JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRAGUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

PRODUCTION OF BRICK USING WASTE PLASTIC MATERIAL AND SAND

A Thesis Submitted to School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree Master of Science in Construction Engineering and Management

By

SENAIT NASISSA WUBETIE

March 2021
Jimma, Ethiopia

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Senait Nasissa Wubetie

Adviser: Dr. Getachew Kebede………………………

Co- Adviser: Engr. Kebene Adeba…………………….

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APPROVED BY BOARD OF EXAMINERS -:

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DECLARATION

I declare that this research entitled **<u>Production of Brick Using Waste Plastic Material and sand</u>** is my original work and has not been submitted as a requirement for the award of any degree in Jimma University or elsewhere.

Senait Nasissa Wubetie ------------------ -----------------

Name Signature Date

As research Adviser, I hereby certify that I have read and evaluated this thesis paper prepared under my guidance, **by Senait Nasissa Wubetie** entitled **"<u>Production of Brick Using Waste Plastic Material and sand</u>"** and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science in Construction Engineering and Management.

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ABSTRACT

Brick is widely used construction material which consists of a mixture of clay plus water called clay brick, and it is a very versatile material used in the construction industry. However, the brick production industry requires a large input of non-renewable natural resources that causes negative impacts on the environment. Also, plastics are one of the materials present in our everyday life which have many chemical and hazardous substances which affect human health and surrounding environment.

This study aims on the production of brick using waste plastic material and sand in the ratio of 1:2, 1:4, and 1:6 of brick size 19cm X 9cm X 4cm. Experimental laboratory investigation was made to determine the properties such as compressive strength, absorption capacity and efflorescence of brick produced from waste plastic material and sand. To achieve the objective, waste plastic material was collected from waste disposal sites and isolated from other waste plastics by their codes on the plastic products and then shredded, washed, dried, and melted within the range of 257-315 °C temperature in open-air. After melting of PET in to liquid-state, fixing proportion and homogenous mixing of the two materials (PET and sand) then fed in to the mold and testing of the samples after 48 hours was conducted. The test results notice that properties of two samples produced from waste plastic and sand satisfy the class-B criteria based on Ethiopian Building Code Standard requirements. The other one sample fall and only satisfies the efflorescent test requirement of the standard. The test result for 1:2 ratio having strength of 17.87mpa, absorption capacity of 1.35%, and nil efflorescent. Thus, a mix ratio of 1:2 is the optimum proportion of PET plastic and sand which fulfills both the compressive strength and water absorption capacity requirements. It can be concluded that PET waste plastic founded to be useful for the production of brick.

***Key Words**: Brick, Strength, Waste plastic*

ACKNOWLEGEMENT

Before all things, I would like to thank almighty God for his very existence in every moment of my life. Secondly, I would like to thank my family Mr. Nasissa Wubetie (my father) and Mrs. Sewnet Geleta (my mother) for their endless support in every path of my life. Also I would like to express my sincere and deepest gratitude to my advisor Dr. Getachew Kebede and my co-advisor Engr. Kebene Adeba for all their unlimited and continuous support, guidance, comments, and efforts throughout my work. Lastly, my gratitude goes to Jimma Institute of Technology and Ethiopian Road Authority (ERA) for providing me a chance for scholarship to accomplish the Master's Degree in Construction Engineering and Management program.

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ACRONOMIES

ABS	Acrylonitrile Butadiene Styrene
ASTM	American Society for Testing and Materials
BS	British Standard
ES	Ethiopian Standard
EUROMAP	European Association for Plastic and Rubber Machinery Manufacturers
HDPE	High-Density Polyethylene
LDPE	Low-Density Polyethylene
PAI	Polyamide Imide
PBT	Polybutylene Terephthalate
PET	Polyethylene Terephthalate
PMMA	Polymethylmethacrylate
WTR	Water Treatment Residual

CHAPTER ONE
INTRODUCTION

1.1 Background of the study

Engineering work is focused on solving an unwanted condition through the application of technologies. These technologies involved may be well established, nascent, or as-yet unimagined. Therefore, a central activity of the engineering work is solving problems. In the national economy and the economic development of any country construction industry plays a vital role. In developing countries, the construction industry is a vital sector in providing mainly new infrastructure in the form of roads, railways, airports as well as new hospitals, schools, housing, and other buildings. It also plays a key part in satisfying basic physical and social needs, including the production of a shelter, the infrastructure, and consumer goods (Sheri, et al., 2006).

The construction industry is the biggest consumer of material resources, of both the natural ones (like stone, sand, clay, lime) and the processed and synthetic ones. Each material used in the construction, in one form or the other is known as construction material, these materials have significant environmental impacts from pollutant releases, habitat destruction, and depletion of natural resources. This environmental impact can happen during the extraction, and acquisition of raw materials, production, and manufacturing processes, and transportation (Muhwezi, et al., 2012).

To meet the growing social need construction industry plays a vital role in providing physical infrastructure. On the other hand, it has a larger part in contributing to environmental problems (Muhwezi, et al., 2012).Selecting environmentally friendly and attractive materials with reduced environmental impacts is primarily done through the exercise of resource protection, and choice of non-toxic materials. Construction materials manufactured from different resources this process affect the environment by depleting natural resources, using energy, and releasing pollutants to the land, water, and atmosphere.

Hence, to minimize the natural resource depletion problems and reduce environmental impact, utilization of Polyethylene Terephthalate (PET) waste plastics for the production of construction material is unquestionable. It's with this understanding that this study was undertaken.

The aim of this research was to produce brick using waste plastic material. To achieve the objectives applying all the requirements procedure starting from literature review, sample collection, conducting relevant laboratory tests, and analysis of results obtained from input data was necessary. Finally conclusion has been formulated and recommendation was forwarded to whom it concerns.

1.2 Statement of the problem

Plastics are one of the materials present in our everyday life; we used them for a variety of purposes due to their inexpensive, lightweight, and durable. But these materials have many chemical and hazardous substances which affect human health and it also serious-environment effects (Ram, et al., 2018).

The analysis on the plastic pile balancing on Ethiopia discussed that in Ethiopia, the per-capital plastic consumption has grown by about 13.1% annually over the past years, from 0.6 kg in 2018 and one of the largest plastic wastes is PET. This places Ethiopia as the second-largest importer of plastic raw material in central and eastern Africa and EUROMAP predicts that Ethiopia will produce 386,000 tons by 2022 and the per-capital consumption will rise to reach 3.8 Kg (Abera & Jelan, 2019).This means our country's usage of plastic is highly increased and it's sustained and needs to manage and treat.

For the production of Fired clay bricks, clay can be excavated and pits have existed. These clay pits accumulate rainwater and became a habitat for mosquitoes this makes an adverse effect on the health of the community and also creates the occurrence of soil erosion.

In Jimma town, the production process of Fired clay bricks started preparing the clay materials from the quarry, tempering, molding, drying, and end firing. Among these processes, firing is the most important for the hardening of the brick by using heat from the burning of woods. But this has an adverse impact on the environmental condition due to the high deforestation of trees and associated environmental impacts (Miskir, et al., 2017).

The profitability of the company can be affected due to local Fired Clay Brick production will need at least 35 days if there are 40,000-50,000bricks that can be molded per day which is not possible to obtain (Miskir, et al., 2017).Therefore, the brick production industry not only requires large inputs of resources it also causes several negative environmental effects. Studies indicate that brick manufacturing has a great impact relating to energy use and carbon emission (Koroneos & Dompros, 2007).

So, it’s important to find new materials with a lower environmental and human health impact, lower energy consumption, and minimum production period with affordable prices.

This study focuses on the production of bricks using waste plastics mixed with sand to produce alternative construction material, to minimize the negative environmental effect of brick, and to reduce the plastic pollution effects due to landfills.

1.3 Research questions

1. What are the durability properties of brick that produced from PET waste plastic?
2. What is the major mechanical property of brick that produced from PET waste plastic?
3. What is the optimum proportion of plastic and sand for brick production?

1.4 Objectives of the Study

1.4.1 General Objective

The main objective of this research is to study the effect of using waste plastic material and sand For brick production

1.4.2 Specific Objectives

- ✓ To determine the durability properties of brick that produced from PET waste plastic
- ✓ To determine the mechanical property of brick that produced from PET waste plastic
- ✓ To determine the optimum proportion of plastic and sand for brick production

1.5 Scope and limitation of the Study

This research study focused on the determination of compressive strength, absorption capacity, and efflorescence properties of brick produced using PET waste plastics. The durability and other related properties were not covered. The finding of the research was limited to the strengths properties of the waste plastic brick compared with the Ethiopian brick standard. The effect of temperature, cooling rate, and molecular weight were not examined due to the shortage of testing tools. Abrasion-resistant and fire resistance tests were also jumped due to unavailability of testing machines.

1.6 Significance of the Study

This research can contribute to construction industries in Ethiopia in various ways like adding one alternative of construction material. It helps the construction industry to use different alternatives for the production of construction materials. Hence, producing waste plastic brick is important to minimize the effects of plastic on the environment through its lifetime and decreases the depletion of natural resources for the production of clay brick. Generally, this research is a better basis to introduce the production of bricks using plastic and sand by determining the applicability of waste plastic brick in our country to transfer the technology from different countries. The use of alternative construction materials in the construction industry in turn helps wise utilization of natural resources to minimize the associated negative effects socio-economic welfare.

CHAPTER TWO

LITERATURE REVIEW

2.1 General Overview

According to Sheri Sheppard, engineering work is focused on solving an unwanted condition through the application of technologies. The technologies involved may be well established, nascent, or as-yet unimagined. Therefore, a central activity of engineering work is solving problems; this statement is the intention of engineering work is to affect the change in the world by modifying procedures or processes or announcing new products, technologies, or awareness (Sheri, et al., 2006).

Amel Dakhil (2013) is also stated that the construction industry plays an important role in the national economy and the economic development of any country. The construction industry in developing countries is a vital sector providing mostly new infrastructure in the form of roads, railways, airports as well as new hospitals, schools, housing, and other buildings. It also shows the main role in filling basic physical and social needs, including the production of shelter, infrastructure, and consumer goods (Amel, 2013).

A vast and rapid growth of construction industries requires a lot of building materials that use natural resources either in their production plant or as the materials themselves this caused by urbanization. More recently the world concern about the demands for the Construction industry is the largest consumer of material resources, of both the natural ones (like stone, sand, clay, lime) and the processed and synthetic ones (concrete, brick, HCB). Each material that is used in the construction, in one form or the other is known as construction material (Sanket, 2016). These materials have significant environmental impacts from pollutant releases, habitat destruction, and depletion of natural resources. This can happen through the extraction, and acquisition of raw materials, production, and manufacturing processes, and transportation (Sanket, 2016). Every material has its own field of application. Stone, bricks, timber, steel, lime, cement, metals, etc. This research produces brick by using Waste plastic with river sand.

As it's stated in the journal of Full Brick, History, and Future, Brick plays a very important role in the field of civil engineering construction and the brick became the constructional element which has a range from history until the 21st century resists fashion influence and building courses. In each period of development, it was able to find usage in many ways. With pressure on recycling and due to the influence on the environment its role will be even more increased (Jan, et al., 2019).

Bricks are very versatile material used in construction such as the construction of walls of any size, floors, arches, and cornices, retaining wall as an alternative of stones in construction purpose, etc. Bricks are classified depending on –quality, building process, manufacturing method, raw Material, location, weather-resisting capability, purpose of using, shape, and region (Raj, P. Purushothama, 2017).

Construction industries have a larger part in contributing to environmental problems. Selecting environmentally friendly and attractive materials with reduced environmental impacts is primarily done through the exercise of resource protection, and choice of non-toxic materials. Construction materials manufactured from different resources this process affect the environment by depleting natural resources, using energy, and releasing pollutants to the land, water, and atmosphere (Sanket, 2016).

Hence, to minimize the natural resource depletion problems and reduce environmental impact, the utilization of waste plastics for the production of construction material is unquestionable.

2.2 History of bricks used in construction

According to the Full Brick, History and Future journal the Big wall (Chinese wall) biggest brick-made construction around the world. Babylonian garden, Hagia Sofia one of the most beautiful churches in the world which has been built later on- Medieval castle Malbork in Poland, which resembles a small city, construction Thadz Mahal in India, the skyscraper, Chrysler Building in New York. All these buildings have one thing in common, which is the material that created them. It is brick, one of the most common and most universal and oldest materials, which is known to us humans and with which are in touch for more than 10,000 years. For 10,000, years the course has been set for brick with few almost to no adjustments.

They can come across the revolution in the last 60 years. They found out many new scales that found their use in the 21st century (Jan, et al., 2019). From this brick, history can be classified into two the time of the neolithic and the medieval period.

Development of Bricks from Wholly Waste Materials The conventional method of brick manufacturing has left important material lots of advancement. The infrastructure such as buildings for housing and industry and the facilities for handling water and sewage requires large amounts of construction material. Since the large demand has been placed on the building material industry, especially in the last decade owing to the increasing population, there is a mismatch between demand-supply management of these materials (Shakir & Ahmed, 2013).

Hence, to meet the continuously increasing demand, researchers are attempting to design and develop sustainable alternative solutions for the construction material. Brick is one of the most accommodating masonry units as a building material due to its properties. Attempts had been made to incorporate wholly waste in the production of bricks without the use of virgin resources as clay, shale, or sand in the production process.

Hence, the natural resources, besides, the engineering properties and the durability will be developed. Thermal conductivity was reduced in bricks by the addition of waste material to the bricks before firing. Another advantage of lightweight bricks is reduced transportation costs.

The cementitious binder, fly ash–lime–gypsum (FL–G), finds extensive application in the manufacturing of bricks, hollow bricks, and structural concretes. The need to conserve traditional building materials that are facing depletion has obliged civil engineers to look for an alternative material. Recycling such waste by incorporating them into building material is a practical solution to the pollution problem. Chihpinetal (2013) did a study on recycling the water treatment residual (WTR) and the excavated soil, the ceramic bodies were prepared and sintered to formulate into building bricks and artificial aggregates. The sintering temperature requirement by WTR was higher than normally practiced in brickwork due to the higher Al_2O_3 and lower SiO_2 content. Test results of specific gravity, water absorption, and compressive strength of the artificial aggregates confirmed its applicability in constructions as various degrees of lightweight aggregates.

Results on the physical and mechanical properties of the bricks qualified them to be used in the building sector as non-load bearing spacing construction materials, where all cement brick samples tested in this study complied with the Egyptian code requirement for structural bricks. Chinetal (2013) also developed technology for reusing the paper sludge and co-generation ashes generated by the paper industry in producing bricks (Shakir & Ahmed, 2013).

2.3 Types of Bricks

Nowadays, there are different types of bricks used in the construction industry; Bricks can be of many types, depending on the (Raj, P. Purushothama, 2017) and (Subramanian, N., 2019) books. There is Quality, Raw Material, Manufacturing Method, Building Process, Location, Weather-resisting Capability, Purpose of Using, and Shape.

2.3.1 Classification of Bricks Based on Quality

The Classification of bricks based on quality as per to Raj (2017) discussion (Raj, P. Purushothama, 2017).

First Class Brick: The dimension is standard. Their colors are constant yellow or red. It is well burnt, fixed texture, a constant shape. The water absorption ability is less than 10%, crushing strength is, 280 kg/cm² (mean) where it is 245 kg/cm² (minimum). It doesn't have efflorescence. When hit by another comparable brick or hit by a hammer provide out a metallic sound. It resists any fingernail appearance on the brick surface when one tries to do it with a thumbnail. It also frees from pebbles, gravels, or organic matters. Furthermore, it is generally used in a building of long stability; say 100 years for building exposures to a harsh environment; for making coarse aggregates of concrete.

Second Class Brick: The dimension is standard; their colors are constant yellow or red. It is well burnt, to some extent over burnt is tolerable. It has a fixed shape; it doesn't have efflorescence. The water absorption ability is between 10% and 15%. The average and minimum crushing strength is 175 kg/cm² and 154 kg/cm². When hit by another comparable brick or hit by a hammer provide out a metallic sound.

It has strongly resisted any fingernail expression on the brick surface one tries to do with a thumbnail. It is used when the construction requires durability less than 15 years like one-storied buildings and short-term sheds.

Third Class Brick: The shape and dimension of this class bricks are irregular. It has soft and light red-colored, under burnt, to some extent over burnt is tolerable. It has efflorescence. The texture is non-uniform. The absorption capacity is between 15% and 20%. The average and minimum crushing strength is 140 kg/cm² and 105 kg/cm². It gives out a dull or blunt sound when hit by another comparable brick or hit by a hammer. It leaves fingernail manifestation when one tries to do with the thumbnail.

2.3.2 Classification of Bricks Based on Manufacturing Method

The classification of bricks based on manufacturing method as per to Subramanian (2019) discussion (Subramanian, N., 2019).

Extruded Brick: It is shaped by making clay and water into a steel die with fixed shape and dimension, then cutting the resulting column into smaller units with cables before firing. It is used in constructions with inadequate budgets. It has three or four holes establishing up to 25% volume of the brick.

Molded Brick: It is molded by hand rather than a machine. Molded bricks between 50 and 65 mm are accessible immediately.

Dry pressed Brick: It is the old-style kinds of bricks that are made by compacting clay into molds.

2.3.3 Classification of Bricks Based on Raw Materials

The classification of bricks based on raw materials as per to Raj (2017) discussion (Raj, P. Purushothama, 2017).

Burnt Clay Brick: It is achieved by pressing the clay in molds then fried and dried in kilns. It is the widely used bricks and needs plastering.

Fly ash Clay Brick: fly ash and clay are manufactured at 1000 °C. Fly ash has a high content of calcium oxide and usually described as self-cementing. It frequently swells when coming into interaction with moisture. It is fewer porous than clay bricks. Not only that, but It proved a smooth surface due to this it doesn't need plastering.

Concrete Brick: It is made of concrete. It is the least used bricks. It has low compression strength and is of low quality. These bricks are applicable to use beyond and under the damp proof course.

These bricks are used for fronts, fences, and interior brickwork because of sound declines and heat resistance abilities. It is also called mortar brick. It can be of diverse colors if the pigment is used during manufacturing and should not be used below ground.

Sand-lime Brick: Sand, fly ash, and lime is mixed and molded under pressure. During wet mixing, a chemical reaction takes place to bond the mixtures then they are molded. The color is grayish as it offers something of an aesthetic view. It propositions a smoother finish and uniform look than the clay bricks. Therefore, it doesn't require plastering. It is used as a load-bearing member as it is greatly strong. It is also known as refractory bricks which are manufactured from especially pointed earth. After burning, it can resist very high temperatures without disturbing its form, dimension, and strength. It is used for the lining of chimneys and furnaces where the normal temperature is predicted to be very high.

2.3.4 Classification of Bricks Based on Their Application

Subramanian (2019) discussed on his book there are different classification of bricks based on their application (Subramanian, N., 2019).

Common Bricks: These bricks are the most common bricks used. They don't have any special features or requirements. They have low resistance, low quality, and low compressive strength and usually used on the interior walls.

Engineering Bricks: These bricks are known for many reasons. They have high compressive strength and low absorption capacity. They are very strong and dense also have a good load-bearing capacity, damp proof, and chemical resistance properties, a uniform red color, classified as Class A, Class B, Class C. Class A is the strongest but Class B is the most used and mainly used for civil engineering works like sewers, manholes, groundwork's, retaining walls and damp proof courses.

2.4 Use of brick

Bricks can be used for different purposes in the construction industry, among which major ones are: Construction of walls of any size, Construction of floors, Construction of arches and cornices, retaining wall, making broken bricks of required size to use as an aggregate in concrete, Manufacture of powdered bricks to be used in lime plaster and lime concrete.

2.5 Characteristics of good brick

Bricks have their own characteristics which can be checked by different methods. According to the Raj P. Purushothama (2017) discussion, brick should be uniform in color, size, and shape, Standard size of brick should be maintained, sound and compact, free from cracks and other flaws such as air bubbles, stone nodules, etc. Bricks edges are sharp and square, it's water absorption are 1⁄5 of their own weight of water when immersed in water for 24 hours (15% to 20% of dry weight), its compressive strength should have a minimum crushing strength of 3.5 N/mm², not show deposits of salts when immersed in water and dried, not change in volume when wetted, neither over burnt nor under-brunt, soundproof, non-inflammable and fireproof (Raj, P. Purushothama, 2017).

2.6 Bricks manufacturing process in Jimma town

Bricks can be manufactured using different processes based on the usage and the material available at the specific area, to show the specific example of Brick Manufacturing process in Jimma town is stated below.

MURTESA local brick production small and micro-enterprise is one of from different brick manufacturing enterprise in Jimma town its brick production is started by excavating Clay soil using hand tools and composed on the plastic cover and air-dried for one week after, air-drying the crushing was started by a shovel to break the lumps in the soil. Any coarser materials were grinded into fine by hand, and any vegetation roots and stones were detached.

Production of fired clay bricks in Jimma Town is done, first by mudding the soil by foot and then molding by hand. Followed by the so-called green bricks which are dried about one month if it is a sunny season, or 2-3 months if it is rainy season. The final step is the brick firing.

The firing method takes place by constructing up a rectangular barrier like structure with 40,000-50,000 dried green bricks. The bottom part has openings to enable the firing method which will last for 3 days. Generally, the local fired clay brick production will need at least 35 days if there are 40,000-50,000 bricks can be molded per day which is not possible to obtain (Miskir, et al., 2017).

The manufacturing procedure of Fired clay bricks in Jimma town contained preparing the clay materials from the quarry, tempering, molding, drying, and firing. Among these procedures, firing is the most vital for the strengthening of the brick.

The firing process to locally create fired clay bricks are by using heat from the scorching of woods. But this has an adverse influence on the environmental condition due to the high deforestation of trees. Traditional brick and tile production requires an excessive deal of fuel during firing. This excess fuel intake increases air pollution. If the wood is used as a fuel, excess intake often contributes to deforestation and associated environmental impacts (Miskir, et al., 2017).

2.7 Durability and mechanical property test for brick

A durability property is classified as water absorption and effloresces. On the other hand, the mechanical properties include compressive strength and flexural strength. Accordingly, different standards including Ethiopia standards major criteria to classify brick to different classes are from mechanical properties (compressive strength) and from durability the water absorption and effloresce.

2.7.1 Water absorption and saturation coefficient

The absorption of a brick is the capacity to absorb water to saturation. The rate of the absorption or the suction of the brick has an important effect on the adhesion of the brick and the mortar because if the brick absorbs waters too quickly from the mortar, the mortar is set quickly and the adhesion will be humble. The absorption controls the durability of clay bricks. The mortar dry depends on the absorption capacity of bricks when the absorption capacity highs bases mortar to be dry & effects in the imperfect hydration of cement in the mortar (Abebe, 2002).

2.7.2 Efflorescence

Efflorescence is a whitish powder of crystallization on brick masonry walls caused by water-soluble salts deposited on the surface upon evaporation of water. Efflorescence will appear if there are soluble salts in the wall materials and moisture to carry these salts to the surface. To overcome efflorescence, it is essential to check the type of brick, quantity, and quality of water used, type of mortar, and particularly the type of admixture (if used) and classification according to efflorescence rating ESC. D4.001(Abebe, 2002).

2.7.3 Compressive strength

Compressive strength is a vital property of bricks and as a result, brick compressive strength has converted as a quality control measure. Finding on masonry indicated that stronger bricks contribute to greater brickwork strength (Altayework, 2013). Compressive strength is the resistance to compression of bricks and is measured in the laboratory by a digital compressive testing machine.

2.8 ASTM, BS and ES specifications for Bricks

2.8.1 The American Society for Testing and Materials

Standard specification for building bricks the American Society for Testing and Materials;(ASTM, 2012).

According to ASTM, Specification for and classification of bricks (C 62- 97a), the physical property requirements in most specifications are compressive strength, water absorption, and saturation coefficient as described in Table 2.1(ASTM, 2012).

Table 2.1: Physical Requirements of Brick according to (ASTM, 2012)

Designation	Minimum compressive strength		Maximum water Absorption by 5hr boiling in%		Maximum saturation coefficient	
	Average of 5 bricks	Individual bricks	Average of 5 bricks	Individual bricks	Average of 5 bricks	Individual bricks
Grade SW	20.7	17.2	17	22	0.78	0.8
Grade MW	17.2	15.2	22	25	0.88	0.9
Grade NW	10.3	8.6	No limit	No limit	No limit	No limit

Grades classify bricks according to their resistance to damage by freezing when wet, as defined in note 1.

Grade SW (Sever Weathering) - bricks intended for use where high and uniform resistance to damage caused by cyclic freezing desired and where the brick may be frozen when saturated with water.

Grade MW (Moderate Weathering) - bricks intended for use where moderate resistance to cyclic freezing damage is permissible or where the brick may be damp, but not saturated with water when freezing occurs.

Grade NW (Negligible Weathering)- bricks with little resistance to cyclic freezing but which are acceptable for applications protected from water absorption and freezing.

Note 1: The word “saturated” with respect to this standard, refers to the condition of a brick that absorbed water to an amount equals to that resulting from submersion in room temperature water for 24 hr.

2.8.2 British Standard Specification for Clay bricks (BS:3921, 1985)

According to BS 3921, bricks are classified based on their compressive strength and water absorption as discussed in Table 2.2.

Table 2.2: Classification of clay bricks (BS:3921, 1985)

Classes of clay bricks	**Compressive strength in N/mm²**	**Water absorption %by mass**
Engineering A	>70	<4.5
Engineering B	>50	<7.0
Damp proof course 1	>5	<4.5
Damp proof course 2	>5	>7.0
All other	>5	No limit

2.8.3 Ethiopian standard for clay bricks

The (ES 86:1990) and (ESC.04.001) for efflorescence which is the former Ethiopian standard specification for solid clay brick was formally replaced by another designation ES-86:2001(ESA, 2011). Bricks are classified as shown in Table 2.3

Table 2.3: Ethiopian standard of solid clay bricks (ES 86:2001) and (ESC.D4.001).

Class	**Minimum compressive strength in MPa**		**Maximum water Absorption in%**		**Maximum saturation coefficient**		**Efflorescence**
	Average of 5 bricks	**Individual brick**	**Average of 5 bricks**	**Individual brick**	**Average of 5 bricks**	**Individual brick**	
A	20	17.5	21	23	0.96	0.99	Nil to slight
B	15	12.5	22	24	0.96	0.99	Nil to slight
C	10	7.5	No limit	No limit	No limit	No limit	Effloresced
D	7.5	5.0	No limit	No limit	No limit	No limit	Effloresced

2.9 Plastics and Their categories

Plastic

Polymers' is a universal term for all plastic materials and means that they are organic, carbon-based mixtures whose molecules are connected together in long-chain patterns.

Plastics are also called Polymers. They are made up of carbon, hydrogen, and sometimes oxygen, chlorine, nitrogen, fluorine, sulfur, phosphorus, or silicon (Madalina, 2017).

Plastics can also be divided into two categories

Thermoset Plastics or Thermosetting Plastics and

Thermoplastics

Thermoset:-polymers refer to stable polymerization and this type of polymer is cured by chemical reaction or heat and becomes infusible and insoluble material.

Properties of a Thermosetting Plastic material

By heating the polymer, it turns into a hard material and gains strength.

It is available in the form of liquid at room temperature and no change in its strength.

It is a Non-Recyclable process.

Thermoplastics:- are made up of linear molecular chains, and this polymer softens on heating and hardens when cooled. They are denoted by a large range of plastic materials.

Properties of Thermoplastic material

by heating the polymer, it turns into a soft material and loses its strength.

It is available in the form of solids at room temperature and gains strength.

It is a recyclable process.

Types of thermoplastic polymers

1, crystalline thermoplastics:-usually translucent with molecular chains which present regular arrangement. These polymers have high mechanical impact resistance than other thermoplastic types. Examples of crystalline polymers are polypropylene (PP), low-density polyethylene (LDPE), and high-density polyethylene (HDPE).

Polypropylene is occasionally recycled. PP is tough and can commonly resist higher temperatures. It is used for lunch boxes, margarine containers, yogurt pots, syrup bottles, prescription bottles. Its identification code is 5.

Low-Density Polyethylene is sometimes recycled. It is a very healthy plastic that tends to be both long-lasting and flexible. Things such as cling-film, sandwich bags, squeezable bottles, and plastic grocery bags are made from LDPE. Its identification code is 4.

High-Density Polyethylene is actually harmless and is not known to transfer any chemicals into foods or drinks. HDPE products are commonly recycled. Things such as bottles for milk, motor oil, shampoos, and conditioners, soap bottles, detergents, and bleaches are made from HDPE. It is harmful to reuse an HDPE bottle as a food or drink bottle if it didn't initially contain food or drink. Its identification code is 2.

2, amorphous thermoplastics:-usually transparent with the molecules arranged randomly. Examples of this type of polymers are polyvinyl chloride (PVC), polymethyl methacrylate (PMMA), polycarbonate (PC), polystyrene (PS), and acrylonitrile butadiene styrene (ABS).

Polyvinyl Chloride is sometimes recycled. PVC is used for pipes and tiles but is most usually originates in plumbing pipes. This kind of plastic should not come in contact with food items as they can be harmful if consumed. Its identification code is 3.

Polyethylene Terephthalate sometimes absorbs odors and flavors' from foods and drinks that are stored in them. These items are able to recycle. PET plastic is used to make many common household items like beverage bottles, medicine jars, rope, clothing, and carpet fiber. Its identification code is 1.

Polystyrene is commonly recycled but also challenging to doing. Polystyrene are items like disposable coffee cups, plastic food boxes, plastic cutlery, and packing foam are made from PS. its identification code is 6.

Code 7 is miscellaneous types plastic not defined by the other six codes. Polycarbonate (PC) and Polypeptide are included in this group. These types of plastics are hard to recycle. Polycarbonate (PC) is used in baby bottles, compact discs, and medical storage containers. Its identification code is 7.

3, Semi-crystalline polymers:- present combined properties of crystalline polymers and amorphous polymers. like polyester polybutylene terephthalate (PBT) and polyamide Imide (PAI).

2.10 Properties of PET plastic

2.10.1 Physical properties of PET plastic

A polyethylene terephthalate (PET) is categorized under amorphous thermoplastics and an identification code of #1. A PET is hard, stiff, strong, absorbs very little water, good gas barrier properties, and chemically stable.

Its physical property was described by Syammaun and his friends (2020) in there research on the effect of coconut-shell ash as a filler and a plastic bottle as a substitution of a porous asphalt mixture (Syammaun, et al., 2020).

Table 2.4: Properties of PET as per (Syammaun, et al., 2020)

Properties	**Values**
Young's Modulus(E)	2800-3100 MPa
Tensile strength(σt)	55-75 MPa
Elastic limit	50-150%
Notch test	3.6 KJ/m^2
Glass transition temperature(Tg)	67-81°C
Vicat B	82°C
Linear expansion coefficient (α)	0.00007 per K
Water absorption	(ASTM) 0.16%
Melting point	>250°C
Boiling point	>350°C (decomposes)
Density	1.38 g/cm^3.
Solubility in water	Practically insoluble
Molar mass	Variable

2.10.2 Chemical properties/Composition of PET plastic

To determine the chemical properties/chemical composition of PET plastic the researcher used secondary data due to the plastic manufacturing companies use the same ingredients and proportions for any plastic-type that is why their identification code numbers are the same all over the world. Its known plastic materials are durable means it degraded slowly it takes at least 50 years (Hayden, et al., 2013) which means it stays without changing its original character for decades. so its chemical composition of any plastic manufactured in any company is the same globally, PET plastic which its identification number 1, is the same all over the world so when we identify its chemical composition with the same procedure and equipment our result is approximately the same this means the case study area doesn't affect the chemical property results.

The result of chemical analysis of PET plastic according to Beata Jabłonska on his Physical and Chemical Properties of Waste from PET Bottles Washing as a component of Solid Fuels paper listed below in Table 2.5 (Beata, et al., 2019).The PET plastic contains relatively high amounts of CaO which is followed by SiO_2 and the presence of these mineral compounds in the material helps to produces binding medium.

Table 2.5: Chemical Composition of PET plastic as per the (Beata, et al., 2019)

Component	**Value in %**
SiO_2	10.32
Al_2O_3	4.49
Fe_2O_3	3.13
CaO	16.0
Na_2O	0.67
MgO	1.32
K_2O	0.3
P_2O_5	0.69
TiO_2	0.07
SO_3	0.27
MnO	0.11
Loss on Ignition	61.2

2.11 Degradation of plastic

Plastic can be degraded in the environment by four mechanisms for plastic degraded into the environment. Photodegradation, thermo oxidative degradation, hydrolytic degradation, and biodegradation by the microorganisms (Hayden, et al., 2013). According to him, the natural degradation of plastic begins with photodegradation due to the Ultraviolet light from the sun which provides the activation energy required to initiate the incorporation of oxygen atoms into the polymer, leading to thermo-oxidative degradation. In this step, the plastic becomes brittle and it's fracturing into smaller pieces until the polymer chains reach sufficiently low molecular weight to be metabolized by microorganisms. The microorganisms change the carbon of the polymer chains to carbon dioxide or integrate it into biomolecules, but this process will take at least 50 years (Hayden, et al., 2013).

So, a solution to these problems will be the recycling procedure is the best technique to treat waste polymer products in contrast to the old-style methods (combustion of waste polymers or burying underground) which lead to a negative effect on the environment through the formation of bags of dust, fumes, and toxic gases because most product plastics are relatively stable, making monomer recovery poor.

2.12 Plastic Recycling process

The recycling process is the best technique to treat waste polymer products in the comparison with the old-style methods (the combustion of waste polymers or burying underground) which lead to negative influences on the environment via the formation of dust, fumes, and toxic gases (Madalina, 2017). Also Kumar (2017) discussed that PET plastic can be safely burnt with no noxious gases being produced due to the only combustion elements PET have oxygen, hydrogen and carbon (Kumar & Singh, 2017).

Type of recycling

A, Mechanical recycling

Primary Recycling: - reuse of products in their original structure.

Secondary Recycling:-In this process, only the thermoplastic polymers can be used, because they can be re-melted and reprocessed in the end products. This process is represented by a physical method, in which the plastic wastes will be shaped by cutting, shredding, or washing into granulates, flakes or pellets of appropriate quality for manufacturing, and then melted to make the new product by extrusion, this method is relatively inexpensive but needs substantial initial investment.

B, Tertiary recycling:-is Feedstock or Chemical Recycling. This process can be used with mechanical recycling as complementation. Chemical recycling is defined as the process in which polymers are chemically changed to monomers or partially depolymerized to oligomers through a chemical reaction (a change occurs to the chemical structure of the polymer).

The resulted monomers can be used for new polymerization to repeat the original or a related polymeric product. This method is able to transform the plastic material into smaller molecules, suitable for use as feedstock material starting with monomers, oligomers, or mixtures of other hydrocarbon compounds. This method wants a lot of investments and skilled personnel.

C, Energy Recovery or Quaternary Recycling:-is Energy Recovery or incineration. This method refers to the recovery of plastic's energy content. The most effective way to reduce the volume of organic materials which involves the recovery of energy is represented by incineration. This method is a good solution because it makes significant energy from polymers, but it's not environmentally suitable because of the health risk from airborne toxic substances (Hopewell, et al., 2009).

2.13 Production of brick using different wastes materials

This was evidenced by researches that attempts were made to incorporate various waste materials in bricks production and different tests were conducted on the bricks manufactured from waste using different standards such as bricks property like physical, mechanical has been positively influenced by the addition of waste material. Moreover, the consumption of waste in brick manufacturing may contribute to the conservation of natural resources, environmental protection, and saving in land for construction.

The review paper development of bricks from waste material by Alaa. A. Shakir (2013) shows the effects of wastes on the properties of the bricks as physical, mechanical properties discussed the utilization of wastes such as natural fibers, textile laundry wastewater sludge, foundry sand, granite sawing waste, processed waste tea, sewage sludge, structural glass waste, PC and TV waste, fly ash, sugar cane bagasse ash, organic residue, steel dust, bottom ash, rice husk ash, silica fume, marble and granite waste, municipal solid incineration fly ash slag (Alaa.A., et al., 2013). The material in brick production improve performance regarding making more ecological and economical brick neither consumes energy resources nor emits pollutant gases gives an economical option to design the green building. Certain bricks are produced without firing which is beneficial over other manufacturing of bricks regarding low embodied energy material.

The review approach on bricks making from waste is useful to provide potential and sustainable solutions (Alaa.A., et al., 2013).

The study looked into the strength properties to waste PET bottles filled in fine sand which is called The ‘bottle brick’ is one such invention. The result showed in the compressive resistance test and split tensile resistances are respectable. The bottle bricks were established to be tougher than conventional bricks and concrete cylinders. The study in Bangladesh on the strength properties of plastic bottle brick and their suitability as construction materials shows the strength properties to waste PET bottles filled in fine sand gave good results. They take five different sizes (250, 500, 1250, 1500, and 2000ml) of waste PET bottle bricks were tested for compressive strength and the largest bricks gave a compressive strength of 17.44MPa. 9 and 12 bottles were prepared with 1000ml bottle brick filled cubes then tested. The 9 bottle brick filled cubes gave a compressive strength of 35MPa and the 12 bottle bricks filled cubes gave a compressive strength of 33.7MPa. They conclude that Waste Polyethylene Terephthalate (PET) bottles packed with other dry solid waste or sand and earth has been effectively used and the bottle bricks were found to be stronger than conventional bricks and concrete cylinders (Muyen, et al., 2016).

The study of Alaa A. Shakir (2013) on Manufacturing of Bricks in the Past, in the Present, and in the Future shows the applicability of Bricks from Wholly Waste Materials such as Chihpinetal. Did a study on recycling the water treatment residual (WTR) and the excavated soil, the ceramic bodies were arranged to formulate into building bricks and artificial aggregates. recycled marble and granite waste of dissimilar sizes in the manufacturing of concrete bricks, with full replacement of conventional coarse and fine aggregates with marble waste scrapes and slurry powder of content up to 40 percent by weight to be used in the building sector as non-load bearing spacing construction materials (Alaa.A., et al., 2013).

Most of the researchers explored the probability of developing clay bricks from waste. Although, their efforts were respected and worthy they didn’t save the virgin resources from the evitable depletion since they are still dug out and utilized in the production processes. Therefore, more efforts should be directed toward different types of industrial waste. For instance, Billet scale, quarry dust, fly ash, bottom ash to be utilized as the main constituents in the bricks (AlaaA. & Ali, 2013).

The studies showed the possibility of using plastic as a binder with the aid of catalyst through de polymerization of PET to replace cement, aggregate, and as a mold. Plastic waste has been used in many ways, in brick production. The compressive strength of the bricks produced to comply with the standard outlined (Siti & Nur, 2018).

The study of Chauhan shows proportional mix ratio of plastic sand brick is 1:2, 1:3, and 1:4 for the purpose of finding the optimum proportion which gives the desired results (Chauhan, et al., 2019).

Generally, in recent years, engineers are trying to utilize waste plastics as construction material, such as Plastic- bottle bricks, plastic as a binder and plastic as a replacement of aggregate, plastic with sand for the production of bricks, hollow concrete blocks, and tiles are some recently manufactured construction materials. Based on the different research common types of plastics that are mostly reprocessed are polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET), polypropylene (PP) and polyethylene (PE), high-density polypropylene (HDPE).

2.14 Sand

Sand is a vital construction material of a natural source. Mixed with cement and lime, millions of tons of sand are used each month for construction as mortar, plasters, and concrete. The word sand is used for rock particles that range in grain size between 2 mm and 1/16 mm or material below 4.75mm Size is termed as fine aggregate. In composition, they are mainly an oxide of silica (SiO_2). Mineralogical, they contain mostly fragmented grains of mineral Quartz (SiO_2) produced as a result of a breakdown of granite, sandstone, and similar rocks by natural processes of weathering and erosion."

"Sand for construction works different construction works requires different standards of sand for construction. Based on Madhav (2017) study he stated brick work and plastering works, used with silt contents should not be more than 4%. Concreting Works: Coarse and should be used with the finest modulus 2.5 to 3.5 and silt contents should not be more than 6%" (Madhav & Er.Buddhi, 2017).

2.15 Proportion of plastic and sand for brick production

The process of developing mixture proportion is often repeated trial-and error efforts to achieve balance between voids, strength paste content, and workability for plastic to sand proportion. Different researchers used general formula for different mix proportion to new material to seek the optimum proportion. According to Dinesh.S (2016) on his research in utilization of waste plastic in manufacturing of bricks and paved blocks research he used different mix proportion by assuming the mold volume, plastic density which he used, and shrinkages and wastages values (Dinesh.S, et al., 2016).

This was evidenced by researches that attempts were made to incorporate various waste plastic materials with sand in production of tiles blocks as well as bricks in different mix proportions for the purpose of finding the optimum proportion and different tests were conducted like physical, mechanical on the manufactured tiles, blocks, and bricks from waste plastic and sand and shows positively influenced by the addition of waste materials.

According to Mr. N. Thirugnanasambantham (2017) research's on manufacturing and testing of plastic sand bricks, shows to find the plastic sand bricks that they possess high compressive strength, he used different mix proportions were 1:3,1:4 and 1:5 these are the ratio which represents the PE plastic, river sand respectively the result shows as 5.56 N/mm2 of compressive strength in 1:5 mix proportion, 0.727%of water absorption capacity in 1:4 ratio and nil efflorescent, high quality in the hardness test and up to 180^{o}c resistance of fire in all ratios generally he concluded that using PE plastic and sand for brick production increases the compressive strength compared to fly ash bricks (N.Thirugnanasambantham, et al., 2017).

The study of Ganesh (2020) on the manufacturing of plastic sand bricks from a polypropylene and polyethylene waste plastic six plastic sand brick samples was prepared based on different plastic to sand ratio and results showed that the plastic sand bricks with 2:1 ratio have high compressive strength up to12.43 N/mm2 as compared to the normal concrete bricks, zero efflloresce, arrange of (zero-slight) a water absorption, and a good fire resistance (Ganesh, et al., 2020).

The study of Arvind Singhak (2018) on the utilization of the plastic waste in the manufacturing of plastic sand bricks looked in to the properties of the brick by mixing PE plastic with sand in 3:7 ratio which represents the waste plastics, stone dust respectively the result shows as 5.6 N/mm2, 0 % of the water an absorption capacity, nil an efflorescent and little scratch visible in the hardness test generally he concluded that using waste plastics which are available everywhere, may be put to an effective use in a brick/a tile making (Arvind & Dr.Omprakash, 2018).

In Chuhan (2019) the study on the use of plastic bottles, and the plastic waste in the making of plastic sand bricks is examined in different mix proportions such as 1:2, 1:3, and 1:4 these are the ratio which represents the PET plastic, river sand respectively, and tests such as compressive strength, a water absorption capacity, and efflorescent tests are examined and the result shows the optimum mix proportion was 1:2 (Chauhan, et al., 2019).

Generally, in recent years, engineers are trying to utilize waste plastics as a construction material there is no knows standards for mix proportion of plastic to sand that is why they take different proportions. To find the optimum proportion different researchers investigate on it, and they get the maximum compressive strength result in different mix proportion as shown above so there is no know mix ratio for plastic to sand for brick production but in any way using plastic for brick production have good results compared to fly ash and sand brick.

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Study Area

The experimental study was conducted in Ethiopia, Oromia Regional State Jimma zone. Jimma is the largest city in south-western Oromia in Ethiopia which is located 355 km by road southwest of Addis Ababa as indicated in figure 3.1. It is a special zone of the Oromia Region and surrounded by the Jimma zone. It has a latitude and longitude of 7^0 40'N 36^0 50'E with an estimated area of 50.52Km².

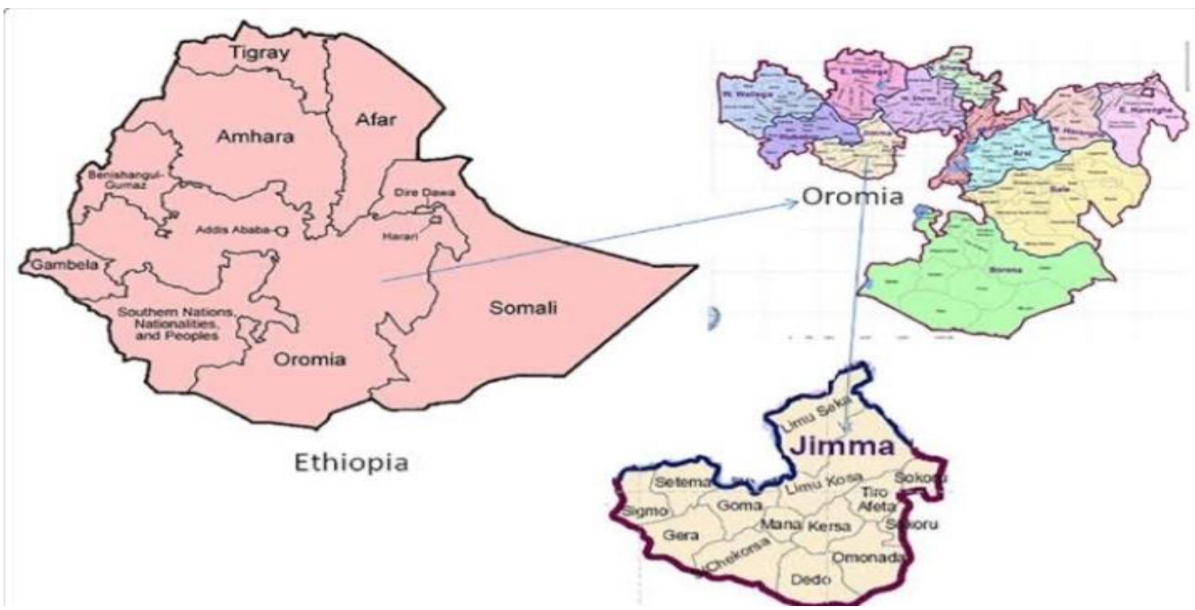

Figure 3.1: Ethiopia, Oromia Regional State Jimma zone map

3.2 Study Period

The research was started on June 1, 2020 and it ended on March 30, 2021 G.C. The research was conducted for 9 months.

3.3 Materials Used for the Study

A, Materials used to produce plastic Brick were

- ✓ PET waste plastic
- ✓ Sand

PET waste plastic used

Plastic wastes used were mainly from water and soft-drink packaging these plastic wastes were collected from the waste disposal areas, different bars and restaurants of Jimma city, especially from Jimma University (JIT) compounds. PET plastic waste was isolated from other plastic wastes by their codes on the plastic products. According to these codes, PET is given the number 1 in a triangle. Plastic wastes have to be shredded into small flakes before melting (Ankit & Dr.Urmil, 2013). But the availability of a plastic shredder is less in Ethiopia. For this reason, the author used a clipper to shred, and as much as possible tries to cut homogeneously. This was for the purpose of simply and effectively cleaning and easy for the melting.

Plastic wastes might become the contact with different wastes and might become from different application areas such as oil containers, soft drinks bottles, and they may be the contact with other wastes at the waste disposal. Here, the plastic wastes were washed by using water and soaps until dirties on them were cleaned well. This was done to reduce the effects of the impurity due to unclean on the production process and on the final product then sun-dried to remove the water present in it.

Figure 3.2: Collected and shredded PET plastic

Fine aggregate Used

Aggregates are materials basically used as filler with a binding material, reduce the shrinkage, and affect the economy. Therefore, it is significantly important to obtain the right type and quality of aggregates on site. They should be clean, hard, strong, and durable, and graded in size to achieve the utmost economy from the paste. Therefore, to judge the quality of the aggregate physical characteristic tests have to be conducted. For this study, the sample was purchased from the suppliers from Jimma town, and there are different sands from different places around Jimma town, and the specific place sands used for this research was sand from Werabe. Their properties were clearly determined. The size of aggregate for the experimental study was between sizes of 4.75 mm-150micro meter diameter sieved fine aggregate was used. The sand is used to make concrete for different construction applications. To clean soil out of them, sands can be washed using clean water before using. Since it has less silt content, sand for this thesis work was used directly without the need for washing. After bought the sand was sun-dried and prepared for use.

Figure 3.3: Fine Aggregate

B, Equipment and tools used for brick production

Tools used to conduct the experiment in the laboratory was such as a metal tray, balance, oven-dry, thermometer, shovel, pycnometer, clipper, drum, and compressive strength testing machine.

3.4 Study Design

In this study design, the study design used was experimental design (laboratory tests) and interprets observations. This study was designed in a way that important and exact information could be getting about recycling of waste plastic which is important for brick production.

3.5 Study Variables

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

Dependent: - Properties of plastic brick

Independent: - Properties of sand and mix Ratio

3.6 Sample Size and Sampling Method

Sampling procedure was taken according to Ethiopian standard, and the material proportion for waste plastic brick is made. The minimum mold samples per each test are 5 molds according to ES standard and the samples for the compressive strength of waste Plastic brick 15 molds 3, samples each for 1:2, 1:4, and 1:6.

The compressive strength, the absorption, and the efflorescence samples for the waste plastic brick have a total of 60 bricks used, and the test is taken on. There are 3 groups for each group 20 bricks are tested with 1:2, 1:4, and 1:6 of waste plastic and sand proportion for all the test are performed. Table 3.1 below shows the sample of mix proportion. For all tests, the mold size used is 19cm*9cm*4cm based on Indian standards. During the sampling method process, it is started by collecting Waste plastic bottle samples from any place and transported to the laboratory for testing and visual observation.

Table 3.1: Sample of mix proportion

List of Group	Mix-Ratio	Mix proportion for one(1) brick in gram	Number of samples for the test according to ASTM and ES		
			For Compressive strength	For Absorption	For Efflorescence
Group-1	1:2	488:976	5	5	10
Group-2	1:4	292.6:1170	5	5	10
Group-3	1:6	209:1254	5	5	10

3.7 Data Processing and Analysis

3.7.1 Secondary Data

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

3.7.2 Primary Data

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

- ✓ Produce Sample bricks
- ✓ Laboratory test of Waste Plastic brick
- ✓ Visual observation (Laboratory Result)

3.8 Experimental Procedures

Melting

Burning of the firewood was done, and a drum was placed on the fire, the plastic pieces were added to the drum to melt. The melting temperature depends on the plastic-type. Byung-Hyun Ryu and his workers have used the processing temperature of 270°c for PET and Aggregate composite (Byung, et al., 2020).

The temperature for melting was controlled by a thermometer, and it starts melting at 257°c but cannot be melting at a controlled temperature due to its open-air melting, so the melting temperature is between 257°c-315°c.

Figure 3.4: Melting of PET plastic

Batching of Sand and PET Plastic

For the fabrication of Recycled plastic bricks, plastic, and sand are mixed in different proportions and bricks containing different amounts of plastic and sand are made. The reason behind taking different proportions of plastic and sand is to find the optimum proportion which gives the desired results.

Figure 3.5: Batching of sand and melted and liquefied PET plastic

Preparation of Brick Mold

The molds used are wood molds and are made in the carpentry shop. All the sides are painted by the oil for the purpose of easily removed and according to Indian standard Mold, size is (19×9×4) cm.

Figure 3.6: Wood Molds

Mixing

Plastic and river sand is mixed in different proportions 1:2, 1:4, and 1:6. The melted and liquefied plastic wastes are mixed with the fillers while stirring mixtures continuously up to get perfect bonding, so that it may be homogeneous.

Figure 3.7: Mixing sand with PET plastic

Molding

Lastly, the mixture obtained after continuous stirring is fed into the mold and compressed by tamping rod and trimmed then left for cooling for 24 hours after which the brick is taken out from the mold test were conducted after casting 48 hr.

Figure 3.8: Waste Plastic Bricks

3.9 Determining physical properties of fine aggregate for Waste plastic Brick production and Mechanical properties of Waste plastic Brick

The physical properties of fine aggregate necessary for describing the type of fine aggregate used in waste plastic brick production, determined in the laboratory according to the ASTM method and testing requirements. The test methods used for the fine aggregate, and for the brick are listed in Table 3.2.

Table 3.2 : Physical Property standards and test methods for fine aggregate and mechanical property standard and test methods for Brick.

Property tests	Test methods
Sieve analysis or gradation and fineness modulus	ASTM C-136
specific gravity and absorption capacity of fine aggregate	ASTM -128
moisture content of fine aggregate	ASTMC- 566
unit weight of fine aggregate	ASTM C-29
compressive strength of brick	ASTM C62-97a,BS3921 and ES 86 2001
Absorption of brick	BS 3921 and ES 86 2001
Effloresces of brick	ESC.D4.001

3.10 Laboratory test of waste plastic brick and reporting of test results and analysis

The properties of fine aggregate which was used for this research, and the final product waste plastic brick compressive strength, water absorption, and efflorescent was tested in JIT, Construction Materials Testing Laboratory using Ethiopian standard specification for solid clay bricks. The test results are analyzed based on the Ethiopian standard specification of solid clay bricks (ES 86: 2001). The results are described in chapter four.

3.10.1 Properties of Fine Aggregate

The fine aggregate used in this study natural sand and it was purchased from the supplier from Jimma town at Agip. To determine its property and to know the suitability of the material, different test procedures were conducted. Silt content of fine aggregate, fineness modulus moisture content of fine aggregate, specific gravity, and unit weight of sand was conducted.

1. Silt Content

Sand used for construction should be clean, free from dust, loam, clay, and vegetable matter. The occurrence of such materials makes concrete or mortar lose the bond between the materials. According to the Ethiopian standard, if the silt content of the sand is more than 6% it shall not be used for construction (Abebe, 2002). In this study, the fine aggregate that was used has a silt content of 3.95% and this value was within the range of the standard, and it passes the requirement.

2. Sieve Analysis or Gradation and Fineness Modulus

Sieve analysis is a method for the determination of the particle size distribution of aggregates using a series of square, or round interlocks starting with the largest. It used to determine the aggregates and fineness modulus, an index to the fineness and coarseness, and uniformity of aggregates. This test method is used primarily to determine the grading of materials proposed for being used as aggregates (ASTMC136-96a, 2001). The fineness modulus of sand should be between 2.2and 3.2 based on the ASTM standard. Fineness modulus is often computed using the sieve analysis results. The fineness modulus is the sum of the total percentages retained. Then each of a specified series of sieves, divided by 100. Finally, filling in the gradation chart and computing the fineness modulus.

1. % Retained= $\frac{\text{W retained}}{\text{W total ret}} * 100\%$
2. % of cumulative finer= W% retained above+ W %retained below
3. % of passing=100%−%Cumulative finer
4. Fineness Modulus= $\frac{\Sigma\% \text{ retained}}{100}$

In this study, fine aggregate that used have a fineness modulus of 2.92 and this was within the range of ASTM standard.

Figure 3.9: Graph for sieve analysis of fine aggregate

3. Specific Gravity and Absorption Capacity of Fine Aggregate

The specific gravity of a substance is the ratio between the weight of the substance and that of the same volume of water. Aggregates, however, have pores that are both permeable and impermeable; whose structure (size, number, and continuity pattern) affects water absorption, permeability, and the specific gravity of the aggregates (Abebe, 2002). According to (ASTMC128-97, 1998) the limitation for absorption capacity ranges from 0 to 2 % weight for fine aggregates.

Calculation

Relative density (specific gravity) (OD) = A/ (B+S-C)

Relative density (specific gravity) (SSD) = S/ (B+S-C)

Apparent relative density (apparent specific gravity) = A/ (B+S-C)

Absorption, %=[(S-A)/A]*100

Where

A=mass of oven dry specimen, g

B= mass of pycnometer filled with water to calibration mark, g

C= mass of pycnometer filled with sample and water to calibration mark, g

S= mass of saturated surface dry sample used, g.

4. Moisture Content of Fine Aggregate

An aggregate was considered as free from water and never absorbing moisture from the environment. This test determined the moisture content of sand. The moisture content of sand was determined by taking a sample and oven-dry them with an adjusted temperature for 24 hours, and from the difference in weight before and after drying, the moisture content is determined. Moisture Content of fine aggregate was determined in accordance with (ASTMC566-97, 1997).

The moisture content is calculated from the equation,

$$\text{Total Moisture Content, \%} = \frac{A-B}{B} * 100$$

Where: A = Weight of the original Sample

B = Weight of oven dried sample

The moisture content of sand used has a value of 2%.

5. Unit Weight or Bulk density of Fine Aggregate

Unit weight can be defined as the weight of a given volume of graded aggregate. It is thus a density measurement and is also known as bulk density. The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them (Abebe, 2002). The bulk density of the aggregate was determined according to (ASTMC29/C29M, 1997). The aggregate unit weight ranges from 1417.95 to 1557.75kg/m3.

The bulk density is calculated for each test specimen using unit weight formula.

$$\text{Unit Weight (Kg/m3)} = \frac{B-A}{C}$$

Where A = Weight of Container (Kg)

B = Weight of Container + Sample (Kg)

C = Volume of container

The unit weight of fine aggregate used in this study, fulfill the requirements.

Figure 3.10: Measurement of unit weight

3.10.2 Properties of Waste plastic Brick

1. Compressive strength test on Brick

The observation and analysis of the compressive strength test of Waste plastic Brick with 1:2, 1:4, and 1:6 ratios (by weight) of PET plastic and sand were conducted. According to ES, 86 2001, and (ASTM, 2012). Compressive strength test was conducted. To get the optimum proportion of PET plastic and sand analyzing the compressive strength test was mandatory, there are five bricks from each ratio were taken which means 5×3=15.

$$\text{Compressive strength} = \frac{\text{maximum load applied}}{\text{Specimen area}}$$

Figure 3.11: Compressive Strength test and result

2. Absorption capacity test on Brick

The observation and analysis of the absorption test of waste plastic brick with 1:2, 1:4, and 1:6 ratios (by weight) of PET plastic and sand were conducted. According to Abebe Dinku construction material laboratory manual (Abebe, 2002) test was conducted.

In this test, first bricks were dried in the oven for 24 hours then weighted. Then they were immersed in water for about 24 hours in a container then taken out, wiped with a cloth, and weighted. For the calculation of absorption, the difference between wet brick and dry brick was done. The difference was the amount of water absorbed by the specimen.

$$\text{Absorption\%} = \frac{W2-W1}{W1} * 100$$

Where: W1- Weight of dry brick

W2- Weight of wet brick

3. Effloresces of Brick test

The standard used for the efflorescent test is ESC.04.001. It was prepared to identify the presence of alkalis in plastic bricks. The first brick specimens were immersed in water for 7 days, and the second brick specimens stored in the drying room without contact with water then at the end of 7 days checked the first set of specimens and then dry both sets in an oven for 3 days then see any difference between the two specimens.

3.11Study Framework

This research was conducted by using a primary and secondary data. In cooperation primary data sources and secondary data sources have been used. Therefore, the objective of the research was achieved in accordance with the methodology outlined below in Figure 3.12.

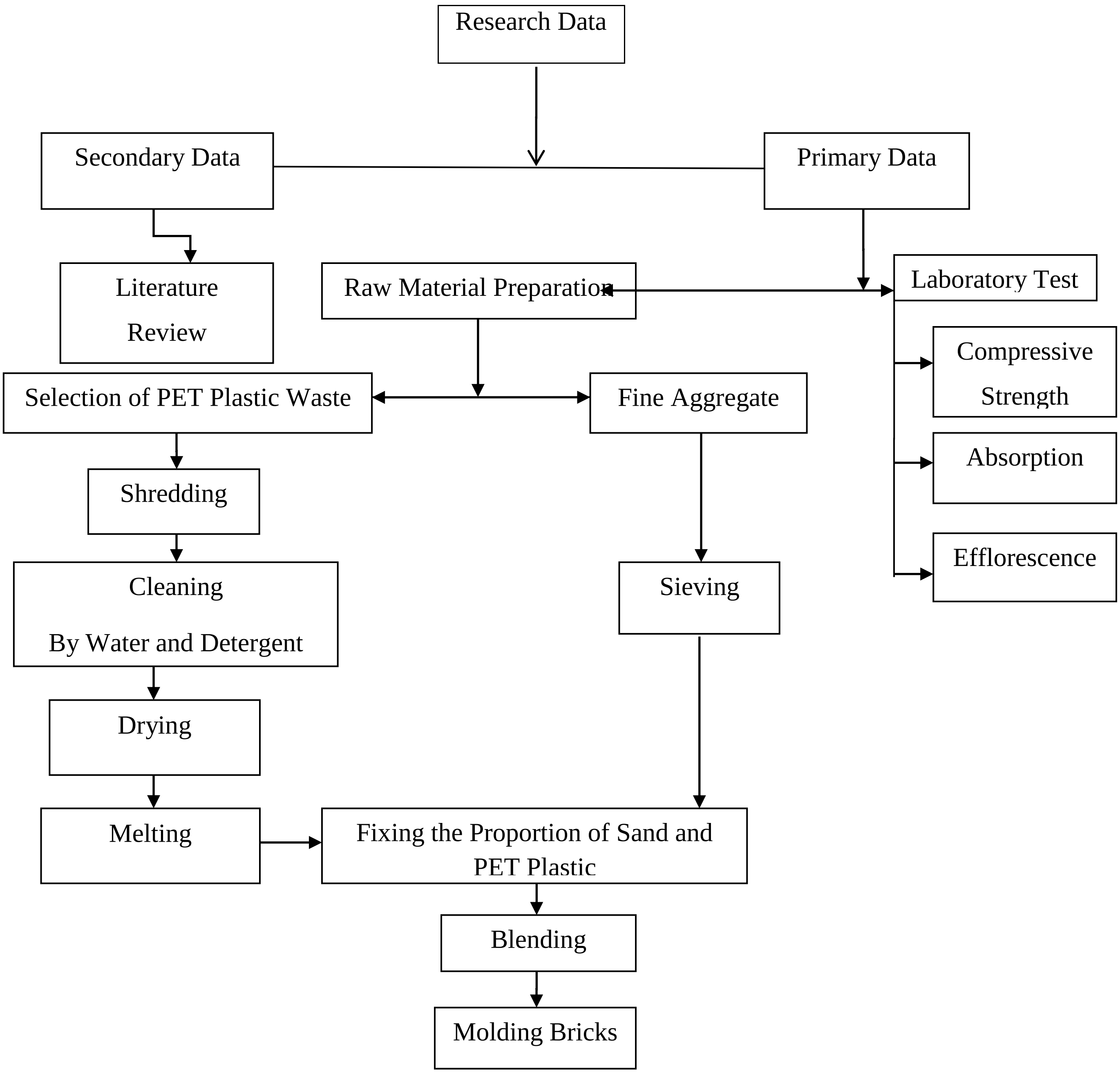

Figure 3.12: Study Design Structure

CHAPTER FOUR
RESULT AND DISCUSSION

4.1 Properties of Materials

4.1.1 Gradation and Fineness Modulus of sand

According to (ASTMC136-96a, 2001) requirement of grading including the percentage passed of the fine aggregate samples that were used for the experiment was shown below in figure 4.1and 4.2. Where the result of the fine aggregate percentage passed on each sieve size used for the sieve analysis with the limit of the standard specification. The fine aggregate size conducted in the experimental test had 4.75 to 0 mm or (pan) of sieve size. The detailed sieve analysis of the fine aggregate was found in the appendix of this research. Therefore, based on (ASTMC136-96a, 2001) standard specification the grading of the sample result fulfills the standard requirement. In this, two trials were conducted for Fineness Modulus and the average of the two FM was used to minimize error.

Average Fineness Modules = ∑cumulative retained (%)/100 = 293/100and 291.1/100 = 2.93+2.91=2.92

Depending upon their size, the fine aggregate can be classified as coarse sand when a fineness modulus is between 2.90 to 3.2; medium sand with a fineness modulus of 2.60 to 2.90, and; fine sand with a fineness Modulus of 2.20 to 2.60. So, in this study, the sample was classified as coarse sand.

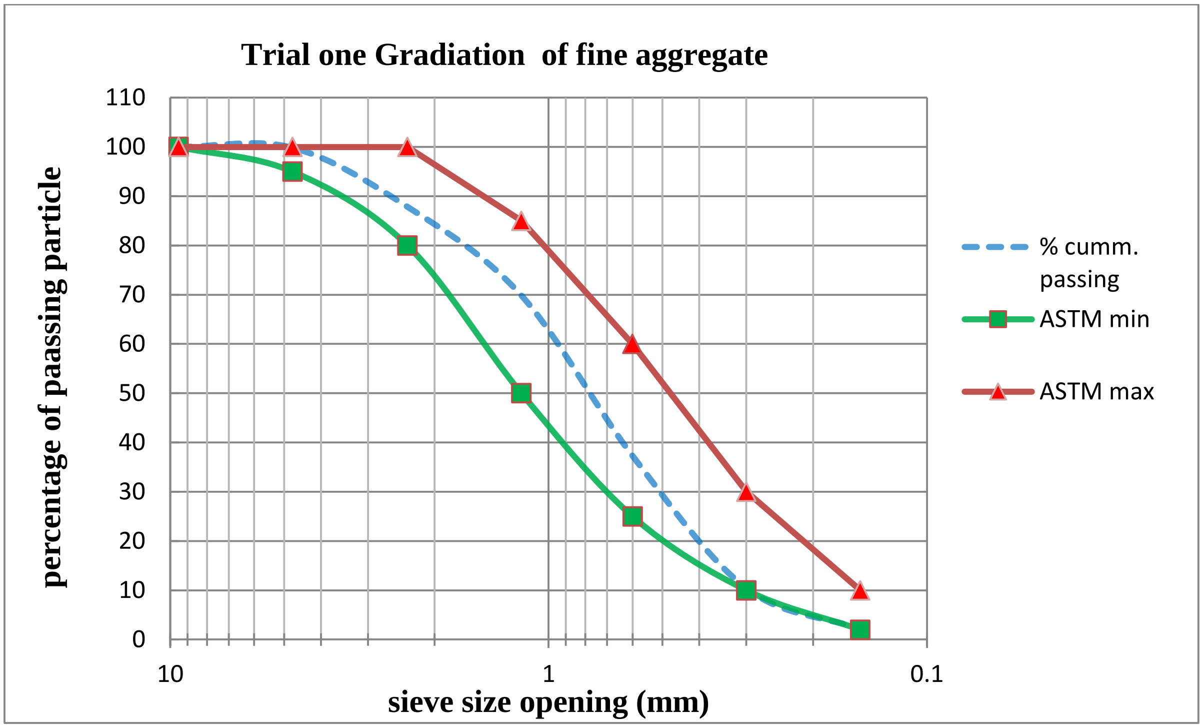

Figure 4.1: Trial one Gradation curve of fine aggregate

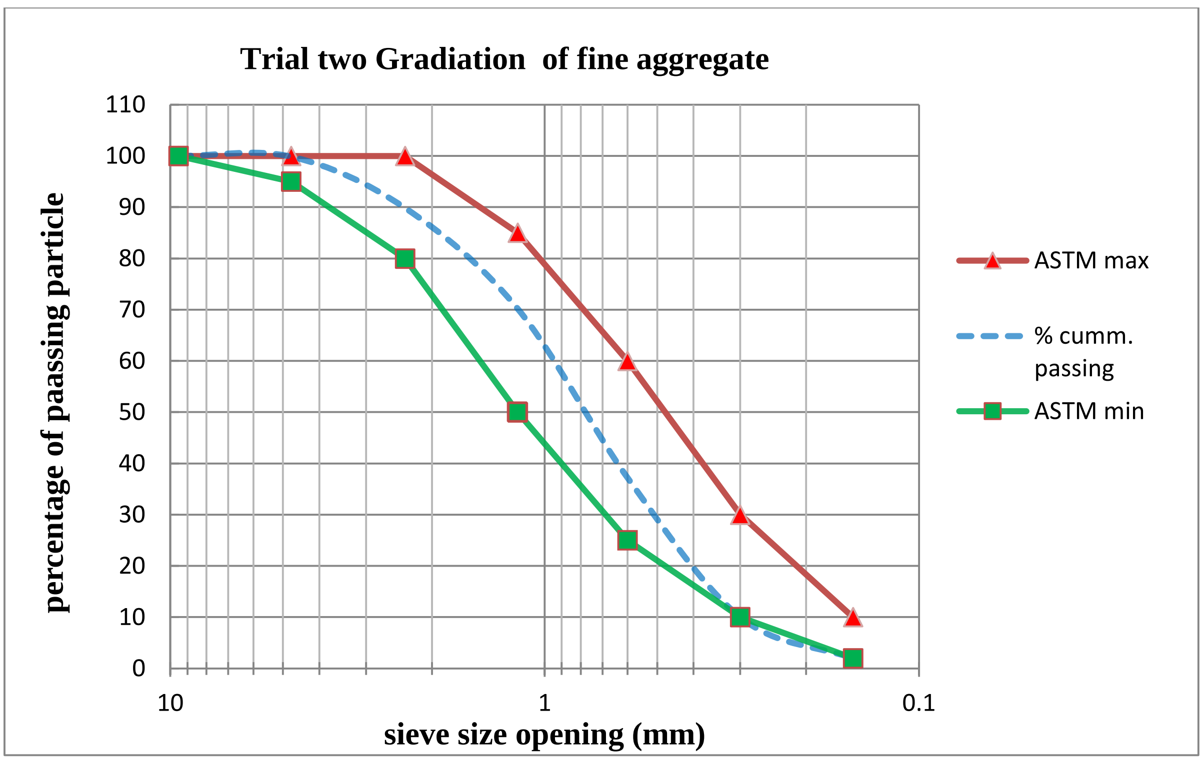

Figure 4.2: Trial two Gradation curve of fine aggregate

The above figures 4.1 and 4.2 show the grain size distribution of fine aggregate which was under limit and upper limit. This indicated that the possibility of the percentage passing in each size of sieves was within the limit of the standard specification.

4.1.2 Unit Weight of Fine Aggregate

Unit weight is one of the other physical properties of fine aggregate. Basically, the fine aggregate used in the experimental test was 1417.95 kg/m^3 loose unit weight. Based on the standard result of ordinary aggregate conducted during the experiment, the test was fulfilling the requirement of the unit weight needed for Waste Plastic brick production.

4.1.3 Moisture content, Specific Gravity and Absorption Capacity of Fine Aggregate

The other physical properties of fine aggregate are moisture content, absorption, and bulk specific gravity which are conducted during experimental. The experimental results were 2, 2 and 2.49% for moisture content, absorption, and bulk specific gravity respectively. According to ASTM C33, the limitation for bulk specific gravity (SSD) is from 2.4 to 3.0, absorption from 0 % to 2%, and moisture contents should be within 0.5% to 2%. Therefore, the experimental result of moisture content, absorption, and the bulk specific gravity of fine aggregate is with ASTM limitation. The calculation for these experiments is shown in appendix B.

From table 4.1, all physical properties of the materials used for this study fulfilled the required standard limitation of the experimental study, and it was safe for the production of Waste plastic brick.

Table: 4.1: Physical properties of Conventional Fine Aggregate

No	Description	Method	Test Result	Allowable limit
1	Fineness Modulus	ASTM C 136	2.92	2.2-3.2
2	Relative Density (Specific Gravity)	ASTM C128		
	Specific Gravity (SSD)	ASTM C128	2.49	2.4-3.0
	Apparent Specific Gravity	ASTM C128	2.54	2.4-3.0
	Absorption %	ASTM C128	2	0%-2%
	Moisture content	ASTM C566	2	0.5%-2%
4	Unit weight/bulk density	ASTM C29	1417.95	1050-1425

4.1.4 Durability property Absorption capacity test on Brick at different ratios

The water absorption test was conducted for 1:2, 1:4 and 1:6 plastic to sand ratios and each have five waste plastic brick samples, for each plastic to sand ratios were undertaken and the result was tabulated as following in Table 4.2. This table shows us the relationship between water absorption capacities with the proportion of plastic to sand.

In this relationship, when the proportion of plastic to sand increases, the water absorption capacity of the brick also increases which means water absorption of brick and plastic to sand proportion has a direct relationship. Thus, one would expect sand amount increases there is void in the specimen due to the void in the specimen there is permeability which increases the specimen absorption capacity. So, increasing the proportion of plastic to sand has a negative effect on the waste plastic brick.

Table 4.2: Absorption capacity result of waste plastic brick

Specimens	**Absorption capacity result, (%)**		
	1:2 ratio	**1:4 ratio**	**1:6 ratio**
1	1.53	2.42	3.92
2	1.27	1.92	4.99
3	1.46	1.61	4.12
4	1.28	1.85	4.44
5	1.37	1.94	3.86
Mean	1.38	1.95	4.27

Average water absorption results of Waste plastic brick at different ratios

As shown in figure 4.3 in the percentage of water absorption of waste plastic brick increases as the plastic to sand ratios increased. The average water absorption percentage obtained was 1.38%, 1.95%, and 4.27 % with respect to the different ratios which mean1:2,1:4 and 1:6 while the maximum individual sample water absorption was 1.53%, 2.42%, and 4.99%. From the result, we conclude that the capacity of the waste plastic brick to resist water absorption is in the settlement with Ethiopian standard which is average 22% and individually 24% and British standards which is brick< 7. This means based on ES and BS it's all proportions satisfied the water absorption requirement.

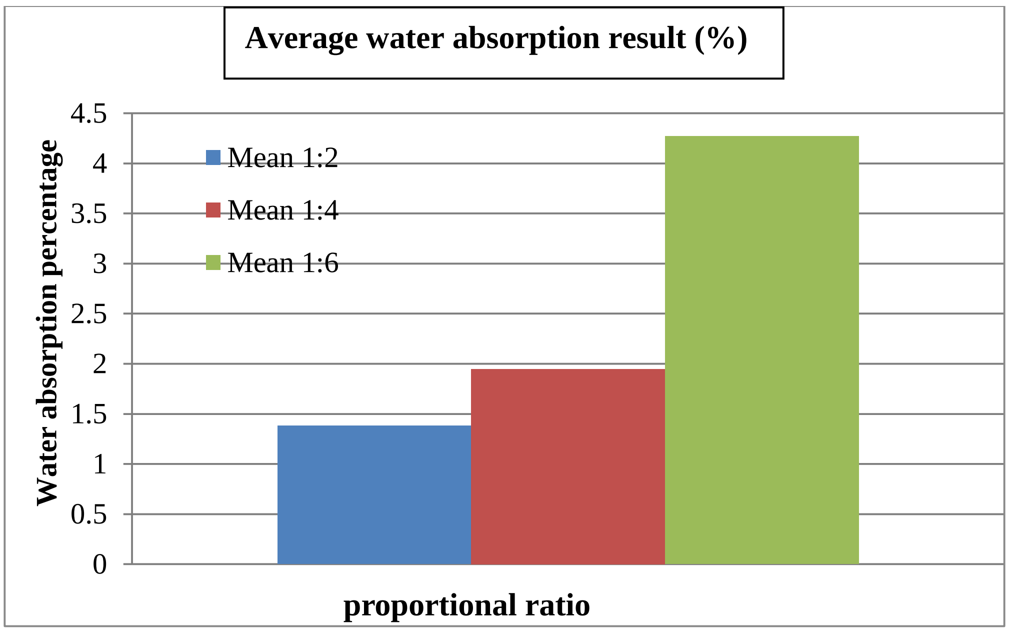

Figure 4.3: Average absorption capacity results of Waste plastic brick at different ratios

The findings of this research beyond to the Ethiopian standard for class-B building brick requirement and approaches to the research conducted by Chauhan (2019) on the title of Fabrication and Testing of Plastic Sand Bricks. The reason behind same difference between our result and Chauhan result was in this study sieving of sand is done by 4.75mm sieve and Chauhan suggested that sieving of sand is done by 600 micro sieve which is very fine sand due to this less porosity exist in the specimen. That is way the water absorption capacity result doesn't the same but near to his research.

4.1.5 Effloresces of Brick test

Efflorescence test for all mix proportions was conducted according to ESC D4.001. The result shows no difference due to efflorescence which means the test result indicates that “nil” here is no noticeable deposit of efflorescence over the surface which shows the waste plastic brick is good resistance to the effect of the alkali, and it can be classified as class A or class B according to ES. The findings of this research confirm to the research conducted by Ganesh (2020) on manufacturing of plastic sand bricks from polypropylene and polyethylene waste plastic.

4.1.6 Mechanical property test on Brick at different ratio

Compressive strength test of the Waste plastic brick was conducted for 1:2, 1:4, and 1:6 ratios as per the test method on (ES 86:2001). Five waste plastic brick samples for each plastic to sand ratio were undertaken and the results are shown below.

Table 4.3 shows us each specimen mechanical property 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 ratios. The waste plastic brick fulfilled beyond the minimum compressive strength requirement of solid clay brick. In this relationship, when the proportion of plastic to sand increases, the compressive strength of the brick decreases which means compressive strength and plastic to sand proportion have an indirect relationship. This is due to the amount of the plastic is less amount than the sand and also due to increasing the amount of sand it’s difficult to mix homogenously. So, increasing the proportion of plastic to sand has a negative effect on the compressive strength of waste plastic brick.

Table 4.3: compressive strength result of waste plastic brick

Specimens	**compressive strength result, (MPa)**		
	1:2 ratio	**1:4 ratio**	**1:6 ratio**
1	17.51	17.12	5.23
2	18.49	16.31	5.37
3	19.46	16.86	5.65
4	17.64	17.04	4.93
5	16.27	17.62	4.73
Mean	17.87	16.99	5.18

Average compressive strength results of Waste plastic brick at different ratios

The minimum average compressive strength classifies the produced brick according to the [ESC.86:2001] as A, B, C, and D and also according to ASTM C62-97a Grade SW, MW, and NW.

Figure 4.4, illustrates the average compressive strength of the three mix proportion result. The compressive strength at 1:2 ratios was to some extent higher than the rest of the ratios and the compressive strength at 1:4 ratios was higher than the 1:6 ratios compressive strength result. The waste plastic brick at 1:2 and 1:4 fulfilled the minimum compressive strength requirement of solid clay brick. The mean compressive strength achieved at 1:2 and 1:4 ratios of 17.87 and 16.99 MPA and the compressive strength at 1:6 ratios was 5.18MPa which is very (minimum) than the above ratios. The maximum mean compressive strength of 17.87MPa and 16.99 MPa was obtained at a mix proportion of 1:2 and 1:4 which is 19.13% and 13.27% greater than the minimum requirement (15MPa) of class-B brick and the maximum mean compressive strength of 5.18MPa was obtained at a mix proportion of 1:6 which is 65.47% less than the minimum standard requirement the waste plastic brick in this mix proportion doesn’t fulfill the minimum compressive strength requirement of solid clay brick. The obtained compressive strength at 1:2 and 1:4 ratios are beyond the minimum compressive strength requirement by 19.13% and 13.27% based on Ethiopian building code Standards as compared with clay brick. According to this analysis, the Waste plastic brick produced with the 1:2 and 1:4 proportion of plastic to sand can be classified as class B according to ES and Grade Moderate Weathering according to ASTM and the 1:6 mix proportion of plastic to sand cannot be classified like the 1:2 and 1:4 ratio classes.

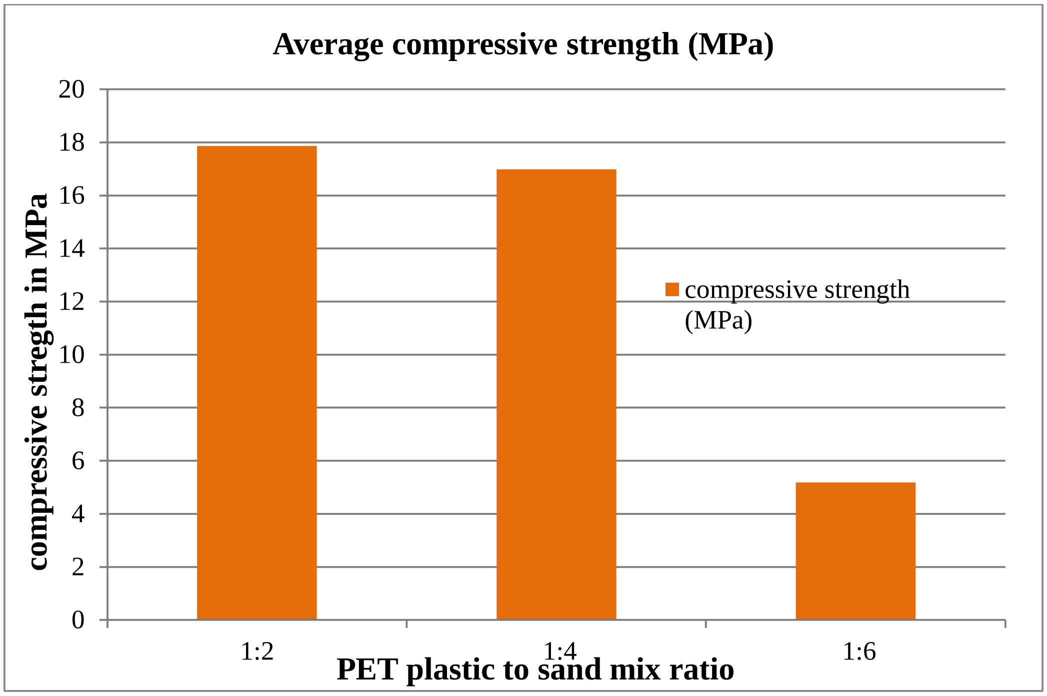

Figure 4.4: Average compressive strength for 48hr Age at different ratio

The findings of this research confirm to the research conducted by Chauhan (2019) on Fabrication and Testing of Plastic Sand Bricks. Because the author suggested that Plastic Sand Bricks made of plastic waste (PET) compressive strength shows high when compared to the conventional clay bricks for the same size. Also Sachin Anant Kamble (2017) suggested on his paper of plastic bricks was the same idea with Chauhan.

4.2 Optimum Proportion of Plastic and Sand for Brick Production

For the production of Waste plastic brick, the main process was the mixing PET plastic waste to river sand proportion (1:2, 1:4, and 1:6). From the produced waste plastic brick, as seen in table 4.4 the maximum compressive strength of 17.87MPa was obtained at a mix proportion of 1:2. The minimum compressive strength of 5.18 MPa was obtained at a 1:6 mix proportion. The obtained compressive strength fulfills the minimum compressive strength requirement set by Ethiopian Authority for standardization and ASTM requirements for building solid clay brick. In accordance with ES brick are classified into four classes based on the minimum compressive strength, Maximum Water absorption, and Efflorescence, comparing the three mix proportion waste plastic to sand, the optimum mix proportion which greatly fulfills the three requirements of Ethiopian Standard is a 1:2 ratio which is class-B. also 1:4 mix proportion also meets the ES requirement for class B but it have greater value of water absorption capacity compared with 1:2 water absorption capacity result. Therefore, the 1:2 ratio PET plastic to sand for Waste plastic brick production has greater and better compressive strength which fulfills the expected standard than the other two mix ratios. Also based on ASTM standard 1:2 ratio are touches MW Grade minimum compressive strength brick requirement this indicates it is moderate resistance to cyclic freezing damage is permissible or where the brick may be damp, but not absorb water to an amount equals to that resulting from submersion in room temperature water for 24 hr. with water when freezing occurs. Also, the test result indicates there is no noticeable deposit of efflorescence over the surface of the waste plastic brick.

Table 4.4: General average result of the three proportions

Ratios	**Minimum Compressive strength (MPa)**		**Maximum Water absorption (%)**		**Efflorescence**
	Mean of 5bricks	**Individual brick**	**Mean of 5bricks**	**Individual Brick**	
1:2	17.87	16.27	1.38	1.53	Nil
1:4	16.99	16.31	1.95	2.42	Nil
1:6	5.18	4.73	4.27	4.99	Nil

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the findings of the study the following conclusions were drawn:

From the properties of PET the secondary data shows that the chemical composition of PET contains relatively high amounts of CaO and SiO_2 that gives a cementitious property for the material.

The PET plastic for the production of brick have good result on mechanical property which is compressive strength test result, also the obtained test results for physical properties which are water absorption and efflorescence test result are good. Water absorption capacity of the produced bricks was less than the maximum absorption capacity requirement (24%) of Ethiopian standards for clay brick, and the test results for efflorescence are nil efflorescence which has good resistance to alkaline effect. Based on the result obtained, brick produced from PET plastic waste and sand does have very good property provided that proper proportions of the materials used. The optimum ratio of waste plastic PET to sand that was used to produce brick with desired property was found to be 1:2.

Generally, PET plastic waste has a positive effect on brick giving strength, for the hydration process with cement mortar as well as esthetical views. The utilization of PET plastic wastes as binding agent alternative to cement for brick production and other engineering applications is possible and being a potential input for the construction sector. The use of the plastic waste as alternative construction material is important to minimize the degradation of natural soil resource and contribute to environmental protection. The use of the plastic waste for brick production also helps to avoid the problem of landfill by the plastic waste material.

5.2 Recommendations

Based on the study conducted on the production of brick using the waste plastic material the following recommendation was made for the concerned bodies.

For the construction industry

The construction industry growth depends on the stakeholder's demand for using new and locally produced materials to use as construction materials. Therefore, Construction Industry in and around Jimma town should need to use new and locally produced materials after a further investigation on it and by examining with the conventional one and inspire the investors to produce new construction materials using the waste plastic because of the availability of plastic materials around Jimma town.

For Another Researcher

Further study is recommended to locally manufacture plastic densifier machine.

Other researchers work on changing the different physical property test result value of fine aggregate which means the moisture content percentage to zero or using oven-dried sand, the FM value used in this paper was coarser sand so change to medium sand because medium sand is more homogeneously mixed with plastic than coarser sand, homogeneously mixing decreases micro-pores in the specimen when fewer micro-pores exist in the specimen the water absorption capacity also less, work on conducting tests on different mix proportions rather than 1:2, 1:4 and 1:6 and work on finding other locally available material which can be replace sand also to compare with the locally brick other researcher investigate on other tests like fire resistance.

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APPENDIX A

BRICK MIX PROPORTION

To prepare mix design there is no any specifications in following the ratios. By predicting that the brick formed at the general formula of cement mortal mix ratio

Waste plastic brick mix ratio =1:2

Let volume of waste plastic brick = 0.000684m^3 for one brick

A, PET plastic =1/3*0.000684 m^3*1380kg- m^3*1.55 wastage and shrinkage

=0.4877kg or 487.7gm.

B, sand =2*0.4877kg

=0.9754kg or 975.4gm.

For 5 brick quantity of PET plastic= 5*488= 2440gm. and sand=5*976= 4880gm.

Waste plastic brick mix ratio =1:4

Let volume of waste plastic brick = 0.000684m^3 for one brick

A, PET plastic =1/5*0.000684 m^3*1380kg- m^3*1.55 wastage and shrinkage

=0.2926kg or 292.6gm.

B, sand =4*0.2926kg

=1.1704kg or 1170.4 gm.

For 5 brick quantity of PET plastic= 5*293=1465gm. And sand=5*1170=5850gm.

Waste plastic brick mix ratio =1:6

Let volume of waste plastic brick = 0.000684m^3 for one brick

A, PET plastic =1/7*0.000684 m^3*1380kg- m^3*1.55 wastage and shrinkage

=0.2090kg or 209gm.

B, sand =6*0.4877kg

=1.2540kg or 1254gm.

For 5 brick quantity of PET plastic= 5*209=1045gm. and 5*1254=6270gm.

Table A.1 sample of mix proportion

List of Group	Mix-Ratio	Mix proportion for one(1) brick in gram	Number of samples for the test according to ASTM and ES		
			For Compressive strength	For Absorption	For Efflorescence
Group-1	1:2	488:976	5	5	10
Group-2	1:4	292.6:1170	5	5	10
Group-3	1:6	209:1254	5	5	10

APPENDIX B

MATERIAL PHYSICAL PROPERTIES

1, Sand sieve analysis: test method ASTM C136

Table: B.1 Trial one Conventional Fine Aggregate Sieve Analysis

Trial one					
sieve size, mm.	**Weight retained**	**% retained**	**%cum. Coarser**	**% cum. pass**	**Grading limit for % passing ES C.D3.201**
9.5	0	0	0	100	100
4.75	3.5	0.175	0.175	99.825	95-100
2.36	240	12	12.175	87.825	80-100
1.18	360	18	30.175	69.825	50-85
0.6	651	32.55	62.725	37.275	25-60
0.3	538	26.9	89.625	10.375	10-30
0.15	165	8.25	97.875	2.125	2-10
Pan	42.5	2.1	100	0	
	2000	**100**	**292.75**		

$$FM1 = \frac{292.75}{100} = 2.93$$

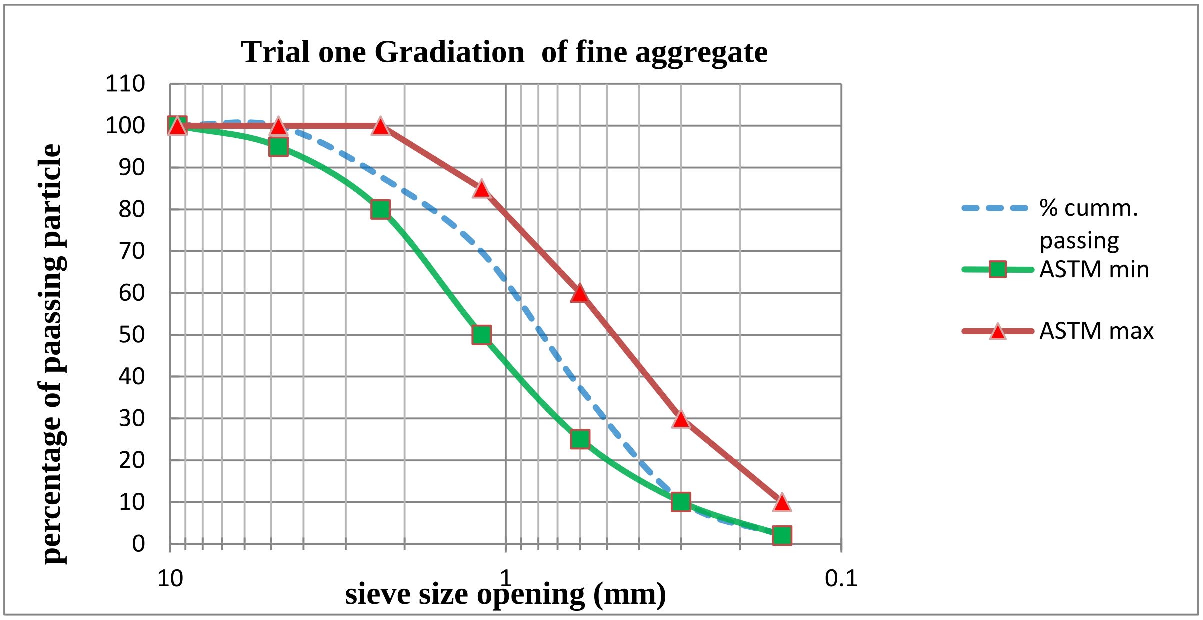

Figure B.1 Trial one Gradation curve of fine aggregate

Table: B.2 Trial two Conventional Fine Aggregate Sieve Analysis

Trial two					
sieve size, mm.	**Weight retained**	**% retained**	**%cum. Coarser**	**% cum passing**	**Grading limit for % passing ES C.D3.201**
9.5	0	0	0	100	100
4.75	3	0.15	0.15	99.85	95-100
2.36	200	10	10.15	89.85	80-100
1.18	393.5	19.675	29.825	70.175	50-85
0.6	660	33	62.825	37.175	25-60
0.3	551.5	27.575	90	10	10-30
0.15	163	8.15	98.15	1.95	2-10
Pan	29	0.95	100	0	
	2000	**100**	**291.1**		

FM2=291.1/100 =2.91

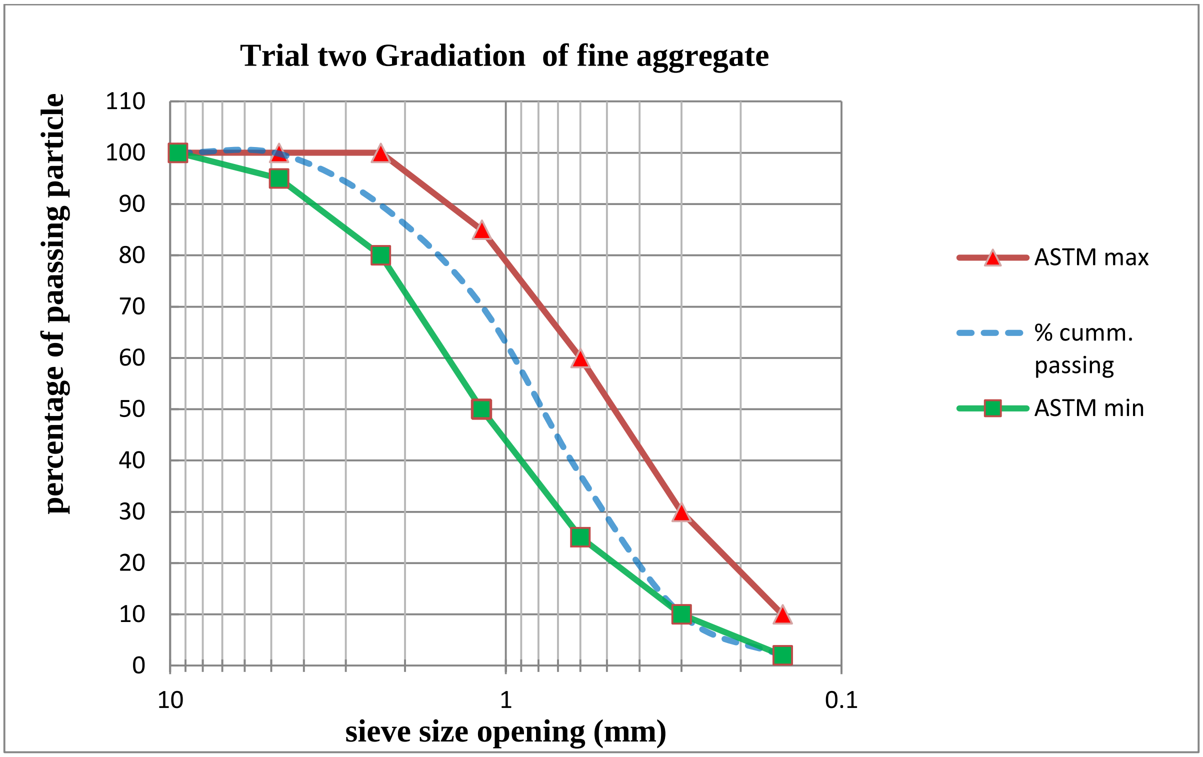

Figure B.2 Trial two Gradation curve of fine aggregate

2, Moisture Content: test method ASTM C566

Table B.3 Moisture content for Normal Fine aggregate

Description	Unit	Sample
Weight of the original Sample,(A)	gm.	500
Weight of oven dried sample, (B)	gm.	490
Moisture Content, % = $\frac{A-B}{B}$ ***100**	**%**	**2**

3.Unit Weight: test method ASTM C29

Table B.4 Unit Weight of fine Aggregate

Description	**Unit**	**Sample 1**		**Sample 2**	
		Without compaction	**With compaction**	**Without compaction**	**With compaction**
Weight of container (A)	Kg/m³	1.053	1.053	1.053	1.053
Weight of container + sample (B)	Kg/m³	8.1265	8.8305	8.159	8.855
Volume of container (C)	M	0.005	0.005	0.005	0.005
Unit weight = $\frac{B-A}{C}$	Kg/ m³	1414.7	1555.5	1421.2	1560
Average Unit weight= $\frac{\text{unit weight of sample 1+unit weight of sample 2}}{2}$	**Kg/ m³**	**1417.95**			1557.75

4. Specific gravity and Absorption: test method ASTM C128

Table B.5 Specific gravity and Absorption of fine Aggregate

Description	Unit	Sample
weight of sample, (S)	gm.	500
mass of pycnometer filled with water to calibration mark, (B)	gm.	1538
weight of picnometer +sample + water (C)	gm.	1841.5
Oven dried weight of sample, (A)	gm.	490
Relative density (specific gravity) (OD) = A/(B +S– C)	gm.	490/1538+500-1841.5=2.49
Relative density (specific gravity) (SSD) = S/(B + S – C)	gm.	500/1538+500-1841.5=2.54
Apparent relative density (apparent specific gravity) = A/(B + S– C)	gm.	490/1538+500-1841.5=2.49
Absorption, % = [(S – A)/A] × 100	%	$\frac{500-490}{490}$ *100=2.04
Specific Gravity	**gm.**	**2.49**
App. Specific gravity	**gm.**	**2.54**
Water Absorption	**%**	**2**

5. Silt content

Table: B.6 Silt contain

Description	Units	Sample 1	Sample 2	
weight of original sample of sand in air, (A)	gm.	1000	1000	
weight of washed and oven dried sample of sand in air, (B)	gm.	963	960	
Silt content (%)=$(A-B)/B*100$	**%**	**3.8**	**4.1**	**Average=3.95**

APPENDIX C

MATERIAL MECHANICALPROPERTIES

Table C.1 Compressive strength test result for 1:2 Ratios

specimens	Dimensions cm			Area cm²	Failure Load KN	Compressive strength MPa
	L	W	H			
1	19	9	4	171	298.23	17.51
2	19	9	4	171	316.31	18.49
3	19	9	4	171	332.71	19.46
4	19	9	4	171	301.68	17.64
5	19	9	4	171	278.03	16.27
Mean						**17.87**

Table C.2 Compressive strength test result for 1:4 Ratios

specimens	Dimensions cm			Area cm²	Failure Load KN	Compressive strength MPa
	L	W	H			
1	19	9	4	171	292.87	17.12
2	19	9	4	171	278.88	16.31
3	19	9	4	171	288.31	16.86
4	19	9	4	171	291.45	17.04
5	19	9	4	171	301.31	17.62
Mean						**16.99**

Table C.3 Compressive strength test result for 1:6 Ratios

specimens	Dimensions cm			Area cm²	Failure Load KN	Compressive strength MPa
	L	W	H			
1	19	9	4	171	89.36	5.23
2	19	9	4	171	91.91	5.37
3	19	9	4	171	96.58	5.65
4	19	9	4	171	84.37	4.93
5	19	9	4	171	80.87	4.73
Mean						**5.18**

Table C.4 Absorption capacity test result for 1:2 Ratios

Specimens	Weight of oven dried,(W1)	Weight of 24hr immersion,(W2)	Absorption capacity (%) = $\frac{W2-W1}{W1}$ * 100
1	1336	1356.5	1.53
2	1450.5	1469	1.27
3	1269	1287.5	1.46
4	1330.5	1347.5	1.28
5	1390.5	1409.5	1.37
Mean			**1.38**

Table C.5 Absorption capacity test result for 1:4 Ratios

Specimens	Weight of oven dried,(W1)	Weight of 24hr immersion,(W2)	Absorption capacity (%) =W2- W1 * 100 / W1
1	1197.5	1226.5	2.42
2	1173.5	1196	1.92
3	1149	1167.5	1.61
4	1216	1238.5	1.85
5	1186	1209	1.94
Mean			**1.95**

Table C.6 Absorption capacity test result for 1:6 Ratios

Specimens	Weight of oven dried,(W1)	Weight of 24hr immersion,(W2)	Absorption capacity (%) =W2- W1 * 100 / W1
1	1072	1114	3.92
2	1072.5	1126	4.99
3	1062	1106.5	4.12
4	1070	1117.5	4.44
5	1076	1117.5	3.86
Mean			**4.27**

APPENDIX D

PHOTO GALLERY



Measurement of unit weight **Measurement of sand** **Sieve analysis**



Melting of PET waste plastic **Molten PET waste plastic** **Measurement of sand**


Measurement of Molten PET waste plastic **Blending**

Preparation of mold **PET waste plastic brick specimens**

Testing for Compressive strength