AN EXPERIMENTAL STUDY ON PRODUCTION OF BRICK BY USING A MIXTURE OF WASTE PLASTIC AND SAND

MSc. THESIS

ELSABETH ALELEGN ASRAS

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

JUNE, 2019

AN EXPERIMENTAL STUDY ON PRODUCTION OF BRICK BY USING A MIXTURE OF WASTE PLASTIC AND SAND

ELSABETH ALELEGN

A THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENTS ON THE DEGREE OF MASTER OF SCIENCE IN STRUCTURAL ENGINEERING

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

HAWASSA, ETHIOPIA

REQUIREMENTS FOR THE

DEGREE OF

MASTER OF SCIENCE IN STRUCTURAL ENGINEERING

JUNE, 2019

HAWASSA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CIVIL ENGINEERING

DECLARATION SHEET

I hereby declare that this MSc Thesis **"An Experimental Study on Production of Brick by Using a mixture of waste plastic and sand"**

" is my original work and has not been presented for a degree in any other university, and all sources of material used for this work are clearly acknowledged.

Name: Elsabeth Alelegn Asras

Signature: ___________________

Place: Hawassa University

Date of submission: ____________________

HAWASSA UNIVERSITY

SCHOOLS OF GRADUATE STUDIES

ADVISORS' APPROVAL SHEET

THIS IS TO CERTIFY THAT THE THESIS ENTITLED "**An Experimental Study on Production of Brick by Using a mixture of waste plastic and sand"**

" submitted in Partial Fulfillment of the Requirements for the Degree of **Master's of Science** with specialization In **Structural Engineering**, the Graduate Program of the **School of Civil Engineering,** has been carried out by Elsabeth Alelegn ID. No PGSTRU /014/09, under our supervision. Therefore we recommend that the student has fulfilled the requirements and hereby can submit the thesis to the department.

TEMESEGEN WONDIMU (PHD)	____________________	____________________
Name of major advisor	Signature	Date
SURAFEL T. (MSC)	____________________	____________________
Name of co-advisor	Signature	Date

ACKNOWLEDGEMENT

I would like to express my deep gratitude from the core of my heart to God, who has given me the strength to carry on, in my hard times and for his invaluable gift being with me throughout in my study as the research comes to end and St. Merry, for providing me with the power and grace to carry out this thesis work.

I am also glad to give thanks for my advisor Dr. Temesgen Wondimu and my co-advisor lecturer Mr. Surafel Tsegaye for their continuous motivation and encouragement during the study. I would like to extend my appreciation to Hawassa university ERA coordinator Mr. Robel, for facilitating my research as well as cooperation in the course and I wish to thank Mr. Mehiretu G. Head of the Civil Engineering Department, for his cooperation in the course of my research and study.

I thank the Ethiopian road authority (ERA) for supporting me financially for my research work and Hawasa university construction laboratory and laboratory technician Mr. Henok for giving me a great support and suggestion throughout my experimental works in laboratories. I'm also extremely grateful to Wolaita Sodo University for sponsoring me graduation study.

Finally my deep and respectful thanks go to my lovely father Mr. Alelegn Asras and my mother Mrs. Tringo Amara for their patience and energetic encouragement throughout my work and also my deepest appreciation and heartfelt thanks go to my four brothers, my sister and all my friends specially Mrs. Elshaday Eshatu for their unreserved moral support in the whole course of the study and to my handsome son the most precise gifts of my life. I do not have words for their love, support, encouragement and patience.

TABLE OF CONTENT

Contents **Page**

LIST OF TABLE

Table **Page**

LIST OF FIGURE

Figure **Page**

LIST OF TABLE IN APPENDICES

LIST OF FIGURE IN APPENDICES

Figure **Page**

ABBREVIATIONS

%A	Absorption of water in percent
ASTM	American Society for Testing and Materials
BC	Burned Clay Brick
BS	British Standard
BW	Boiling Water
CO_2	Carbon dioxide
CMA	Cleaning Management Agency
C20	Compressive strength of concrete
CS	Canadian Standards
CW	Cool Water
E-1	Specimens symbols for absorptions test
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
PE	Polyethylene
PET	Polyethylene terephthalate
PETE	Polyethylene terephthalate plastic bottles
PP	Poly Propylene
rHDPE	Recycled High Density Polyethylene
TPB	Trial Plastic Bricks
W_1	Weight of dry clay bricks
W_2	Weight of saturated clay bricks
IS	International Standard

ABSTRACT

Plastics are the most multipurpose man made materials in the world and generally used as medicine package, liquid container, water bottles, pipes and roof cladding etc. Plastic has a disastrous impact on our environment because of its non-degradable rather very slow nature of degradation. It is a well-known fact that plastic takes almost 400 years of time to decompose completely. Improper disposal of plastic has a negative effect on the marine life, ground water and on our environment. In Ethiopia out of total 83 plastic bottled water factories only 4 factories recycle the plastic bottle and remaining plastic bottles does not get recycled and disposed safely which is a cause of concern from environment perspective. So the present research work has been conducted to use waste plastic in the construction activities in form of producing bricks which would help minimizing the negative effects of waste plastics in our environment along with producing cost effective alternative engineering masonry plastic bricks. Experimental tests were conducted by casting several test specimens of bricks of size 25 cm x 12 cm x 6 cm with different plastic to sand ratios such as 20:80, 25:75, 30:70, 35:65, 40:60 and 45:55. The brick specimens were tested for their physical properties according to ASTM specifications. The test results showed that the specimen with 20:80 percentage ratios has fewer bonds between plastic and sand because of which it does not give a proper rectangular shape of plastic bricks while 50:50 plastic to sand ratio has not been mixed well. The compressive strength and water absorption test results indicated that bricks made with 35% of plastic and 65% sand gives higher compressive strength and lower water absorption. Finally optimum plastic bricks found to be qualified according to negligible weathering of ASTM specification, ES 89 : 2001 and British code depending on physical properties of material strength and durability which are used for load bearing structural wall for minimum story building and non-load bearing wall for any structural masonry building.

CHAPTER ONE

1 INTRODUCTION

The aim of this study was to examine the production of bricks from waste plastic by using it as a binding material. Which used to solve waste plastic problem is emphasized in developing countries this time by polluting environment because urbanization is very new occurrence. Knowing engineering properties of this waste plastic material as alternative binding material to make brick and improve the strength and durability of the investigated by reducing cost of transportation of bricks walling material transported from Addis Ababa to Hawassa study area. In addition to that this experimental work used to reduce environmental pollution comes from waste plastic and compare the new plastic brick with that of convenient one based on strength, durability and cost effectiveness of the plastic bricks. Finally this chapter contains background of the study, statement of problems, objective of the studies, significance of the studies and thesis structure.

1.1 Background of the Study

The conspicuous importance of plastics pollution is due to its inexpensive and durable nature. In addition to these plastics is extensively used due to ever their characteristics like versatility, lightness, hardness, chemical resistance etc. There are different types of plastics and it's a new engineering material in which researchers are interested to produce safe and strengthen material that could enhance the strength of structure. The global yearly spending of plastic materials has increased from about 5 million tons in 1950 to almost 100 million tons today. However, in our countries the consumption as well as disposal of waste plastics is rapidly increasing day to day which affected living organism. Now days in Ethiopia raw materials required by the local plastic products manufacturing sub sector plastic resins are entirely imported. During the period 2009–2011, the local plastic manufacturing sub sector has imported on average 67,235 tons of various type plastic polymers of which the largest share (40.58%) is accounted by polyethylene, profile on production of recycled plastic waste. Today it is unattainable for any vital sector to work powerfully without usage of plastic starting from agriculture to industries. Thus we cannot exclude the use of plastic. So recycling of plastic should be the better option as Aiswaria et al.,(2018). Because of its non-biodegradable nature, it affects our environment and a cause of concern. The idea of using waste plastic in construction site is started in 2001 when PET bottles are installed as structural wall incorporate with mortar. Many companies are recently selling composite rail road ties manufactured from polyester. There are different types of plastics with them varies purposes in the world there is thermoplastics like (HDPE, LDPE, PE, PP) and thermo set. Polyethylene Terephthalate (PETE or PET) Polyethylene terephthalate (PET, or sometimes PET is a widely used plastic material that is lightweight, strong and often transparent. It's common in food packaging, including plastic water bottles. It also used in construction industry as concrete reinforcement.HDPE; High Density Polyethylene is also type of polyethylene high strength to weight ratio and it’s stronger than PET and low density polyethylene. Global plastic fabrication is continuously growing and reached 322 million tons in 2015, generating revenues for plastic manufacturers of about 750 billion dollars Woldegiorgis, (2017),Nils Simon and Maro Luisa Shulte, (2017). LDPE have low strength to weight ratio small tensile strength relative to HDPE but have similar properties recycled for different purpose. Therefore this study examines mechanical or physical properties of standard clay bricks and plastic bricks experimentally. Finally based on the experimental results has been identified for which type of structure the bricks made of plastics can be used. Today waste plastics used in construction industries in the form of fine aggregate, course aggregate and as well as use as a cementing material which is a way of reducing plastic waste which is a key factor for environmental pollution. Presently waste plastics are effectively converted into useful permanent structural and non-structural materials as (Mariganes and Rahesh 2018).

Loukham et al.(2017) performed tests to examine the properties of bricks manufactured by mixing sand and waste plastics. They expected to provide some information regarding the suitability of such sand plastic bricks for use in construction industry. Based on their finding the study to evaluate the effects of plastic bricks by including waste plastic bottles as a binding material study mechanical properties of plastic bricks to minimize plastic bottles waste which is a big deal pollute the countries urban area specially tourist area such as; lake Hawassa, lake Bahirdar and so on. Therefore, this study executed for replacing burned clay bricks manufactured according to Ethiopian standards. Also its way of reduction of cost of energy consumption during firing process of clay bricks

This experimental investigation inspect the effects of 20:80, 25:75, 30:70, 35:65, 40:60 and 45:55 of worn waste plastics and sand ratios on bricks. Finally this work tries to produce purposeful plastic bricks which can be cost effective and better in terms of compressive strength and temperature resistant along with lower water absorption which may replace the standard clay bricks.

1.2 Problem of Statement

The firing temperature control of the brick factories in our country during production of bricks show that they have consuming high amount of energy and wood which leads to deforestation for their kiln but it is done with the observation of their kiln operator's. Over and under firing of clay-bricks is their usual losing. Moreover, burning process is high energy consumptive due to no controlling mechanism involved during firing process of production of burned clay bricks.

The advantage of plastic bricks is cost reduction by minimizing the fuel cost during its production along with reducing mass of infill walls which leads to decrease earth quake force comes from mass of infill wall. It also reduces the use of the natural raw materials used for clay burned bricks.

This research aimed at developing light weight and cost-effective plastic bricks will be cost effective and beneficial of developing countries like Ethiopia. In developing countries there is a problem of using quality solid clay bricks due to their cost and strength.

With global waste generation rates growing faster than ever but still there is no great amount of change in developing countries and there is a problem of using quality solid clay bricks due to their cost. Plastics play a substantial role in the building and construction industry in a way that used for pipes and valves plastic are used due to their superior resistance to corrosion. So, using waste plastic bottles in manufacturing of bricks is a sustainable solution as plastics has a nature of non-degradable for a long time. So, this research will help in saving our environment from disposal of waste plastics bottles and pollution.

1.3 Objective of the Study

1.3.1 General Objective

The general objective of this study is to adopt and evaluate the effectiveness and efficiency of bricks production from waste plastic and sand.

1.3.2 Specific Objectives

- To determine the mechanical properties of bricks made with waste plastic particularly from plastic bottles (PETE) and comparing it with properties of standard burned clay bricks.
- To compare the light weight plastic bricks with that of burned clay bricks and classifying load bearing of infill wall or non-load bearing wall based on their strengths.
- To compare the cost effectiveness of plastic bricks over the conventional clay bricks along with identifying the benefits in terms of reducing environmental pollution.

1.4 Significance of the Study

The victorious completion of this research will have significance for production of bricks industries in Ethiopia. Structural engineers focused on the need to control strength and stability of structure within the proper design of structure and material used affect the strength and stability of structure and they should aware of to make it cost effective. This study will conduct an experimental investigation on the bricks made up of waste plastic by replacement of binding material for conventional brick production which has an advantage of cost reduction by reducing the energy required for brick manufacturing process along with studying mechanical properties of bricks as well as classifying the bricks whether its load bearing or not. Last but not the least it will help in minimizing waste plastics pollution and save our environment.

1.5 Thesis Structure

This thesis is divided into five major chapters. The first chapter is the introduction part which includes background of the problem, objective of the study and significance of the research. Chapter two describes the literature review of different literatures including books, historical records, thesis reports and websites which are relevant to the study topic. Moreover, Ethiopian standards for solid clay bricks (ES 86:2001), ASTM and BS standards have been reviewed. Chapter three describes methodologies used in this study including methods of laboratory tests, research tools, preparation of raw materials, types of tests done for the sampled raw materials, laboratory tests done for the fired clay bricks, laboratory test for plastic bricks and study of the brick factories in and around Addis Ababa Alemgena site and method of reporting the results. In chapter four, the laboratory test results are summarized and discussed. Chapter five includes conclusions and recommendations.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

Bricks have been a major construction and building material for a long time. The dried-clay bricks were used for the first time in 8000 BC and the fired-clay bricks were used as early as 4500 BC. The worldwide annual production of bricks is currently about 1391 billion units and the demand for bricks is expected to be continuously rising. Quarrying operations for obtaining the clay are energy exhaustive, adversely affect the landscape, and generate high level of wastes. The high temperature kiln firing consumes significant amount of energy as well as releases large quantity of greenhouse gases. Clay bricks, on average, have an embodied energy of approximately 2.0 kWh and release about 0.41 kg of carbon dioxide (CO_2) per brick. It is also noted that there is a shortage of clay in many parts of the world. To protect the clay resource and the environment, some countries such as China have started to limit the use of bricks made from clay (Zhang 2013).finally this chapter reviews on production of burned bricks, plastic bricks, advantage of plastic brick and classification of bricks based on strength and durability test.

2.1.1 Production of Bricks from Clay Materials through Firing

Clay brick is defined as a hard masonry unit, usually made of clay, molded into a rectangular shape while plastic. It is treated in a kiln at an elevated temperature to harden, so as to give it mechanical strength and to provide it with resistance to moisture; after being removed from the kiln, the brick is said to be burnt, hard-burnt, kiln-burnt, fired, or hard-fired. Since the production cost of clay brick is extensively affected by the cost of energy required for firing, different mechanisms have been used to reduce the energy required for it. Traditional methods of firing consume much energy.

In Ethiopia brick market, one can find both under burnt and over burnt clay bricks. The under burnt clay bricks have poor quality and the over burnt bricks have poor aesthetical values due to their partly darker color. The degree of firing of clay bricks does not only affect the quality but also increase the cost of production. It is the most widely used for the construction of structural and/or non-structural walls. It is small building unit, solid or cored not in excess of 25%. Brick is commonly produced as a rectangular block composed of inorganic, nonmetallic substances of mineral origin and hardened by heat or chemical action (Abebe 2002).

2.1.2 Constitute of Clay Bricks

Clay is one of the richest natural mineral on earth. It is the basic materials in the production of bricks. The unique plastic characteristics of clay soils are a result of the giant amount of surface area inherent in this particle size and shape. Clay is well suited to the manufacture of bricks. It is plastic when mixed with water, and easily molded or formed into the desired shapes; it has sufficient tensile strength to maintain those shapes after molds are removed; and its particles are highly fused at high temperatures. It is this plasticity which facilitates the molding and shaping of moist clay into usable shapes. So, it is important to know the types and mineralogical composition of clay which determines the quality of the end product. Ingredients of good clay should have composition of 50-60% silica (sio_2), 20-30% alumina (Al_2O_3), 10% cao, <1% of Fe_2O_3 and alkalis sodium hydroxide (NAOH) and potassium hydroxide (KOH) of small amount is included (Altaye 2013).

Cement

The most important components of portland cement from the strength development point of view are C2S and C3S which, on hydration, form the same compounds in reverse proportions. C3S2H3 is the final product of hydration of both C2S and C3S, the reactions of hydration can be written for C3S and C2S respectively, as follows

$$2(3Cao.SiO_2) + 6H_2O \longrightarrow 3CaO.2SiO2.3H2O + 3Ca\ (OH)\ 2$$

$$2(2CaO.SiO_2) + 4H2O \longrightarrow 3CaO.2SiO_2.3H2O + 3Ca\ (OH)$$

2.2 Production of Bricks from Waste Plastics

The services, with which plastic can be used in miscellaneous applications, which is only growing with new innovative use such as in polyester for cloth production, are likely to increase consumption in the future. Thus, unless recycling gains thrust, the amount of under attack waste is likely to increase compounding the environmental challenge. Growth in recycling plastic after end-of-life is leisurely resulting in increase in net disposal in the environment. Waste plastics bottles are failing to reach landfills in case of scattering it's the improper way of disposing plastic bottles and identified as the cause of environmental pollution. So, using plastic bottles as plastic bricks for partition wall plastic and blocks it may be reducing the disposition of air and increasing attractiveness of tourist area by removal of waste and by transforming it to usable walling structural material. PET bottles are being experimented to act as non- load bearing and partition walls in many parts of world. The present paper attempts to bring out various methods by which PET can be used as a successful building material alternative as in concrete reinforcement or non- load bearing and facade walls. The solution proposed solves the problem of its discarding and in the process; provide new properties to the construction element itself by reducing its weight (Chowdhury, Maniar and Suganya 2013).

The main objective of the study is to examine the behavior of C30 grade of waste plastic mix concrete with and without super plasticizer. They found by experiment with forty-eight cube specimens and eight beams for C30 grade concrete with four different volume of waste plastic (0%, 5%, 10%, 15%). The study also include the effects plasticizer during cast which is recommended by IS. The researchers examined that mechanical properties of waste plastic concrete mix namely, fresh concrete, dry density workability, compressive strength and flexural strength have been studied and they found that the mechanical properties of plastic concrete with plasticizer increases by 5% than mix concrete only with waste plastic. But at the end they concluded that addition of plasticizer in plastic concrete for flexural strength is not making a change as (BabooRai 2012).

Mr.L., et al. 2018 examined a way of minimizing waste plastics in India that rising in the world as well as in their countries by incorporating the waste plastic using extruder and experimental study of plastic bricks the pastes used during tests are m-sand, waste plastic, Thermocol and water. However, varies percentage of plastic also tested by standard specification compressive strength test, absorption test, and efflorescence tests were done. The finding were optimum value of the experiment was 15% waste polyethylene plastics so it gives 13mpa compressive strength and6.6% of absorption of water.

On the other hand, (Owamah and Sojobi 2014), the researcher was to assess an alternative way to use solid low-density polyethylene (LDPE) waste plastic as partial replacement of sand in concrete. They used an experimental investigation with different mix ratio such that 1:1:2, 1:1.5:3 and 1:2:4 then they correlate those ratios by their mechanical properties.

The researcher finally concluded that 1:1:2 give a better result and the replacement LDPE waste plastic is used in non-load bearing structure such as partition walls and roof tiles.

Ashwini Manjunath B T (2016) assessed the partial replacement of E- plastic waste as coarse aggregates in concrete. Since it solved that the partial solution to reduce environmental disposing and ecological problems. They examined an experimental study on the use of E-plastic waste as coarse aggregate as well as fine aggregate in concrete structure with different trial percentage replacement of waste plastic (0%, 10%, 20% and 30%) which the research also correlates the result with the concrete compressive strength of C20 grade of concrete. They showed that comparative study with Normal Weight Concrete (NWC) and the compressive strength is high for 0% and 10% although identified medium compressive strength for 20% and 30% of E-plastic replacement of aggregates it also gives the same tensile strength result as compressive strength. And the flexural strength given that good result for those 0%, 10%, 20% E-plastic replacement of coarse aggregate and not good for 30% E-waste plastic finally the researcher concluded that the strength of concrete structure with the conventional 28 days compressive strength, tensile strength and the flexural strength of concrete is reduced to by 52.98% when coarse aggregates were replaced by 20% of E-plastic waste.

The aim of this study is to assess the possibility of using plastic bottles in concrete blocks. This research is different from others in that it is not plastic mixed with concrete specimen rather than it used by placing plastic bottles inside concrete masonry and analyzed the compressive strength of concrete block. The researcher was used to designed testes for eight plastic blocks, seven concrete cylinders and six hollow concrete blocks. In each eight plastic blocks 500 ml bottles was positioned and they correlated with ASTM C140 standards. The result shows that concrete blocks with plastic bottles were 57% higher compressive strength than the standard one (Sina and Alkaban, 2016).

Furthermore, maximum plastic wastes are increases in industries and in the house hold and in each country waste consumption is diverse. In India plastic consumption is high in several regions. In order to rise above this issue, we have to use it in effective way. The paper is about recycling waste plastics to beam. They examined plastics are used 100% on structural part of beam as a replacement concrete. So, plastics are used to construct full of plain beam with and without reinforcement although they used to test both beams by flexural test. The main aims of the authors were recycling waste plastic to beam and reduce waste from environment and they used HDPE as raw material. The finding was the flexural strength of plastic beam could replace for C20 grade of concrete (Mariganes & Rahesh 2018).

However, the researcher also investigated production of bricks from manufactured sand and PET plastics with different proportions or ratios of plastics as well as amount of M-sand such as 1: 2, 1:3, 1:4, 1: 5 and 1:6 then the researcher also investigate the compressive strength, absorption of water, durability and thermal resistance of soil bricks. The aim of the paper investigated new engineering material as well as reduction of wastes from environment. However, the test were concluded that compressive strength increases up to certain limits of plastic content and decreases after certain limits but the optimum value of average compressive strength 1:4 scours best result. While, absorptions of water for plastic bricks decreases as amounts of plastics increases. However for the durability test 7 days curing test result have high strength than other (Aiswaria, et al. 2018).

Finally the main aim of researchers where they used to assess the plastic nature in construction fields with limited additions. It will be definitely a cost economical and can be applied in different forms. The waste plastics in house hold is large and increases with time. In each country waste consumption is different, since it is natural by socioeconomic characteristics and waste management programs, but the level of plastics in waste consumption is high. In order to overcome this, they were investigated various properties such as compressive strength, split tensile strength and water absorption of paver blocks consisting of plastic wastes, unconventional materials such as quarry dust and fine aggregate of various percentage replacement are used. Then they concluded that using 20% of recycled plastics does not affects properties plastic pavement block also the paper came up with result due to trial mixture of fine aggregate waste plastic quarry dust (Mohan D.M.S1, 2018).

Plastic has also become one of a vital part of our life. World production of plastics was estimated to be around 299 million tons in the year 2013 which is expected to rise further. The present study attempts to understand the effect of variation of plastic to sand ratio on the mechanical properties of the waste plastic brick manufactured. The researcher investigated that production of bricks from waste plastics and river sand with different ratio of plastics and different ratio of sand 1:3, 1:4, 1:5 and 1:6 then finally they also studied compressive strength, absorption test, apparent porosity and bulk density of each plastic bricks ratio.1:6 ratio has highest value compressive strength and minimum bulk density and low water absorbent as content of plastic increases (Padmini 2018).

Diptikar, Yirgalem, & Aman, (2018) assessed use of waste plastics waste glass and fine aggregates for making roof tiles, hollow plastic blocks the research conducted experimental analysis done by physical test such as compressive strength analysis, absorptions of water for durability test and temperature effects for thermal resistance test for roof tiles and hollow plastic block. Finally the test result compared with standard specification of ASTM C129 and ASTM C936 for non-load bearing structure minimum compressive strength requirement 4.14mpa and 5% absorptions of water respectively. The findings also finally concluded that for hollow plastic blocks optimum strength are assessed for 33% use of molten plastic and 11.2 fine glass and 11.2% fine sand and 44.6% of coarser glass are like better than other mixing proportions while for roof tile 32% of molten plastic with 68% of glass and sand were used. The investigation also concluded that plastic roof tiles better to use in wet weathering conditions due to less amount of water absorptions than normal roof tiles.

2.2.1 Advantage of Plastic Bricks Masonry Wall

The most important benefits of these alternative innovative materials compared to conventional materials such as brick can include: The walls built by these bottles are lighter than the walls built by brick and block, and that makes these buildings to show a good response against earthquake. Due to the compaction of filling materials in each bottle, resistance of each bottle against the load is 20 times higher compared to brick. And these compressed filling materials, makes the plastic bottle to be prevented from passing the shot that makes the building as a bulletproof shelter. Constructing a house by plastic bottles used for the walls, joist ceiling and concrete column offers us 45% dwindling in the final cost. Separation of various components of cost shows that the use of local man power in making bottle walls can lead to cost reduction up to 75% compared to building the walls using the brick and concrete block. It must be noted that the refined manpower can lead to reducing the construction time and the relative costs also become lower. Using the non-brittle materials can reduce construction waste. Unlike brick, plastic bottle is non-brittle. So due to the frangibility property, the percentage of producing construction waste in brick is more than plastic bottles. Plasticity is a characteristic which makes the buildings performance higher against the unexpected load. Since the plastic bottles are not brittle, they can be flexible and resist sudden loads without failure. This characteristic can also increase the buildings bearing capacity against the earthquake pandey, Gotmare, & Wankhade, (2017).

The most world issue in this experimental work used to solve minimize waste plastic which affects our world as well as specially developing countries like Ethiopia. The study was used to examined multi dimensional relation between the source of plastic waste and the stake holders involved in the process from waste plastic to recycling stage (Woldegiorgis 2017). So this experimental work used to create sustainable environment and to protect marine living things and human health. The Cleaning Management Agency(CMA) has not correct designing to collect the environmental waste plastics there is gradual conversion of waste plastic to commercial production.

2.3 Classification of Bricks Based on Strength and Durability Test

There are different types of requirements to classify bricks according to different standards. Brick selection is made according to the particular purpose in which the brick will be used. Standards for brick cover specific uses of brick and classify the brick by performance uniqueness. The performance criteria include strength, durability and aesthetic requirements. ASTM International (ASTM) publishes the most widely accepted standards on brick. Ethiopian standard burnt bricks are good in quality bricks however they also consist of some defected bricks. So, based on strength and durability test burnt bricks are classified into four types and they are a follows. First class brick, Second class brick, Third class brick and Fourth class brick. First class bricks first class bricks are good quality bricks compared to other classes. They are molded by table-molding and burnt in large kilns. So, these bricks contain standard shape, sharp edges and smooth surfaces. They are more durable and having more strength. Those class one, class two and class three can be used for permanent or use in the form of load bearing structures. While, burned clay bricks have good properties by strength as well as durability but it is more expensive than Hollow Concrete Block wall material. To the extent that can be ascertained, load-bearing brickwork was chosen in each case because it was understood to suggest economic advantages over other forms of construction. The use of load-bearing brick work was estimated to give a saving of 7 per cent over reinforced concrete framed construction. There is a lot of influence about the actuality of reinforced masonry. Although bricks belong to the predictable and usual building materials, reinforced concrete frames are favored in construction industry nowadays. In that case the masonry is used purely as an infill wall. The load bearing capacity of masonry is only significant for the design of some story constructions. On the other hand, it is possible to allot with RC frame and construct multi storied load bearing masonry structures, when good quality bricks are used in concurrence with reinforcement. There is need and considerable scope in this country of intensifying experimental, research and study in the field of load bearing masonry in order to make better and more economical use of this wonderful and versatile building material, the brick. In India, we have been trying to keep pace to some extent with the developments taking place in other countries in regard to masonry. Many experiential studies and researches are carried out on load bearing masonry originated from different sources, they are experimental in construction industry mainly reducing the cost of construction and improving quality of structures built with them.

In this context, the authors have studied various properties and usage of different eco-friendly construction materials like clay bricks, fly ash bricks and cellular light weight concrete blocks. A suitable plan is selected and structural elements are designed as per Indian standard codes with these materials. From this, based on resources, cost optimized solutions are derived

According to Kabtamu & Alemu, (2017), determined whether its locally produced clay bricks in Jimma town is used for load bearing structural wall or not. Why because its quality still in questions since it's produced locally and distributed to construction site without engineering quality test is done according to standard specifications. So they examined the physical test such as compressive strength test, bulk density, absorption of water, efflorescence test of different locally produced clay bricks in Jimma town and Burayu bricks factory. They used the methods of collecting data, laboratory test, and comparing the bricks quality according to different standard specifications of bricks test result as well as comparing with hollow concrete block classes according to Ethiopian standard as follows: according to different literatures (ES 86:2001) for class A&B average compressive strength of 20 MPa and 17 MPa respectively for class C&D average of five bricks compressive strength should be 10 MPa and 7.5 MPa respectively.

So finally Jimma bricks are not qualified according to all standards Ethiopian standard, British standard ,Indian standard and ASTM standard the compressive strength of test sample gives 5.5 MPa they assessed that Burayu bricks factory in Ethiopian standard testes classified under class C load bearing structural wall and has absorption of water 18% less than standard 20% of the specifications while no one of locally produced bricks are qualified in absorption of water according to British standard. But the result competitive with standard higher load bearing structural infill walls class A hollow concrete blocks for Ethiopian code specifications.

Srinivasank., et al. (2019) were analyzed to carbon dioxide free cementious materials to replace instead of bricks use plastic bricks by including effects geopolymer on waste plastic such as fly ash, crushed stone and manufactured sand from mix proportions of 0%, 5%, 10% and 15% of waste plastics 15% use of waste plastic mix proportions has maximum compressive strength of 27.2 MPa which have higher strength classifications of burned clay bricks according to standard specifications in ASTM. From the investigation 60% of waste plastics are infill lands and it dispose the environment so, they decided to use waste plastic including in construction industry to minimize the environment from waste pollution. Since Geopolymer has cementing properties when it mixed with plastics has increasing in properties of binding mixed materials. So the result showed that Geopolymer effects on plastic bricks it improve the strength plastic bricks.

According to Gopu, et al. (2016) investigated plastic bricks manufacturing machine which have role of heating mixing and compacting of plastic bricks during compaction process for the investigation purpose has been used grinding waste plastic bottles, Thermocol acts as binder and sand compositions are used different locally testing method clay brick tests also studied like free fall of the brick and scratch tests both are done the result showed that composite plastic brick was competent than the clay brick and cement brick. So the study simplifies production of plastic bricks by substitute manual production to machineries since plastic brick production difficult to handle manually.

CHAPTER THREE

3 MATERIAL AND METHODOLOGY

3.1 Introduction

In this chapter the materials used in the investigation are described with their sources, and their physical and chemical properties. Laboratory investigations on bricks are carried out in the ASTM standard specification. Trial and error mix ratio method is applied to come up with the optimum value of the experimental work. After some trails it is found that both optimum mixture of plastic and sand quantity were fixed. Finally, a designed mix of superb workability is obtained. The standard Ethiopian bricks production factories have brick size of $(6\times12\times25)cm^3$. For this study also the same size with the standard one has been used.However, now researchers are exploring the use of alternative materials which good preserve natural resources and save the environment. In this study, utilization of molten plastic waste as full substitution of cement and river sand in laboratory for production of plastic brick has been done.

3.2 Materials Description

In this chapter, the methods of raw materials collection, the production processes of plastic bricks and laboratory tests conducted at different stages proportion of waste plastic of the plastic bricks production utilized for this study are discussed.

Waste plastic bottles (PET or rHDPE)

HDPE which, now day's useful and valuable polyethylene plastic as civil engineering materials. HDPE is relatively stress-free to recycle and is also the most recycled type of plastic. HDPE has slight branching, giving it tougher intermolecular forces and tensile strength than LDPE. Polypropylene (PP) is a thermoplastic addition polymer made from the combination of propylene monomers. It is used in a variety of requests to take in wrapping for consumer products, plastic parts for various industries Also, density of pp is lies from 0.9-0.92 g/cm^3 and use Normal Weight Concrete material such as Portland cement, water, river sand for both plastic brick material and concrete pavement (Mariganes and Rahesh 2018).

River sand

It is a naturally occurring granular material which is composed of mineral particles and the most abundant widely used in concrete structural work as a raw material. For this experimental work the properties of Yirgalem sand properties were studied and have specific gravity of 2.3 absorption of sand were 1.04%. The properties results were specified in Appendix A-1. The arrangement of sand varies depending on the local rock conditions and sources, but the most constituent of sand in inland continental settings and non-tropical coastal region is silica dioxide (SiO_2) in the form of quartz (Dinesh, A. and Kirubakaran 2016).

Plastic bottle

Plastic bottles are used as an important element, so we have gone through every property of the PETE bottles so as to ensure a stable structure. Polyethylene Terephthalate Ethylene (PETE) bottles is thermoplastic materials. This type of plastic are polymers and with or without cross linking and branching, and they soften on the application of heat, with or without pressure and require cooling to be set to a shape. The following are properties of plastic bottle (Pandey, Gotmare and Wankhade 2017):

- Flexible over a wide temperature

- Heat resistance
- Chemically stable.
- Do not absorb moisture.
- Transparent

Polyethylene yearly international production is around 80 million tones. Many kinds of polyethylene are known, with most having the chemical formulae (C2H4) n. Thus, PE is usually a mixture of similar polymers of ethylene with various values of polyethylene is of low strength, hardness, and rigidity but has high ductility and impact strength as well as low friction. It displays durable creep under persistent force, which can be reduced by addition of short fibers.

The usefulness of polyethylene is limited by its softening point of 80 degree Celsius. For public commercial evaluations of medium and high density polyethylene the melting point is typically in the range 120 –180 degree Celsius. The melting point for average, commercial, low density polyethylene is typically 105 –115degree Celsius. These temperatures diverge toughly with the type of polyethylene. Polyethylene consists of non-polar, soaked, great molecular weight hydrocarbons. Therefore, its organic performance is similar to paraffin. The individual macromolecules are not covalently linked. Because of their symmetric molecular structure, they tend to crystalline, generally polyethylene is crystalline. Higher crystallite increase density and mechanical and chemical stability. Polyethylene burns slowly with a blue fire having a yellow tip and gives off a perfume of paraffin. Polyethylene is a good electrical insulator. It offers good tracking resistance; however, it becomes easily electro statically charged (Srishadurya, Priyanga and R. 2017).

3.2.1 Physical Properties of PET and Sand Materials

Table 3.1 Physical properties of PET and Sand

MELTING POINT	260◦C	Yirgalem river sand were used for this experimental work	properties of Sand
Long Term Service Temprature	115◦C-170◦C	Moisture Content	2.04%
Specific Gravity	1.3- 1.4	Specific Gravity	2.34
Absorption Of Water	0.07-0.1%	Absorption of Water	1.04%

Figure 3.1: Extruded Waste Plastic Sample

3.3 Methodology

Figure 3.2 Sand Sample Used for Experimental Work

Table 3.2: Mix proportions of Experimental Work

Specimens	TBP1	TBP2	TBP3	TBP4	TBP5	TBP6
Waste plastic	20%	25%	30%	35%	40%	45%
River sand	80%	75%	70%	65%	60%	55%

Total volume of burned bricks = $15\times25\times12\times6 cm^3$=$27000cm^3$

Total volume of trial plastic brick=$90\times25\times12\times6\ cm^3$=$162000cm^3$

3.3.1 Description of Methods

For this experimental research, river sand and waste plastics have been used to prepare the bricks and six trial composition plastic bricks have been developed. The mechanical properties of plastic bricks have been examined and compared with that of burned clay bricks. The mixtures done with trial mix and the compressive strength value and durability test of plastic brick compared with the standard Alemgena clay brick factory production. The mortar mix from the mixture bowl was then placed into a 252 × 122 × 602 mm metal sheet mould in five equal layers. Each layer was then manually compacted using a steel plate. The mold was then slightly overfilled with the mixtures. Again, the mixtures in the mold were placed and compaction made manually. The specimens were finally removed from the mold. Once the bricks were made, they were wrapped with plastic and kept in the lab for 24 hours before starting to test.

Figure 3.3: Steel Plate Mold for Production of Bricks

Figure 3.4: Steel Compactor during Production Process

3.3.2 Experimental Procedure

The aim of this study is to spread the using waste plastic in production of plastic brick in Ethiopia Hawassa. Then laboratory tests were done on the compressive strength of the brick and durability and finally classifying based on ASTM specification whether it is suitable for load bearing or non-load bearing structure (partition wall of plastic bricks). The method is being started with the collection of raw material such as river sand and waste plastic bottles. Although the laboratory test is existence produced as strength of bricks and comparatively studies the laboratory result with that of standard one. The following are steps to follow during experiment.

1. Collect the raw PET waste plastic bottles from the disposed environment.
2. Remove dust from collected plastic bottles and rag to make it fine.
3. Prepare required amount of, river sand, and water.
4. Sieve the sand to remove dust particles as well as large particles from the sand.
5. Shredded plastic melt the plastic up to become liquid may become liquid form.
6. Mix properly sand with melted plastic.
7. Mold the mixture uses the extruder to give shape of brick.
8. Provide for mechanical test

3.3.3 Testing Methods

The laboratory tests were divided into two categories: compressive strength and durability tests of material. The durability tests are both saturated and unsaturated conditions of bricks. The difference between the two categories is that the soaked bricks underwent the water absorption test. The experimental program began with the water absorption test after the firing process was completed. Following the water absorption test, the bricks were tested for compressive strength and breaking load. At the end of the compression test, the unsaturated bricks were crushed into a fine powder.

The laboratory tests are:

Compressive Test

The results obtained from compression tests on hardened concrete cubes are used to check that its strength is above the minimum specified and to assess the control exercised over (Abebe 2002). However testing compressive burned clay bricks are Compressive strength or crushing strength is the property of brick which represent the amount of load carried by brick per unit area. According to BS the minimum compressive strength of brick should be $3.5N/mm^2$. The compressive strength test for curing 7 days for those trial mix proportion and temperature effects also tested measuring by using thermometer. Compressive strength of bricks reduced when they are soaked in water. But according to this standard 7-$14N/mm^2$ stands for good quality brick types.

Absorption Test

Absorption of brick is its capacity to absorb water to saturation. The rate of absorption or suction of brick has an important effect on the adhesion of brick and mortar because if the brick absorbs water too quickly from the mortar, the mortar will set too soon and adhesion will be poor.

Afterward 24 hours of saturated, absorption, loss of material and loss in compressive strength for specimen which sustain the tests were determined. Before the compression test, a total of thirty plastic brick specimens and five were subjected to a water absorption test. First, the brick specimen was weighed, then it was immersed in water at room temperature for 24 hour and finally it was removed from the water tank and patted dry with a lint-free cloth. After their removal from the water, these specimens were measured again. Then the mass of saturated bricks and the oven dried specimen is measured and the differences in weight were determined. Finally concluded that the lesser water absorbed by brick have the greater its quality

Percentage specifications of bricks weight of specimens for different classifications of bricks depending on qualities of bricks. For first class up to 20%, second class 22%and for third class brick below 25% is recommended. A commonly accepted and major standard throughout the world is that of ASTM. Test for saturation coefficient Saturation coefficient or CW/BW ratio is a measure of the relationship of two aspects of water absorption: the amount easily absorbed water and the amount absorbed under pressure. The earlier (CW) is determined by the 24-hour cold water absorption test, and the second (BW) by the 5-hour boiling water absorption test. It is the ratio of the twenty-four hours cold water absorption value over the five hours boiling absorption value, is an approximate indication of the space available in the brick to contain the expansive Pressure of freezing of water; i.e., the lower the saturation coefficient the more space there is for the freezing pressure to be relieved, thus it is less likely for the burned clay brick to be offended.

CHAPTER FOUR

4 LABRATORY TEST RESULTS AND DISCUSIONS

4.1 Introduction

The use of waste plastic bottles for the production of bricks is an optimal method to investigate an alternative and cost effective plastic brick. In addition to that used to protect Environmental pollution comes from the waste plastic. In this study, waste plastic bottles have been used to incorporate with sand to produce sand bricks. The bricks have been tested to study the compressive strength, water absorption and coefficient of saturations. In the recent past research, the replacement and addition have be done with the direct inclusion of polyethylene or plastic fiber, polyethylene terephthalate (PET) bottles in shredded form, chemically treated polyethylene fiber, PET in binding ingredient form by replacing cement. Most of replacements have been done by volume calculation, and showed the increasing in compressive strength as the plastic increased up to certain limits. In this study, recycled plastic bottle have been introduced in crushed and as molten liquid form.

4.2 Laboratory Tests and Results

The result in this study suggests the opportunity for converting plastic waste into an economically feasible product in the form of production bricks. The test was begin with 50:50 percent ratio of plastic and sand or using equal proportion of sand and plastic make a segregation between them due to plastic was less denser than sand and it is departs from it. While 20% of plastics and 80% of sand have no workable bondage between sand and plastics since binding materials waste plastics less than sand.

Figure 4.1: Casting of Plastic Bricks Process

4.2.1 Absorption Test Result

Absorption test results according to ASTM C67 section 8.3.2.1 absorption test result calculation is done as follows.

$$\%\mathrm{A} = \frac{W2 - W1}{\mathrm{W1}} \times 100$$

Figure 4.2: Alemgena Brick Production Site

Absorption Test

Absorption test results according to ASTM C67 section 8.3.2.1 absorption test result calculation is done as follows.

$$\%A = \frac{E1 + E2 + E3 + E4 + E5}{5}$$

$$\%A = \frac{13.59\% + 15.14\% + 15.38\% + 14.59\% + 13.97\%}{5} = 14.564\%$$

In this test, bricks are measured in dry condition and let them wrapped up in fresh water for 24 hours. After 24 hours of soak, those are taken out from water and clean out with cloth. Then, brick is measured in saturated condition. The difference between mass is the water absorbed by brick. The percentage of water absorption is then determined. The smaller amount of water absorbed by brick the greater its quality. Quality brick doesn't absorb more than 20% water of its own weight.

So the result showed that average of five bricks water absorption is 14.564% which is less than 20% of absorption of water of weight of bricks according to ASTM standard According to British standard (as cited Kabtamu & Alemu, 2017) the absorption of good quality of bricks should have less than 7% of dry weight of bricks so this result shows has less quality according to BS standard specifications.

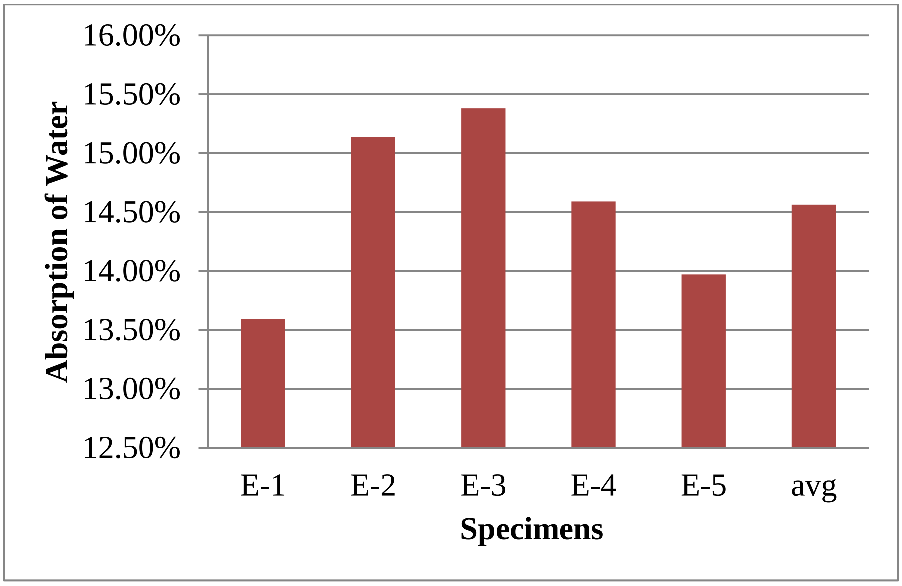

Figure 4.3: Clay Bricks Absorptions in Percent

The absorption test averages of five specimens are as follows %A of each five specimens

Absorption Test Results

$$\%A = \frac{W1-W2}{W1} \times 100$$

Average of five bricks are summations of absorptions of water in percent those five individual bricks divided by five.

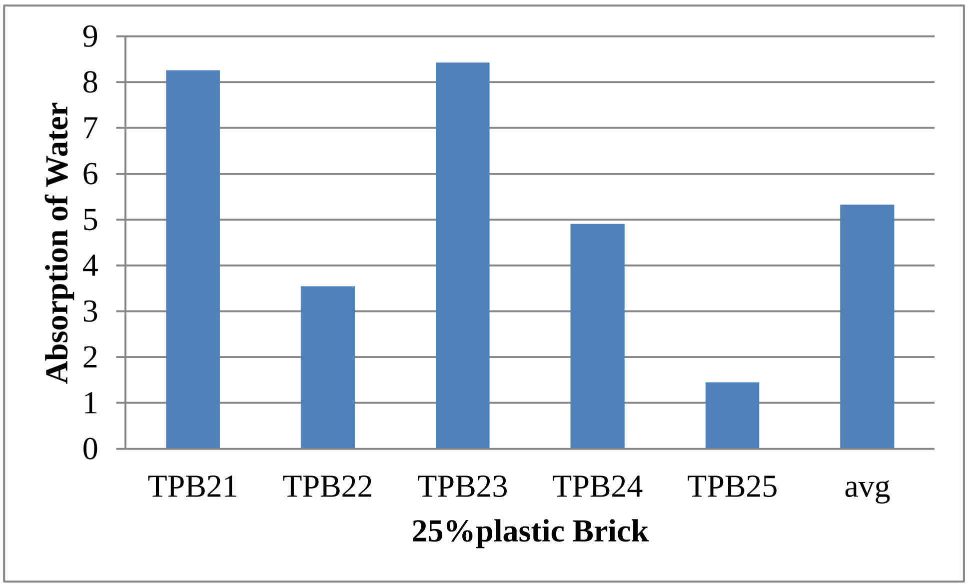

Figure 4.4 Absorption Test Results for25%to75% trial plastic brick

$$\%A = \frac{TPB21 + TPB22 + TPB23 + TPB24 + TPB25}{5}$$

$$\%A = \frac{7.63\% + 3.42\% + 7.77\% + 4.68\% + 4\%}{5} = 5.327\%$$

Figure 4.5: Absorption of Water 25% of PETE Plastics

$$\%A = \frac{W1 - W}{W1} \times 100$$

$$\%A = \frac{TPB31 + TPB32 + TPB33 + TPB34 + TPB35}{5}$$

$$\%A = \frac{7.168459\% + 8.098592\% + 6.15942\% + 0.940439\% + 0.877193\%}{5}$$

$$= 4.6488\%$$

$$\%A = \frac{W1 - W2}{\mathrm{W1}} \times 100$$

$$\%A = \frac{\mathrm{TPB41 + TPB42 + TPB43 + TPB544 + TPB45}}{5}$$

$$\%A = \frac{1.572327\% + 1.298701\%\% + 1.497006\% + 1.19403\% + 1.470588\%}{5}$$

$$= 1.351805\%$$

Absorptions of water for this test also attain ASTM C936 recommended based 5% of dry weight of specimens.

$$\%A = \frac{W1 - W2}{\mathrm{W1}} \times 100$$

$$\%A = \frac{\mathrm{TPB51 + TPB52 + TPB53 + TPB54 + TPB55}}{5}$$

$$\%A = \frac{0.917\% + 0.633\%\% + 0.935\% + 0.929\% + 0.585\%}{5}$$

=0.860799%

$$\%A = \frac{\mathrm{TPB61 + TPB62 + TPB63 + TPB64 + TPB65}}{5}$$

$$\%A = \frac{1.95\% + 3.215\%\% + 1.558\% + 0.923077\% + 0.90909\%}{5} = 1.7102$$

The results calculated above are summarized as shown in the table below.

Table 4.1: Average of Five Bricks Absorption Test

Specimens	**TPB2**	**TPB3**	**TPB4**	**TPB5**	**TPB6**
Average absorption of water	5.33%	4.65%	1.35%	0.86%	1.71%

From the above table we have observed as the plastic amount increases the absorption of plastic brick decreases which means absorption is one way of durability test of bricks so the plastic bricks passes all requirement standard specification less than 7% of absorption of water.

Figure 4.6: Soaking of in Water Plastic Bricks for 24hr

Saturation coefficient of bricks are calculated according to section 8.4.2.2 of ASTM C0067.The specimen was soaked in clean water (soft, distilled or rain water) at 15.5°C to 30°C in such a manner that water circulates freely on all sides of the specimen. Heat the water to boiling, within 1h, boil continuously for specified time, and then allow cooling to 15.5 to 30°C by natural loss of heat. Remove the specimen, wipe off the surface water with a damp cloth, and weigh the specimen. Complete weighing of each specimen within 5 min after removing the specimen from the bath.

.

$$SC = \frac{w_{2-}w_1}{w_3 - w_1} \times 100$$

4.2.2 Compressive Strength Result for Clay Bricks as Well as for Different Plastic Brick Ratios

Compressive Strength Test Result for Burned Clay Bricks

Figure 4.7: Measuring Weight of Bricks for Compressive Tests

$$\mathrm{CS} = \frac{\mathrm{BC}-1+\mathrm{BC}-2+\mathrm{BC}-3+\mathrm{BC}-4+\mathrm{BC}-5}{5}$$

$$\mathrm{CS} = \frac{20.5\% + 22.32\%\% + 5.5\% + 18.656\% + 18.55\%}{5} = 17.1MPa$$

Figure 4.8: Load vs. Time Graph for Compressive Strength Result of 5.5mpa

Compressive Strength Result for Plastic Bricks For 25% Plastics

$$\mathrm{CS} = \frac{\mathrm{TPB21} + \mathrm{TPB22} + \mathrm{TPB23} + \mathrm{TPB24} + \mathrm{TPB25}}{5}$$

$$CS = \frac{3.269\% + 2.424\%\% + 2.71\% + 2.104\% + 3.457\%}{5} = 2.793mpa$$

Compressive strength of 25% of volume of plastic have less strength than other mix proportions of plastic with sand its strength almost similar strength with minimum requirements of unburned clay bricks 2.06MPa.

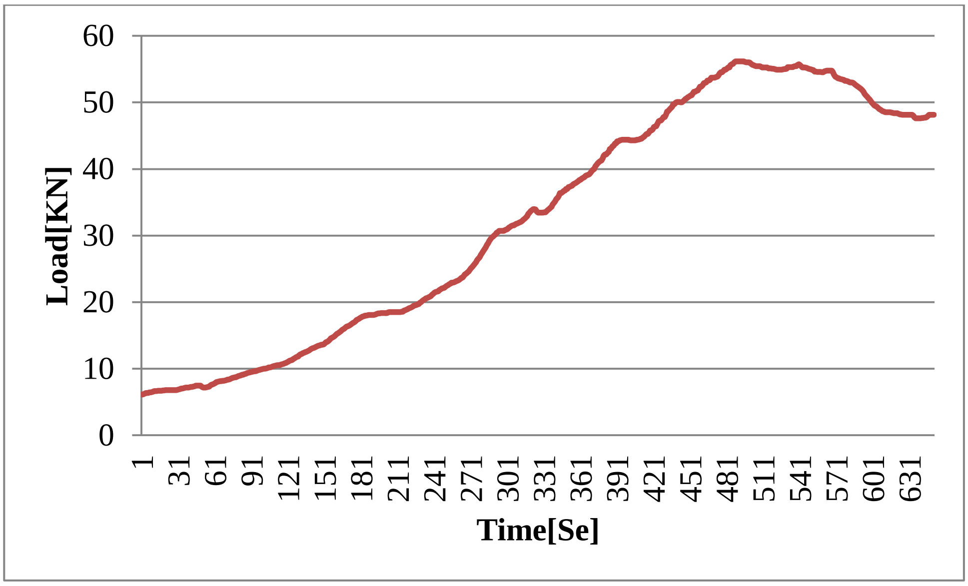

Figure 4.9: Load vs. Time Graph of 25% of PETE Plastic Bricks

This figure shows failure graph of compressive strength test the result clarifying that as plastic amount is more less than optimum value of the experiment have minimum failure load of 56.179KN as well as less compressive strength than other tests relatively but the failure shows ductile failure due to plastic ductile nature.

Compressive Strength Result for Plastic Bricks For 30% Plastics

$$CS = \frac{\text{TPB61} + \text{TPB62} + \text{TPB63} + \text{TPB64} + \text{TPB65}}{5}$$

$$CS = \frac{7.439\% + 7.849\%\% + 6.179\% + 6.202\% + 6.213\%}{5} = 6.776MPa$$

This result shows that average compressive strength of 30% use of waste plastics is increasing in strength about 59% more than 25% use of plastic mixing ratio. So as binding material plastic content increase the void between sand and binding material plastics are decreases and bonding of the later plastic brick is higher than the former 25% use of plastic content.

Compressive Strength Result for Plastic Bricks for 35% Plastics

Compressive strength tests for trial plastic brick four passes ASTM requirements for average of five bricks 10.3MPa as well as individual bricks minimum requirements are 8.6 MPa negligible weathering conditions but, for this TPB4 the result shows that 15MPa of strength also attained so in Ethiopia since there is medium temperature or has no freezing area in most parts of the regions. However, ASTM C129 standard specifications for non-load bearing wall minimum of 4.14 MPa.

$$CS = \frac{\text{TPB31} + \text{TPB32} + \text{TPB33} + \text{TPB34} + \text{TPB35}}{5}$$

$$CS = \frac{9.213\% + 15.894\%\% + 10.577\% + 9.66\% + 9.211\%}{5} = 10.911mpa$$

Figure 4.10: 35% of Plastic Brick Sample

The graph has high failure load than 25%, 30%, 40% and 45% of the graph since the result of 35% use of plastics gives optimum value of the experiments

Compressive Strength Result for Plastic Bricks for 40% Plastics

$$Avg = \frac{\text{TPB51} + \text{TPB52} + \text{TPB53} + \text{TPB54} + \text{TPB55}}{5}$$

$$Avg = \frac{7.218\% + 7.871\%\% + 6.764\% + 8.684\% + 8.5\%}{5} = 7.807mpa$$

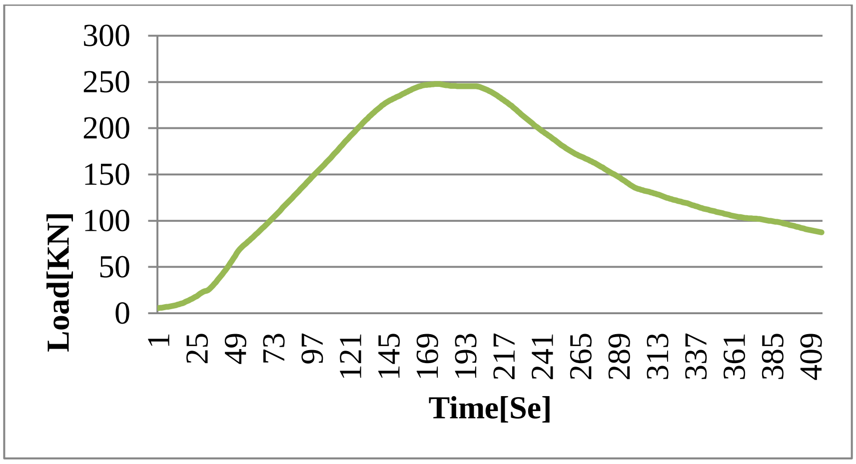

Figure 4.11: Load vs. Time Graph of 40% Plastic Bricks

Compressive strength result for plastic bricks for 45% plastics

$$CS = \frac{\text{TPB61} + \text{TPB62} + \text{TPB63} + \text{TPB64} + \text{TPB65}}{5}$$

$$CS = \frac{8.18\% + 7.576\%\% + 6.179\% + 7.7\% + 7.71\%}{5} = 7.469MPa$$

Average compressive strength of 45% use of plastics also gives higher strength than 25% and 30% but has a compressive strength less than 35% and 40% of plastic bricks.

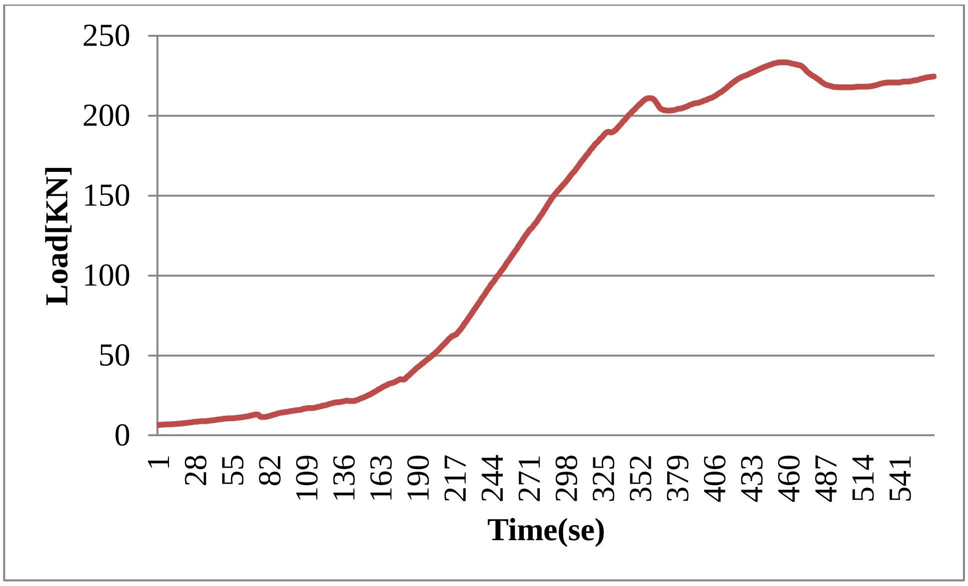

Figure 4.12: 45% of Load vs. Time Graph

Load vs. time graph of this figure has failure load than 25% and 30% of plastic bricks but lower result of 35% and 40% use of plastics.

Average Compressive Strength of those Five Trial Plastic Bricks

Table 4.2: Compressive Strength Average of Tested Specimens

Specimens	TPB2	TPB3	TPB4	TPB5	TPB6
Average Compressive Strength	2.793mpa	6.776mpa	10.91mpa	7.807mpa	7.469mpa

4.2.3 Bulk density of Clay Bricks and Trial Plastic Bricks

Table 4.3: Bulk Density of Clay and Each Trial Mix Bricks

Specimens	Average Weight (kg)	Area (mm^2)	Height (mm)	Volume (mm^3)	Bulk Density (kg/m^3)
Clay brick	1.934	23643.6	55	130039.8	1487
TPB2	2.664	27077.04	5.8	157046.83	2140
TPB3	3.358	27437.04	5.85	160506.68	2060
TPB4	3.242	25954.86	5.85	151835.93	2140
TPB5	3.146	27529.76	5.9	162425.58	1940
TPB6	3.314	28395.84	5.9	167535.45	1590

Table 4 above showed that bulk densities of bricks are decreases as amount of plastic increases and also according to ES 86 : 2001 (as cited Kabtamu and Alemu 2017) maximum requirement of bulk density 2200 kg for burned clay brick since it loses some amount of weight from original or unburned clay bricks. So all tested plastic bricks bulk density is below the maximum requirement according to Ethiopian standards.

4.2.4 Curing Effects of Plastic Bricks for Different Selected Ratios for 30% And 35% Use of Waste Plastics.

30% of Waste Plastics Used in Mixing Proportions

Table 4.4: Curing Effects of Plastic Sand Bricks for30% Pastic Used

TPB3	Weight (kg)	Load(KN)	Area	Compressive strength (N/mm)
1	3.1	95.493	26128	3.655
2	3.09	138.985	27600	5.319
3	3.17	116.84	27600	4.472
4	2.86	110.437	27328.1	4.04
5	2.61	120.85	27328.1	4.42

Average	2.966	116.521	27196.8	4.38

Average of five bricks compressive strength results of cured bricks are 4.38MPa which is less than the air dried plastic bricks strength of 30% plastic brick has an average compressive strength of 6.776MPa which shows the cured plastic bricks are decreased in compressive strength by 35.36% of air dried bricks.

35% of Waste Plastic Used Curing Effects of 7 Days Immersed in Water

Table 4.5: Compressive Strength Result of 7 Days Cured Plastic Bricks

TPB4	Weight	Load	Area	Compressive Strength (MPa)
1	2.98	233.346	28473.6	8.18
2	3.09	233.346	28524	7.576
3	2.81	178.824	26703	6.99
4	3.26	181.839	26128	6.96
5	3.15	206.895	25553	8.097
Average	3.058	206.85	27076.3	7.5606

The result above showed that curing effects of bricks decreases the compressive strength of brick by 30% from the optimum value of plastic brick as the properties of the burned clay brick specified in the standard specification. However the result still has the strength more than the higher load-bearing class of Hollow Concrete Block.

4.3 Test for Temperature Effects on Strength of Plastic Bricks

The compressive strength of bricks are affected by melting of plastics with different temperature variations from 250◦**c** to 300◦**c** As mixing duration increases the temperature increases which leads to decrease in compressive strength. Plastic melting and mixing time should be limited since its binding properties decreases. So the test for optimum trial mixing proportions TPB4 or 35% plastic to 65% sand result is listed in table below.

Table 4.6 Test for Temperature Effects on Strength of Plastic Bricks

Specimens	Weight(kg)	Temperature(◦c)	Load(KN)	Time(min)	Compressive strength(MPa)
TPB41	3.26	250	193.82	15	6.94
TPB42	2.83	280	128.24	20	4.59
TPB43	2.56	300	122	25	4.39

4.4 Cost Analysis for Bricks

Consumption of Alemgena clay bricks for 80,000 brick production they use 10 truck which costs 1000 birr per each truck and 4 truck cementing materials which costs 4000 per each truck cost of firing energy were 20 truck wood with 4000 cots per truck is consumed per day. Which is a key factor for producing global warming so reduction of burning of clay by replacing optimum trial plastic brick four class C bricks according to ES: 2008 (as cited Kabtamu & Alemu, 2017) to attain strength of bricks. The site has high quality of bricks relative to different factories available here in Ethiopia. from laboratory test result Alemgena site bricks classified under class A brick both in compressive strength as well as in absorption of water also classified under class A bricks according to ASTM C67.

4.4.1 Cost Analysis for Plastic Bricks

Engineering cost analysis considering all direct cost (variable cost) and indirect cost (fixed cost) of expenses during production processes. Variable cost including labor costs, the costs linked with employee's wages and benefits, the cost of materials, which are the costs of tangible inputs such as waste plastic from collector, cost of sand. While fixed costs are equipment and its installation, energy costs, which are the costs of electricity and fuels used in the production of plastic bricks so generally rough estimation of production of plastic bricks are shown in table 8 below.

Table 4.7: Cost Analysis for Optimum Plastic Bricks

Item no	Materials	cost/unit	Unit	Quantity	cost/brick
Variable Cost					
1	Waste Plastic Bottle	2.5	kg	0.826	2.5
2	Sand	0.479	kg	3	1.439
3	Labor	70	per day	15	0.11
Total				**4.049**	
	Fixed cost				
1	Machineries				0.33
2	Mold and Vibrator				-
Total				**4.42**	

Estimation of material cost for production of this plastic bricks are original cost of machine that used for grinding melting and mixing process of plastic brick is 500,000 birr and there is also estimation of 60 mold and the equipment investment return rate cost and depreciation cost have been analyzed. Total or production costs of bricks are the summation of variable cost and fixed cost. The estimated amount of production of plastic brick and machine efficiency is listed in table below.

Table 4.8: Total Number Production of Bricks

Machine Cost	Total Mold	Bricks per Mold	Mix per Day	Total Bricks
500,000 birr	60	5	4	1200

Investments return rate and depreciation cost analysis of equipment cost done from total amounts of 620,000 birr assume investment rate of 5% and machine will be used for 7 years

Depreciation Cost of Equipment per Day Were Done as Follows

$$\text{IRR} = \frac{620{,}000}{7 \times 26 \times 12} = 283.88 birr\ per\ day$$

$$\text{Cost per total number of brick} = \frac{total\ birr}{totall\ number\ of\ bricks\ per\ day}$$

$$\text{cost per brick} = \frac{283.88}{1200} = 0.237$$

Investment return rate

$IC = 1/7(620{,}00(1 + 0.05)^7 - 620{,}000))$ =36057.46 birr per year

$$IC = 0.0963\ per\ brick$$

Total equipment cost per brick is 0.333 birr per bricks.

Assume profit of 18% of cost of one bricks then sell price is 5.08 birr per bricks finally this result showed that from burned clay bricks due to since there is all brick factories are available in Addis Ababa city cost of bricks as well as long production process of burned clay bricks and transportation cost also considered from Addis to Hawasa.

4.5 DISCUSSIONS

4.5.1 Discussion Compressive Strength, Absorption of Water and Saturation Coefficient Based on Standard Specification and Classification of Plastic Bricks

Bricks are used for both structural and non-structural masonry works. However from ASTM C62, standard methods of sampling and testing of bricks there is also specifications on compressive strength for physical tests and durability test by testing absorption test and saturation coefficient. So good quality of bricks have properties of at least minimum requirement of compressive strength and the absorption of water and saturation coefficient should be less than 20% percent weight of dry brick and 0.8 ratio of cooling absorption of water immersed for 24 hours to immersion of bricks for 5hours in boiling water. The study showed that compressive strength of plastic bricks increases as amount of plastics mix ratio increases up to certain limit which up to optimum value of 35% of PETE wastes and 65% of sand have compressive strength of 10.91mpa which classified under good quality bricks according to ASTM negligible weathering condition and also classifications of plastics bricks according British Standard (BS) 7-14 MPa class A brick. But according to Bose M., Bansal B (2018) different from this study in a way they investigated concrete bricks with partial replacement of fine aggregate with different proportions 0-15% of waste plastics with five interval ratio of waste plastics are used. As amount plastics increase compressive strength of concrete brick decreases since plastic in nature do not react with water unless it decrease bondage between ingredients of the concrete structure. (Puttaraj, et al. 2018) where investigated plastic soil bricks the study have maximum optimum strength of 7 PMa which is classified to class C clay brick and minimum water absorption less than 1% score more durability properties than burned clay bricks class A of BS. They also assessed 60-80% range of plastic to soil ratio were used. Since they are used high amount of plastics they got less strength than plastic sand bricks as well as sand have high amount of silica content than soil naturally this also by itself loss the strength of bricks as amount of sand become less. From common tests of ASTM, ES and BS compressive strength and absorptions of water of plastic bricks for class A bricks classifications for all bricks individually less than 8% percent. So those plastics bricks 25%, 30%, 35%, 40%and45% all is passes these requirements. But 30% 40% and45% of plastic bricks classified under class C individual result of five bricks prepared for tests of burned clay bricks 7.5mpa.According to ES 86:2001 (as cited tokabtamu & Alemu, 2017),Burayu brick factory Ethiopia average compressive strength of should have been classified as class C bricks average compressive strength of 10.3 MPa. While this optimum results of plastic bricks are qualified according to British Standard, ASTM and ES Standard Specifications and the plastic brick used for both non load bearing and load bearing structural wall.

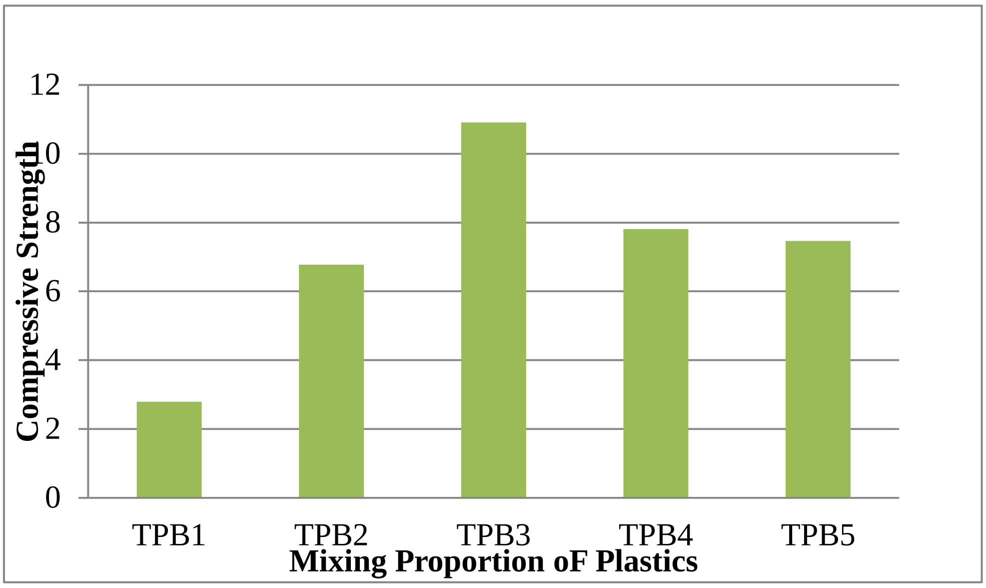

Figure 4.13: Averages of Five Bricks Compressive Strength for Trial Plastic Bricks

Due to PETE ductile plastic nature during the compressive tests of the plastic bricks it shows that its failure are smooth failure which sand by itself give brittle failure but compositions of both material gives ductile-brittle failure of bricks. As amount of plastics increases up to reach optimum trial mixing proportions the compressive strength also increases finally its compressive strength also decreases after optimum trial plastic brick gradually. According to Kabtamu and Alemu, (2017) for structural engineering, one of the most essential things in design of load bearing members understands of material strength beside member forces. It is confirmed by laboratory test as shown in Fig15.In the case of clay brick design strength is compressive strength which in turn affects the masonry strength built using bricks, Compressive strength is significant to structural engineer calculating structural brickwork strengths in accordance with the recommendations of the Structural Masonry Codes of Practice.

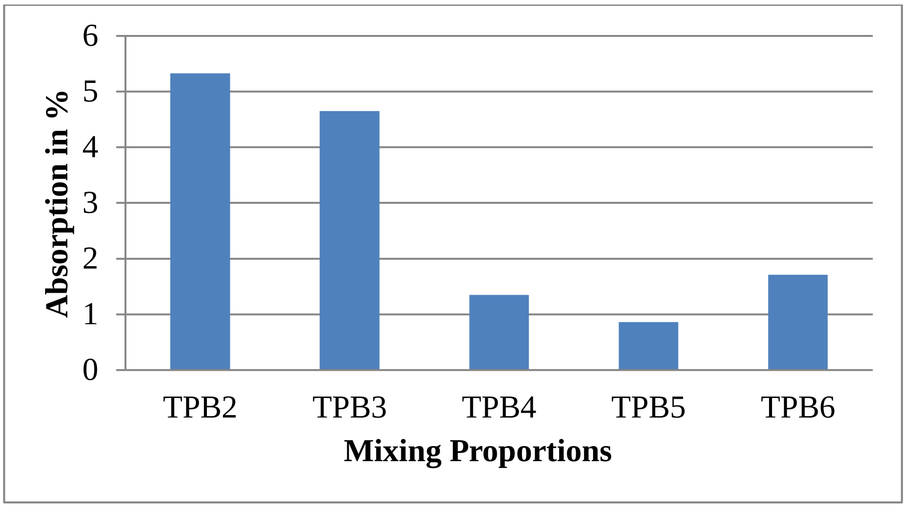

Figure 4.14: Absorption Test Result Graph

4.5.2 General Discussion on Cost Effectiveness and Advantage of Plastic Bricks over the Conventional One

The advantage of plastic brick is the alternative load bearing structural plastic brick for construction industries as well as it gives a cost effective bricks for the developing countries and it is also easy during production process which it attains its strength during remolding after 30 minutes of the casted brick this fast production process is also other advantage of plastic brick over the clay brick which it takes minimum 8 days for production process of burned clay bricks. Besides, recycling used plastic material reduces the quantity of plastic waste and therefore it has positive effect in creating better environment for living. The process of plastic waste recycling does not have any adverse effect on the environment. The cost analysis result on production of bricks from waste plastic brick is cost effective. Since the produced process reduce consumption of energy consumed for production process of burned clay bricks and reduce cost of transportation for the construction purpose.

Advantage of Plastic Bricks:

- Less absorpant of water which indicate its good in quality

- Skilled labor is required
- Lower remolding time is required
- Curing is not required
- Protect environment from pollution
- Minimum production energy is used for plastic brick than the convenient one
- The other important advantage of this plastic brick production from waste plastic and sand is to protect tourist area in Ethiopia like Hawasa lake, Bahirdar lake and different tourist area as well as to minimize waste plastic by consumption of high amount of waste plastic including in construction industry as walling material and soon.

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Plastic waste is one of the major solid wastes in our world and which is disposed to the environment. So using waste plastic bottles in construction is a way of reduction of environmental pollution and also means of minimizing cost of energy consumption during firing process of clay bricks. From the results obtained, the following conclusions were made:

Considering the compressive strength test results of five different mixes of brick samples, TPB4 is found to have the optimum compressive strength value i.e 10.91 Mpa. Out of TPB1, TPB2, TPB3, TPB4, TPB5 and TPB6 trial mixes TPB5 found to have lowest water absorption and the optimum plastic bricks are classified as good bricks quality according to ASTM negligible weathering conditions. A plastic brick with optimum mix has higher strength and durability while it loses its strength smoothly after optimum limit due to bonding between pastes decreases due to segregation of sand and plastics because of the density of liquid form of plastics are less than sand and its flow above sand more than mixed properly. This result also indicates that except TPB2or 25% plastic to75% sand mix rario all plastic brick mix samples have very competitive compressive strength greater to that of higher class of Hollow Concrete Block of 5.5 MPa as wall as used for load bearing structural wall according to Ethiopian standard. . The experimental investigation also indicates that plastic bricks are cost effective compare to normal bricks found in Hawassa city. While cost of one normal brick in market is 11 Birr, the cost of plastic brick is estimated to be 5.08 Birr which is almost 50% less compared to normal brick. The density of brick also decreases as plastic content increases which are below 2200 kg/m^3 maximum requirement according to Ethiopian standard. Finally this experimental work decrease in compressive strength as both mixing time and temperature increases during production process.

5.2 Recommendations

For future work it is recommended to use if crushed stone are used as partial substitution of sand although it is used as a filler material along within molten plastic bottle. To minimize the cost of sand, it is recommended to produce used for production of plastic bricks using manufactured clay or having sand 50-60% of clay around production area Hawasa sandy clay soil is preferable for this plastic brick production which canto it make its high resistance to fire than other types of clay soil because of silica content. In recent research studied effects of Geopolymer effects on plastic wastes and to get alternative structural materials that may be replace concrete structural works since Geopolymers also can be tried in plastic bricks which can help are available early to minimize use of naturally abundant sand for construction concrete structural works.

Grinding to fine powder and mix with some plasticizer like Thermocol crushed stone and bitumen increases binding properties of waste melted plastic. Cement produces tri calcium silicate after dehydration of the cement. this properties of cement also C-S-H form also done for plastic binding material since PETE has $(C_2H_2)n$ for future study if addition of calcium carbonate may be increases the binding properties of the waste plastic and for reduction cost of bricks using blended clay with sand is recommended. Seismic effect of this new engineering material and further temperature variation effect should be recommended. Further study the durability test like efflorescence test and hardness test for plastic brick.

REFERENCES

" Profile on production of recycled plastic waste." n.d.

A.o, sojobi, and owamah hi. "evaluation of suitability of ldpe(low density polyethylene) as fine aggregate." *nigerian journal of technology*, 2014: 405-425.

Abebe, dinku. *Construction material manual.* 2002.

Aiswaria, k, abdulla khansa, akhil e b, and v g lakshmi haritha. "manufacturing and experimental investigation of bricks with plastics and m-sand." 2018.

Aiswaria, k1, khansa abdulla, e b akhil, and haritha lakshmi v g4. "manufacturing and experimenta linvestigation of bricks with plastic and m-sand." 2018.

Ashwini manjunath b t* . "partial replacement of e-plastic waste as coarse-aggregate in concrete." *international conference on solid waste management*, 2016: 731 – 739 .

Asst.prof.mr.l., parthiban, moorthi s.rama, sakthivel r., sathish a., and vignesh s. "experimental study of plastic bricks using polyethylene wastes as partial replacement of m-sand." *international journal of scientific research & engineering trends*, 2018.

Baboorai, 1 s.tabinrushad,2 bhaveshkr,2 ands.k.duggal. "study of waste plastic mix concrete with plasticizer." *international scholarly research network*, 2012: 1-5.

C gopu, mohan, mathew jikku, ninan kurian jithin, and thomas moolayi john. "fabrication of plastic brick manufacturing machine and brick analysis." *international journal for innovative research in science & technology|*, 2016.

Chowdhury, swaptik, aastha tashkant maniar, and om. Suganya. *Polyethylene terephthalate (pet) waste.* 2013.

Dinesh, s., denish a., and k 3 kirubakaran. "utilisation of waste plastic in manufacturing of bricks and paver blocks." *international journal of applied engineering research*, 2016: 0973-4562.

Diptikar, behera,, damtew, yirgalem, and mola aman. "experimental investigation on recycling of plastic wastes and broken glass into construction materials." *debre berhan university, debre berhan, ethiopia*, 2018.

Emiru, aster. "effect of cow dung, cement and fiber on earthen brick." n.d.

K., srinivasan, vignesh s., mohan r., abinash s., jeeva s., and gokulshankar g. "an experimental study of geopolymer brick by using of waste plastics." *international research journal of engineering and technology*, 2019.

Kabtamu, getachew, and mosisa alemu. "laboratory investigation of locally produced clay bricks quality and suitability for load bearing element." *international journal of engineering research & technology*, 2017.

Loukham gerion, singh, singh pongsumbam boss, and thokchom suresh. *Manufacturing bricks from sand and waste plastics.* 2017.

M., monda, bose b. P., and p. Bansal. "recycling waste thermoplastic for making lightweight bricks." *1rajendra mishra school of engineering entrepreneurship*, 2018.

Manjunath, ashwini. "partial replacement of e-plastic waste as coarse-aggregate in concrete." *international conference on solid waste management*, 2016: 731 – 739.

Mariganes, g, and s2 rahesh. "experimental investigation on plastic beam." *international journal of pure and applied mathematics*, november 2018: 591-610.

Mohan d.m.s1, vignesh.j2, iyyappan.p3, c.suresh4. "utilization of plastic bags in pavement blocks." *international journal of pure and applied mathematics*, 2018: 1407-1415.

Owamah, hi, and a.o sojobi. "evaluation of suitability of ldpe(low density polyethylene) as fine aggregate." *nigerian journal of technology*, 2014: 405-425.

Padmini, dr. Khwairakpam. "an experimental study on plastic waste brick." 2018.

Pandey, simanshu p., sakshi gotmare, and prof. S.a. wankhade. "waste plastic bottle as construction material." 2017.

Puttaraj, hiremath, mallikarjun, shetty, shanmukha, rai.p.g, navaneeth, and t.b prathima . "utilization of waste plastic in manufacturing of plastic-soil bricks." *international journal of technology enhancements and emerging engineering research, vol 2, issue 4 102*, 2018.

Sina, asafia, and amani alkaban. "use of recycled plastic water bottles in concrete blocks." *creative construction conference*, june 2016.

Sina, asafia, and amani alkaban. "use of recycled plastic water bottles in concrete blocks." *creative construction conference*, 2016.

Sina, asafia, and amani alkaban. "use of recycled plastic water bottles in concrete blocks." *creative construction conference*, 2016.

Srinivasank., vignesh s., abinash mohanr s., jeeva s., and gokulshankar g. "an experimental study of geopolymer brick by using of waste plastics." *international research journal of engineering and technology*, 2019.

Srishadurya p, priyanga m., and anuradha r. "experimental investigation of strength characteristics on beams using plastics." 2017.

Srishadurya, p.1, m. Priyanga, and anuradha r. "experimental investigation of strength characteristics on beams using plastics." 2017.

Swaptik chowdhury, aastha tashkant maniar, and om. Suganya. *Polyethylene terephthalate (pet) waste.* 2013.

Woldegiorgis, yohannes f. "economic and environmental impacts of plastic waste: a case study in addis ababa city, ethiopia." 2017.

Zhang, lianyang. "production of bricks from waste materials." 2013.

APPENDICES

Appendix A-1: Laboratory Test Result According To (Abebe 2002) Of Properties of Sand.

Fine aggregates generally consist of natural sand or crushed stone with most particles smaller than 5 mm (0.2 in.).

Silt content: the objective of the test is to determine the silt (finer than No. 200 sieve) content in sand.

A simple test which can be made on site to give a guide to the amount of silt in natural sand is the ‘field settling’ test. This test should not be used for crushed rock sands.

According the Ethiopian standard it is recommended to wash the sand or reject if the silt content exceeds a value of 6 %.

Procedure:

Graduated cylinder having a capacity of greater than 100ml was taken

30ml of sand was poured to the cylinder

Approximately ¾ of the cylinder was filled with water for 1000ml cylinder 750ml of water is filled and 300ml 0f sand was filled also

The cylinder was shacked vigorously for about a minute

The cylinder was then left for about an hour to allow the silt to settle on the layer of the sand

The amount of fines forming a separate layer on the top of the washed sand was measured and recorded.

Test Results:=

Where:$A = 7ml$

$$B = 293ml$$

A = amount of silt deposited above the sand

B = amount of clean sand

Calculation:

Silt content (%) = $\frac{A}{B} * 100$

Yirgalem River Sand used for the thesis work

$$Silt\ Content = \frac{7}{293}\ X\ 100 = 2.389\% < 6\% \quad OK!$$

Appendix A-2 Specific Gravity and Absorption

To determine bulk and apparent specific gravity, and absorption of the fine aggregates

Procedure:

500g of fine aggregate sample was added immediately in to the pycnometer and filled with water to approximately 90% of the capacity

In order to eliminate all air bubbles the pycnometer was rolled, inverted and agitated. Finally the level of water was brought to the calibrated capacity of the pycnometer

Then the total weight of the pycnometer, sample and water was determined and recorded.

$C = 0.9976Va + 500 + W$

Where:

C = weight of pycnometer filled with sample plus water, [g]

Va = volume of water added to pycnometer, [cm^3] and

W = weight of pycnometer empty, [g]

The fine aggregate was removed from the pycnometer in order to dry at a temperature of 105^0C, and then cooled at a room temperature for about an hour and then the dried sample was measured

The pycnometer filled to its calibration capacity with water was then determined

$B = 0.9976V + W$

Where:

B = weight of flask filled with water, [g]

V = volume of flask, [cm^3] and

W = weight of the flask empty, [g]

Table A 1: Weight and Volume of Sand Sample for Computations of Specific Gravity and Absorption

Fine aggregate used for tests
W = 360g V = 1000ml Va = 780ml A = 490g

Where:

W = weight of pycnometer

V = volume of flask/container

Va = volume of water added to pycnometer [cm^3]

A = weight of oven dry sample in air [g]

Calculation:

C = 0.9976Va + 500 +W

= 0.9976*(780) + 500 + 360

= 1638.128g

B = 0.9976V + W

= 0.9976*(1000) + 360

= 1357.6g

Bulk specific gravity:

$$Bulk\ sp\ gr = \frac{A}{B + 500 - C}$$

$$Bulk\ sp\ gr = \frac{490}{1357.6 + 500 - 1638.128} = \mathbf{2.23}$$

Bulk Specific gravity (Saturated-Surface-Dry Basis):

$$Bulk\ sp\ gr\ (SSD\ Basis) = \frac{500}{B + 500 - C}$$

$$Bulk\ sp\ gr\ (SSD\ Basis) = \frac{500}{1357.6 + 500 - 1638.128} = 2.278$$

Apparent Specific Gravity:

Apparent specific gravity = $\frac{A}{B + A - C}$

Apparent specific gravity = $\frac{495}{1357 + 495 - 1638.032}$= **2.34**

Absorption:

$$Absorption\ (\%) = \frac{500 - A}{A} x100$$

$$Absorption\ (\%) = \frac{500 - 495}{495} x100 = \mathbf{1.04}\%$$

Volume of bricks= volume of sand +volume of plastics with different mixing proportions

Density of plastic used are 1370kg/m^3, M=ρ×V ×% of plastics

For 20% plastics and 80 % volume of sand using 0.5kg of plastics with 3.37kg of sand for 0.0018 m^{3}volume of brick so total volume used in different mixing ratio of for one brick listed in table form as follows

Table A 2: Amount Of Plastic and Sand Used In Mixing Proportions for One Bricks

Different Mix Proportions	Shredded Plastic (kg)	Amount of Sand (kg)
TBP1	0.5	3.16
TBP2	0.71	2.95
TBP3	0.85	3.15
TBP4	0.863	2.61
TBP5	0.986	2.53
TBP6	1.11	2.32

Compressive strength result for Alemgena clay bricks type

Table A 3: Compressive Strength Result for Burned Clay Bricks

Specimens	Wight (kg)	Force (KN)	Area(mm^2)	Height (mm)	Compressive Strength (Mpa)
BC-1	1.88	542.389	26450	55	20.50
BC-2	1.9	527.4	23625	56	22.32
BC-3	1.88	123.829	22732.6	54	5.50
BC-4	2	423.08	22677.96	54	18.66
BC-5	2.01	422	22732.6	56	18.55
Average	1.934	407.7396	23643.63	55	17.11

Compressive strength result of each five trial mix plastic bricks

25% trial plastic bricks

Table A 4: Compressive Strength Result For 25% of Plastic Mix

Specimens (TBP)	Wight (kg)	Force (KN)	Area(mm^2)	Height (mm)	Compressive Strength (MPa)
1	3.42	87.288	26702.305	57	3.269
2	3.45	64.725	26702.305	58	2.424
3	3.26	73.93	27327.36	58	2.71
4	3.19	56.179	27327.36	59	2.104
5	3.47	98.607	27327.36	58	3.457
Average	3.358	76.14558	27077.34	58	2.793

30% trial plastic brick

Table A 5: Compressive Strength of 30% of Plastic Mix

Specimens (TBP)	Weight (kg)	Force (KN)	Area(mm^2)	Height (mm)	Compressive Strength (MPa)
1	3.42	212	27326.4	57	7.439
2	3.09	218.839	27879.6	58	7.849
3	3.26	176.262	27326.4	58	6.179
4	3.4	176.94	27326.4	60	6.202
5	3.4	177.2	27326.4	59	6.213
Average	3.314		27437.04	58.5	6.7764

35% trial plastic bricks

Table A 6: Compressive Strength of 35% of plastic mix

Specimens (TBP)	Weight (kg)	Force (KN)	Area (mm^2)	Height (mm)	Compressive Strength (MPa)
1	3.38	256.858	27879.6	57	9.213
2	2.8	325.979	20509.5	58	15.894
3	3.42	294.876	27879.6	58	10.577
4	3.14	275.471	24978	60	9.668
5	3.47	262.773	28527.36	59	9.211
Average	3.242	283.191	25954.812	58.4	10.9126

40% trial plastic bricks

Table A 7: Compressive Strength of 40% Plastic Mix Proportion

Specimens (TBP)	Weight (kg)	Force (KN)	Area(mm^2)	Height (mm)	Compressive Strength (MPa)
1	3.41	237.384	28288.12	57	8.5
2	3.16	201.583	27927.55	58	7.218
3	2.79	196.61	27879.6	58	7.871
4	2.67	168.952	24978	60	6.764
5	3.7	247.739	28527.4	60	8.684
Average	3.146	210.454	27520.134	59	7.8074

45% trial plastic bricks

Table A 8: Compressive Strength of 45% Plastic Mix Proportion

Specimens (TBP)	Weight (kg)	Force (KN)	Area(mm^2)	Height (mm)	Compressive Strength (MPa)
1	2.71	233.346	27324	57	8.527
2	2.91	233.346	28527.6	58	7.576
3	2.38	176.262	28800	60	6.179
4	2.56	210.437	28800	60	7.7
5	2.76	211.437	28527.6	59	7.71
Average	2.664	212.966	28395.84	59	7.5384

Table A 9: Bulk Density of Plastic Bricks

Specimens	TPB2	TPB3	TPB4	TPB5	TPB6
1	2246.99	2195.68	2126.94	2114.83	1740.00
2	2227.63	1910.93	2353.83	1950.86	1758.73
3	2056.79	2056.87	2115.01	1725.40	1377.32
4	1978.52	2073.697	2095.18	1781.57	1481.48
5	2189.29	2108.84	2061.65	2161.66	1639.80
Average	2138.19	2064.71	2138.86	1937.56	1590.11

Table A 10: Absorption and Saturation Test Result for Burned Clay Specimen's Brick Specimens

Clay	W1	W2	W3	%A	W2-W1	W3-W1	SC
1	1.84	2.09	2.1	13.59	0.25	0.26	0.96
2	1.85	2.13	2.14	15.14	0.28	0.29	0.97
3	1.95	2.25	2.26	15.38	0.3	0.31	0.97
4	1.85	2.12	2.13	14.59	0.27	0.28	0.96
5	1.79	2.04	2.04	13.97	0.25	0.25	1.00
Average	1.83	2.14	2.10	14.28	0.27	0.278	0.97

Absorption and saturation results of trial plastic bricks are listed as follows:

25% of Plastic Bricks

Table A 11: Absorption And Saturation Coefficient For 25% of Plastic Bricks

Clay	W1	W2	W3	%A	W2-W1	W3-W1	SC
1	2.30	2.49	2.50	8.26	0.19	0.20	0.95
2	2.54	2.63	2.64	3.54	0.09	0.10	0.94
3	2.61	2.83	2.84	8.53	0.22	0.31	0.71
4	2.65	2.78	2.79	4.91	0.13	0.14	0.93
5	2.76	2.80	2.81	1.45	0.04	0.05	0.80
Average	2.57	2.71	2.70	4.96	0.12	0.16	0.87

Table A 12: Absorption and Saturation Coefficient for 30% of Plastic Bricks

TPB3	W1	W2	W3	%A	W2-W1	W3-W1	SC
1	2.79	2.99	3.0	7.168	0.2	0.21	0.952
2	2.76	2.93	2.95	8.09	0.17	0.1	0.94
3	3.19	3.22	3.23	6.159	0.03	0.04	0.71
4	3.42	3.45	3.46	0.94	0.03	0.04	0.75
5	3.14	3.16	3.18	O.877	0.02	0.04	0.5
Average	2.508	3.15	1.918	3.0378	0.056	0.086	0.7704

35% of Plastic Bricks

Table A 13: Absorption and Saturation Coefficient for 35% Plastic Bricks

TPB3	W1	W2	W3	%A	W2-W1	W3-W1	SC
1	3.08	3.12	3.13	1.2987	0.04	0.21	0.95
2	3.18	3.23	3.24	1.5723	0.05	0.10	0.94
3	3.34	3.39	3.4	1.4970	0.05	0.06	0.05
4	3.35	3.40	3.41	1.19	0.05	0.06	0.83
5	3.40	3.45	3.46	1.47	0.05	0.06	0.83
Average	3.27	3.43	3.44	1.33	0.05	0.10	0.72

Table A 14: Table 20 Absorption and Saturation Coefficient for40% Plastic Bricks

45% of Plastic Bricks

TPB5	W1	W2	W3	%A	W2-W1	W3-W1	SC
1	3.27	3.3	3.31	0.9174	0.03	0.04	0.75
2	3.14	3.16	3.17	0.6369	0.02	0.03	0.65
3	3.18	3.21	3.22	0.9434	0.03	0.04	0.75
4	3.2	3.23	3.24	0.9375	0.03	0.04	0.75
5	3.4	3.42	3.42	0.5882	0.02	0.03	0.65
Average	3.238	3.325	3.33	0.76285	0.026	0.036	0.71

Table A 15: Absorption and Saturation Coefficient 45% Plastic Bricks

TPB6	W1	W2	W3	%A	W2-W1	W3-W1	SC
1	3.1	3.3	3.32	1.9455	0.02	0.04	0.55
2	3.11	3.16	3.17	3.2154	0.05	0.06	0.833
3	3.21	3.23	3.24	1.5576	0.02	0.03	0.65
4	3.21	3.23	3.24	0.9231	0.02	0.03	0.65
5	3.3	3.42	3.44	0.909	0.12	0.14	0.8571
Average	3.186	3.325	3.34	0.91605	0.046	0.06	0.70802

Appendix B- Figures

Figure B- 1: Firing Hole Inspection Control in Alemgena Site

Figure B- 2: Plastic Preparation for Making 30% Plastic Brick Making

Figure B- 3: 35% and 65% Preparations of Plastic and Sand Respectively

Figure B- 4: Mixing Process of Sand and Plastics

Figure B- 5: 45% Plastic Bricks Preparation for Test

Figure B- 6: Steel Sheet Mold for Making Bricks

Figure B- 7: Absorption Test Put Plastic Bricks for 24hr in Cool Water

Figure B- 8: Compressive Strength Testing Process

Figure B- 9: Weight Measurement of Bricks during Test

Figure B- 10 Thermometer Used for Measuring Temprature Variation

Figure B- 11Absorption Test Sample of Burnt Clay Bricks