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Production of Hollow Block Using Waste Plastic and Sand

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Abstract: In building construction, hollow concrete block (HCB) is a versatile material used in the construction industry, consisting of a mixture of cement, sand, and optionally fine aggregates with water. The cost of these materials, which make up the concrete block, is expensive. So we should use a renewable natural resource that causes negative impacts on the environment. Plastics are one of the materials present in our everyday lives, which have many chemical and hazardous substances that affect human health and the surrounding environment. This study aims to produce hollow blocks using waste plastic material in the ratio of 1:2, 1:3, 1:4, and 1:5 of hollow block size 40cm X 20cm X 10cm of different Polyethylene Terephthalate (PET) and High-Density Polyethylene (HDPE) waste plastic and sand content. This research discussed the material used, the methodology was followed, and the production of hollow blocks and Quality control test of prepared material samples compared with the standard material specification. In this research work, many characteristics that have relevance to the production of Hollow blocks were considered. The plastic is shredded, washed, dried, and melted within the range of 257-315°C temperature in open-air. After melting of PET and HDPE into liquid-state, fixing the sand materials' proportion, mixing the sand materials fed into the mold, and testing the samples after 48 hours was conducted. The test results notice that properties of two samples produced from hollow block satisfy the class-B based on Ethiopian Building Code Standard requirements. The test result for the 1:2 ratio having 3.87Mpa. Therefore, the hollow block production has high compressive strength and low water absorption, which fulfills the standard requirement comparing with the surface property of HCB and aesthetics. The rough surface of HB creates bondage with mortar, which is easier for plastering purpose.

Keywords: Plastic Waste, Hollow Block, Polyethylene Properties, Plastic, Sand

1. Introduction

A hollow concrete block is one of the most common masonry units in construction and engineers have worked to ensure concrete responds to new requirements related to environment protection [19]. It consists of hardened cement and may be completely solid or contain single or multiple hollows. It is made from conventional cement mixes and various types of aggregates. These include: sand, gravel, crushed stone, expanded shale or clay, volcanic ciders, scoria, pumice, etc. Various types of blocks are manufactured to be used for wall construction.

Concrete masonry unit or concrete block is an important and common member in building construction in Ethiopia. Usage of plastic water bottles are increasing rapidly in Ethiopia and this country is facing the challenge of overflowing of landfills and impacts of disposal of plastic water bottles.

This research intends to study the possibility of using recycled plastic water bottles and sand for the purpose of building construction with the focus of verifying the compressive strength. Hollow concrete block is a significant kind of masonry units existing for the builders and its application for masonry construction is increasing continuously [8]. Hollow concrete blocks may be used, as alternatives to bricks and traditional stones in construction and buildings. Due to its smaller weight and ease of transfer compared to bricks. Moreover it provides an advantage of uniform quality as well as speeding in construction and the largest durability. On one hand economically, they are less expensive, and consume less cement and less involvement of laborers. In addition, they can be used, in different places. Such as the interior walls, exterior walls bearing, and columns, the compound walls, and retaining walls etc. [10] several researches completed particularly to study the compressive behavior of concrete blocks mixed with other materials.

Thus, many researchers and scientists worldwide find new ways to reduce these wastes or as a better alternative to use them as resources with added values. In the past several decades, various industrial wastes are being studied extensively as a substitute replacement material for binding agent, fine and coarse aggregate. Substitution of alternative materials in concrete has been found to improve mechanical and durability properties, and this practice can lead to sustainable concrete development. It is characteristically sub angular to round in shape and has high thermal conductivity, making it suitable for molding and casting operations. Molding sands are recycled and reused multiple times during the casting process. It has been successfully used as a landfilling material for many years, but landfilling is also becoming a problem due to rising disposal costs.

The demand for new construction is ever increasing with the rise in population. Hence the need for the non-renewable binding agent (cement) has become a challenge. The future seems to be in the dark for the construction sector.

Architects around the world are using plastic as a way to build low income and sustainable informal settlements in developing countries. A German national Andreas Froese invented the technique that involves disposable PET bottles, debris, and earth as raw material for construction. PET bottles are filled with sand or soil or landfill dirt or mud and are used as bricks or blocks to construct houses. The technology has been adopted in different countries, including Nigeria, South Africa, the Philippines, and India. Thanks to this technique, more than 300,000 PET bottles have been reused in more than 50 construction projects in Honduras, Columbia, Bolivia [2].

Plastic as a binding material and aggregates will not be crushed easily since plastic are polymers made up of long string molecules consisting of carbon atoms bonded with other atoms such as hydrogen, nitrogen, oxygen, fluorine. They develop a crystalline structure that is strong, hard, and more resistant to chemical penetration and degradation. Hence it will be a boon to the construction industry if plastic can be utilized as a binding agent, like cement [9].

Plastics are one of the materials present in our everyday life; we used them for various purposes due to their inexpensive, lightweight, and durability. But these materials have many chemical and hazardous substances that affect human health like caners, lugs problems, irritation in the eye, etc. and it also serious-environment effects like pollution of air, water, and soil [11]. With this problem, our use of plastic can increase day by day.

Currently, in our country Ethiopia many governmental and private factories which fabricate a large number of plastic materials; there is sixty-three water factory available in the market that produces dozen of bottled water, packing plastic, plastic bags, plastic dish, plastic bucket and simultaneously the number of oil holding hard plastic are used in day to day activity of human life. According to the Olumuyiwa study, 67,235 tons of plastics have been imported annually by Ethiopia [5]. From this, 40.58% or 27,283.8 tone was polyethylene and the related. Improper removal of these plastic wastes results in spoils soils, plants, blocks waterways, and choking or killing animals when being fed. Generally, plastic waste has already become a serious environmental problem in Ethiopia.

In Jimma town, the production process of hollow block started preparing the HB materials from the quarry, tempering, molding, drying, and end firing. Among these processes, firing is the most important for the hardening of the brick. Locally produced, fired clay bricks have a firing stage, which gives the brick's strength using heat from the woods' burning. But this hurts the environmental condition due to the high deforestation of trees. If timbers are used as fuel, excess consumption often contributes to deforestation and associated environmental impacts [4]. The main objective of this study is to produce hollow blocks using waste plastic and sand.

2. Literature Review

2.1. General Review on Waste Recycling

Recycling is the process of converting waste materials into new materials and objects. The recyclability of a material depends on its ability to reacquire its properties in its virgin or original state. It is an alternative to conventional waste disposal that can save material and help lower greenhouse gas emissions. Recycling can prevent the waste of potentially useful materials and reduce the consumption of fresh raw material, thereby reducing; energy usage, air pollution (to incineration), and water pollution (from landfill).

Recycling is a key component of modern waste reduction and is the third component of the “reduce, reuse, and recycle” (waste hierarchy). Thus, recycling aims for environmental sustainability by substituting raw material input to redirecting waste outputs out of the economic system. Some ISO standards related to recycling, such as ISO 15270:2008 for plastics waste and ISO 14001:2015 for environmental management control of recycling practice.

Recyclable materials include glass, paper, cardboard, metal, plastics, tires, textures, and electronics. Composting or other reuse of biodegradable waste – such as food or garden waste is also a recycling form. Recycling has been a common practice for most human history, with recorded advocates as far back as Plato in the fourth century BC.

There is evidence of scrap bronze and other metals being collected in Ethiopia and melted down for continuous reuse in pre-industrial times [1]. Paper recycling was first recorded in 1031 when Japanese shops sold the re-pulped paper. In Britain, dust and ash from wood and coal tiers were collected by “dustmen” and down cycled as a base material used in brick making. The main driver for these recycling types was the economic advantage of obtaining recycled feedstock instead of acquiring virgin material and the lack of public waste removes in ever more densely populated areas. One 2016 study found that 32% of plastic packaging ends up in our oceans every year.

Table 1. *Energy saving or recycling.*

Materials	Energy savings Versus new production
Aluminium	95%
Cardboard	24%
Glass	5-30%
Paper	40%
Plastic	70%
Steel	60%

2.2. Why Is It Important to Recycle

The three golden rules of sustainability we were taught as kids are Reduce, Reuse, and Recycle. But for some reason, "recycle" was the one most highlighted. As we learn more and more about going green, it is becoming clearer that recycling is the least important of those three totems. Sure, recycling is important, but if we reduce that we were using and reused what we were using in place of single-use options, there would be significantly less stuff in the world to recycle, and less stuff is key to not getting too hyperbolic here but saving the planet.

If waste is not recycled, it can negatively impact our environment in many ways. Waste can emit greenhouse gases that contribute to global warming and, therefore, climate change. Non - recycled waste can contribute to air pollution, water pollution and put animal and human lives at risk. Alternatively, if we recycled, we can significantly reduce the amount of pollution our waste creates, according to [2]. Recycling is also crucial because of how waste can impact animal; waste can cause loss of natural habitats and contributes to negative impacts like climate change and global warming. This can also destroy animal's natural habitat. When animals and biological organisms lost their habitats, they can die off or starve.

2.2.1. The Ecological Case for Recycling

Life-cycle analysis can be a useful tool for assessing the potential benefits of the recycling program. Suppose recycled plastics are used to produce goods that would otherwise have been made from new (virgin) polymer. In that case, this will directly reduce oil usage and emission of greenhouse gases associated with virgin polymer production (less the emissions owing to the recycling activities themselves). However, suppose plastics are recycled into products previously made from another material such as wood or concrete. In that case, savings in polymer production requirements will not be realized [12].

It has been estimated that PET bottle recycling gives net benefit in greenhouse gas emissions of 1.5 tons of CO2-e per ton of recycled PET (NSW) and the reduction in landfill and net energy consumption. An average net reduction of 1.45 tons of CO_2-^{e} per ton of recycled plastic has been estimated as a useful guideline to policy [18]. Life-cycle analyses have also been used for the plastic-recycling system to evaluate the net environmental impacts (Arena et al.; Perugino et al.). These find greater positive ecological benefits for mechanical recycling over landfill and incineration with energy recovery.

2.2.2. Economic Issue Related to Recycling

When we consider the whole life costs of products made from recycled plastic, the benefits become obvious. Case studies show that recycled plastic products are a smart, cost-effective investment over the long-term due to their durability and longevity. For example, plastic fencing does not require treating or painting, saving on project costs in the building stage. Besides, recycled plastic products do not rot and require minimal maintenance.

Developing the habit of buying only what you need and reusing products rather than purchasing a new one saves a lot on budget. In most states in America, it is the cost to dispose of wastes than to recycle. Some recycling companies buy waste from neighborhoods for their recycling activities. This brings you an extra income that you can channel into your budget.

2.2.3. Improve Performance

Recycled plastic produces strong and versatile products suitable for a wide range of construction applications. One of the main advantages of plastic is its high strength to weight ratio. Plastic products are generally light and can help alleviate manual handling issues and ease compliance with Health and Safety regulations.

A good example of this is recycled plastic curbstones. These products are available in a full range of curb components, all of which are lightweight, which means that the parts can be placed manually rather than requiring mechanical handling. At the same time, these products retain the necessary impact, strength, and corrosion resistance (BSEN1433 standard).

2.2.4. How Recycling Benefits the Environment Saves Yards of Landfill Space

Waste is disposed of in the landfill, which causes some environmental problems for future generations. Not all the solid waste that is dumped in landfills is biodegradable. Even waste that takes a long time to decompose will cause environmental problems. It can emit greenhouse gases or toxic substances that are harmful to the environment and the people working around landfills. Choosing to recycle materials like paper, aluminum cans, cardboard, scrap metal, plastic, etc., means you are keeping them away from landfills.

When you dump waste in landfills, it will start emitting greenhouse gases when it begins to rot. You would be familiar with a foul smell that is usually found near landfills. These greenhouse gases pollute the environment and attract insects, flies, and bugs. When you recycle the waste instead of sending it to the landfills, you directly reduce pollution. Further, recycling various products leads to fewer carbon emissions, reducing the carbon footprint of that product.

2.2.5. How Recycling Benefits the Economy Saves Money

Recycling and using recycled products will help you save money. For example, you can recycle vegetable and fruit waste, grass, and leaves to make compost. Additionally, you can sell your recyclable waste to recycling companies. This means recycling can put some money in your pockets when you don't opt to dispose of it.

(i). Creates Jobs

Recycling creates several job opportunities in any community. Some people can find jobs in the recycling sector and places where recycled products and recycling-related materials are produced. This sector is ripe with work opportunities for middle-class people and those with limited education. Jobs in recycling are also known as green jobs due to the positive impact on the environment. Green jobs are essential for our economy and have an equally significant hand in making our planet a better place to live in.

The Role of Recycling Businesses in Opening New employment opportunities [3]. The recycling industry has grown quickly in recent decades, and this boom has translated into social, environmental, and economic benefits for society. One of these is the creation of jobs in the recycling industry and recycling self-employment opportunities. There are also several training options available for those interested in pursuing a career in the recycling industry.

(ii). Recycling Industry Job Statistics

1) According to the REI, the US recycling industry employed 1.25 million people, whereas the US solid waste management industry used only 0.25 million people. The REI study says that "there are more than 56,000 reuse and recycling establishments in the U.S". REI also states that, on average, the recycling industry pays higher average wages than the solid waste management industry.
2) Another report stated that wider government focus on the recycling industry could create 10,000 new jobs in the UK by 2020.
3) A study by "Friends of the Earth" said that over 51,000 recycling jobs could be created in the UK if 70% of collected waste was recycled. If industrial and commercial waste were recycled simultaneously, another 18,800 additional jobs would be created. The study suggested that the government must be ambitious in setting yearly recycling rates. Sufficient actions to stop producing and selling products that can't be reused and recycled can take the recycling rate to 75% by 2025.
4) On an EU level, if a goal of 70% recycling of the main recyclable materials was met, estimates suggest that up to 322,000 direct recycling jobs could be created in the 27 EU countries. EU countries would recycle an extra 115 million tons of textiles in the process, including wood, ferrous and non-ferrous metals, plastic, paper, bio-waste, and glasses. Recycling this amount of wastes and material could create another 160,900 indirect and 80,400 induced jobs. Therefore, the total potential is more than 563,000 net new jobs.

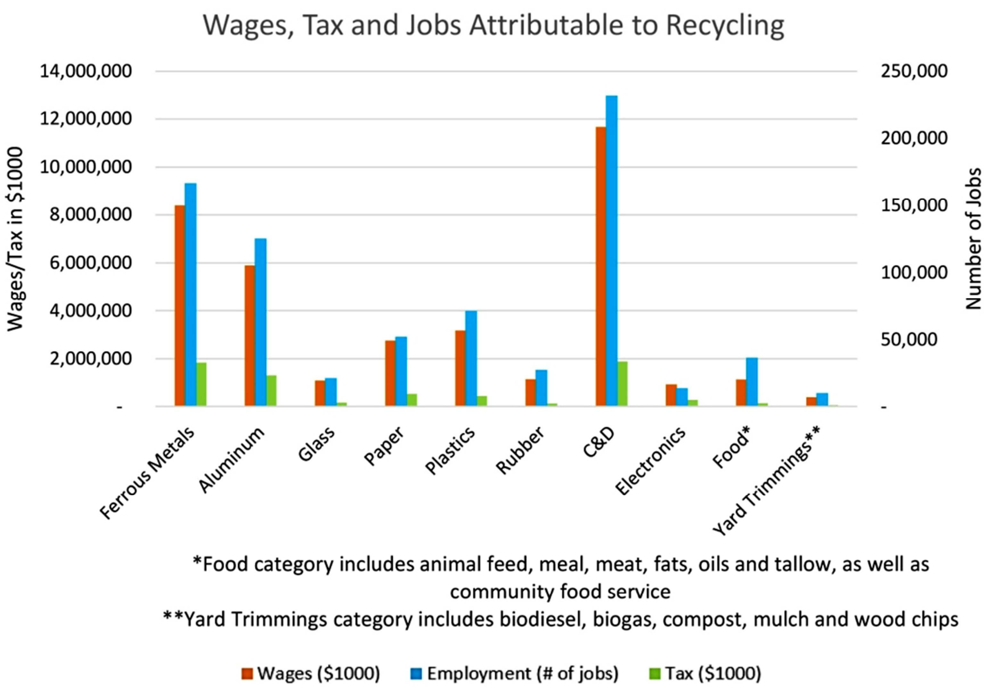

Figure 1. *Recycling Industry Job Statistics.*

2.3. Identification and Classification of Plastic Materials

Plastics are also called polymers. Plastic materials can be classified into different categories. According to their chemical structure and temperature behavior, plastics can be divided into thermoplastic and thermosetting plastics.

Families of Polymers

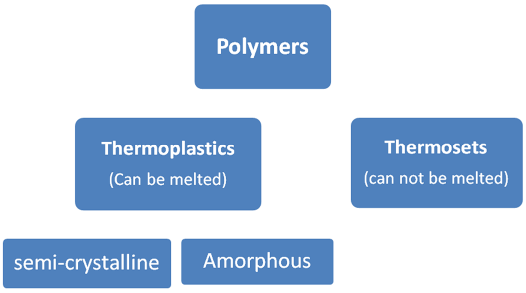

Figure 2. *Polymers families.*

2.3.1. Thermoplastic Materials

These plastic materials' properties do not change considerably if they are melted and then cooled and solidified. They can be repeatedly melted or dissolved in various solvents. They are more elastic, less brittle, and do not lose elasticity when subjected to prolonged heating. They are less apt to age thermally. They can be remolded again and again in any shape after heating. Many of them possess extraordinarily high insulating properties and are water repellent. They are polymers of linear structure, i.e., their molecules are elongated and are thread-like. This, type of structure is fusible, soluble, highly plastic, capable of forming thin, flexible threads and films.

Properties of Thermoplastic material:

1) By heating the polymer, it turns into a soft material.
2) It is available in the form of solid at room temperature.
3) It is a recyclable process.
4) It can be converted into liquid form by heating, and Vice-versa also takes place in another direction.
5) Loses strength by heating and also gains strength by the action of cooling.
6) Temperature; the servicing temperature is 150°C.

Thermoplastic Examples:

1) Polyethylene
2) Poly Vinyl Chloride (PVC)
3) Teflon

Thermosetting Plastic Materials

They undergo great changes when subjected to high temperatures for quite some time. They are said to be baked and no longer can melt or be dissolved. They are less elastic, more brittle, and lose their elasticity when subjected to prolonged heating. So they cannot be remolded in different shapes once they are set and hardened. When insulated, they can withstand high temperatures without melting or losing their shape and mechanical strength. Thermosetting plastic substances are space-polymers, and the molecules branch off in various directions during polymerization. This structure makes them very rigid, poorly soluble, fusible, and incapable of forming elastic threads and films.

Properties of thermosetting plastic material:-

1) By heating the polymer, it turns a hard material.
2) It is a Non-Recyclable process.
3) The liquid is converted into solid, which is done by heating, and its Vice-versa is not possible.
4) Gain strength by the action of heating.
5) No change in the strength by the action of cooling.
6) Temperature: the servicing temperature is 300°C.

Thermosetting plastic Examples:

1) Epoxy Resin
2) Phenolic (Bakelite)
3) Vinyl Easter Resin
4) Cyan ate Ester
5) Poly Ester

2.3.2. Types of Plastic

The world is full of plastics. Whether you realize it or not, practically everything you see and use daily is entirely or partly plastic material. Your television, computer, car, house, refrigerator, and many other essential products utilize plastic materials to make your life easier and more straightforward. However, all plastics are not created alike. Manufacturers use a variety of different plastic materials and compounds that each possesses unique properties. Below are 7 of the most popular and commonly used plastics:

1) Acrylic or Polymethyl Methacrylate (PMMA)
2) Polycarbonate (PC)
3) Polyethylene (PE)
4) Polypropylene (PP)
5) Polyethylene Terephthalate (PETE or PET)
6) Polyvinyl Chloride (PVC)
7) Acrylonitrile-Butadiene-Styrene (ABS)

2.4. Types of Recycling

Understanding the various types of recycling will help you know what can and cannot be recycled. The recycling industry is more important now than it ever has been. Each year there is a rising need for consumers to recycle items that they discard responsibly. In this guide, we will talk about the three types of recycling and why they are important.

You should first understand that recycling is the recovery or reuse of materials or products that may otherwise be discarded or thrown away. Any time we reuse materials or products rather than throwing them away is considered recycling. Any time you drop off your recyclable goods, they will be recovered and reprocessed to make new products. It keeps them out of landfills.

All recyclables will fall into three main types of recycling:

1) Primary,
2) Secondary and
3) Tertiary.

2.4.1. Primary Recycling

Primary recycling is where a recyclable material or product can be recovered or reused without altering its current state. A lot of primary recyclables will be repurposed for the same use as it was created for. Primary recyclables should not be changed in any way. You may think of these types of recyclables as secondhand use. You may utilize them, donated, or sold. Here are some examples of primary recycling—glassware – dishes, glass jars, etc. Toys – donate to charities, friends, or family Electronics – reuse in another area of your business, sell to recover some cost, or donate.

2.4.2. Secondary Recycling

Secondary Recycling will be repurposed without having to reprocess them. SO, the material may be reused in a different way than it was initially intended. It often happens with DIY crafts and can make a huge difference in ensuring recyclable material stay out of landfills. Here are some secondary recycling examples: Cut egg cartons in half and use them to plant seedlings. Cut off the top half of a plastic bottle to use it as a plant pot—reuse plastic, paper, wood, metals to do any type of DIY project.

2.4.3. Tertiary Recycling

Tertiary recycling involves the chemical altering of the products or material to make it reusable. It may be done internally or externally. If external, the recyclables are recovered and reprocessed through a public facility. It would involve sorting recyclables and placing them in bins to be transported by a reprocessing facility. Internal recycling would be where no public service is concerned. Some factories or manufactures may conduct internal tertiary recycling.

2.5. Ingredients of Hollow Block

Ingredients in hollow blocks are additive material, which makes the hollow block more dense and strong enough. Those ingredient materials have their unique characteristic to join together and create one single block. Different waste recycled plastic materials also have different composition patterns. These ingredients are a different material to materials, depending on which the final combined material properties are needed. The hollow blocks' dimensions are not confined; since plastic can be formed to any shape, a range of shapes and sizes is modified to the customer's need.

2.6. Plastic Waste

Plastics are commonly used substances that play an important role in almost every aspect of our lives and can be made to different shapes when heated. It exists in different forms such as cups, plastic bags, food, and drinking containers, and become waste materials. Diversity of plastic application is related to their specific properties, low density, easy processing, good mechanical properties, good chemical resistance, excellent thermal and electrical insulating properties, and low cost (compared to other materials).

Therefore need for proper disposal and, if possible, use of these wastes in their recycled forms. It can be done through the process of plastic management. Waste management regarding plastic can be done by recycling; if recycled, it will become a major pollutant to the environment.

There are various physical properties of Polyethylene Terephthalate (PET):

1) It is having high chemical resistance and good resistance to UV rays.
2) It is a white cream in color.
3) Its density is 1.38 gr/cm3
4) It is insoluble in water
5) It is resistant to acid, oils, and fats.

Table 2. *Properties of PET plastic.*

Property	Result
Chemical formula	$(C_{10}\ H_8\ O_4)n$
Density (g/cm^3)	1.38 at (20°C)
Melting point	> 150°C,

2.7. Sand

Sand is a granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. Sand can also refer to a textual class of soil or soil type, i.e., soil containing more than 85 percent sand-sized particles by mass. The composition of sand varies, depending on the local rock sources and conditions, but the most common sand in inland continental settings and non-tropical settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz. The second most common type of sand is calcium carbonate. Sand is a non-renewable resource over human timescale, and sand suitable for making concrete is in high demand.

Table 3. *Properties of Sand.*

S. No	Tests	Results
1.	Specific gravity	2.62
2.	Bulk density	1690 kg/m^3
3.	Fineness modulus	2.92

Classification of Sand

Generally, sand can be classified into the following categories from different aspect: -

1) According to the mode of the origin point of view, we can divide it into three subcategories:

a) River sand
b) Pit sand &
c) Marine sand

2) Under the Grain size point of view, we can divide into three subcategories:

a) Coarse sand
b) Medium sand &
c) Fine sand

2.8. Previous Related Studies

Many literature works have been done on the manufacturing of plastic related sustainable building materials. Such as: - mainly eco-brick and so on. Most of the hollow blocks are combined with the help of different materials. Of those works of literature are:

Seltzer et al. concluded that the first bottle house was prepared by William F. Peck’s in Nevada (USA). It was constructed in the year 1902. The house was made with 10,000 beer bottles. It was the first house of its kind; later on, many houses were constructed with bottle bricks.

Aditya Singh Rawat and R. Kansal [14] mentioned that plastic bottle bricks' construction cost is very cheap compared to the baked bricks' construction. They also concluded that the weight of the bottle brick is very less than the baked brick.

V. Srinivasan et al. [15] revealed that plastic consumption is very high globally, and recycling plastic is not helping reduce the problem. Rather, it adds more pollution as the recycling process degrades the plastic. It requires further production, thus leaving the recycled plastic as a waste. He also mentioned that about 70% of the plastic waste is leftover and thus causes the plastic waste disposal problem.

Pratima P. et al. [16] investigated that plastic bottles are cheaper in comparison to blocks. Plastic bottles also provide greater strength than blocks. Due to the non-biodegradable behavior of the plastic, it takes thousands of years to biodegrade. It has led to a drastic increase in water and land pollution due to the plastic's disposing problem.

Nitin Goyal et al. [17] concluded that bottle block houses are non-brittle, bio was climatic, re-useable and easy to build, and light in weight. They also mentioned that making eco-blocks will employ the poor people without causing any harm to them.

Z. Muyenet al. [2] concluded that the bottle bricks are cheaper than the bake bricks. These bricks are having higher strength and low construction cost. They made the cubes made of soil-filled plastic bottles (Eco-brick), and the compressive strength of the cube created with nine bottles was obtained as 35 MPa on the 28th day.

2.8.1. Eco-bricks

An Eco-brick is a plastic bottle packed with used plastic to a set density. They serve as reusable building blocks. Eco-bricks can be used to produce various items, including furniture, garden walls, and other structures [4]. Eco-bricks are produced primarily to manage consumed plastic by sequestering it safely by terminally reducing the packed plastic's net surface area to secure the plastic from degrading toxins and micro plastics effectively.

To enable Eco-brick's production at a minimal environmental cost, the global Eco-brick Alliance promotes low-technology methods that do not require fuel, electricity, or specialized equipment. Typically, producers use a wood or bamboo stick to pack plastic into the plastic bottle [5] manually. Any size of transparent polyethylene Terephthalate (PET) plastic bottle can be used to make an eco-brick.

The plastic in an Eco brick is very durable and will never break down, making it an ideal building material. They are used in developing countries to construct furniture and even buildings, and they are also used in the UK to build children's playgrounds.

In South Africa, there are many sustainable construction projects underway, including outdoor classrooms, community gardens, and a composting toilet. In Guatemala, there are many schools built from the plastic bottle Eco brick.

2.8.2. Plastic Sand Brick

The materials used for the fabrication of the plastic sand bricks are PET bottles and river bed sand. For this, plastic PET bottles are collected and sorted. Generally, the cold drinks bottles are made of PET, and those bottles are used to fabricate the bricks. The PET bottles cannot be used as they are in their usual shape and size; for the use, the bottles need to be cut into smaller pieces of the same size.

Figure 3. *Manufactured Plastic Sand Bricks and mold.*

3. Methodology

3.1. Research Design and Study Area

The study was conducted at Jimma zone, southwestern Ethiopia, located 346km by road southwest of Addis Ababa. Its geographical coordinates are between 7° 13'- 8° 56N latitude and 35°49'-38°38'E longitude with an estimated area of 19,506.24. The town is found in an average altitude area of about 5400 ft. (1780 m) above sea level. It lies in the climatic zone locally known as (Woynā Dagā) which is considered ideal for agriculture and human settlement.

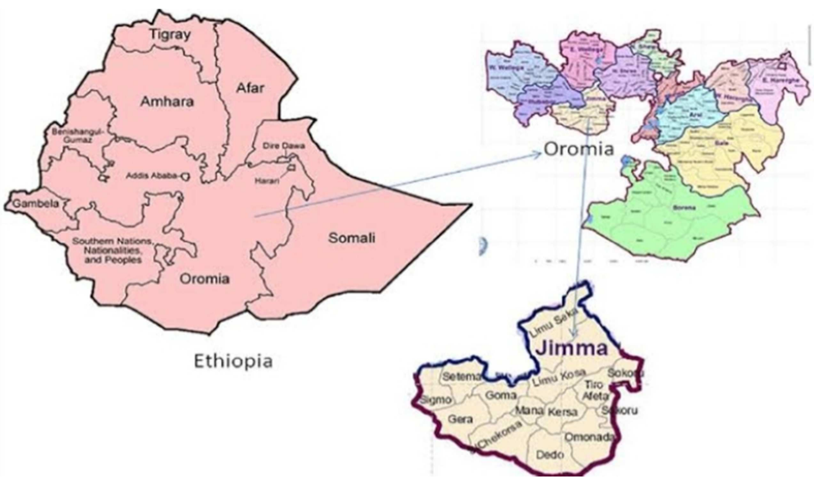

Figure 4. *Ethiopia, Oromia Regional State Jimma zone map.*

3.1.1. Study Period

The study was conducted from October 2020 to January 2021.

The research was started in October 2020 and completed in January 2021 G.C. It was conducted for three months as per the attached work plan, which all works were run according to the timetable.

3.1.2. Research Design

The research design is based on a purposive sampling selection process. A representative sample of both sand and waste plastics materials will be surveyed, and the research will be conducted using both descriptive and analytical methods. It means that the research laboratory's methodology is the analysis of sample data and will be collected from the site. After comprehensively organizing literature reviews of other previous published research, designate the effects of using waste plastics for hollow production blocks. In particular, for sand material, the ASTM & ACI laboratory producer will be conducted.

3.2. Study Variables

The study variables of both dependent and independent were assessed in this research, which shows the property of block by plastic waste.

3.2.1. Dependent Variable

Percentage of waste plastic.

3.2.2. Independent Variable

Mix Ratio, Absorption capacity, Compressive strength, and Cost of production

3.3. Sampling Size

The sampling procedure needs to be conducted to select samples that are representatives of the study. The sampling procedure used in this research was purposive sampling. The sample size was determined according to the test specimen number required to conduct the compressive Strength test for hollow block and meet the study's objectives.

The samples are prepared in a cubic form and hollow block form to easily compare the compressive strength with the ordinary HCB. There is four mixing ratio batch which will be experimented to get the optimum strength. There are three tests for each mixing ratio sample: compressive test, water absorption, and impact test. A total of 12 block specimens were prepared, which were used to determine the highest mechanical strength.

Table 4. *Sample of mix proportion.*

List of Group	Mix-Ratio	Mix proportion for one HB (gr)	Number of samples for the test according to ASTM and ES	
			For Compressive strength	For Absorption
S1	1:2	2842.25: 5684.25	2	2
S2	1:3	2131: 6394.08	2	2
S3	1:4	1705: 6821.2	2	2
S4	1:5	1421.08: 7105.417	2	2

3.4. Data Collection Process

To achieve the research's objective, information was gathered through literature review, compressive strength test on the samples prepared, absorption test, and reviewing the HCB producers' cost data, and analyzing the samples' production costs.

a) Literature review: this part was carried out to have a clear idea and information on the materials used to produce a hollow block and produce it. After conducting a literature review, the production of HB was carried out.

b) Compressive strength and absorption test on the samples: those tests were carried out on the hollow block prepared to compare the compressive strength with ASTM specification.

3.5. Data Processing and Analysis

In processing and analyzing, the gathered data has been tested experimentally and came up with the research output. Compressive strength of HB for each mixing ratio was recorded, and the average result of the HB with various dosages of sand was compared concerning the control. Finally, the analysis results have been presented according to the research objectives, and at the end, a conclusion was formulated, and then the recommendation was forward to the concerned body.

3.5.1. Secondary Data

The study reviewed different published papers related to the full history of HB, plastic, and waste plastic and waste materials for HB production as secondary data. The documents showed the possibility of Plastics being one alternative construction material.

3.5.2. Primary Data

The following points are those Primary data that were important to conduct the study:

1) Collecting plastic wastes for recycling purposes.
2) Produce Sample hollow blocks
3) Laboratory test of Plastic block
4) Visual observation (Laboratory Result)
5) Reporting of test results and analysis

3.6. Materials Used for the Study

The main materials used for the hollow block fabrication are waste plastics (the PET plastic bottles & HDPE plastics) and river bed sand. For the production process, waste plastics are collected and sorted. Generally, the cold drinks bottles are made of PET, and the caps are of HDPE; those bottles are used to fabricate the HB.

The material used for this experimental research is: -

1) Waste plastic (HDPE & PET)
2) Sand

3.6.1. Sources of Materials

a) Sand is a locally available material in the market, but we have used it from the construction laboratory. Natural river sand was used as a fine aggregate. River sand was washed and dried before use in making the plastic and sand composite block. The sieve sizes used for particle size distribution were 2.36, 1.7, 1.4, 1.18 mm, 600, 300, 150, and 75μm; the sand used was retained on 1.4 mm and 1.7 sieves. A shaker machine does the sieve analysis.

b) Plastic materials are found from many different waste sources. And they can be easily collected from many sources since PET and HDPE plastics are everywhere. The waste plastics (HDPE) were collected from the Jimma Institute of Technology student cafeteria, and the PET plastics were collected from streets around the registrar's office and student dormitory.

3.6.2. Instruments and Tools Used in the Study

This research was done using different instruments to produce the HB, from the initial to the product. Almost all of the production process instruments were accessed from the Jimma Institute of Technology (JIT) campus in the construction laboratory. One instrument which is prepared outside of the campus is mold. Those instruments that have been used and applied were described as follows:

1) Mold: - for casting the specimens.
2) Sieve: - for sand size determination.
3) Balance for: - weight the materials used.
4) Mixing tools: - drum.
5) Compressive strength machine

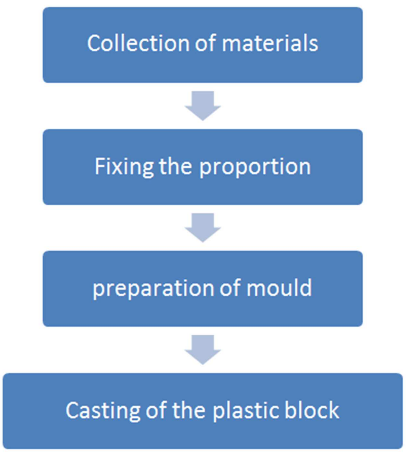

Figure 5. *Routes of fabricating HPB.*

3.6.3. Material Preparation

Before the process, the plastic materials should be washed carefully to remove dust, muddy and organic substances. If the bottle is not washed between various uses, the bacteria from the user's hands and mouth accumulate. The PET bottles can't be used as they are in the usual shape and size for production; the bottles need to be cut into smaller pieces of relative size to be comfortable for the melting process. The plastic is then melted in a drum mix with sand to cast in a desired shape and dimensions. There is a little journey from the waste collection to the production of a final building hollow block.

3.6.4. Collection of Materials

Waste collection schemes are an essential first step in any waste management and recycling process. First of all, sorting and deciding which types of plastic materials are needed for the procedure. As discussed in the literature review, plastic materials are not suitable for the recycling process. And the other thing which limits the collection of waste plastic is that some types of plastics can't be processed together. So the collection phase is determined by types of plastic suitable to each other while in recycling.

Plastic materials are found from many different waste sources. And they can be easily collected from many sources since PET plastic bottles are everywhere. PET type plastics are found in potable water packaging, and HDPE type plastics are also found in this bottle as a cap and food oil package. So when plastic bottles are once collected, plastic types PET and HDPE are also found. These waste plastics are collected from:

1) On the street
2) Schools
3) Administrative offices
4) Households
5) From curbsides (recycling bins)

Curbsides are one of the easiest ways of collecting plastic wastes. They are a container which placed in a different location of a town. Anyone who has used these water bottles can put them in this curbside container instead of throwing them away on the street. In addition to the main target of collecting plastic waste, these curbside containers are a helper in waste management. So introducing these curbside containers with awareness makes the collection step faster and easier.

Figure 6. *Recycling_bins (curbside) in Singapore.*

Other materials used in the production of the hollow block are river bed sand. The river bed sand is the one which we can use in the production of HB. The coarse grain size of river bed sand is preferable for the strength of the hollow block.

3.7. Fixing the Proportion

After collecting the waste plastics from different sources to the production area, the plastic bottles are cleaned and washed. Next to washing the waste plastic materials, the plastics are separated based on their type (PET & HDPE) and cut into small pieces. When plastics are shredded into a small size, they will be melted faster than the large-sized. So the PET and HDPE are cut into small pieces and different proportions. Since the HDPE and PET are different plastic-type their melting point also slightly different. So HDPE type plastics are a little higher number than the PET type in a single block making.

For the fabrication of hollow blocks, plastic and sand are mixed in different proportions, and blocks containing different amounts of plastic and sand are made. Plastic and river sand are mixed in different ratios. Taking different proportions of plastic and sand is to find the optimum proportion that gives a higher mechanical property. The
). Based on the mixing ratios, samples were then denoted blocks made of these ratios will further be investigated for various desired properties.

Figure 7. *Proportioning of plastic and sand.*

3.8. Plastic and Sand Mixing Ratio

For comparison purposes and quality check, four types of plastic and sand mixing ratio were used, i.e., 1:2, 1:3, 1:4, and 1:5 (

as sp1, sp2, and sp3, respectively.

Table 1. Plastic and sand mixing ratio.

No.	Sample	Mixing ratio	Weight of material (g)		Percentage of each material in a mixture	
			Plastic	Sand	Plastic	Sand
1.	S1	1:2	2842.25	5684.08	33.33	67.66
2.	S2	1:3	2131	6394.875	25	75
3.	S3	1:4	1705.3	6821.2	20	80
4.	S4	1:5	1421.08	6821.2	16.6	83.4

3.9. Preparation of Block Mold

After the completion of fixing the proportion, preparation of mold is required. The material used for making the mold can be either iron or wood. The iron made mold is stronger than the wood mold, depending on the iron type. The mold made from iron is durable, and it can be designed in detachable form as a concrete cube mold or in fixed form.

Both the cast iron mold and wooden mold are preferred to be detached because the casted hot plastic mix is remolded after the mix is cooled and dried. A hot melted plastic can't stand within itself and deform within a time. The mixed plastic is not remolded immediately as in making HCB because the plastic is glued to the mold surface, so it is cooled and then remolded. When the casted plastic is cooled and dried, it gains strength property, and finally, it will be easier to remove from the detachable mold.

In this investigation, the molds used are wooden molds and are made in the carpentry shop. The wood molds are advantageous over the iron mold because anyone can make themselves easily. They do not need welding to join sides of the mold as the iron; the wood sides are joined by nail. The entire mold's sides and surfaces should be even for the hollow block to have a better surface finish. Both fixed and detachable molds can be used for this purpose, but the detachable one is easily demold. Wooden mold will be cost-effective and serve the purpose, whereas if a better surface finish is needed, then cast-iron molds can be used. The molds are lubricated with grease or oil to prevent ruptures on the hollow block surfaces while demolding. Different dimensions of Hollow blocks (L * W * H):

1) 4 inch block: (400x100x200)
2) 6 inch block: (400x150x200)
3) 8 inch block: (400x200x200)

Figure 8. *Timber (wood) Mold.*

3.10. The Procedure of Casting Block

The procedure of casting plastic-sand block is a simple one. The first step is batching, in which sand and plastic waste, i.e. (PET and HDPE together) are weighed. Then different proportions according to the weight are taken for casting the block. After the firewood's burning is done and a drum is placed on the fire, the plastic pieces are added to the drum to melt. The melted plastic mixed with sand is then done by adding sand to the drum and stirring it continuously. Lastly, the mixture obtained after continuous stirring is fed the melted plastic-sand mix into the mold and compressed by a tamping rod. The casted plastic-sand block is left in the mold for 24 hours for cooling purposes. After the mold's 24 hour duration, the hollow block is taken out for the curing state.

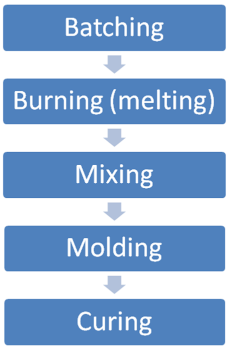

Figure 9. Process of Casting Plastic-sand Block.

3.10.1. Batching

Measurement of materials is known as batching. The cut waste plastic pieces are rinsed with water and then dried, after which the weights of plastic pieces are measured. Firstly the two types of plastics (PET & HDPE) are measured separately. The plastic part and sand are weighted independently in three different ratios to determine which optimum ratio has better mechanical strength.

Measurement can be taken by any balancing instrument, which has a gram on its measuring scale. The measuring of these materials is done using (measurement device name), which is available in the Jimma university laboratory. For the measurement ratio, various proportions of the cut plastic pieces with sand are taken for blocks.

3.10.2. Melting

After completions batching, the plastic wastes were taken for burning in which the plastic pieces are dropped one by one into the container and allowed to melt. In this burning process, the plastic pieces are prepared for melting. The burning process can be done differently, starting from manually by burning woods, using huge mechanical burning machines. Depending on the financial, the burning method may vary, but the mechanical burning machine is encouraged if it is financially affordable.

In this investigation, due to financial problems, we have used woods for the burning process. For melting the plastics, we use local materials like huge iron dishes and drums. The Plastic weighted pieces are put in a drum for melting the plastics. In the first step, stones are placed to support the drum, and firewood is also arranged. While the stones holding the drum and the firewood are ignited.

First, the Drum or burning dish is cleaned and washed to remove previous waste material attached to it. Next, it will be heated to remove moisture from the drum surfaces. While the dish or drum is on fire, we brush it with oil to melt easily and prevent stick with the drum surface. Then plastic pieces are put little by little into the drum and allowed to melt; the plastic melts around 150°C.

3.10.3. Mixing

Pieces of plastic are added into a drum for melting until it reaches the required melting property. River sand is used for addition in a plastic-sand mixture. When the melted plastic's temperature in the drum increases, the plastic pieces slowly turn into muddy like property. At this time, when the plastic is near to gain moody property, the river bed sand is added little by little into the mixing drum. The river sand and the melted plastic are stirred continuously so that both get bonded perfectly. As the plastic pieces melt, it starts bonding with the sand particles, and hence the mixture required for the molding block is attained.

Figure 10. *Melting the plastic (HDPE & PET) to mix with sand.*

3.10.4. Molding (Casting)

Before filling the mold, some oil is applied to the mold walls to be easily removed at the last block. An adequate application of oil on the inner surfaces of the mold is essential. Otherwise, as after solidification, the block will not come out easily and remove the mold, some pressure must be applied to rupture the block's edges. So proper oiling is needed before filling the mixture in the mold.

In the molding process, the prepared plastic-sand mixture into the wooden or cast iron mold and then compressed by a tamping rod. The pressure is applied by the tampering rod, so as the mixture gets filled properly in the mold, it is left for cooling in the air. Then the block can be removed from the mold after 24 hours.

Figure 11. *Casting the mixed plastic and sand.*

3.10.5. Curing

The blocks are to be the cure for 48 hours to cool off completely. The block is de-molded and is left for another 24 hours. Plastic is not a material that required curing; hence 48 to 72 hours is the maximum period to cool the block. Once the block has passed its cooling period, it can be checked for imperfections such as protrusions, which can be trimmed using a blade or hot knife.

Figure 12. *Hollow block sample.*

4. Results and Discussion

4.1. Laboratory Tests and Results on Soil Samples

The laboratory tests were conducted and provide detailed information on the Hollow block. The test result information helps to check the strength and chemical properties based on the literature.

In this research work, some characteristics that have relevance to the production of Hollow blocks were considered. The physical properties of plastic that are more important for Hollow blocks' production and that determine mixing, remolding, and the chemical property of plastics, mechanical strength, and water absorption have been determined.

The laboratory tests conducted and established numerical values for the HB sample parameter, primarily the different plastic to sand ratio is prepared. These sample values are subsequently used to determine the optimum ratio of the highest compressive strength.

4.2. Properties of Plastic

Following are the general properties of plastics.

4.2.1. Strength

The plastics are sufficiently strong and can be used for load bearing structural members. The strength of plastics can further be increased by reinforcing them with various fibrous materials.

4.2.2. Fire Resistance

Plastics, being organics in nature, are combustible. But the resistance to fire temperature depends upon the plastics structure.

1) Cellulose ace tale plastics burn slowly.
2) Polyvinyl chloride (PVC) plastics are non-inflammable.
3) Phenol formaldehyde and urea formaldehyde plastics are used as fire proofing materials.

4.2.3. Durability

Plastics generally possess sufficient durability, provided they offer sufficient surface hardness. Thermoplastics varieties are found to be attacked by termites and rodents.

4.2.4. Chemical Resistance

Plastics offer great resistance to moisture, chemicals and solvents. Many plastics are found to possess excellent corrosion resistance. Plastic are used as convey chemicals

4.2.5. Thermal Resistance

The plastics have low thermal conductivity and therefore foamed or expanded verities of plastics are used as thermal insulators.

4.2.6. Moisture Resistance

This property depends upon verities of plastics used, for example, cellulose plastics are considerably affected by the presence of moisture, whereas polyvinyl chloride plastics offer high resistance to moisture.

4.2.7. Ductility

Plastics generally have low ductility and hence plastics structural members may fail without prior warning.

Miscellaneous properties

In addition to above properties, plastics have following qualities.

1) Plastics are available in variety of colors, both opaque and transparent.
2) Plastics possess excellent insulating property, so used as electric insulators.
3) Plastics are clean, light and shinning, so they need not be given any finish such as painting, polishing, etc.
4) Normally thermo plastics have low melting point and cannot be used where temperature or heat condition persists.
5) They possess good optical and sound absorption qualities

4.3. Physical Properties of Sand

4.3.1. Size Gradation

According to the test method of ASTM C136 [7], sieve analysis was carryout and the test result. The coarse grain size of river bed sand is preferable for good bondage and later plastering of the hollow block. The sieve sizes used for particle size distribution were 2.36, 1.7, 1.4, 1.18 mm, and the 600, 300,150, and 75μm; the sand used was retained on 1.4 mm and 1.7 sieves. A shaker machine does the sieve analysis.

4.3.2. Unit Weight or Bulk Density of Fine Aggregate

Unit weight is one of the other physical properties of fine aggregate. The fine aggregate used in the experimental test was 1417.95 kg/m³ loose unit weight. Based on the expected result of ordinary aggregate conducted during the experiment, the test fulfilled the unit weight needed for Waste Plastic block production.

4.3.3. Silt Content

According to the test method of ASTM C117, the silt content of sand was carried out to determine the silt content of the sand. First, the weighted sample sand was added into cylindrical water containing the place the jar on a level surface for 24 hours until the sand, silt, and water are separated, then measuring the height of sand and silt in the jar using the ruler. The test results are shown in Table 5.

Table 6. *Silt content result.*

Description	Measurement
Wight of sample	0.5
Volume of water	250ml
A=Height of silt	0.3cm
B=Height 0f clear sand	6.9cm
Silt content (%)=A/(A+B)	4.17

According to ASTM C33, silt content should not be greater than 6%. The sand has less silt content than ASTM limitations; thus, it can be applicable to use the sand for the production of the hollow blocks.

4.4. Compressive Strength Test

Universal Testing Machine (UTM) was used to determine the compressive strength of the HB. The observation and analysis of the hollow block's compressive strength test with 1:2, 1:3, 1:4, and 1:5 ratios (by weight) of both HDPE and PET plastic and sand were conducted, according to [13, 5]. A compressive strength test was performed. To get the optimum proportion of plastic (HDPE & PET) and sand analyzing the compressive strength test was mandatory; two cubic trials from each ratio were taken, 2 × 4=8. That means eight trials are taken from four mixing ratios.

$$\text{compressive strength} = \frac{\text{maximum load aplied}}{\text{specimen area}}$$

Figure 13. *Compressive strength test by UTM.*

错误!未找到引用源。 shows each specimen compressive strength result and the relationships between compressive strength with the proportion of plastic to sand. The compressive strength at 1:2 ratios was to some extent higher than the rest of the other ratios. The waste plastic block fulfilled beyond the minimum compressive strength requirement of HCB. In this relationship, when the proportion of plastic to sand increases, the hollow block's compressive strength decrease, which means compressive strength and plastic to sand proportion have an indirect relationship. So, increasing the proportion of plastic to sand has a negative effect on the compressive strength of HB.

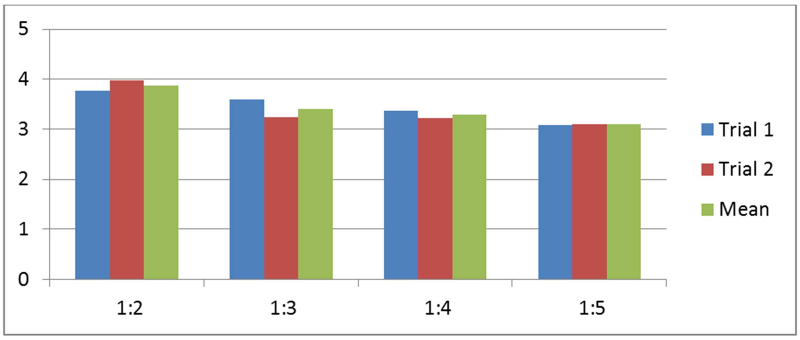

Figure 14. *Compressing strength chart.*

Table 7. *Compressive strength result of hollow block.*

Specimens	Compressive strength result, (MPa)			
	1:2 ratio	1:3 ratio	1:4 ratio	1:5 ratio
1	3.77	3.59	3.37	3.07
2	3.97	3.24	3.21	3.10
Mean	3.87	3.41	3.29	3.09

4.5. Optimum Ratio for the Plastic and Sand

Generally, for the production of hollow blocks, the main process was the mixing of plastic (PET & HDPE) to river sand proportion (1:2, 1:3, 1:4, and 1:5). As seen in Table 8, the maximum compressive strength of 3.97MPa was obtained from the produced block at a mixed proportion of 1:2 at trial two. The minimum compressive strength of 3.07MPa was obtained at a 1:5 mix proportion at trial one. The obtained compressive strength fulfills the minimum compressive strength requirement set by Ethiopian Authority for standardization and ASTM requirements for building block. Therefore, the 1:2 ratio plastic to sand for HB production has greater and better compressive strength, which fulfills the expected standard than the other two mix ratios.

Table 2. *General mean result of the proportions.*

Ratios	Minimum Compressive strength (MPa)		Maximum Water absorption (%)
	Mean	Individual HB	Individual HB
1:2	3.87	3.77	1.67
1:3	3.41	3.24	2.51
1:4	3.29	3.21	2.62
1:5	3.09	3.07	2.81

4.6. Other Laboratory Test of the Research

4.6.1. Water Absorption Test

In this test, the hollow blocks are weighed in dry condition and let them immersed in freshwater for 24 hours. After 24 hours of immersion, those are taken out from the water and wipe out with a cloth. Then, the block is weighed in wet condition. The difference between weights is the water absorbed by the block. The percentage of water absorption is then calculated. The less water absorbed by the hollow blocks means the greater its quality.

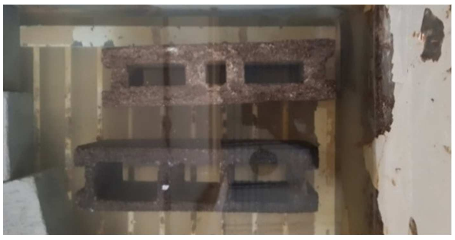

Figure 15. *Sample immersed in water.*

The water absorption is calculated as follows:
Where: W1=Weight of dry sample
W2=Weight of wet sample

$$W = \frac{W2-W1}{W1}$$

Table 9 shows us the relationships between water absorption capacities with the proportion of plastic to sand. In this relationship, when the proportion of plastic to sand increases, the HB water absorption capacity also increases, which means water absorption of block and plastic to sand proportion has a direct relationship. So, increasing the proportion of plastic to sand has a negative effect on the waste plastic block.

Table 9. *Absorption capacity result of hollow block.*

Specimens	Absorption capacity result, (%)			
	1:2 ratio	1:3 ratio	1:4 ratio	1:5 ratio
1	1.67	2.51	2.62	2.81

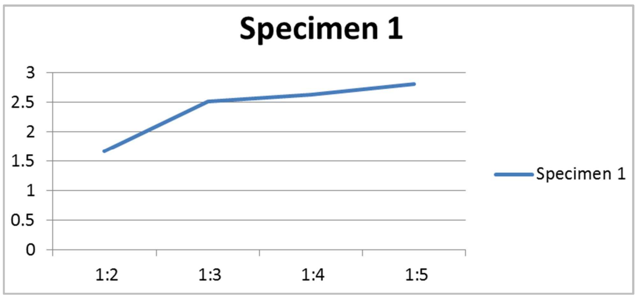

Figure 16. *Water absorption result chart.*

The water absorption that hollow blocks should be classified as normal, medium, or lightweight. In this research, the raw materials used in the mix have the different properties of water absorption, which affects the property of hollow blocks product. We can say plastic has zero water absorption, and considerably sand has water-absorbing property, so the plastic content increases the water absorption capacity of our product decrease. The water absorption of hollow blocks of the best product meets the requirement of [6]. ASTM C1492 – 03. The product is suitable to use as walling materials.

4.6.2. Temperature Effect Test

Plastic is highly susceptible to temperature, but in Plastic hollow blocks, the presence of sand imparts insulation. Generally, two specimens of the hollow block are taken to the laboratory for testing and tested one by one. In this test, the HB specimen is put in oven-dry until it changes on the block specimen breaks' surface. The specimen is no change in the structural properties of the wall up to 150°C. The mentioned temperature, the specimen shows visible cracks and melting behavior.

4.6.3. Impact Test

In this research, the researchers used the traditional method to check whether HB materials are manufactured in a rigid (dense) configuration and remain rigid during usage. The impact test is done by dropping the HB from a height of 1.5m and observe the crushing. There is a brake in to two in the characteristics of the hollow block.

5. Conclusions

The research carried out has shown some comparisons of the compressive strength, water absorption, and production cost of hollow blocks. The following conclusions and recommendations are drawn out from the investigation undertaken on hollow block production.

This study's main objective was to produce a hollow block using the waste plastic material and sand. To achieve this study's aim, the researcher collected different related literature and conducted different tests for the intended materials and specimens to determine the effects of using plastic waste on block properties. Therefore, based on the findings of the study, the following conclusions were drawn:

1) Hollow blocks' production using waste plastic (HDPE & PET) and sand as alternative wall making materials showed good properties regarding its physical and chemical compositions.
2) The secondary data shows that the chemical composition gives it a cementation property for plastic properties.
3) An increase in compaction pressure shows nearly the same effect on cement contents' increase in compressive strength.
4) The maximum mean compressive strength of 3.87MPa was obtained at a mix proportion of 1:2, which is greater than the minimum requirement of class-B HCB (3MPa).
5) The thesis result concluded that it is possible to produce hollow blocks using waste plastics and sand to fulfill the compressive strength, uses no cement content at all, and adaptable to the environment as walling material for low-cost housing.

Generally, it is concluded that recycling waste plastic as a binding agent in the production of wall hollow block has compressive strength and water absorption, fulfilling ASTM requirements. And also reduce the cost of production, lightweight, soundproof when we compare with the surface property of HCB and simultaneously which have aesthetic value and eco-friendly

The utilization of PET plastic wastes as a binder agent alternative to cement for hollow block production and other engineering applications is possible and potential input for the construction sector.

According to the study conducted on comparing compressive strength, water absorption, and production of plastic-sand block, the following recommendations were made for concerned bodies.

5.1. For the University

This research had difficulty getting the construction lab apparatus to conduct a traverse strength test, fire resistance test, and mechanical heater machine to melt the plastic without polluting effect and achieve the desired property. So we recommend the university fulfill the above-required equipment so that future researcher students can get the opportunity to modify and improve this research.

5.2. For Micro and Small Enterprises

The production process of this construction walling material is easy, and also the raw material needed can be collected from the street and in much amount in dump area. The material produced has comparable strength, light Wight, aesthetic, and reduction of production cost, which can replace the ordinary HCB. Since the main ingredient of HCB cement is expensive, this kind of product will be profitable.

5.3. For the Community

Plastic waste residuals found in various forms in our environment can be reutilized as a binding agent with portable and lightweight to reduce construction material weight and give strength by reducing cement consumption. So it is recommended that to be introduced to the product. Also, they should adopt the use of plastic waste with sand in various low-cost construction materials.

5.4. For Further Research

There are many modifications to the production of this hollow block construction walling material product.

1) Future researchers are recommended to check other ratios next to 1:5. The ratio above this may have adequate strength versus more economical.
2) The melting of plastic and mixing with sand could be better in a mechanical heater machine.
3) Other ingredients can be added to minimize plastics and sand since the plastics are higher shrinkage.

Appendix

Appendix A. Mix Proportion

To prepare mix design, there are no specifications in following the ratios. Predict that the capacity of the mold to take the amount of sand by putting sand into it. Then the sand was measured, and the ratio is calculated based on the total sand weight.

Waste plastic and sand mix ratio=1:2

The weight of PET and HDPE plastic of HB=1/3*8526.5gm=2842.17gm

Weight of sand=5684.33gm

Waste plastic and sand mix ratio mix ratio=1:3

The weight of PET and HDPE plastic of HB=1/4*8526.5gm=2131.6.625gm

Weight of sand=6394.875gm

Waste plastic and sand mix ratio mix ratio=1:4

The weight of PET and HDPE plastic of HB=1/5*8526.5gm=1705.3gm.

The weight of sand=8525.5 - 1705.3gm

=6821.2gm

Waste plastic and sand mix ratio mix ratio=1:5

The weight of PET and HDPE plastic of HB=1/6*8526.5gm=1421.08 gm.

The weight of sand=8525.5 - 1421.08gm

=7105.42gm

Table 10. *Sample of mix proportion.*

No.	Sample	Mixing ratio	Weight of material (g)		Percentage of each material in a mixture	
			Plastic	Sand	Plastic	Sand
1.	S1	1:2	2842.25	5684.08	33.33	67.66
2.	S2	1:3	2131	6394.875	25	75
3.	S3	1:4	1705.3	6821.2	20	80
4.	S4	1:5	1421.08	6821.2	16.6	83.4

Appendix B. Material Physical Properties

2 Water absorption

Table 11. *Moisture content.*

Specimens	Absorption capacity result, (%)			
	1:2 ratio	1:3 ratio	1:4 ratio	1:5 ratio
1	1.67	2.51	2.62	2.81

Appendix C. Material Mechanical Properties

Table 12. *Compressive strength test result for 1:2 Ratios.*

Specimens	Dimensions cm			Area cm²	Failure Load KN	Compressive strength MPa
	L	W	H			
1	40	10	20	208	78.41	3.77
2	40	10	20	208	82.57	3.97
Mean						3.87

Table 13. *Compressive strength test result for 1:3 Ratios.*

specimens	Dimensions cm			Area cm²	Failure Load KN	Compressive strength MPa
	L	W	H			
1	40	10	20	208	74.67	3.59
2	40	10	20	208	67.34	3.24
Mean						3.41

Table 14. *Compressive strength test result for 1:4 Ratios.*

specimens	Dimensions cm			Area cm²	Failure Load KN	Compressive strength MPa
	L	W	H			
1	40	10	20	208	70.09	3.37
2	40	10	20	208	66.76	3.21
Mean						3.29

Table 15. *Compressive strength test result for 1:5 Ratios.*

specimens	Dimensions cm			Area cm²	Failure Load KN	Compressive strength MPa
	L	W	H			
1	40	10	20	208	63.85	3.07
2	40	10	20	208	64.48	3.10
Mean						3.09

Appendix D. Photo Gallery

Figure 17. *Photo Gallery1.*

Figure 18. *Photo Gallery2.*

Figure 19. *Photo Gallery3.*

Figure 20. *Photo Gallery4.*

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