold the weight of the building or structure is determined through compression strength testing. Compressive testing clarifies how a material will respond to compression

Determine the size and weight of the paver samples and clean the testing device's bearing surface. Place the specimen in the device in a way that the opposing sides of the solid shape will receive the load and then adjust the sample centrally on the base plate of the machine. Set the machine (give details of the sample to machine) to apply load at a specific rate as per conditions and start the test. When a fracture appears, the machine will automatically stop applying load.

Figure 3-10 Compression Testing

3.8.2 Split Tensile test on the paver (ASTM C 496)

An indirect method of assessing concrete's tensile test is the split tensile test. The tensile strength of the concrete is the 10-12 percent of the compressive strength of concrete.

First draw diametrical lines on the two ends of the specimen. To make sure the ends of the specimen are in the same axial location. Next, note the specimen's weight and dimensions and adjust the compression testing device to the necessary range. Place the specimen on the lower plate after placing the plywood strip and the specimen should be positioned over the bottom plate with the lines drawn on the ends vertical and centered. Then place the second piece of plywood over the specimen and the upper plate should be lowered until it just touches the plywood strip. Apply the amount of pressure gradually until the specimen breaks, then record the value.

The following formula is used to calculate the direct tensile strength according to ASTM C 496:

$$F_{ct} = \frac{2P}{3.14\, lD}$$

Figure 3-11 Split Tensile Test

3.8.3 Water Absorption test on paver brick (D 570 – 98)

Water absorption help us to find the amount of water that has been absorbed by sample. One of the most important properties of a good quality concrete is low permeability, especially one resistant to freezing and thawing. A concrete with low permeability resists ingress of water and is not as susceptible to freezing and thawing. Water enters pores in the cement paste and even in the aggregate.

Take the already prepared sample for testing and clean it well. Then note down the weight of the sample as W1. After taking the initial weight, take the water tank that filled with water and place the sample in it in such a way that sample is fully submerged in water for 24 hours. After 24 hours take out the sample from water container and clean it's exterior surface with towel and again note the weight as W2 which is higher than w1.

Now the Absorption of water can be calculated from this relation:

$$\text{Water absorption} = \frac{w2-w1}{w1}$$

Figure 3-12 Water Absorption Test

3.8.4 Weather effect on paver sample

The main objective of this test is to check the sustainability against the weather because almost all pavers installation in an area that is directly exposed to the open area and area where light traffic can move so through this test we can predict the weather effect on plastic pavers bricks.

First take the sample of plastic paver and clean it properly. Then note down the weight of the sample and take pictures of the samples. Next is Place the sample in an open area where rays of sun and rainwater directly fall without any hurdle. Specify the time of checking and testing and take the sample for testing according to the specified period. Again note the weight of the sample and check the water absorption if rain was fallen during that period. Deeply check the environmental effect on the color of the brick. Investigate the effect by taking weight and physical observation.

3.8.5 Temperature effect on plastic paver

Temperature is one of the most important points in the case of using plastic in any kind of material or product. The main object of this test is to investigate the temperature effect on the plastic paver.

First take the sample of plastic paver and clean it properly. Then note down the weight of the sample and place the sample in the oven (make sure the oven maintains a temperature of 100°c) for 24 hours. After this period take out the sample from the oven and again note the weight of the sample. Check the effect of the sample by calculation.

Figure 3-13 Samples Placed in Oven

3.8.6 Acid Dip test on paver block

The main objective of this test is to check the reactions of the Sulfuric acid with the pavers. As Sulfuric acid is a strong acid and it reacts with concrete. When sulfuric acid comes into contact with concrete, it reacts with the calcium hydroxide ($Ca(OH)_2$) present in the cement paste. This reaction produces calcium sulfate ($CaSO_4$) and water. The formation of calcium sulfate leads to the loss of calcium hydroxide, a necessary compound for the strength and stability of the concrete. This test is performed to check the results of the Sulfuric acid with plastic made paver.

Take a Plastic Tub and add distilled water in it. Add 5 percent Sulfuric acid in it to the weight of water. Now mix it and place the samples in it and make sure that all the samples are completely dipped in it. Leave the samples dipped in it for 24 hours and after 24 hours take the samples out from the tub and then take weight of these samples. Now carefully observe the samples and note the changes takes place on the surface of samples

Figure 3-14 Acid Dip Test

Chapter 4

RESULTS AND DISCUSSIONS

4.1 MATERIAL PROPERTIES FOR FINE AGGREGATES

The results of the test performed on sand are given below.

4.1.1 Fineness Modulus Test

Table 4-1 shows the results of fineness modulus test. The fineness modulus of sand should be within the range of 2.3 to 3.1 according to **ASTM C 117-05.**

Table 4-1 Fineness Modulus of Fine Aggregate

Sieve Size (BS)	Sieve Size (mm)	Weight Retained (g)	Percentage Weight Retained (%)	Cumulative Percentage Retained (%)
No. 4	4.75	0	0	0
No. 8	2.36	0	0	0
No. 16	1.18	40	2	2
No. 30	0.6	668	33.4	35.4
No. 50	0.3	591	29.55	64.95
No. 100	0.15	493	24.65	89.6
Pan	-	206	10.3	99.9
Sum				291.85

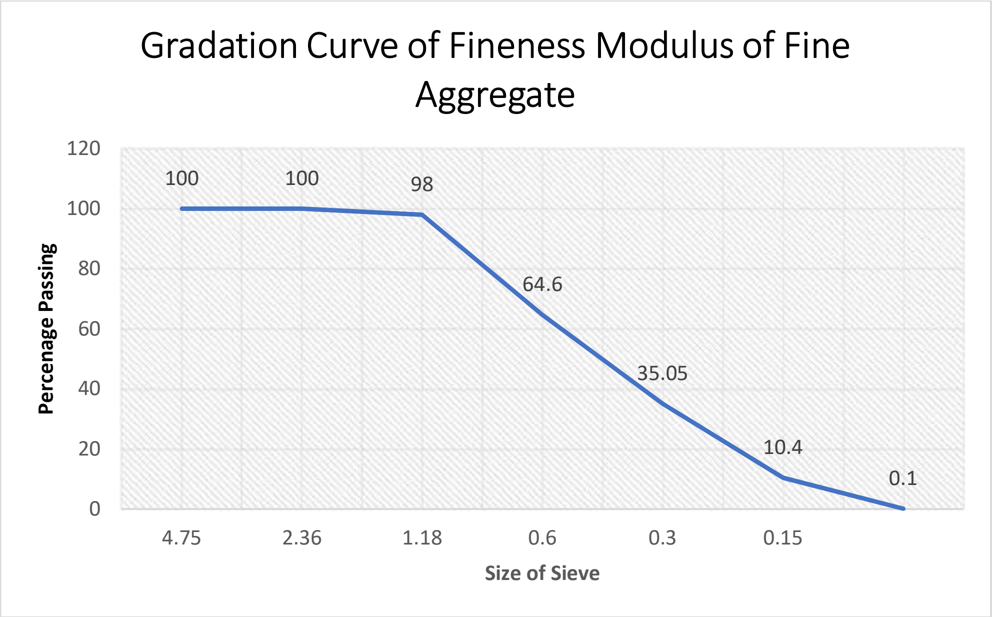


Figure 4-1 Fineness Modulus of FA

$\frac{291.85}{100}$ = 2.9185. The Fineness modulus of Fine aggregate is 2.918. This sand has fineness modulus results are within the range of the standard code. Its means that our sand is well graded. The graph shows that the size of this sand is mostly below the 1.18 mm, and the maximum weight retained are, between the 1.18 mm up to 0.15 mm.

4.1.2 Specific Gravity and Water Absorption of Fine Aggregate

The test results of Specific gravity and water absorption of fine aggregates are given below at Table 4-2. The specific Gravity of fine aggregate should be within the range of 2 – 3 according to **ASTM C128.**

Table 4-2 Specific Gravity and Water Absorption Test of Fine aggregate

pycnometer + Sample Weight	**Pycnometer + Weight**	**Weight**	**Weight**	**Specific Gravity**	**Apparent Specific Gravity**	**Specific Gravity SSD**	**Water Absorption**
		SSD	**OD**	**OD**			
C	B	S	A	A/(B+S-C)	A/(B+A-C)	S/(B+S-C)	(S-A/A)*100
2076	1690	600	589	2.75	2.90	2.80	1.87%

The Specific Gravity of Sand is 2.80 and Water Absorption is 1.87%. As the Specific gravity is 2.80 which is within the range of 2 to 3. So, our sand is well graded and able to use.

4.1.3 Silt Content test

The results of silt content test are given at Table 4-3. There should be 3 – 4% of silt and clay particles present in the fine aggregates.

Table 4-3 Silt Content test of Fine Aggregate

Total Weight	2000 g
Weight Passed from #200	75.5 g
Silt Content in Sand	3.78%

The Silt Content test is performed with the Fineness modulus test. There is 3.78% Silt content in Sand. By performing this test, it is observed that the silt present in sand is 3.78 percent which is acceptable for the use in the construction

4.1.4 The density of Fine Aggregate

Results of density of Fine aggregates are given at Table 4.4. The range of density of sand is 1.52 to 1.68 g/cm^3 according to the **ASTM C 29**.

Table 4-4 Density of Fine Aggregate

Diameter of Density Mould (cm)	-	16
Height of Density Mould (cm)	-	24.55
The volume of Density Mould (cm^3)	V_c	4933.52
Weight of Density Mould (gm)	W1	4476
Weight of Loose Aggregate in Mould (gm)	W2	11295
Weight of Compacted Aggregate in Mould (gm)	W3	12245
Loose Bulk Density (g/cm^3)	$W2-W1/V_c$	1.39
Compacted Bulk Density (g/cm^3)	$W3-W1/V_c$	1.58

This sand has a density of 1.58 g/cm^3 which is in the range of standard. As the density of our aggregate is within the range so it is fit for use.

4.2 Test Results of Coarse Aggregate

Different tests are performed at coarse aggregates to check the properties. These tests are performed according to the ASTM standards. Results of these tests are given below.

4.2.1 Fineness Modulus of Coarse Aggregates

Results of fineness modulus of coarse aggregates are given at Table 4-5. The size of aggregate used was less than 10 mm. which is also called as pan crush.

Table 4-5 Fineness Modulus of Coarse Aggregates

Sieve Size (BS)	Sieve Size (mm)	Weight Retained (g)	Percentage Weight Retained (%)	Cumulative Percentage Retained (%)
3 Inch	75	0	0	0
1.5 Inch	37.5	0	0	0
1 Inch	25	0	0	0
¾ Inch	19	0	0	0
½ Inch	12.5	0	0	0
3/8 Inch	9.5	3	0.15	0.15
#4	4.75	339	16.95	17.1
#8	2.38	1237	61.85	78.95
	Pan	402	20.1	99.05
		1981	99.05	195.25

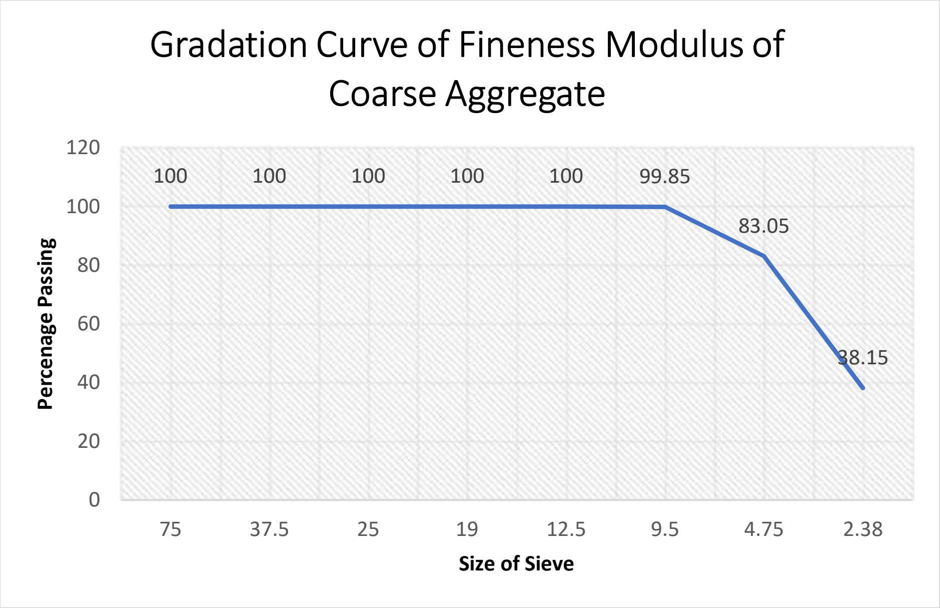


Figure 4-2 Fineness Modulus of CA

The Fineness Modulus of Coarse aggregates is $\frac{195.2}{100} = 1.95$. Size of aggregates that we used was 10 mm pass. Which have all the particle size less than 10 mm and greater than 4.75 mm. that's why the results of fineness modulus of coarse aggregate are 1.95. this size is selected due to the size of pavers and the properties required for the casting.

4.2.2 Specific Gravity and Water Absorption of Coarse Aggregates

The test results of Specific gravity and water absorption of coarse aggregates are given below at Table 4-6. The specific Gravity of fine aggregate should be within the range of 2.5 to 3 according to **ASTM C127-4.**

Table 4-6 Specific Gravity and Water Absorption of Coarse Aggregates

Oven Dry Weight of Aggregates (gm)	1963
SSD Weight of Aggregates (gm)	2064
Weight of Aggregate in Water (gm)	1387
Specific Gravity	2.90
Water Absorption %	4.89%

The specific gravity of our sample is 2.90. which is within the range of standard Aggregate absorbs 4.89 percent of water. Aggregates was almost in dry condition and that's why it absorbs extra water than normal conditions.

4.2.3 The density of Coarse Aggregate

Results of density of Fine aggregates are given at Table 4.4. The range of density of sand is 1.45 to 2.082 g/cm^3 according to the **ASTM C 29-C29M**.

Table 4-7 Density of Coarse Aggregates

Diameter of Density Mould (cm)	-	16
Height of Density Mould (cm)	-	24.55
Volume of Density Mould (cm$^{\wedge 3}$)	Vc	4933.52
Weight of Density Mould (gm)	W1	4476
Weight of Loose Aggregate in Mould (gm)	W2	11389
Weight of Compacted Aggregate in Mould (gm)	W3	12589
Loose Bulk Density (g/cm^3)	W2-W1//Vc	1.41
Compacted Bulk Density (g/cm^3)	W3-W1/Vc	1.65

As the Density of Coarse Aggregate is 1.65 g/cm^3. The density of coarse aggregate is well and good for working. Density is mainly depending on the weight of the sample, so it should be in the standard range for proper use.

4.3 SPECIMENS TESTING RESULTS

The results of all the tests performed on plastic-made pavers are given below

4.3.1 7 Days Compressive Strength Test

Table 4-8 shows the results of compressive strength after 7 days

Table 4-8 7 Days Compressive Strength Test

Ratio	Sample No	% Replacement of Cement	Strength on 7 Days (MPa)	Average Strength of 7 Days
1:0.5:0.75	1	100%	26.33	26.56
1:0.5:0.75	2	100%	25.48	
1:0.5:0.75	3	100%	27.87	
1:0.75:1.0	1	100%	46.40	43.40
1:0.75:1.0	2	100%	43.99	
1:0.75:1.0	3	100%	39.80	
1.0 1.0 1.25	1	100%	36.63	35.65
1.0 1.0 1.25	2	100%	36.60	
1.0 1.0 1.25	3	100%	33.73	
42 MPa Concrete	1	0%	25.20	26.4
42 MPa Concrete	2	0%	26.60	
42 MPa Concrete	3	0%	27.40	

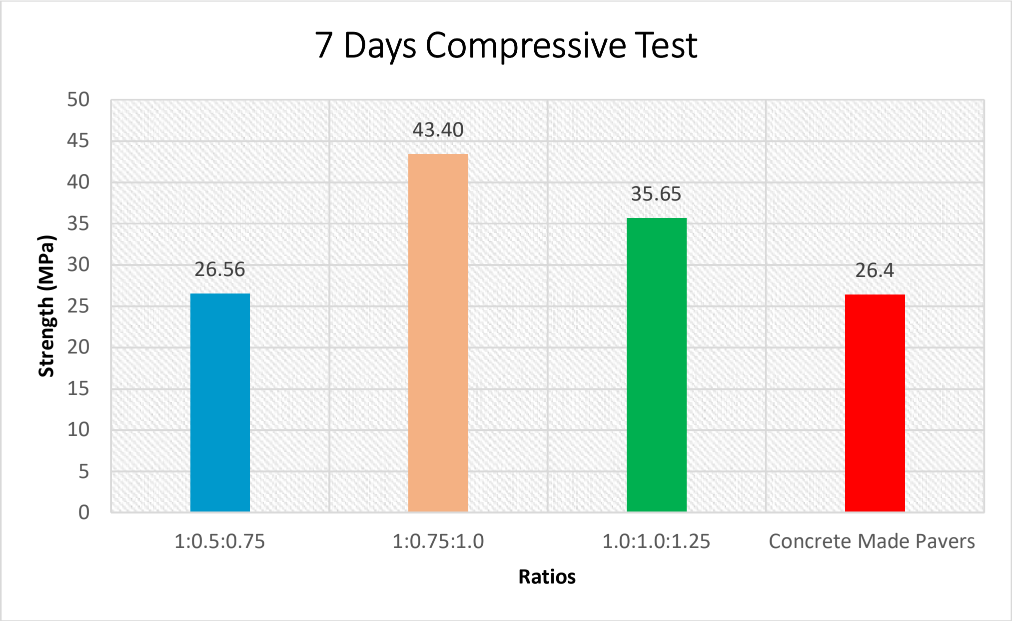


Figure 4-3 7 Days Compressive Strength Test

After 7 days testing, After conducting thorough testing over a span of seven days, we observed that recycled plastic pavers reached their highest level of strength when produced with a specific ratio of 1:0.75:1. Interestingly, these plastic pavers outperformed traditional concrete pavers by achieving 100% of their target strength in just one day, whereas concrete pavers typically take 28 days to reach their full strength. This significant finding underscores the exceptional strength of recycled plastic pavers, positioning them as a strong alternative to traditional concrete in construction. Additionally, it's important to note that our experiments revealed other promising ratios, particularly those within the 1:0.5:0.75 range, as detailed in Table 4-8. This variety of viable ratios highlights the versatility of recycled plastic pavers, providing architects and engineers with more options to tailor their designs for optimal strength and durability.The accompanying graph vividly illustrates the stark difference in strength between recycled plastic pavers and conventional pavers. Specifically, the 1:0.5:0.75 ratio stands out as a noteworthy contender, matching the strength of conventional pavers. This graphical representation serves as a compelling visual demonstration of the superiority of recycled plastic pavers, showcasing their ability to compete with and, in some cases, outperform traditional concrete pavers across various formulation ratios.

4.3.2 14 Days Compressive Test Results

Table 4-9 14 Days Compression Test

Ratio	Sample No	% Replacement of Cement	Strength on 14 Days (MPa)	Average Strength of 14 Days
1:0.5:0.75	1	100%	25.13	25.91
1:0.5:0.75	2	100%	26.59	
1:0.5:0.75	3	100%	26.02	
1:0.75:1.0	1	100%	45.60	42.68
1:0.75:1.0	2	100%	42.81	
1:0.75:1.0	3	100%	39.63	
1.0 1.0 1.25	1	100%	35.67	35.59
1.0 1.0 1.25	2	100%	36.79	
1.0 1.0 1.25	3	100%	34.31	
42 MPa Concrete	1	0%	37.79	37.17
42 MPa Concrete	2	0%	36.9	
42 MPa Concrete	3	0%	37.01	

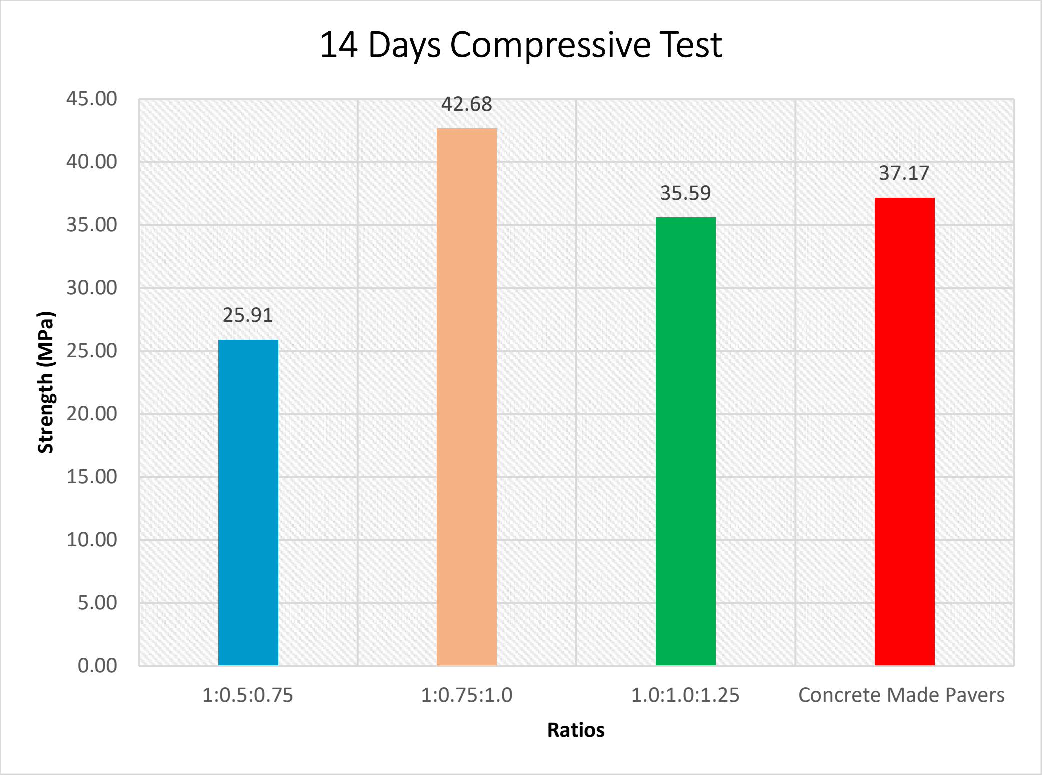


Figure 4-4 14 Days Compressive Strength

During the 14-day testing phase, a notable development emerged. The conventional pavers exhibited a strength level of 98 percent in comparison to their intended target strength. In parallel, the recycled plastic pavers maintained the same level of strength as previously observed. It's worth noting that there was a minor variation attributed to procedural limitations, but this variance was minimal. This finding underscores a crucial point: there is no discernible decrease in the strength of recycled plastic pavers over time. They consistently exhibit the same impressive strength as observed during the initial 7-day testing period. In stark contrast, the conventional pavers still fell short of reaching their full target strength. This discrepancy highlights the resilience and stability of recycled plastic pavers, as they continue to perform consistently, while the conventional counterparts struggle to achieve their desired strength even after the extended testing duration.

4.3.3 28 Days Compressive Test Results

Below are the results of compressive strength after 28 days.

Table 4-10 28 Days Compressive Strength Test

Ratio	**Sample No**	**% Replacement of Cement**	**28 Days Strength**	**Average Strength of 28 Days (Mpa)**
1:0.5:0.75	1	100%	29.22	27.39
1:0.5:0.75	2	100%	28.65	
1:0.5:0.75	3	100%	24.30	
1:0.75:1.0	1	100%	41.58	43.05
1:0.75:1.0	2	100%	43.28	
1:0.75:1.0	3	100%	44.30	
1.0:1.0:1.25	1	100%	32.57	34.64
1.0:1.0:1.25	2	100%	37.86	
1.0:1.0:1.25	3	100%	33.49	
Concrete for 42 MPa	1	0%	40.60	41.30
Concrete for 42 MPa	2	0%	41.40	
Concrete for 42 MPa	3	0%	41.90	

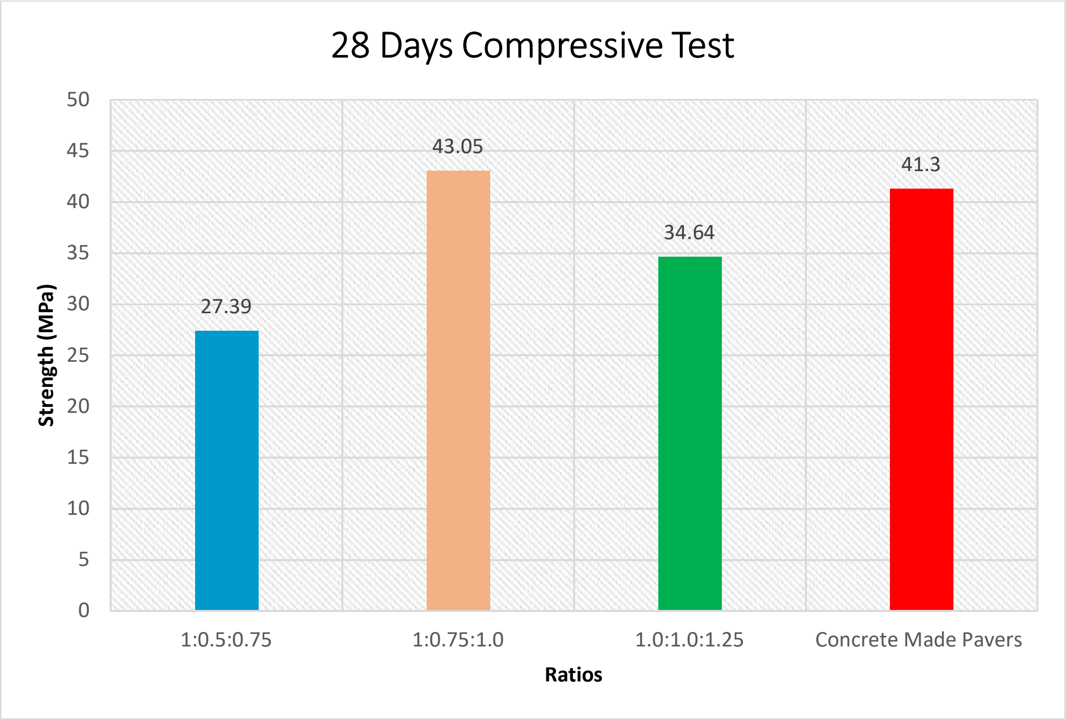
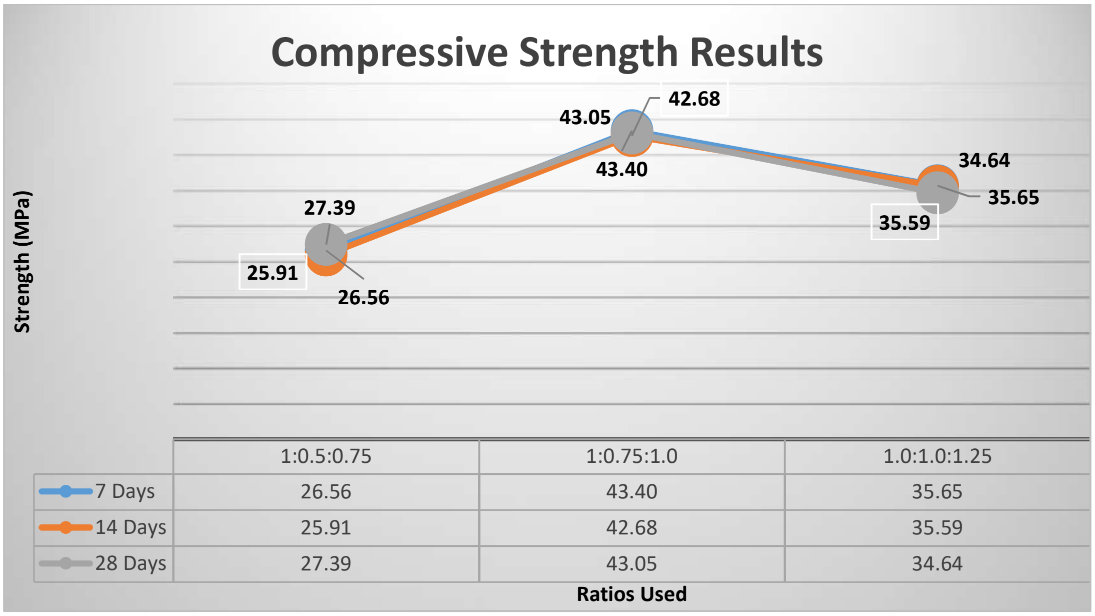


Figure 4-5 28 Days Compressive Strength

Upon reaching the 28-day milestone in our testing regimen, a compelling and consistent trend became evident. The recycled plastic pavers exhibited no discernible change in their strength levels compared to the results obtained at 7 and 14 days. This steadfast performance implies that the strength of recycled plastic pavers remains unaltered over time, cementing their reputation as a remarkably stable and durable construction material. Intriguingly, this mirrors the behavior of conventional concrete samples, which also attained their target strength within the same 28-day period, as corroborated by the data presented in our table. Crucially, when subjected to compression tests, the recycled plastic pavers consistently demonstrated superior strength compared to their conventional counterparts. This compelling outcome strongly suggests that these specific formulation ratios have the potential to serve as viable replacements for traditional pavers in load-bearing structures. The robust performance of recycled plastic pavers, combined with their enduring strength, positions them as a promising alternative for various construction applications, offering both sustainability and strength in equal measure..



	1:0.5:0.75	1:0.75:1.0	1.0:1.0:1.25
7 Days	26.56	43.40	35.65
14 Days	25.91	42.68	35.59
28 Days	27.39	43.05	34.64

Figure 4-6 Combined Compressive Strength Results

As in this graph, it is observed that the strength of 1:0.5:0.75 ratio is less and up to 27 MPa. Which is lower from all of the other ratios. This is due to the more waste plastic in the pavers as compared to the other ratios. When the melted plastic is more as compared to the sand and aggregate, it shows segregation. The sand mixes with the melted plastic but the aggregates settled down during the time of shifting the material in the mold. Due to this the upper side of the paver and the left and right side of pavers are weak due to the lower amount of aggregate present in it.

At second ratio 1:0.75:1. It shows highest strength which is 43 MPa. This strength is achieved due to the accurate amount of material present in it. The amount of plastic and aggregate are same which is the reason that the bonding between the plastic and aggregates are uniform and the strength is highest.

At third ratio 1:1:1.25. this ratio shows lower strength than our optimum ratio and higher results than the first ratio where the plastic is high. This is due to the amount of plastic present in this ratio. The amount of plastic is less than the aggregate which causes the loose bond between the aggregate and plastic. this is due to the higher amount of coarse aggregates as compared to plastic. This shows that if the plastic is lesser than the aggregates, the strength decreases due to the loose bonding.

4.3.4 Split Tensile Test

Below are the results of Tensile strength after 7,14 and 28 days.

Table 4-11 Split Tensile Test on 7, 14 and 28 Days

Ratio	Replacement of Cement	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
1:0.5:0.75	100%	6.21	6.84	4.89
1:0.75:1	100%	6.28	6.21	6.26
1:1:1.25	100%	8.04	11.27	6.26
Concrete Paver	0%	7.00	8.00	9.00

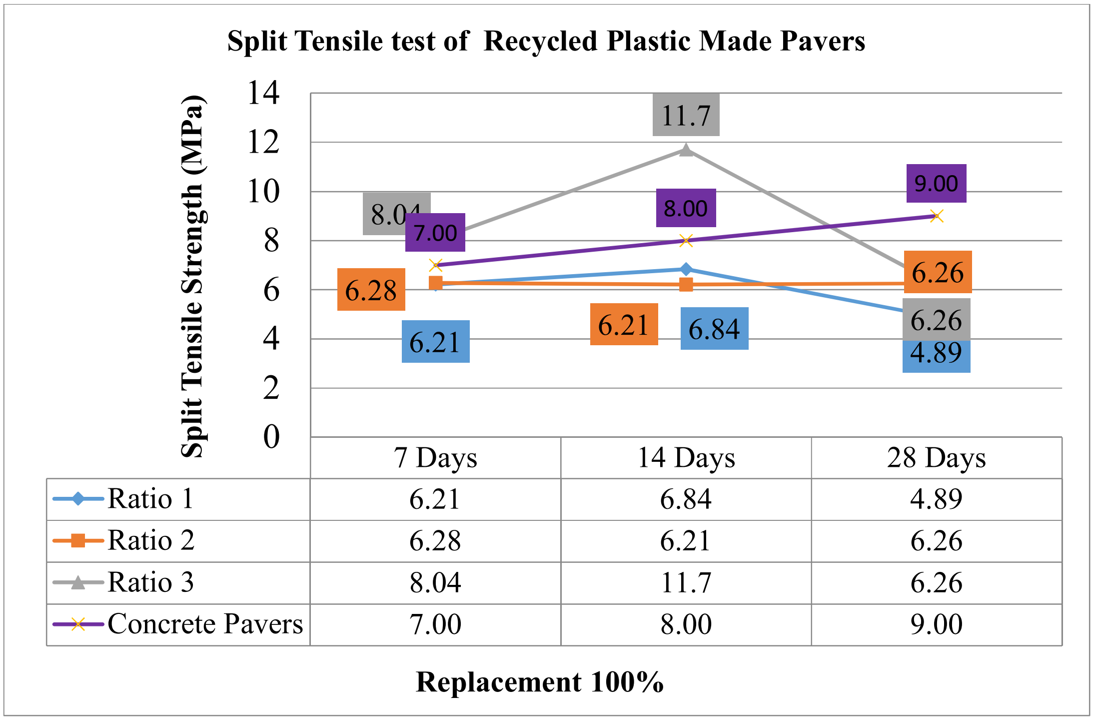


Figure 4-7 Combined Split Tensile Strength Results

In split tensile test the recycled plastic made pavers shows different tensile strength on different ratios. Our main ratio 1:0.75:1 shows average shows 6.2 MPa and remain almost constant for 7, 14 and 28 days. Ratio 1:0.5:0.75 shows average of 6.4 MPa strength at 7 and 14-days testing but it decreases at 28 days testing up to 4.8 MPa. It is due to the limitations of the casting, which tell us that if the sample remains more time in oven, the bonds of plastic starts breaking which results to lose in the bonding between the plastic and aggregate. That's why the strength decreases at the 28 days of that ratio. Ratio 1:1:1.25 shows a different scenario, it shows 8.04 MPa at 7 days testing which increased up to 11.27 MPa at 14 days testing and then decreased to 6.26 MPa at 28 days testing. This shows that if the procedure followed accurately without doing any mistake, we can achieve the strength up to 11.27 MPa. Conventional pavers strength increases from 7 to 9 as shown in table 4-11.

4.3.5 Water Absorption Test

Test Results of water absorption test are given at Table 4-12.

Table 4-12 Water Absorption Test on Pavers

Ratio	Initial Weight (g)	After Weight (g)	Weight Difference (g)	Percentage Difference
1:0.5:0.75	2245	2279	34	1.51%
1:0.5:0.75	2257	2281	24	1.06%
1:0.5:0.75	2290	2319	29	1.27%
1:0.75:1	2411	2447	36	1.49%
1:0.75:1	2481	2512	31	1.25%
1:0.75:1	2476	2511	35	1.41%
1:1:1.25	2524	2562	38	1.51%
1:1:1.25	2450	2489	39	1.59%
1:1:1.25	2502	2546	44	1.76%

Concrete samples	2349	2497	147	6.3%
Concrete samples	2280	2403	123	5.4%
Concrete samples	2402	2543	142	5.9%

Recycled plastic made pavers shows very less water absorption as compared to the conventional pavers. If the water absorption will be low the sample will have good strength. Soo in this test the recycled plastic made pavers show better results as compared to the concrete paver. Our main ratio 1:0.75:1 shows average of 1.39% water absorption, whereas other ratio 1:0.5:0.75 & 1:1:1.25 shows 1.28% and 1.62% of water absorption. This shows that when the amount of aggregates increases the percentage of water absorption increases. The specimen which have maximum amount of plastic shows least water absorption and least amount of plastic's specimen shows maximum water absorption in all of three ratios. But when we compare these absorption results with the conventional pavers we observe that recycled plastic made pavers are much better than the conventional pavers in this test.

4.3.6 Placing Samples in oven at 100 degree

Test Results of temperature test are given at Table 4-13.

Table 4-13 100-degree temperature Effect

Ratio	Initial weight (g)	Final weight (g)	% of Reduction in weight
1:0.5:0.75	2250	2240	0.44
1:0.75:1	2485	2477.5	0.30
1:1:1.25	2455	2442.5	0.51

This test is performed to check the effect of temperature on the samples. Main reason is, these samples are casted after melting in the plastic, so there is a need to check the pavers at high temperature. When these samples are placed in the oven for one day at 100 degree, they reduce their weight very little. Which shows that the moisture present in the sand and aggregates evaporates and a dry sample is obtained. There is no change in the shape and size of the paver. This shows that these pavers are workable at that places where temperature is too high.

4.3.7 Placing Sample for 30 Days at Open Atmosphere

Test Results of atmosphere affect test is given in Table 4-14

Table 4-14 Weather Effect Test

Ratio	Initial weight (g)	1 Day After Rain (g)	7 Days Sunny Days (g)	14 Days Normal Days (g)	28 Days Hot Days (g)
1:0.5:0.75	2294	2305	2294	2294	2294
1:0.75:1.0	2487	2497.5	2482	2482	2482
1:1:1.25	2525	2529	2525	2525	2525

Assessing the impact of weather conditions on recycled plastic pavers when exposed to the open atmosphere was deemed necessary, and a dedicated test was carried out for this purpose. Specimens were deliberately placed in an outdoor setting for a duration of 30 days, during which readings were systematically recorded at specific intervals. Over this period, the specimens were subjected to various weather conditions, including rain and sunny days.

Remarkably, the specimens exhibited remarkable resilience and stability throughout the testing period. There was no discernible alteration in their shape, color, or weight. This remarkable consistency in appearance and weight suggests that these recycled plastic pavers are well-suited for use in outdoor construction projects.

Notably, the specimens maintained the same weight as when initially placed, indicating that any water absorbed during rainy periods subsequently evaporated during sunny days, leading to no net change in overall weight. This observation reinforces the durability and weather-resistant properties of recycled plastic pavers, making them a reliable choice for site applications, even in variable weather conditions. These findings bolster the case for considering recycled plastic pavers as a sustainable and robust choice for outdoor construction projects..

4.3.8 Acid Attack test

Test Results of Acid Attack test is given in Table 4-15

Table 4-15 Acid Dip Test

Ratio	Initial Weight (g)	After Weight (g)	Weight Difference (g)	Percentage Difference
1:0.5:0.75	2205	2235	30	1.27%
1:0.5:0.75	2240	2265	25	1.04%
1:0.5:0.75	2255	2285	30	1.22%
1:0.75:1	2355	2360	5	0.23%
1:0.75:1	2415	2420	5	0.22%
1:0.75:1	2460	2475	15	0.67%
1:1:1.25	2525	2535	10	0.40%
1:1:1.25	2450	2465	15	0.61%
1:1:1.25	2380	2410	30	1.26%

Acid attack test is performed to check reaction of acid with the recycled plastic made pavers. When the specimens are placed in Sulfuric acid for 24 hours, specimen shows following results. Firstly, the increase their weight same as in the water absorption test. Secondly, the ratio 1:0.5:0.75 shows a little color change on its surface and changed in to orange color. This is due to the more plastic in that ratio as compared to the other ratios. Remaining two ratios did not change their color but slightly increased their weight.

4.4 COST ANALYSIS

Cost of everything depends on its raw material. If the raw material's cost is high than the cost of the whole process increases. Cost of concrete made paver and recycled plastic made paver is given below:

Table 4-16 Cost Analysis

Sr. No	Material	Weight	PKR	Total Cost	Strength
4	Recycled Waste Plastic	Ratio 1:0.5:0.75	265	-	26 MPa
5	Recycled Waste Plastic	Ratio 1:0.75:1	220	-	43 MPa
6	Recycled Waste Plastic	Ratio 1:1:1.25	192	-	35 MPa
7	Concrete	M (42 MPa)	42	-	42 MPa

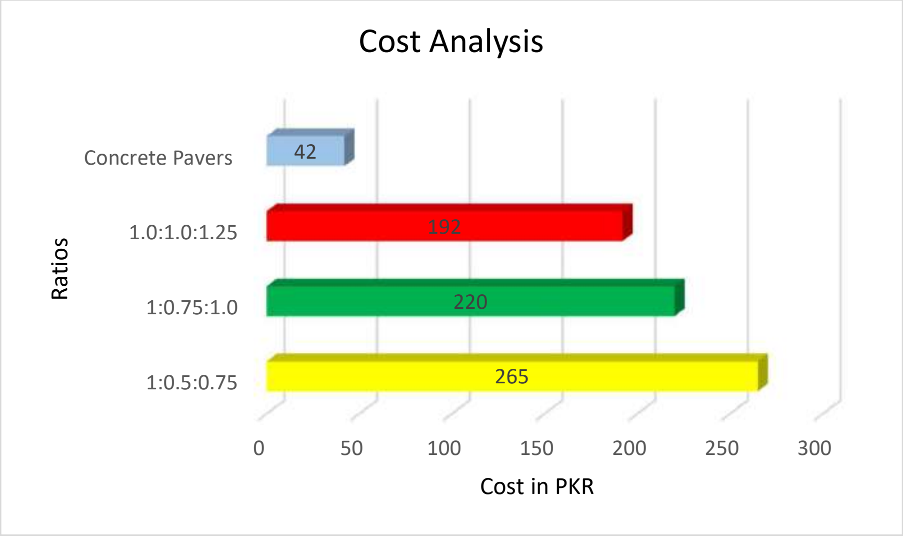


Figure 4-8 Cost Analysis Graph

4.4.1 Concrete Paver

This type of pavers is used normally everywhere and the raw material for these pavers are water, cement, sand and crush. As at most places, water is available. Main cost depends on the cement, sand and aggregates. Normally price of one kg of cement is Pakistan is 42 PKR. But when we produce pavers in bulk form, the overall cost reduces for a single piece of paver.

Nowadays, cost of one single unit of concrete made paver is 42 PKR.

4.4.2 Recycled Plastic made Paver

As we use the wastage of PET plastic. Now the cost of single unit of paver depends on the raw material. If we take the wastage of PET plastic, then cost of this paver is 2 to 3 PKR. But if we take the crushed plastic from a factory which collects the waste plastic and cut it into pieces, then the cost of single unit of this paver rises to 200-265 PKR.

1 kg of Plastic = 200 PKR

1 kg of sand = 4 PKR

1 kg of Aggregate = 5 PKR

Table shows that the maximum price of one paver is 265 rupee, it we purchase the waste plastic from factory. But if this plastic is taken from garbage, the cost reduces to only 12 rupees of single unit of paver.

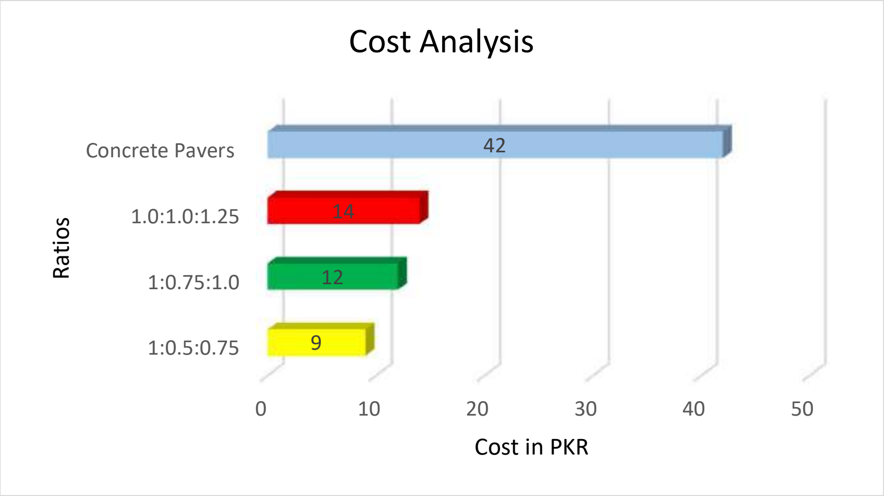


Figure 4-9 Cost Analysis (b)

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

The end results of this research conclude*:*

- The replacement of cement with waste PET plastic is possible.
- The specimens are manufactured by using three ratios and different tests are performed on all of these ratios. The best results that was found on 1:0.75:1.
- At this Ratio the bond between the plastic, sand and crush is uniform, that is why it shows better results rather than others
- Other main concern is to get a comparatively good compressive strength as compared to the concrete made pavers, and got a maximum compressive strength of waste plastic made pavers on the ratio of 1:0.75:1. Which is 46 MPa, but average strength on this ratio is 43 MPa.
- As the remaining ratios also shows good results having 35.1 MPa strength on the ratio of 1:1:1.25, and 26.89 MPa on 1:0.5:0.75.
- As all these specimens are cement less so there is no need for curing. After pouring the material in the mold, sample took approximately 10-15 minutes to cool down and after that it is ready to use.
- Water Absorption is lower than the concrete made pavers so it is also a good property of plastic made pavers.
- Overall, it is concluded that mechanical properties of recycled plastic made pavers are better as compared to the conventional pavers.
- Cost analysis shows that these pavers are comparatively higher in price up to 84% as compared to the concrete made pavers. This cost can be reduced by collecting the waste plastic from the garbage and then use it in samples. As according to this way, the cost will be reduced, and then the conventional pavers have 65% extra cost as compared to recycled plastic made pavers

- For Ratio 1:0.5:0.75, these plastic recycled pavers can be used at different locations where there is no heavy traffic load like pedestrian, ways, footpaths, parks and at that area where the required compressive strength is up to 25 MPa.
- For Ratio 1:0.75:1, these plastic recycled pavers show highest results, which means these can be used as a load bearing pavers which are used at the streets and roads and other areas for load bearing structure. At this ratio kerb stones are also be used and may be replaced with the concrete made stones.
- For Ratio 1:1:1.25, these specimens can be used at that area where the strength required up to 35 MPa.
- To give them a better look we may add different kind of colors in it and make different kind of shapes according to the mold shape.

5.2 RECOMMENDATIONS

As all the ratios shows different results so according to their results, recommendations are

More test should be performed on the recycled plastic pavers which include:

- Additional durability tests to comprehensively evaluate the long-term performance of recycled plastic pavers in various environmental conditions.
- Further research should explore a broader range of formulation ratios to optimize the strength and suitability of recycled plastic pavers for diverse construction applications.

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