WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

PRODUCTION OF INSULATION BRICK FROM BREWERY SPENT DIATOMITE, PLASTIC WASTE AND SAWDUST

BY: GROUP MEMBER **ID**

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A RESEARCH PROJECT TO BE SUBMITTED TO THE WOLKITE UNIVERSITY, COLLEGE OF ENGINEERING AND TECHNOLOGY, DEPARTMENT OF CHEMICAL ENGINEERING IN PARTIAL FULFILLMENT FOR THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF SCIENCE IN CHEMICAL ENGINEERIG (POCESS STREAM).

August, 2013

Wolkite, Ethiopia

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ABSTRACT

Insulation brick is the most important material which use for multi-purpose. In our project insulator brick is produced from locally available and feasible waste materials such as plastic waste, spent diatomite from brewery industry and sawdust from furniture has been studied. Now a day disposal wastes material become a serious problem. This research project work is aimed to utilize plastic wastes of polyethylene terephetalet as binding agent, diatomite with less dense and saw dust with bio based reinforcement property in the production of insulation brick to save heat forms of energy applications. The produced insulation bricks with different ratios of plastic waste, diatomite (Kieselguhr), and sawdust were analyzed for their physio-mechanical characteristics such as flexural strength, water absorption, thermal conductivity and compressive strength. The maximum bending strength of 17.72MPa was obtained at the optimum process variables (pressing pressure of 68.5kPa, plastic composition of 60%, diatomite 30% and sawdust 10%). The maximum and the average water absorption of the brick were 0.28% and 0.11% respectively. The maximum compressive strength at 14 days was observed as 17.66 N/mm^2 for maximum diatomite case and minimum compressive strength at 14 days was observed as 6.64 N/mm^2 for brick with 20% diatomite content and Minimum thermal conductivity was observed as 0.0164 W/m ^{o}C for brick with 45 % diatomite content. The optimum composition ratio for all test was PET/diatomite/sawdust of (60/30/10) which given thermal conductivity=0.01728W/m^{o}C, compressive strength=10.16N/mm^2, water absorption=0.041% and flexural strength=17.72 MPa. Investigation on the technical and economic feasibility of the work for insulator brick production was performed. Results from the feasibility study indicated that the proposed work was feasible with rate of investment (ROI) 14.27% and the payback period of the project is estimated to be 2years. The produced insulation bricks have light weight but better physio-mechanical properties compared to conventional insulation bricks.

Key words: insulation bricks**,** polyethylene teteraphatalet**,** Kieselguhrr**, s**awdust, flexural strength, physio-mechanical characteristics, and thermal conductivity**.**

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CHAPTER ONE

1. INTRODUCTION

1.1Background Study

Now a day plastic removal is increase based on the increment of usage of plastics because Plastics are versatile, lightweight, flexible, moisture resistant, strong and relatively inexpensive However, durable and very slow to degrade. When the waste plastics are disposed to the landfill site which cause for blocking of sewer and soil deterioration due to less degradable rate. To solve this problem recycling of plastic play a great role. Waste plastics alone or blended with other materials can be used in production of various profiles such as roof tiles, floor tiles, pavement tiles, wall tiles, draining canal, boutique shopping toys, park benches, fences, poles and the like based on the proportion of raw materials and the required properties of the final products [1]. Using of plastic Waste as binders increased durability, reduced cracking increased skid resistance and have low cost and lighter than cement and concrete brick. The performance and longevity of manufacturing insulators with plastic blended diatomite and sawdust are significantly better compared for the normal insulators bricks [2].

Insulation brick is one of the essential requirement for conservation of energy in dairy and food industries as many unit operations involving heating and cooling processes. The saving of energy is not only important to reducing the emission of greenhouse gases in the environment. Increasing awareness towards the environment and public health is leading to an integrated evaluation of insulation materials and whilst no one questions their positive action, there is still significant potential for improving their overall performance. There are various types of insulation materials which can be used in the dairy industry at several place like cold stores, steam and chilled water pipelines, milk silos and tanks, etc. to save the energy loss. The appropriate insulation must be selected on the basis of temperature, thermal conductivity and other factors that might limit application. The optimization of insulation considering saving of energy, cost of insulation and its installation is one of the basic requirements to achieve optimum benefit. There is a need to develop more efficient insulating materials in terms of heat transfer, water repellent properties, ease of application, strength, etc. The thickness must be determined for the particular application according to the type and temperature range.

Insulation material not only saves the heat loss and energy, but it also helps to protect the contained structure which makes it an essential input required for dairy and food industry.

Insulating bricks provide a fairly good compromise between mechanical and thermal properties and can be used for multi-story buildings.

In the world energy consumption is ultimately become increasing, due to increasing population number. Hotels, Restaurants, student cafeteria and many food providing center waste their time and energy for recooking by protecting internal and external heat lose so the food. Especially in our country use wood for food cooking this lead deforestation. Production of insulator brick from locally available solid waste material such as diatomite, plastic and sawdust will solve this and other related problems. Insulator brick once install can serve for along pried of time, minimum for 30 years without losing its performance. It can be manufacture in different shape and size depending on its purpose.

1.2 Statement of the Problem

Ethiopia as a developing country is experiencing genuine difficulty in the area of proper solid waste disposal and management of plastic waste. This is due to the inability of plastic materials to biodegrade and its subsequent persistence in the environment. This unfortunate situation is compounded by several factors including the poor attitude towards waste disposal and the over-reliance on ineffective waste disposal techniques. It is common to find rivers, gutters and roadsides which are choked and filled with waste plastic materials. Solid wastes including diatomite & plastics, once used and dumped without decomposing results in unsightly sceneries, blocking of water movement channels, and cause wide spread of diseases like malaria and cholera as a result of creation of bleeding grounds. On the other hand, food center like restaurant, hotel cooked a lot of food in a day, from this only small amounts food provide for the customer as cooked. The rest store in the refrigerator, the other at room temperature and became cold due to this reason these foods need heating to be provide hot food for the customer. some foods like egg, chicken, rice, potato etc. can be dangerous because its easily contaminated by bacteria called **Bacillus cereu**s, this required at least 175^{o} F to ensure this dangerous Bactria is killed [3].no one care for reheating these foods at desired temperature, this could make us dangerous health problem related with this cold food expose to food poison. For reheating a lot of fuel and electric power spent. These problem motivate us to manufacturing insulator bricks from such materials. The aim of this study was to investigate the feasibility of conserving the environment by collecting such wastes and converting them in to useful product.

1.3Objectives

1.3.1General Objective

The main objective of this project is production of insulation bricks from brewer spent diatomite (Kieselguhr), plastic (PET) & sawdust.

1.3.2Specific Objectives

- ✓ To determine best ratio of diatomite, plastic and sawdust to produce insulator brick
- ✓ To develop sample product
- ✓ To characterize physio-mechanical properties (water absorption, thermal conductivity and compressive strength) of the produced insulation bricks
- ✓ To design a blender

1.4Significance

Production of insulator brick from locally available solid waste material have a significant usage in waste reduction which is dumped in cities and towns due to this unpleasant sceneries, flooding due to blocking of sewer, diseases caused by like cholera and malaria together with soil degradation may reduce. Especially in food provide center, like in restaurants and in the hotels play a great role in energy, cost and time reduction by keeping thermal insulation of stored food avoid recooking. Additionally, recycling of plastics and producing of alternative building materials. For construction industry will provide alternative and cheap finishing materials. Generally, when this project comes in to force its one contribution in cost reduction and unnecessary energy consumption, food poisons, deforestation and etc.to enhance cleaner urban cities, may reduce blockage of urban drainage system clogged by plastic waste and promote job creation in recycling process.

1.5 Scope

The study focused on the process of making insulator brick from waste materials like plastics, diatomite, and sawdust, which were collected from different dumping sites. The scope of work in this project are basically divided in to three major parts,

(1) prepare sample yield and identify best ratio of raw materials,

(2) result analysis,

(3) Blender design.

1.6 Limitation

- Availability of lab equipment
- Electric power
- Accuracy
- Internet access
- Lack of enough time

Finally the aim of our project is to minimize solid wastes by producing insulator brick from these solid wastes (sawdust, plastic wastes and spent grain).

CHAPTER TWO

2. LITERATURE REVIEW

2.1History of insulator brick

The use of insulator brick dates back to the earliest men because man at a point in time needs to tame fire. Historically the Egyptians were the first to melt iron in vessels and furnaces, which were simply a hollow of earth filled with iron ore and charcoal. Advancements in steel making technology was brought about by the invention of the Bessemer converter in 1856.This was a steel vessel lined with refractory materials which have grown from craft to an applied science [4]. The art of brick making also first took place in the molds of ancient Egyptian artisans. , this probably took place during the first Egyptian Dynasty, about 3200-2660 BC, when semidried mud bricks were used for construction of shrines and tombs[5]. Fired clay bricks were first made in Chaldea [6]. Medieval alchemists first used clay as a refractory material to line retorts, crucibles and furnaces. It was not until the middle of the 18th century that fire bricks were made in England by common brick making methods of special fire clays then available. The joining of these two crafts signaled the birth of the refractory industry [6].

2.2Insulator bricks

Insulating bricks provide a fairly good compromise between mechanical and thermal properties and can be used for multi-store buildings. Insulating bricks are available from different manufacturers in different thicknesses and geometries. Some have a high amount of small cavities filled with air or another filler, others have larger cavities filled with insulating materials, like perlite, mineral wool or EPS.As a measure of thermal performance, usually the equivalent thermal conductivity is considered. This is the effective thermal conductivity of a composite material that is made up of two or more other materials. For commercially available insulating bricks, the equivalent thermal conductivity declared by the manufacturer is usually based on simulations of the thermal transport in the bricks and not on a heat flow measurement of the whole brick. Air-filled bricks have declared values of equivalent thermal conductivity down to 90 mW/(m·K), whereas bricks filled with insulating materials have declared values down to 70 mW/(m·K).

2.3Type of insulator brick

The Insulation can be classified into three groups according to the temperature ranges for which they are used.

A. Low Temperature Insulations (up to 90 °C)

This range covers insulating materials for refrigerators, cold and hot water systems, storage tanks, etc. The commonly used materials are Cork, Wood, 85% magnesia, Mineral Fibers, Polyurethane and expanded polystyrene, etc.

B. Medium Temperature Insulations (90 – 325 °C)

Insulators in this range are used in low temperature, heating and steam raising equipment, steam lines, flue ducts etc. The types of materials used in this temperatures range include 85%Magnesia, Asbestos, Calcium Silicate and Mineral Fibers etc.

C. High Temperature Insulations (325 °C – above)

Typical uses of such materials are super-heated steam system, oven dryer and furnaces etc. The most extensively used materials in this range are Asbestos, Calcium Silicate, Mineral Fiber, Mica and Vermiculite based insulation, Fireclay or Silica based insulation and Ceramic Fiber

- Additional capacity
- Low maintenance cost
- Longer service life
- Higher thermal efficiency
- Faster response.

2.4Characteristics of insulator brick

The characteristics of insulator bricks are a remarkable combination of the properties of refractories and traditional insulation material.

1. Lower Thermal Conductivity

The low thermal conductivity -0. 1kcal/m.hr.oC at 600 °C, this means at 75ºC thermal conductivity is 0. 0125kcal/m.hr.oC, in 14 hours around 0.175kcal/m can be transfer through it, means around 10 ºC temperature can be drop in 14 hours from installed insulator bricks. Blanket- allows construction of thinner linings with the same thermal efficiency as that of conventional refractories. Hence, for the same outer envelope dimension the furnace volume is much higher. It is 40 % more effective than good quality clay insulation brick and 2.5 times better than asbestos product. Insulating property of this brick is better than calcium silicate product [7].

2. Light Weight

It is one tenth of the weight of clay insulating brick and one third that of asbestos / calcium silicate boards. For new furnaces structural supports can be reduced by 40%.

3. Lower Heat Storage

Insulator bricks linings absorb less heat because of lower density. Furnace can be heated and cooled at faster rates. Typically, the heat stored in an insulator bricks lining system is in the range of 2700 - 4050 kCal/m2 (1000 - 1500 Btu/Ft^2) as compared to 54200-493900 kCal/m^2 (20000

- 250000 Btu/Ft^2) for conventionally lined system.

5. Chemical Resistance

Insulator resist most of the chemical attack and is unaffected by hydrocarbons, water and steam present in flue gases.

6. Mechanical Resilience

This property permits fibre lined furnaces to be shop fabricated and shipped to site in assembled form without fear of damage.

7. Low Installation Cost

No special skills are required as application practices are standardised. brick linings require no dry out or curing times and can be heated to the capacity of the burners after installation is completed without concern for cracking or spalling.

8. Simple Maintenance

In case of physical damage the defective section can be quickly removed and a replacement piece added. Whole panel sections can be prefabricated for fast installation with minimal down time.

9. Ease of Handling

All product forms are easily handled and most can be quickly cut with a knife or scissors. Vacuum formed products may require cutting with a band saw.

10. Thermal Efficiency

The low thermal conductivity of insulator bricks can be advantageously made use of by the lesser lining thickness and reduced furnace volume. The fast response of insulator bricks lined furnace also allows for more accurate control and uniform temperature distribution within the furnace. The other advantages offered by insulator bricks are summarized below

- Lightweight furnace
- Low down time
- Increased productivity

2.5 Raw material for insulator brick

2.5.1 spent grain (Diatomite earth)

Diatomite also known as Diatomaceous earth is a naturally occurring, soft, siliceous sedimentary rock that is easily crumbled into a fine white powder. The powder has an abrasive feel similar to pumice powder, and is very light due to its porosity. Diatomite is a highly porous material that exhibits high absorption capabilities and has a good chemical inertness. Major applications are filtering aids, metal polishing, thermal insulation, and Portland cement [8]. Diatomite in its natural state is a soft rocklike material consisting of the skeletal remains of a variety of single celled microscopic plants known as diatoms. They are generally amorphous, hydrated or opaline silica, $S\grave{I}O_{2\ x\ n}$. H_2O, with various amounts of impurities such as silica sand, clay minerals, metal salts and organic matter. Because of these contaminants, silica content may range from 58% to 90% of the dry product [9]. Its unique diatomite structure, low bulk density, high absorptive capacity, high surface area and relatively low abrasion are attributes responsible for its utility as a functional filler and as an extender in paint [9]

Table 1 the physical and typical chemical Properties of diatomite

Physical properties	**Typical chemical properties**
Color- white, cream to yellow	Silicon Dioxide (SiO_2) 82.17%
Moisture- Approximately 6%	Aluminum Oxide (Al_2O_3) 6.74%
Bulk Density- Approximately 0.4%	Iron oxide (FeO_2) 3.15%
PH- 6.2 to 6.9	Calcium Oxide (CaO) 0.04%
Water absorption- 150-170%w/w	Magnesium Oxide MgO 0.03%
Oil absorption- 115 -125w/w	Titanium Oxide(TiO_2) 0.06%
	Sodium Oxide(Na_2O) 0.30%
	Potassium Oxide(K_2O) 0.04%
	Phosphate Oxide(P_2O_5) 0.09%
	Manganese Oxide(MnO) 0.01%
	Strontium Oxide(SrO) 0.01%
	Sulphur Trioxide(SO_3) 0.04%
	Loss on ignition L.O.I 5.93%

2.5.2 Sawdust

This is a third component that binds with the plastics and diatomite in production thermal insulator brick is sawdust. many research studies have been conducted using rice husk and sawdust as insulation raw materials [10], result showed that they produced good insulating bricks. Sawdust is used to make a material (insulator brick) which is increasing insulation behavior and improve strength by creating excellent bond with plastic waste (PET) and diatomite. In this case, sawdust is used to improve the insulation property of the bricks as well as flexural strength by filling gap of the mixture. Sawdust is well insulating and light weight gradient because of the surface of the wood is microscopic porous in nature.

Table 2 Physical property of raw sawdust and residual sawdust

Material	Moisture content (%)	Apparent specific gravity	Porosity	Water retention	Water drainage
Raw Sawdust	10.0	0.16	0.84	0.60	40.0
Residual Sawdust	_	_	0.79	0.70	3.1

2.5.3Diatomite and saw dust compound as filling material for the insulating bricks

Thermal conductivity measurements Two guarded hot plate measurement devices were employed for determining the thermal conductivity of the bricks and its constituent materials: a large scale device according to the relevant norms and a small scale device for tests on small samples of materials Large scale guarded hot plate device, the thermal conductivity of the insulating bricks was determined using a guarded hot plate device. The same procedure was employed for the high proportion of sawdust and waste plastic, high proportion of diatomite and sawdust and equal proportion of these three raw materials in mixture that used production of insulator bricks. The guarded hot plate device accords to the relevant norms for the measurement of thermal conductivity, namely SN EN 12667 and ISO 8302 [11,12]. With a metering zone of 300 x 300mm and a plate size of 750 x 750 mm, samples up to 1000 x 1000 mm can be measured with this device. Its accuracy is approximately2%.

The temperature difference between the hot and the cold plates was 10 K and the mean temperature of the measurement was 10 °C. After conditioning in a climate chamber at 23 °C and 50% RH until stable weight was reached, the 16 3/7-bricks where put flat into the guarded hot plate device on the lower cold side, in a 4-by- 4 square arrangement. By moving the bricks close together, the gaps between them were less than 2 mm wide. In this arrangement of the bricks, the individual bricks connected the metering and guard section of the hot plate. As the bricks varied slightly in width (164±1 mm, corresponding to the height in the horizontal 4-by-4 arrangement), rubber blanket of known thermal conductivity of 5 mm thickness was put below and another one on top of the bricks. Thus, the height differences of the bricks were evened out and a good contact was established to the plates. The added thermal resistance of the two layers of rubber was subtracted from the measured thermal resistance before the conversion to equivalent thermal conductivity an expanded polystyrene (EPS) sample of known thermal conductivity and dimensions of 750 x 750 mm served as reference in an asymmetric measurement. I.e. the hot plate was located between the brick matrix and the EPS sample, with cold plates sandwiching these three layers using the material properties of the waste plastics (PET bottles), the diatomite and the sawdust mixing, the equivalent thermal conductivity of a 3/7-brick was determined numerically, using the software BISCO from Physibel.

The geometry was measured on thebricks used for the experiment and includes a 2 mm gap between the bricks in order to reflect the conditions of the thermal conductivity measurement. Also the mean temperature of the simulation of 10 °C was the same as for the measurements. The temperature difference between the hot and the cold side in the simulation was 20 K. The simulation yields the heat flux q through the brick, from which the equivalent thermal conductivity λ equation can be calculated according to the following formula.

$$\lambda_{eq} = \frac{q \cdot d}{\Delta T \cdot b}$$

Where d is the thickness of the brick, ΔT the temperature difference and b the width of the simulated Monolithic architecture, i.e. the construction of a building or of parts of it from a single material, is an approach that captivates builders and planners by its simplicity and the avoidance of complicated details and certain building physics problems. In cold climates, though, it is difficult to find materials that fulfil structural and modern insulation requirements for the building envelope at the same time. This is the reason why the layered approach is very common today. In the layered approach, the structural and insulating functions of the building envelope are separated and different materials are employed for these functions. Such an approach usually requires more steps during the construction process, which can lead to higher building costs. Furthermore, the design of openings and punctuations of the building envelope can be more complicated. Thus, a number of monolithic materials is currently available, with insulating concrete, autoclaved aerated concrete and insulating bricks probably being the most common ones. Often, these materials require higher thicknesses in order to reach the same structural and thermal performance as that of a layered construction. In the current work, we substituted the clay, gypsum and lime stone filling of an insulating brick by the diatomite, sawdust and waste plastics-based filling in order to further reduce its thermal conductivity. This opens the possibility to either increase the performance of the thermal envelope or to reduce the thickness of the bricks. First, an overview on insulating bricks will be given, followed by a short description of diatomite materials in the subsequent Section. The results, which show that the thermal conductivity of insulating bricks can be reduced strongly using diatomite and sawdust, are presented in appropriate proportion in 160_170°C melted waste plastic(PET).

2.6 Identification of optimal parameter and type of polymer for manufacturing insulator bricks

Available polymers of all kinds may be used to bind sawdust and diatomite, but the performance of binding ability and thermal resistance is different. Polymers can be classified according to their origin, structure chain, molecular weight, density, thermal and deformation properties etc. However, in this insulator bricks research the focus falls on thermal and deformation properties. HDPE and PET plastic waste are well compatible for this research propose. Melting point difference of HDPE and PET are insignificant both are melting in the temperature range of (160-180°C). but HDPE is being recycled in this time in Ethiopia, and very costly as compare PET.PET is not recycled in this time in our country, and it is very cheap and available everywhere, excellent binding with sawdust and diatomite within 160-170 °C temperature range and has very less sad effect in this manufacturing process as compare to the other polymer type. For this reason we choose PET plastic waste in this research. The better way is to find compatible PET with diatomite and sawdust is the preparation of several trial blends with the different composition ratio, range of temperature for mixing. Blending time above melting point of PET and rotation of wood stirrer. Then testing its properties. [13] At the King Fahad University has performed test on some selected composition ratio. To blend the polymer they assembled a special blender. The blender comprised of a shear blade, a heating oil bath and a DC motor capable of producing rotation up to 2000 rpm. They followed the recommendations of the manufacturer of the polymers to approximate the tentative polymer concentrations, blending time and blending temperature for each of the collected polymers. The homogeneity of blending was ensured by visual inspection using an optical microscope.

Table 3 Recommended Blending Temperature for Some Selected Polymers

Polymer type Recommended	Recommended blending temperature (°C)	Maximum blending Temperature (°C)
Linear low density	------------	-------
Linear low density Polyethylene (LLDPE)	160-170	200
Polypropylene(PP) Styrene-butadiene-styrene (SBS)	170-180 160-170	200 200
Crumb rubber	170-180	200
PET(polyethylene terephthalate)	160-170	170

2.7Thermal conductivity of insulator brick

Several research groups reported on the thermal performance of regular and insulating bricks. Al-Hadhrami and Ahmad used a guarded hot-plate setup to study different clay and concrete bricks with and without fillings and found equivalent thermal conductivities between 260 and 980 mW/(m·K) [14]. That means that most bricks were not particularly optimised with respect to their thermal properties. Pavlík and co-workers determined the equivalent thermal conductivity of insulating bricks with small cavities with different fillings, namely air, PU foam, EPS and mineral wool [15] the thermal conductivity of the insulating bricks was determined using a guarded hot plate device. The same procedure was employed for the perlite and the aerogel fillings. The guarded hot plate device accords to the relevant norms for the measurement of thermal conductivity, namely SN EN 12667 and ISO 8302 [11,12].

2.8 Purpose of Insulation

A thermal insulator is a poor conductor of heat and has a low thermal conductivity. Insulation is used in buildings and in manufacturing processes to prevent heat loss or heat gain. Although its primary purpose is an economic one, it also provides more accurate control of process temperatures and protection of personnel. It prevents condensation on cold surfaces and the resulting corrosion. Such materials are porous, containing large number of dormant air cells. Thermal insulation delivers the following benefits:

- Reduces over-all energy consumption
- Offers better process control by maintaining process temperature.
- Prevents corrosion by keeping the exposed surface of a refrigerated system above dew point
- Provides fire protection to equipment
- Absorbs vibration

2.9 Research gap

Several research groups reported on the thermal performance of regular and insulating bricks. Al-Hadhrami and Ahmad used a guarded hot-plate setup to study different clay and concrete bricks with and without fillings and found equivalent thermal conductivities between 260 and 980 mW/(m·K) [14]. That means that most bricks were not particularly optimized with respect to their thermal properties. Pavlík and co-workers determined the equivalent thermal conductivity of insulating bricks with small cavities with different fillings, namely air, PU foam, EPS and mineral wool [15]. For that they employed a hot-box device, i.e. two controlled chambers of different temperatures separated by the material to be studied. The highest thermal conductivity was reported for air, with 124 mW/(m·K), and the lowest for mineral wool, with 77 mW/(m·K).The influence of filling some or all of bricks with diatomite and sawdust were studied numerically by Arici and colleagues [7], who found a 28% increase of insulation performance when the whole bricks were filled with diatomite and sawdust instead of air. Kočí et al. [16] used finite element simulations in order to numerically determine the thermal conductivity of a commercially available insulating brick with different fillings. With input data for the thermal conductivities determined experimentally using the pulse method, Kočí et al. [16] found thermal conductivities of 74 mW/(m·K).

for rice husk and bagasse fillings and 71 mW/(m·K) for sawdust fillings. How the actual clay of the insulating bricks can be optimized has been demonstrated by Sutcu [17] who measured thermal conductivity of clay with different amounts of waste admixtures, like sawdust and rice husk resulting in a drop of thermal conductivity from 680 mW/(m·K) with no admixtures to 390 mW/(m·K) for 30 % admixtures. This improvement in thermal properties was accompanied by a decrease in compressive strength from 31 MPa down to 7 MPa. As there is a clear lower boundary for the thermal conductivity with currently used filling materials, we employed highly insulating material, namely diatomite or (diatomite earth), as filling material, which has a thermal conductivity that is approximately half of that of conventional materials.

The goal was to reduce the thermal conductivity of the insulating bricks and the thickness needed for a given U-value. Silica diatomite is a fairly new building insulation material, that is characterized by very low thermal conductivities between 15 and 19 mW/(m·K), compared to 25to 45mW/(m·K) for the most common insulating materials. Furthermore, it is vapors diffusion open, hydrophobic and good fire ratings can be achieved [8]. Different diatomite product types are currently commercially available, namely constriction brick, tiles, renders, fertilizer and non-translucent elements [9]. Diatomite granules which can be compacted into boards or used as additives for renders, are the most economical in their production. Hence, we developed a paste-like mixture of diatomite.

CHAPTER THREE
3.MATERIALS AND METHOD

3.1MATERIAL

3.1.1RAW MATERIALS

The raw materials we are used to produce insulator brick are sawdust, PET and spent grain (diatomite). We collect these raw materials sawdust from furniture work place in gubre, spent grain (diatomite earth) from zebider brewery factory found in gubre and PET from waste disposal place in Addis Ababa.

Figure 1: raw materials of insulation brick

3.1.2Equipment’s

For the production and characterization of insulator bricks from PET plastic waste ,diatomite and sawdust the main equipment used were:

- hydraulic press to mold the insulator bricks,
- thermometer to measure temperature during melting,
- size analyzing sieve,
- analytical balance,
- desiccator used to store samples in a moisture-free environment,
- drying chamber (oven),
- melting drum, wooden stirrer,

- molder,
- scissor,
- safety equipment (eye glass or goggle, leather glove, face mask),
- Aluminum foil,
- flexural strength testing machine,
- thermal conductivity testing machine and
- compressive strength testing machine.

3.2Methods

The production of insulator brick begins with processing of raw materials. Raw material processing involves collecting, drying, crushing and grinding. The raw materials are initially dry in air to avoid the moisture content. The raw materials were then crushed using a pestle and mortar until a suitable ratio for coarse particles to fine particles was achieved. Insulator bricks were produced using melting, blending, molding and discharging procedures. The cleaned and dried PET plastic waste was melted in metal drum using wood fuel at heat source.

The melted PET plastic waste was then mixed with diatomite and sieved sawdust and moulded into the required insulator bricks. The product was then cooled, labeled and trimmed. Cooling was done using ambient temperature. The process block diagram for the main processes for production of insulator bricks from plastic waste, diatomite and sawdust blend is given as explained in Figure 2.

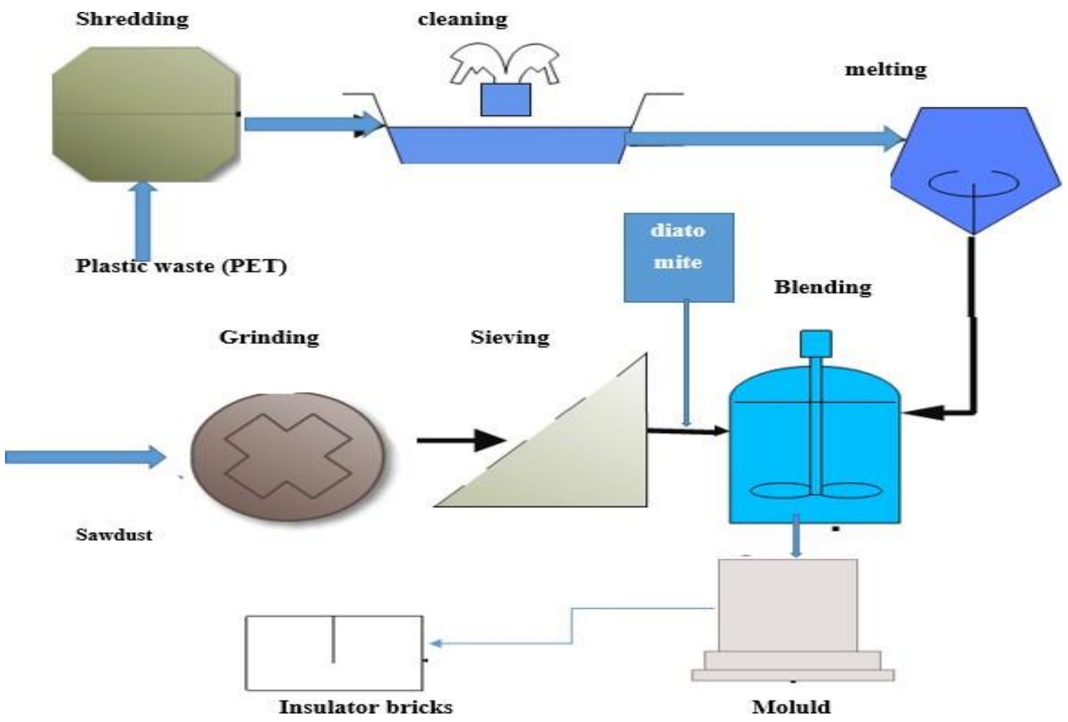


Figure 2 production process of insulator brick

3.3Step description

a) Collection raw material

The raw materials which use in the production of insulator brick are collected from different sites. Plastics (PET) are collected from was waste disposal area and the diatomite earth (Kissinger) are collected spent brewer industry. The sawdust get from wood furniture.

Figure 3 plastic (PET) disposal

b) Cleaning of the PET Wastes

Plastic waste may have different types of dirties as they were used for different purposes. Some of them may be used as containers of oils, lubricants, chemicals and cosmetics. They can also be in contact with soil or other wastes when disposed after their usage. So, they have to be properly washed before recycling processes. To wash them different types of detergents and soaps can be used as require

Figure 4 cleaning of (PET) waste

C) Size Reduction of the PET Wastes

To make it easy for cleaning and melting, plastic wastes collected from different waste disposal areas has to be reduced into the required size using size reducing or shredding machines [18]. The size reducing equipment such as scissor, shredder and crusher can be used to reduce the size of the plastics.

d)Melting of plastic waste

The waste is crushed in order to facilitate the cast and placed in a drum where they are heated. Melting of plastic waste and progressive addition of reinforcing fillers have to be combined and mixed vigorously in order to make the blend homogeneous. The melting temperature depends on the plastic type. P. Herrera-Franco and his coworkers was used the processing temperature of 160, 170 and 180°C for PET, diatomite and sawdust composite [19]. According to this study, temperature at 170°C gives a composite with better flexural strength.

e) Mixing of Melted Plastic with diatomite earth and sawdust

The melted and liquefied plastic wastes are mixed with the fillers while stirring the mixture so that it may be homogeneous. Some study has reported that when some percentage of plastic waste such as PET are used as a binder to produce polymer concrete, they gave a material with better compressive and flexural strength than cement Portland concert. In any case, their results showed that the inclusion of plastic waste eliminates the shrinkage cracking of concrete and reduces the drying shrinkage to some extent [20].

f) Forming of the insulator bricks

Most insulator bricks are formed by dry pressing. In such method, the free flowing powder containing organic binder or a low percentage of moisture flows from a hopper into the forming die. The melted plastic is then mixed with the grinded sawdust and diatomite and transferred to mold fixed with pressing machine. The pressing process is done immediately after melting and blending as much as possible. The blend in the mold is hydraulically pressed to the required Pressure for 13 minutes as mentioned by Tabbara [21]. Several other methods are also used where the brick body is in a wetter, more moldable form. Extrusion plus punching is used to produce irregularly shaped insulator bricks and thinner insulator bricks faster and more economically. This involves compacting a plastic mass in a high-pressure cylinder and forcing the material to flow out of the cylinder into short slugs. These slugs are then punched into one or more insulator bricks using hydraulic or pneumatic punching presses. Ram pressing is another insulator bricks forming method often used for heavily profiled insulator bricks. With this method, extruded slugs of the insulator bricks body are pressed between two halves of a hard or porous mold mounted in a hydraulic press. The formed part is removed by first applying vacuum to the top half of the mold to free the part from the bottom half, followed by forcing air through the top half to free the top part [22].

Excess material must be removed from the part and additional finishing may be needed. Another process, called pressure glazing, has recently been developed. This process combines glazing and shaping simultaneously by pressing the glaze (in spray-dried powder form) directly in the die filled with the insulator bricks body powder. Advantages include the elimination of glazing lines, as well as the glazing waste material (called sludge) that is produced with the conventional method [23]. Most insulator bricks are formed by dry pressing. In such method, the free flowing powder containing organic binder or a low percentage of moisture flows from a hopper into the forming die. The mold is first coated with vegetable fat to facilitate the withdrawing of insulator bricks from it. It should be spread out so as to cover the entire mold. The produced insulator bricks are discharged out of the mold by pushing up the metal sheet supporting the insulator bricks using the whole designed beneath the mold. This operation must be carried out before the cooling of the mixture.

g) Cooling and Drying of the Product

After formation of insulator bricks in the mold, the mold is placed in a basin containing water till the cooling of the mold which allows obtaining a rigid insulator bricks with plastic as a binding material. The composite insulator bricks usually must be dried after forming, especially if a wet method is used. Drying, which can take several days, removes the water at a slow enough rate to prevent shrinkage cracks. Continuous or tunnel driers are used that are heated using gas or oil, infrared lamps, or microwave energy. Infrared drying is better suited for thin insulator bricks, whereas microwave drying works better for thicker insulator bricks. Another method, impulse drying, uses pulses of hot air flowing in the transverse direction instead of continuously in the material flow direction [24].

Figure 5: - produced and dry insulator brick

3.4Experimental Design

The experimental conducted based on the composition ratio of raw materials, mixing time and pressing load. We prepare 6 trials to know the compressive strength flexural strength, water absorption and thermal conductivity of insulation brick. Due to shortage of time and the overlap of lap activity with the other students experiment we did not conduct many trials. The selection of PET from 45%-60% because the molten linkage plastic with diatomite and sawdust is difficult, If the percentage of plastic decrease below 45% the product is brittle and above 60% the thermal property and compressive strength weak. The following trial was prepared In order to determine where the combination of the factors give insulation brick with better strength, low thermal conductivity and low water absorption.

Table 4 experimental design

Run Orders	Composition ratio of (PET)plastic waste/diatomite/sawdust	Mixing time(min) Above160℃ (melting Point of PET)	Pressing Pressure (KPa)	Flexural Strength (MPa)
4	60/35/5	10.00	68.5	
3	60/30/10	10.00	68.5	
5	60/25/15	15.00	68.5	
2	60/20/20	15.00	68.5	
1	55/30/15	20.00	49	
6	45/45/10	20.00	78.4	

3.4.1Melting and Mixing

The PET plastic waste, the drinking water bottle, were melted in a metal drum using wood fuel as heat source. Heating was continued until the plastic was completely melted. Derric Dean suggests melting temperature of non-branched HDPE to be 160℃[25]. According to the present study, melting of the plastic to the temperature of 160℃ gives a composite with better flexural strength. This study also used the temperature of 160℃ to melt the PET plastic waste.

To measure the temperature, thermometer was employed. Results from DSC analysis for PET Waste characterization also proved that PET melts at a temperature of 160℃. At the above temperature range the plastic waste was totally melted and liquefied in 20 minutes. So the procedure as follows; Melt blending technique was employed for preparing the Samples.360g of the plastic waste was weighed on an analytical balance and heated in oven. At fluid condition, diatomite and sawdust mix was slowly added, while the speed of the mixer was maintained at 300 rpm and temperature was kept between 160°C and 170°C. The concentration of diatomite used was be 30%, 35% and 45%, and sawdust used was 10%, 15% and 25% by weight of the blend. Mixing was carried out for 20 min to produce homogenous mixtures. And put into molding then apply 78.4 kPa load for 13 min to have high flexural strength. Once the plastic was liquefied, it was blended manually with diatomite and sawdust by using wooden stirrer. Continuous stirring is followed to make the mixture homogeneous as much as possible. However, for large scale industrial production, automatic mixer is recommended.

According to Guendouz,flexural strength increases with plastic composition but declines after 60% [1]. Using the above as the reference, the waste plastic composition for the current study were analyzed with the HDPE plastic waste composition of 45%, 55% and 60%. The rest un mentioned composition is reserved for diatomite and sawdust composition.

a) Melting (PET) plastic waste

Figure 6 melting process of production system

3.4.2 Molding

Rigid steel mold was used in the manufacture of the insulator bricks but due to the absence of this mold we used wood mold and filled manually with the melted plastic waste, diatomite and sawdust blend. For large scale production, pouring the blend and discharging the insulator bricks need to design automatic and continuous process. The blend was prepared by varying the composition ratio of PET plastic waste to diatomite to sawdust using the total quantity of 560g as basis. The blend in the mold was then high loadly pressed to the required pressure for 13 minutes' step by step. The pressing has two successive steps. First, the blend was rapidly transferred to the mold and pressed to 49 kPa for 5 minutes. This was done to make the blend to gain the shape of the mold. Next, it was pressed by applying the additional 29.4 kg stone on the preface one to gain the required pressure for 8 minutes. Pressing load was increased gradually in order to ovoid out flow of the blend. Due to shape ability of plastic materials, the pressing load has to be a pressure less than for the marble tile. For this study the load used were, 49, 64 and 78.4 kPa. This load rang was obtained by trial and error method. The model mold for this insulator bricks was prepared from wood sheet into the size of 18cm x 17cm x .1.2 cm and 10cm x10cm x 5cm respectively, due to requiring 10cm x 10cm x 5cm shape for measuring flexural strength and 18cm x 17cm 1.2cm needs for thermal conductivity test as manual procedure of laboratory test.

Figure 7 using weight as pressing load in production process

3.5Characterization of Phyisico-Mechanical Properties of insulator bricks

Properties of the product were analyzed and compared to the building code standards and to that from literature. The main tests which were conducted to test the performance of the product include: Water absorption, thermal insulation and bending or flexural Strength tests. All these tests were conducted following the conventional procedures and standards.

3.5.1Water Absorption Test

Mechanical properties and moisture absorption behavior are related to each other. Insulator bricks which absorb less water will show better mechanical properties. The standard methods for water absorption are mostly short-term tests; hence the results obtained are limited Only to surface diffusion phenomena and not equilibrium throughout the thickness of the test specimen. Water absorption test was conducted based on plastic-diatomite-sawdust composition, weight and thickness of the product. To evaluate effectiveness of the produced insulator brick, water absorption test was done in order to determine the water absorption resistance capacity of the insulator brick. The water absorption test was conducted by immersing the product in water (using water immersion test) following standard methods (ASTM C97) [31]. The test was done at room temperature and pressure. Percentage increase in weight was calculated using the following formula as described by Murilo[26]

Water absorption(A),% $\frac{wf\_wo}{wo} * \mathbf{100}$ …………………………………(3)

Where Wf and Wo are weight after and before immersion respectively

3.6.2Flexural Strength Test

Flexural strength also called bending strength is defined as its ability to resist deformation under load. Flexural specimen was prepared according to ASTM D790M, three center point loading. The specimen dimension was 10 x 10 x 5 cm and support span was 96 mm. The force was applied by a rigid cylinder with 20 mm in diameter acting on the middle part of the metallic side of the specimen until the first crack appears in the composite. To obtain the accurate results, the surface of insulator brick was constantly monitored during the experiment by careful observing [27]. Generally, flexural strength test is required in order to determine the amount of force that the brick can with stand on bending before breaking [28]. The reason why the flexural strength test is preferred as the main properties of the insulator bricks is that it indirectly describes the tensile and compression strength of the material. The test was conducted at civil Engineering and Construction lap using an instrument named **ELE 50KN** as shown below

Figure 8 setup of flexural strength testing machine

The flexural strength (σ) was calculated using the following modified formula

$$\sigma = 3/2\frac{fPl}{bt^2} -------------- (4)$$

Where, l = 2/3L, b = span of the specimen(mm), P =load (kN), f = 0.06166 (bending load factor), σ = flexural strength (kPa), t = thickness of the insulator bricks(mm), L = total length of the insulator bricks(mm).

CHAPTRE FOUR

RESULTS AND DISCUSSION

4.1Phyisico-Mechanical Characterization of insulator bricks

4.1.1Water Absorption

The water absorption test was conducted for all 6 experimental samples in a randomized order and the result was tabulated as follow in Table 5

Table 5 Water absorption percentage of insulator bricks

Experimental Run Order	**Composition ratio** **Of PET/diatomite/sawdust**	**Water Absorption** **Percentage** (%))
4	60/35/5	0.09
3	60/30/10	0.041
5	60/25/15	0.0320
2	60/20/20	0.0270
1	55/30/15	0.189
6	45/45/10	0.282

The average water absorption percentage obtained is 0.11% while the maximum individual sample water absorption was 0.28%.The water absorption capacity of the insulator bricks may be reduced due to less micro-pores exist in the product. Another reason may be from the plastic properties of water hating (hydrophobic). From the result of water absorption test, as amount of diatomite increase in composition, water absorption was increase. When amount of sawdust increase in composition, to some extent water absorption increase. We conclude that the ability of the insulator brick to resist water absorption is in agreement with British standards which is 0.5% maximum from our manufactured insulator brick. This was important because it help improving life time by preventing decomposition, and light weight at all time.

4.1.2Flexural strength

The flexural strength test is conducted to know the strength and bending resistance by applying load of the product. It also used to predict service life.

Table 6 Flexural strength test experimental value

Run Orders	Composition ratio of (PET)plastic waste/diatomite/sawdust	Mixing time(min) Above160℃(melting Point of PET)	Pressing Pressure (KPa)	Flexural Strength (MPa)
4	60/35/5	10.00	68.5	16.33
3	60/30/10	10.00	68.5	17.72
5	60/25/15	15.00	68.5	18.11
2	60/20/20	15.00	68.5	19.5
1	55/30/15	20.00	49	13.13
6	45/45/10	20.00	78.4	10.51

According to British standard (BS 4131) the minimum flexural strength required for insulator bricks is 3Mpa. This shows that the produced insulator bricks can with stand loads before breaking. From the above the test, the minimum and the maximum flexural strength obtained were 10. 51 MPa and 19.5 MPa respectively and agree with [29]. While the average is 16.49Mpa. This confirms with J. Aghazadeh Mohandesi and his coworker's [30], study results as diatomite amount increases the flexural strength decreases. When plastic and sawdust increase the flexural strength also increase. It is also difficult to press the molten plastic and diatomite and sawdust mixture with higher pressure, because as pressure rises the mixture flows out of the mold in its molten state.

4.1.3Compressive strength test

Mechanical test measuring the maximum amount of compressive lode a material can bear before fraction. The test piece, usually in the form of a cube, prism, or cylinder, is compressed between the platens of a compression machine by a gradually applied load. The test is conducted as per IS 3495: [32].

$$\frac{\boldsymbol{N}}{\boldsymbol{mm^2}} = \frac{\boldsymbol{maximum\ load\ at\ failure\ in\ N}}{\boldsymbol{average\ area\ of\ thebed\ face\ in\ mm^2}}$$

So the result of compression test shows in the following table.

Table 7 results of compressive strength test

Run Orders	Composition ratio PET/Diatomite/Sawdust (%)	7 Days Strength N/mm^2	14Days Strength N/mm^2
6	45/45/10	13.68	17.6
1	55/30/15	9.81	11.14
4	60/35/5	8.1	9.29
3	60/30/10	7.6	8.92
5	60/25/15	5.13	7.34
2	60/20/20	4.97	6.64

The compressive strength of the brick decreases with increasing in sawdust content. The maximum compressive strength at 14 days was observed as 17.66 N/ mm^2 and minimum compressive strength at 7 days was observed as 4.97 N/ mm^{2}for brick at composition ratio 60/20/20. Study result show that the compressive strength of the insulator bricks increase with amount of composition ratio of diatomite increase.as composition ratio amount of plastic increase the compressive strength of insulator bricks decrease. When the amount of composition ratio of sawdust increase, the compressive strength of insulator brick relatively decrease.

4.1.4Thermal Conductivity Test

Thermal conductivity test is performed based on the concept of steady state condition and as per IS 3346: 1980. In this test a heater coil is placed in between two bricks and two bricks are tied together to avoid heat loss. A thermocouple is also placed near heater coil to measure the temperature. The whole assembly except 2 sides is insulated with a highly. Insulating material named glass wool to avoid heat loss from other directions and to allow heat flow in one direction. Another two thermocouples are placed at other two faces which are exposed to air. The heater coil is connected to electric circuit through ammeter, volt meter and dimmer stat. The whole arrangement is kept in a closed room to avoid air flow which causes delay information of steady state condition.to start the process first connect continuous water supply

to the inlet of water chamber.

Figure 9 Thermal insulation testing machine

Then switch on the power to start the experiment and power input will be adjusted by dimmer stat. start the supply of water. Switch on the central heater. Switch on the ring guard heater. After switching on the power the temperature at heater coil raises and the temperature at outer face also raises after some time. After achieving the steady state condition temperatures at heater coil is noted as T1 and temperature at outer surface is noted as T2. Then after 1.5 hours note down the reading of temperature sensors in 10 min interval with the help of digital temperature indicator and multi-channel switch till observing change in consecutive reading of temperatures. (± 0.2^{o}c).

Table 8Thermal conductivity test

Sr.No	Central heater				Ring Guard heater		Cooling plate	
	P	Tp(min)	PV_c(0c)	T1	PV_R(°c)	T_2(°c)	T3(°c)	T4(°c)
1	0.4	10	55.1	56.1	60.8	56.64	36.1	29.6
2	0.4	10	55	55.1	60	54.3	35.5	29.7
3	0.4	10	55	54.4	60	54.4	36.0	29.5
4	0.4	10	55	54.2	60	54.4	36.3	29.6
5	0.4	10	55	54.2	60	54.5	36.4	29.5
6	0.4	10	55	54.1	60	54.6	36.6	29.9
7	0.4	10	55	54.1	60	54.7	36.7	30
8	0.4	10	55	54.1	60	54.8	36.8	30.1
9	0.4	10	55	54.1	60	54.9	36.9	30.2
10	0.4	10	55	54.2	60	55	37	30.4
11	0.4	10	55	54.1	60	55	37.2	30.6

$A = \frac{\pi}{4d^2}$ Where, A=area of sample& d is diameter of specimen=0.1m

$Q = \frac{p}{Tp} * \frac{3600}{EMC} * 1000(w)$ Where, p=number of pulses& EMC=3200pulses/KW-hr

$Th = \frac{(PVC+T1)}{2}$ °C where, Th=hot plate temperature

$Tc = \frac{T3+T4}{2}$ (°C) Where, Tc=cold plate temperature&T3-T4= surface T° of cooling plate

$K = \frac{Q*x}{2A(Th-Tc)}$ where,K=Thermal conductivity &x=thickness of specimen

Calculation

$$Q = \frac{0.4 * 3600}{600 * 3200} * 1000(w) = 0.75$$

$$A = \frac{3.14 * 0.1^2}{4} = 7.85 * 10^{-3}$$

Th= let take at(100min) process

$$Th = \frac{55.1 + 55}{2} = 55.05℃$$

$$Tc = \frac{35.5 + 29.7}{2} = 32.6℃$$

$$K = \frac{Q * x}{2A(Th - Tc)} (\frac{w}{m}℃)$$

$$K = \frac{0.75 * 0.012}{2 * 7.85 * 10^{-3} * 22.45} = 0.0167(\frac{W}{m}℃)$$

The overall result thermal insulation test lists the following table.

Table 9 Results of thermal conductivity test

Run order	Composition Ratio	Thickness (mm)	Pulse (KW)	Time Pulse	T1 (^{O}C)	PVc (^{O}C)	T3 (^{O}C)	T4 (^{O}C)	K (w/m^{o}c)
4	60/35/5	12	0.4	10	55.1	55	35.5	29.7	0.0171
3	60/30/10	12	0.4	10	56.1	55.1	36.1	29.6	0.01728
5	60/25/15	12	0.4	10	54.2	55	36.3	29.5	0.01752
2	60/20/20	12	0.4	10	54	55	36.7	29	0.01764
1	55/30/15	12	0.4	10	54.2	55	36.4	29.71	0.017
6	45/45/10	12	0.4	10	54	55	36.2	29.32	0.0164

From the above calculation Minimum thermal conductivity was observed 0.0164 W/m°c for insulator brick whose composition ratio 45/45/10 and the maximum thermal conductivity 0.017664 at composition ratio of 60/20/20. From this result we can conclude that when amount of diatomite content increase thermal insulation also increases. When amount of sawdust increase in the composition to some extent thermal insulation is increase. But when the amount of plastics increase in composition thermal insulation decrease.

The very insulating material that aerogel extracted very carefully from jelly in moderated drying system, has k-value 0.0235 W/m℃ with 50mm thickness. According to energy technology network minerals wool of insulation materials which have k-value (0.03-0.04) w/m°c with 100mm thickness can be keep the 450℃ hot plate for 14 hours by losing only 5℃ temperature [27]. Our experimental thermal insulator brick we got k-value range 0.0164- 0.01764 W/m℃ with 12mm thickness so our insulator brick exists within above range. When the thickness of the brick increase the thermal resistance of the brick will be increase means thermal conductivity decrease. Therefore, the optimum composition ratio that best for all test was PET/diatomite/sawdust of (60/30/10) which given thermal conductivity=0.01728w/m℃, compressive strength=10.16N/mm^2, water absorption=0.041 and flexural strength=17.72 Mpa. The propose using 60% of plastic as constant and change diatomite and sawdust amount for around four trials Because plastic is sticky in nature and it is difficult to get homogeneous mixing when the amount of diatomite and sawdust high in composition. According to British standard (BS 4131) the minimum flexural strength, water absorption, compressive strength and thermal conductivity required for insulator bricks is 3 MPa,0.38%,4.12N/$mm^2$and 0.025(w/m℃)respectively this show that the produced brick s were within the best range of the above description.

4.2Thermal Properties test

This task could be done using furnace as heat sores due to lack of Thermo gravimetric Analysis. Frist we put the brick samples, in the furnace with 500 ℃ set for four hours. We observed it without significance weight loss, then we put again another the same brick sample in furnace and set 600℃ for four hours. We observed small phase change without significant weight loss. Another identical sample was put and set the temperature at 650 ℃ for same time. After the temperature of 650℃ there is only 75% of the insulator brick's material remained. So the insulator brick has ability to with stand only temperature up to 650℃ without being decomposed.

4.3Case study

According to organization food agency the cooked food which is free from any poisoning bacterial, have good delicious test and advisable to eat keep within (50-55℃) temperature range One food can be cooked enough within range of (70-75℃) temperature. This insulator brick is not compostable once install can serve for long period of time. We prepare a sample which can hold mug then add hot water in to the mug after that the mug inserted in to the sampled insulator sample brick.

Measuring Time=1hr

Sample thickness= 12mm

Diameter sample insulator brick=50mm

Diameter of mug=25mm

Initial Surface temperature of mug=75 °C

Final surface temperature mug after 1hr=25 °C

$$S = \frac{10 + (Ts - Ta)}{20} * (Ts - Ta)$$

Total heat loss/hr (Hs) = S × A

Where:-**S** = Surface heat loss in K Cal/hr.m^2

Ts = Hot surface temperature in °C

Ta = Ambient temperature in °C

A = the surface area in m^2 Heat Loss Calculation

A .Unmodified system

$$\boldsymbol{S = \frac{10 + (Ts - Ta)}{20} * (Ts - Ta)}$$

Ts = 75 °C

Ta= 25 °C

S = [10 + (75 – 25)/20] × (75 – 25) = 625 kCal/hr-m^2 but this formula used for 1m^2 area in our case the area of sample **(A)** = 2πd^2/4(m^2) =2*3.14*0.025/4=0.00098m^2

Total heat loss/hr (Hs) = S × A

(Hs)=2πd^2/4(m^2) *(625kcal/hr-m^2), =0.6125kcal/hr

B. Modified System:

Measuring Time=1hr

Initial Surface temperature of sample brick=25^{o}c Surface temperature of brick after 1hr= 25.65°C

S = [10+ (25.65-25)/20] × (25.65 – 25)

S=6.52 kCal/hr m^2 similarly in our case

A=2πd^2/4(m^2) ,

A= 2*3.12*(0.05^2)/4=0.0039m^2

Total heat loss/hr (Hs) = S × A

(Hs)=6.52kcal/hr-m^2 *0.0039m^2=0.025kcal/hr

The required for insulated sample to reached ambient temperature

In 1 hr =0.025kcal/hr

X hr = 0.6125kcal/hr

X = 0.6125*1hr/0.025=24.5 hr

C. Thickness calculation

Suppose We have a mug of diameter 25mm with hot water at temperature of 100℃.then insert this mug in our insulation material, Maximum allowed insulation temperature at outer wall is 35 ℃ as we calculated in the above allowed heat loss per hour is 104.95j/h insulation used is insulator brick produced from PET plastic waste, diatomite and sawdust with thermal conductivity for that temperature range of 0.0167w/m℃.now we have to find out the required insulation thickness which can prevent the temperature loss up to 24 hours. The total heat transferred (Q) from inserting mug through such insulating material depends on following factors:

Where: -Rp: - radius insert material

Ri: - radius of insulation

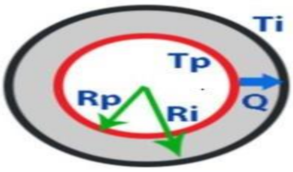
Tp: - operating temperature of fluid inside the mug

Ti: - maximum temperature allowed on the outside surface insulation. Typically, 35℃.

N: - length of insert material, typically mug=0.1m

K: - thermal conductivity of insulating material

Q: - total heat transfer through insulator brick



Formula for un steady state heat transfer through insulating material wrapped around a inserting material, typically mug is as follows:-Q=$\frac{2\pi KN(Tp-TI)}{\ln(\frac{RI}{Rp})}$

we know that allowed heat loss per hour=104.95J.

Assume heat loss is constant through insulator brick in 24 hours.so after 24hours amount of heat loss through the brick is calculated as follow

$In\ one\ hour = 104.95J\ heat\ loss$

$In\ 24\ hours = \quad X?\ heat\ loss$

$Rp = \frac{25}{2} = 12.5mm\ ,$

TP=100℃,

Ti=35℃,

X = 2518.8J Loss in 24 hours,

K =0.0167 $w/\ m$℃,

Q = 2518.8J/m, Q/N=25188J/m, or Q/N=6.9967w/m

$$\frac{Q}{N} = \frac{2 * 3.14 * 0.0167 * (100 - 35)}{\ln(\frac{Ri}{Rp})}$$

$$6.9967(\frac{w}{m}) = \frac{6.(\frac{w}{m})}{\ln\frac{Ri}{0.0125}}$$

$$ln\frac{Ri}{0.0125} = 0.9743$$

$$e^{0.9743} = \frac{Ri}{0.0125}$$

Ri=0.03312m or Ri=33.12mm

Hence, insulation thickness=Ri-Rp=33.12mm-12.5mm=20.62mm, so the required thickness of insulation brick which used to keep the 100℃ for 24 hours is 20. 62mm.this is economical thickness. Let as analysis simple energy saving calculation, take one family house as sample, they boil tea three times a day, in (morning, afternoon and evening) for the first boil, stove consume 750 W power, so three time around 2250W, if this family install this insulator brick once they boil only once, therefor around 1500 W power energy save per day, in month around 14000W power can be saved. if the community once install this insulator brick, they will be save their energy consumption, time, cost and can improve their quality of life. in our country energy consumption system of, not modernized, so this simple way energy saving mechanism important for our community.

CHAPTER FIVE

5.MATERIAL AND ENERGY BALANCE

5.1MATERIAL BALANCE

5.1.1 MATERIAL BALANCE FOR MIXER

According to Law of conservation of mass Energy can neither be created nor be destroyed, only one form of energy can be converted to other. In its general form it can be written as: –

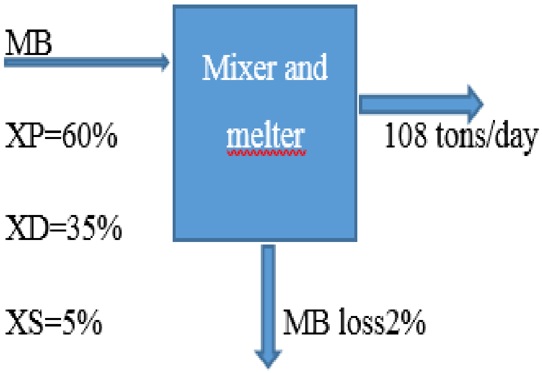
(Mass flow in the system) = (Mass leaving the system) + (Mass accumulated in the system)

Assumptions:-

- No generation and consumption
- The plant is working for 300days/year &24hr/day
- The capacity of the mixer is 90%
- Capacity loss from the mixer is 2% of the total modified bitumen
- there is no specific reaction taking place, during blending, between bitumen and polymer,
- There is no specific change in terms of mass takes place
- Production capacity = 120 tons/day.
- Capacity of mixer calculation, 120 tons/day × 90%=108 tons/day
- The mixer has a capacity of 108 tons/day & from these the loss from the process is Assumed to be 2% of the waste plastic, diatomite and sawdust.

From lab test: -

- The capacity loss of (PET) from cleaner and shredding is 6.75% and 4.25% respectively.
- The capacity loss of sawdust from grinding and sieving is 5% and 10%respectively.
- As we described in the above the proportion we get in lab test was 60% (PET)plastic,35% diatomite and the rest is sawdust.so calculation is as follow;



Where MB: -mass of raw materials

XP: -mass fraction of plastic

XS: -mass fraction of sawdust &XD mass fraction of diatomite

Input=out put

MBXP*+MB*XD+MBXS-MB*2%=108tons/day

MB*0.6+MB*0.35+MB*0.15-MB*0.02=108tons/day

0.98MB=108tons/day

MB=110.2tons/day put in mixer

Loss=110.2tons/day*0.02=2.2tons/day

Mass of (PET) plastic waste=110.2*0.6=66.12tons/day

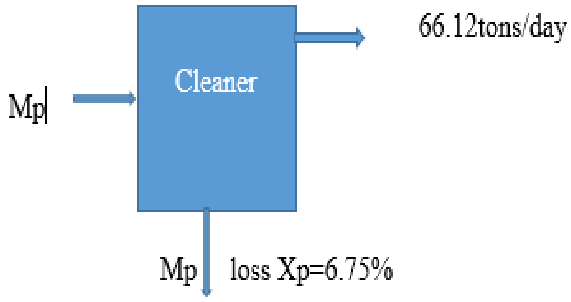
Mass of diatomite=110.2*0.35=38.57 tons/day

Mass of sawdust=110.2*0.05=5.51tons/day put in to mixer per day.

Where:-

Mp mass of plastic

Xp mass fraction of plastic loss

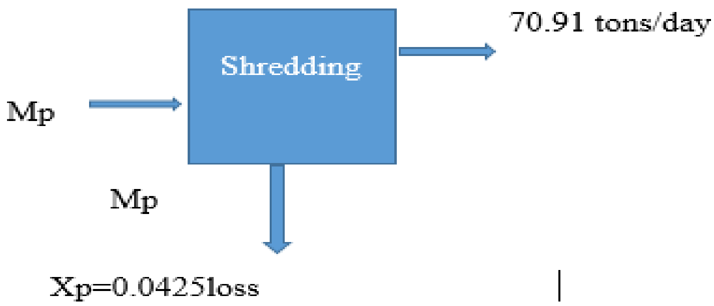


Input=out put

Mp-Mp*0.0675=66.12tons/day

0.9325Mp=66.12tons/day,

Mp=70.91tons/day plastic put in to the cleaner



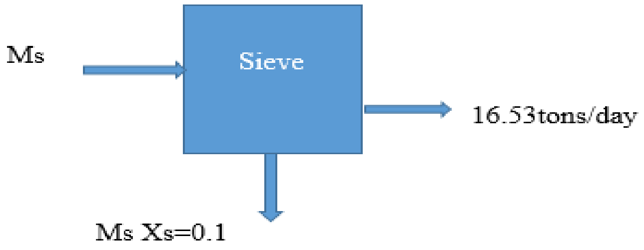
Where: - Mp mass of plastic

Xp mass fraction of plastic loss from shredding

Mp-Mp*Xp=70.91 tons/day

0.9575MP=70.91 tons/day

MP=74.1 tons/day(PET)plastic waste raw materials required per day



Where:-

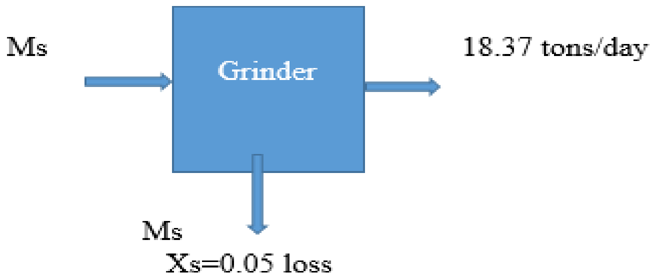
Ms=mass of sawdust adds into sieve per day

Xs=mass fraction of sawdust lost from sieve per day

Ms-Ms*Xs=16.53tons/day

0.9Ms=16.53tons/day,

Ms=18.37 tons/day



Where: -

Ms=mass of sawdust material required per day

Xs=mass fraction of sawdust lost from grinding per day

Ms-Ms*Xs=18.37 tons\day

0.95Ms=18.37tons/day

Ms=19.34 tons'/day sawdust material need per day

So total raw material require per day in this factory are the summation of the 3raw materials

Mp+Md+Ms= (MT) =74.1tons/day +19.34tons/day+38.75tons/day

MT=132.19 tons'/day raw materials enough for 24 hours.

5.2 Energy balance

5.2.1 Energy balance in oven for insulation brick production

The major unit operation where heat and energy flow change in insulator brick production is in the heater device. The heater uses electrical energy as a source of heat. This electrical energy is converted to heat through the process of conduction, convection, and radiation in metal melting drum. The given parameters to calculate the energy as follows;-

Mass of insulator brick out of melting drum (mixer) = 108 tons/day

Assume Temperature of insulator brick after mixing (To) = 25^0C

Assume Temperature of (PET) plastic before interring to oven (T1) = 30^0C

Ready for melting (PET) plastic waste moisture content =1.705%

Assume Temperature of (PET) plastic waste when it go out of oven **(**T2**) =**170^0C

Latent heat of evaporation for water **(λ) =**800kcal/**k**

Change in temperature (ΔT) = T2 – T1 --(1)

$$(\Delta T) = 170^0C - 30^0C = 140^0C = 413.15K$$

Specific heat capacity of (PET) plastic (Cp) = 1.853 J/Kg.K

Specific heat capacity of insulator bricks diatomite and sawdust (CIb) =1.593 J/Kg.K

Heat required by the product: -

(sensible heat) = mass of (PET) plastic × ΔT* Cp plastic --- (2)

Sensible heat = 2755 kg/hr×413.15K×1.853J/kg.K = 2109136.94725 J/hr

Mass of water in (PET) plastic waste evaporated = total mass of (PET) plastic × (moister content of waste plastic interring in melting drum) ---(3)

2755kg/hr × (1.705%) = 46.97275Kg/hr

Assuming that: -

Work done by pressure and volume = 0

The internal energy (U) = is equal along the two end of the oven (U1=U2)

The speed of wire mesh interring and living the oven is at the same speed (u1=u2)

The height of the oven is equal along the two ends (Z1=Z2)

The final simplified form of the equation will be Q in=W out

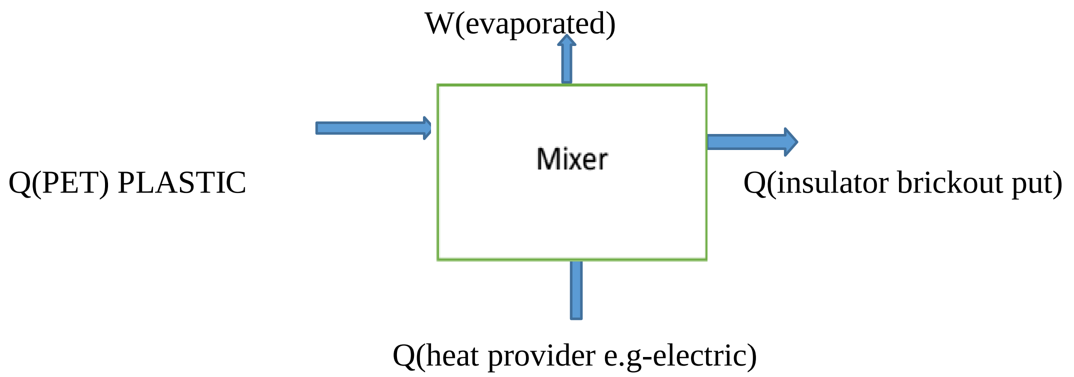
Overall energy=Energy in + Energy generated = Energy out + Consumption + Accumulation……………………………………………………………………………(4)

Where:-

Energy generated = 0

Consumption= is the energy taken by the (PET) plastic waste

Accumulation= is the energy preserved by the oven



Q(PET)plastic + Q electric = W evaporated + Q brick

Qplastic= Mplastic × Cp p × (T1 – T0)

Q plastic= 2755kg/hr × 1.853 J/kgK (30-25) k = 25525.075J/h

Q brick = M brick × cpB × (T2-T1)

Q brick = 4500 kg/hr × 1.593J/kgK × (170-30) K =1003590.0J/hr

Heat required for water = mass of water × latent heat of evaporation W evaporated = 46.976kg/hr× 80J/kg = 3758.08J/hr

Q plastic + Q electrical = Q brick + W evaporated

Q electrical = Q brick + W evaporated - Q plastic=981823.005J/hr

5.3Mixer design

Mixer is a mechanical component which is powered by using manually or especially how a day by using motor and it uses different components. Mixing equipment must be designed for mechanical and process operation. Although mixer design begins with a focus on process requirements, mechanical design is essential for successful operation. Based on different aspects mixer can be categorized into different types. Portable, entering, or turbine mixers account for the largest number of mixers built for the process industries, and other common mixer categories with their unique features. High viscosity mixers, High-shear mixers, double motion mixers, dry solids mixers, static mixers and other mixers are entitled to unique application because of the unique structure of the blade, container and other components. The mixer which we are about to design is called conical ribbon screw mixer. We choose this mixer because of the following advantages: -

- Optimal mixing homogeneity
- Short mixing time
- Excellent reproducibility of batch production and flexibility of batch size
- Minimum wear and low maintenance
- Easy access to mixer/easy to cleaning
- Excellent mixing at any product level
- Low power
- Suitable for shear, heat ,sensitive solid materials
- Gentle blending action

5.4 Construction and working principle of the mixer

The major difference of conical screw ribbon mixer from other vertical mixers is on its blade. The blade is constructed on a hallow tube. A plate is revolved on the tube is screw pattern to do screws function and on the same tube another plated revolved in counter direction by providing enough space from internal screw. The outer ribbon is tapered which rotates around tanks periphery. Solid shaft inserted in the tube to rotate the blade. Mixing action mainly done by the internal screw. When it rotates after addition of the materials to be mixed the screw lifts it up to the top and spread it though out the tank. And the outer ribbon collects the scattered mixture and brought back to the bottom for another cycle. When this cycle repeats itself intense mixing will take place.

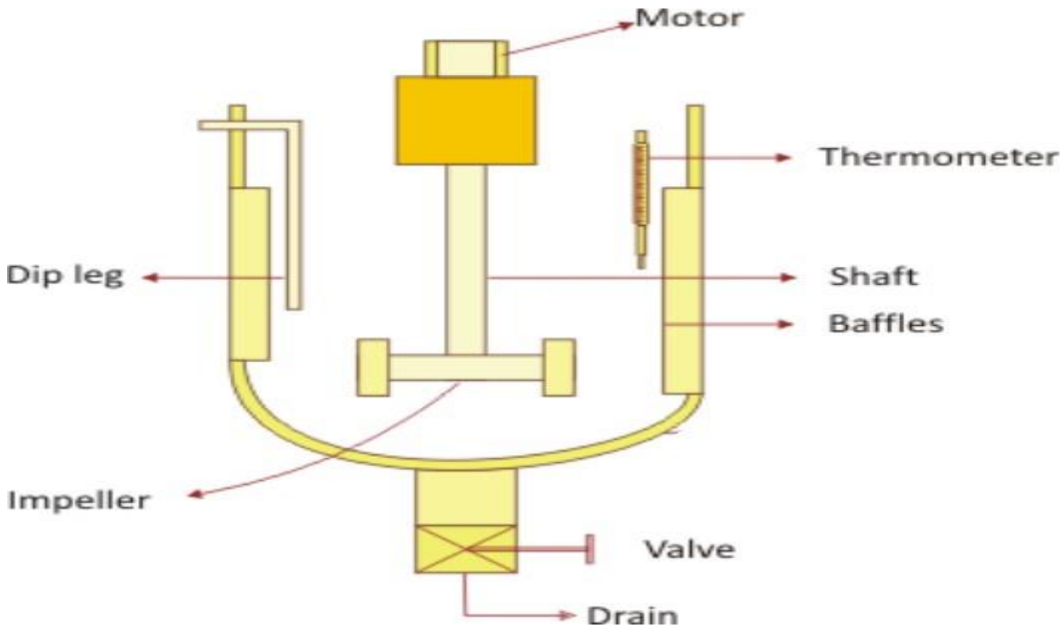


Figure 10 mixer geometry

5.5 Design specification

The given specification is: -Assuming three batch (shift) operating hours and 24working hours per day so eight-hour work per batch so: -

Mass of (PET) plastic per batch will be =66120/3=22040Kg/batch

Mass of diatomite per batch =38570/3=12856.67Kg/batch

Mass of sawdust per batch=16530/3=5510kg/batch

Volume =mass/density

Density of diatomite=2125Kg/ m^3

Density of PET =1380Kg/ m^3

Density of sawdust=210kg/m^3

Total volume =volume of diatomite + volume of PET+ volume sawdust

$$Total\ volume = \frac{38570}{2125} + \frac{66120}{1380} + \frac{16530}{210} = 144.78m^3/day$$

And giving 10% allowance for design purpose

V mixer= (144.78*10%)+144.78=159.258 m^3/day

Mixer=6.64m^3/hour

- Time of mixing per batch will be 10min and totally with preparation and full process will be =250min
- Free space volume refers space needed to mix a batch=19.9m3

5.6Design discussion and calculations

In order to maintain uniform blending care should be taken so using Indian experience let us take the length of the internal screw to be be 1m and assuming uniform mix take place at 100path and one path will have 200revolution with motor capacity of 2000revolution per minute. Time for mixing will be (100path*200rev)/2000rev/min=10min.We have selected screw mixer due to its blade type compatibility with(PET) plastic blending since it requires extrusion type of blending. Calculating superficial velocity superficial velocity is a flow velocity used for mixing purpose

Vs =Q/A   Where Q is volumetric flow rate

$$Area\ of\ cylinder = \frac{2\pi d^2}{4}$$

Assuming diameter (d) of cylinder =1.1m, h (height) =1m, so total area will be A=1.8997m^2

Substituting to the above equation of superficial velocity the superficial velocity will be 0.058m/min

5.7major parts of the mixer

Essential parts of the mixer are; -

- Tank
- Blade
- Shaft and bearings
- Motor and reducer
- Pin
- Feeding port
- Discharge and flow control valve
- Supports and main frame
- Bolt and nuts

5.8 part design

5.8.1Tank

The tank of the mixer provides the space to the mixing action, use as heater for melting plastic and protects and holds the molten melted plastic from scattering. Inside the tank the blade performs its function. Its shape is cylindrical which is configured vertically. Its shape provides the following functions;

- Optimal mixing homogeneity
- Short mixing time
- Flexibility of batch size
- Easy cleaning
- Maximum Complete discharge Volume of frustum $V = \frac{\pi d^2 h}{6}$

Where;- D= diameter of cylinder& h=high of cylinder

Let assume d=1.2m and h=1.5m

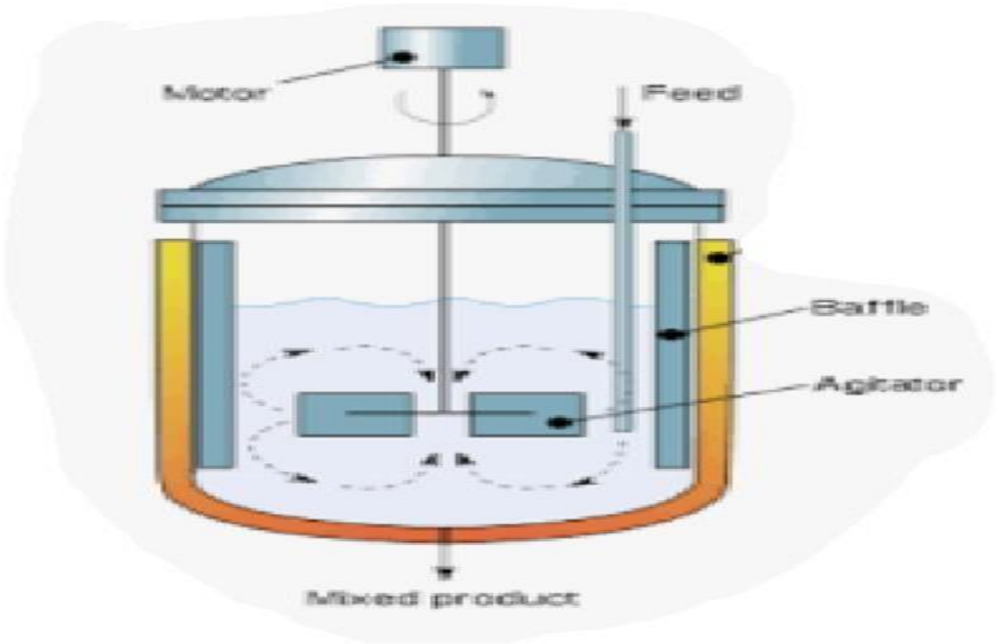


Figure 11 tank geometry

This is using the formula but we need 1.1m3 depending on the cost we can use the available one but most of the time the available volume of cylinder is using this formula:

$$V = \frac{\pi d^2 h}{6} = 2.512m^3$$

The thickness of the tank sheet metal depends on the pressure created in it on the time of mixing operation. Because there is no pressurized fluid in the tank and the flow of the fluid is axially

the pressure in the tank will be expected to be low as atmospheric pressure, so thickness 5mm is sufficient.

5.8.2Screw ribbon blade/agitator

It has the major role in mixing process. The working principle the mixer mainly relies on it. It contains three main parts;

1. Tube-the outer blade and the internal screw will be welded on it. It is the link between the blade and the shaft. It is connected by the means of pin. In addition to strength matter 5m have 1520mm height. Its diameter will be52mm.

2.internal screw-it carries quarter of the total volume weight and take it to its upper portent will revolve around the height of the tube which is 1500mm with pitch of 150.Its width will be 175mm carry quarter of the total volume and a thickness of 5mm to provide enough space for welding. Outer ribbon- it shape follows the tanks shape which is conical. Its function is to collect and return the scattered mixture to the bottom from the wall of the tank for further path. While it is fully immersed in the mixture fluid it will be assumed to be from bending stress, and to protect it from bending its width will be minimized so that it has a width of 30mm and a thickness of 8mm.Load on the machine is weight multiplied by gravity so,

The load will be =108000kg*9.81m/s2=1058400N totally and per batch assuming three batch 352800N. Torque needed to rotate with screw will be calculated by relating it with a power screw. TR=fdm((l+µfdm)/ µdm-fl)/2

Where TR=torque, Dm=mean diameter=216mm, L=pitch length=150mm, F=coefficient friction=0.2

$$TR = \frac{52385 * 0.216}{2} * \frac{(0.15 + 3.14)}{(3.14 * 0.216 - 0.2 * 0.15)} = 2492.7Nm$$

5.8.3Motor and reducer

An electrical motor supplies the power for the mixer. The motor rotates clockwise a and anticlockwise when it mix and discharge the product. For design calculations, impeller power must be a calculated quantity, unless power has been measured on a previously built, identical mixer. Impeller power calculations based on empirical laboratory measurement can be used successfully for most mixer design. However, as a good design practice, total calculated impeller power should not be more than about 85 or 90% of motor power. Impeller power can be as little as 50% of motor power for a conservative design with uncertain process conditions. There for it will be 31KW motor with speed 2000rpm.The motor if its necessary reducer with the flags will be purchased from market.

5.8.4Pin

It connects the shaft and blade and transfers the rotating motion of the shaft to the blade. Therefor it is subjected to double shear. The load on the pin is the sum of weight of the blade and weight of the mixture; -

Weight of blade in selection=813.9N

Wight of mixture on the blade can handle at once=11842N

If the pin to pin carries the load the shear force on each blade will be =3947.5N

5.8.5Discharge valve

It is a flow control valve. It is a kind of butterfly valve. The closing mechanism is provided by disc that sits in the middle of the valve body and rotates. When the lever is turned, this disc moves sideways or upright to allow or block the flow of the fluid. Its internal diameter is 150mmit is suggested by the company because of its availability.

Figure 12 butter fly type valve

On the design of the mixer the heat supplying technique we have found it so difficult to integrate so we just as a startup recommend an integration of a wired type of attached heater uniformly attached to inside the mixer in between the thickness of the frustum with the integration of a thermostat device with sensor. In the heating process attaching the pre heater will allow as to minimize the heat required inside the mixer so by heating the raw material before blending up to hundred degree Celsius and integrating a steam heating system to the screw type of mixer which allow it to conduct the heat up to hundred degree Celsius to the screw and the screw will heat the pre heated mixture up to hundred and seventy and considering some heat loss of around five present maximum to minimize the cost this can be reached by using or integrating a thermocouple which will facilitate uniform heating process.

Our design mixer; have similar property with the above designing mixer in small scall It has diameter 0.423m can be measured.

$$Areaof\ cylinder = \frac{2\pi d^2}{4} = 0.281m^2$$

Height =60cm could be measured V= πd^2h/6

V=0.0562m3/hours

Capacity of mixing, assuming uniform mix take place at 100path and one path will have 50revolution with manual capacity may be of 60revolution per minute. Time for mixing will be (100path*50rev)/60rev/min=84min.

Power require can be calculated as follow,

Our design mixer use resistance with voltage of 200V and resistance of 20Ὼ.so power consumption was;

Power=VI or I^2 R, I=V/R=10A

P=VI=2000w or 2kw for melting PET plastic waste.

1.Cleaner

Mass of (PET) plastic waste intering in cleaner in a day Mp=70.91tons/day

Density of (PET) plastic waste=1380Kg/$\boldsymbol{m^3}$

The Volume of the cleaner available per day Vc=Mp/ρ_p, where Mp is mass of plastic and ρ_p is density of (PET) plastic waste

$$Vc = \frac{70910}{1380} = 51.38m^3/day$$

And giving 10% allowance for design purpose Vc=(51.38*0.1)+51.38=56.518$\boldsymbol{m^3}$/day

Vc =2.355$\boldsymbol{m^3}$/hour,

2.Shredder

Mass (Mp) of (PET)plastic waste need in a day

Mp=74.1tons/day=74100kg/day

Density of (PET)=1380Kg/day

$$Vs = \frac{mass\ of\ plastic}{density\ of\ plastic} = \frac{74100}{1380} = 53.69m^3/day$$

And giving 10% allowance for design purpose Vs=(53.69*0.1)+53.69=59.059m^3/day

Vs=2.46m^3/hour

3.Grinder

Mass (Ms) of sawdust need for grinding per day Ms=19.34tons/day=19340kg/day

Density of sawdust=210kg/m^3

$$Vg = \frac{19340}{210} = 92.1m^3/day$$

And giving 10% allowance for design purpose

Vg=(92.1*0.1)+92.1=101.305m^3/day are required. Vg=4.22$\boldsymbol{m^3}$/hour

CHAPTER SIX

6.1Economic analysis and cost estimation

6.1.1 Economic analysis

The aim of this section is to present information regarding the economic feasibility for the Production and optimization of insulator brick from waste plastic, diatomite and sawdust. This economic evaluation is based on the utilization of 32400000kg per year of blended insulator bricks.

Given Plant parameters.

- Capacity, kg per year 32400000 kg per year
- Number of shifts /day 3
- Working days/year 300

Attempts the design of a process and plant it is the responsibility of the chemical engineer to make economic evaluation. The evaluation determines whether one should undertake the project, abandon it, continue with it (but with further research) or take it to the pilot plant stage. Even if insufficient technical information is available to design a plant completely, we must still make and economic evaluation to determine if it is economically and financially feasible. A project economically feasible when it is more profitable than other competing project, and financially feasible when management can raise the capital for its implementation.

6.1.2 Machinery and equipment cost

Table 10 Equipment cost

No	Item	Quantity	Size(m3/day)	Unit price(Ethiopianbirr)	Power intake
1	Mixer	1	159.258	150,000	7.5Kw
2	Heater	1	-	91,000	124Kw
3	Shredder	1	59.059	75,000	74Kw
4	Grinder	1	101.305	100,000	60kw
5	Sieves	8	-	625 total=5000	0.03kw
6	Motor Machine	2		10000total=20000	8 litter
6	Cleaner	1	56.518	160,000	5.7kw
7	Weight Balance	1	-	9615	0Kw
8	Moulding Machine	3	-	33333.333 total= 100000	4.5Kw
9	Conveyor	1	-	12,000	0.75Kw
Total		9		602,615	276.48Kw

6.1.3Building requirement

Assuming an experience from India for the plant area needed including the plant as well as other building and storage requirements is assumed to be 5,000m^2. And the factory is installed depending on the collection sites which will be implemented for providing waste plastic this is done depending on the number of collection sites in the region in a way of minimizing transportation Cost.

Table 11 Building requirement cost

No	Building and spacing For production and related activities	Total area (m^2)	Unit price (birr/m^2)	Total price (birr/m^2)
1	Raw material storage	500	200	100,000
2	Work space	2500	200	500,000
3	Office	500	200	100,000
4	Laboratory	200	200	40000
5	Other common facilities like recreational areas	300	200	60000
6	Road facility	500	200	100000
Total		4500		900,000

6.1.4 Manpower requirement

Table 12-man power cost

Work specification(skilled man power)	Required number	Gross monthly salary in birr	Yearly salary in Birr
Manager	1	8000	96,000
Production head	1	5000	60,000
Quality head	1	6000	72,000
Purchasing and sales head	1	3000	36,000
Accountant	1	1500	18,000
Secretary	1	1500	18,000
Laboratory Technicians	1	3000	36,000

Mechanical Engineer	1	5000	5000	60,000
IT personal	1	2500	2500	30,000
Controller	1	3000	3000	36,000
Semi-skilled man power				
Production Supervisor	2	2100	4200	50,400
Mechanics	1	1700	1700	20,400
Production line Workers	10	1300	13000	15,600
Raw material storage area Workers	7	1100	7700	92,400
Final product storage area workers	6	1100	6600	79,200
Unskilled Workers				
Security guard	3+1	1000	4000	48,000
Collection personal	4	1500	6000	72,000
Cleaners	7	900	6300	75,600
Total				1,359,600

6.2cost estimation

6.2.1Cost of raw materials

60% (PET)plastic waste,30%diatomite and 10% sawdust are appropriate composition ratio, as men shed in the above so using the capacity 32400000Kg/yr of plant. So by finding the required material from above and multiplying it by the working day of the year the following results were found. There is 74100kg/day (PET) plastic waste, diatomite 38570 kg/day and sawdust 19340kg/day and totally around 132010kg/day and yearly 22230000kg/yr plastic waste, 11571000kg/yr diatomite and 5802000kg/yr sawdust, and totally around 39603000kg/yr raw materials are required in this factory.

Table 13 Raw material cost

Raw material	Unit price (birr/kg)	Total annual cost (kg/yr)
Waste plastic	2	44460000
Diatomite	2	23142000
Sawdust	6	34812000
Total		102414000

6.2.2Cost of utility

Three different utilities are examined in the insulator brick production process. The electricity for the melting of waste plastic, for shredding waste plastic, cleaning machine, for grinding, for sieving or the energy required for the equipment's, light, fans and other equipment. The water required for the production of insulator bricks specially for cleaning of plastic waste includes the water required for laboratory, sanitation and etc. fuel for motor machine which used to rotate blender or agitator during blending process of melted waste plastic with diatomite and sawdust.

Table14 cost of utility

Utilities	Annual amount	Unit price (birr)	Annual cost
Electricity	72944kw	0.35	25530.75 birr/kw
Fuel	2400 litter	17	40800birr/litter
Water	210,000 litter	0.00315	661.5 birr/L
Total			66992.25

6.2.3Fixed capital cost estimation

Table 15 fixed capital cost estimation

	Components	Normalized (%)	Cost(birr)
	Purchased equipment cost(PEC)	602,615	602,615
1.Direct cost	Purchased equipment Installation	Purchased equipment installation,45%PEC	271176.75
	Instrumentation and Control	Instrumentation and control,9%PEC	114496.85
	Piping	Piping,16% PEC	96418.4
	Electrical	Electrical,10%PEC	60261.5
	Building	Building,25%PEC	150653.75
	Yard improvement	Yard improvement,13%PEC	78339.95
	Service facilities	Service facilities,40%PEC	241046
	Land	Land,6%PEC	36156.9
A Total direct cost			1651165.1
2.Indirect cost			
	Engineering and supervision	Engineering and supervision,10%PEC	60261.5
	Construction expenses and contractors fee	Construction expenses,11%PEC	66287.65
	Contingency	Contingency,6%PEC	36115.9
B. Total indirect cost			162665.05
Fixed capital investment =A+B			1813830.15

6.2.4 Estimation of total product cost

Table 16 estimation of total product cost

	Components	Normalized(%)	
	Purchased equipment cost(PEC)	602,615	602,615
manufacturing cost	Depreciation (10% of fixed capital)	Purchased equipment installation,12%PEC	72313.8
	investment plus 2% of building		
	Local tax 3% of fixed capital investment	Local taxation 3%,FCI	54414.9045
	Insurance	0.8% fixed capital Investment	14510.6412
	1.Fixed charges	Total of the above Cost	141239.3457
	Let fixed charge be 15% of total product Cost	15%TPC	941595.638
2.Direct product cost			
	Raw material cost	------------------------	…………
	Direct super visionary and clerical Labor	15% of operating labor cost	203940
	Utilities	- - - - - - - - - - - - - - - - - - - -	- - - - - - - - - - - - - - - - - - - -
	Maintenance and Repairs	5%FCI	90691.51

	Operating supplies	15% of maintenance and repairs	13603.73
General expense	Administrative cost	5% TPC	47079.782
	Distribution and selling cost	14%TPC	131823.4
	Research and development cost	5%TPC	47079.782
	Financing	2%TCI	42678.35
Total production cost=			104140723.7

Then, Total Production Cost **(TPC) =MC+GE**

TCI=FCI+15%TCI

$$TCI = \frac{FCI}{(1-15\%)} = \frac{1813830.15}{(1-15\%)} = 2133917.824$$

Profit Analysis

Gross earn cost

The current price of insulation bricks depends on the thickness and thermal insulation ability of bricks. According to energy technology network, using material with higher thermal conductivity (resulting in higher k-values and poorer performance as an insulation material) means that a greater thickness is required to achieve the same performance. Mineral wool and natural fiber insulation material typically have range of thermal conductivity measured in k- values from 0.03 to 0.04 w/mk. Mineral wool cost around $4.40-7.80 per square meter and natural fiber around $10/m^2 for 100mm thickness.as discuses in the above, we calculated the k-value is=0.0135w/mk with measured thickness around 12mm.this means our insulator bricks are excellent insulation in minimum thickness, very light weight and very easy to enstalation.so unite price 84birr/m^2 and 8 birr/kg with 50mm thickness.as compare to the other this is very cheap if this project come into force to plant level.

The industry will produce a packed blended insulator bricks of 50mm thick size and 32400000Kg/yr.

$$unit\ price\ cost = \frac{TPC}{plant\ capacity\ 32400000}$$

Annual revenue = 8birr/kg *32400000kg/yr=259200000birr

Total production cost = 104140723.7

Gross annual profit = Annual revenue-total production cost Gross annual profit

= 259200000-104140723.7

Gp=15059276.3

Income tax on gross profit (35%) = 15059276.3*0.35 birr=5270746.69

Net profit after tax = net profit before tax – profit tax= 155059276.3-54270746.69

Net profit after tax=10788529.6birr/yr approximately the net profit after tax per year

A) Before tax

$$ROI = \frac{NET\ profit\ before\ tax}{FCI} * 100\% = \frac{15059276.3}{18138301.5} * 100\% = 18.67$$

B) After tax

$$ROI = \frac{NET\ PROFIT\ \ after\ tax}{TCI} * 100\% = \frac{10788529.6}{18138301.5} * 100\%$$

ROI**=14.27%**

C)**Payback period**

$$PBP = \frac{FCI}{profit\ after\ tax + depreciation} = \frac{18138301.5}{10788529.6 + 181380.15} = 2YEAR$$

PAY BACK PERIOD approximately 2year

CHAPTER SEVEN

7.CONCLUSION AND RECOMMENDATION

7.1CONCLUSION

The use of waste plastic in insulator brick production as binder has not yet started in Ethiopia. The fruitful research works conducted on it in the country are few. The results of this research together with that of related previous researches are found to be encouraging for the future researchers who are interested to work in this field. The main raw materials used for the production of insulator brick were diatomite, sawdust and PET plastic wastes. The diatomite was collected from birr industry that as filter and through as waste. Plastic wastes with basis of PET were preferred for this thesis work. This was because that different types of plastics melt and burn at different temperatures and have different physical and chemical properties. Hence, narrowing the plastic waste type to only PET minimized the complex effects due to variation in the plastic types. The diatomite in the in the insulator brick acts as increasing insulator propose, fire retardant and hardening agent, sawdust as increasing insulator propose and it help the brick to be light weight. While the PET plastic waste serves as bonding agent to hold the diatomite and sawdust particles together and to enhance the insulation property of the brick. The presence of the plastic also reduces the breakability of the brick when it is exposed to the bending and the impact forces. Relative to the conventional methods that uses cement and clay, utilization of PET waste also helps to produce insulator brick with less thickness to weight ratio so that reduces the quantity of the raw materials required. This makes it more economical in the raw materials consumption. For the production of insulator brick the main process variables considered were pressing pressure (49, 68.5 and 78.4 kPa), mixing time and temperature (10min, 15min and 160-170℃), composition ratio. For the produced insulator brick, the maximum flexural strength of 19.5MPa was obtained at plastic to diatomite to sawdust composition of 60/20/20 %, mixing time for 10min and maximum mixing temperature 170℃ and pressing pressure of 68.5 kPa. And maximum thermal insulation ability was found at composition of PET plastic waste to diatomite to saw dust (45/45/10) was 0.0164w/m^{o}c. The minimum flexural strength of 10.51MPa was obtained at plastic to diatomite to sawdust composition of 45/45/10 %, mixing time 20min and pressing pressure of 78. 4kPa.actually all trying composition had high thermal insulation, as compare the minimum thermal insulation was obtained at plastic to diatomite to sawdust composition of 60/20/20% was 0.01764 w/mk.

Both the obtained minimum and maximum flexural strengths are higher than the minimum flexural strength (3MPa) set by British standard (BS 4131) agency for insulator brick to be used for thermal insulation in dairy and food industry or external application. Both the obtained minimum and maximum thermal insulation are higher than the minimum thermal insulation (0.05w/mk) set by British standard (BS4131) agency for insulator brick to be used in dry and food industry. Therefore, insulator brick produced from diatomite, sawdust and PET plastic waste as binding agent have better flexural strength and thermal insulation which fulfill the expected standard. As observed from BBD, pressure is the most influencing factor within the considered process variables range. The optimum pressing pressure and mixing time determined by this thesis work is 68.5kPa and 10min. Other factors such as (PET) plastic waste to diatomite to sawdust ratio was affect the flexural strength, when amount diatomite increase in constant plastic ratio flexural strength decrease. But as plastic and sawdust increase in composition flexural strength was increase. Thermal insulation was affected by composition ratio, as amount of diatomite and sawdust ratio increase in composition within constant PET, thermal insulation was increase. But when amount of plastic increase to some extent thermal insulation was decrease. The optimum composition ratio for all test was PET/diatomite/sawdust of (60/30/10) which given thermal conductivity=0.01728w/m°c, compressive strength=10.16N/mm^2, water absorption=0.041 and flexural strength=17.72 Mpa. This was maximum in the considered ranges. The result obtained from thermal properties of sample analysis showed that the insulator brick produced from PET plastic waste, diatomite and sawdust can with stand higher temperature up to 650 ℃ without being decomposed. The insulator bricks produced in this thesis have less thickness, breakable, light weight but better flexural strength and water resistant capacity relative to the other conventional insulation bricks. So, it can be concluded that utilization of PET plastic wastes as binding agent with diatomite and sawdust in the production of insulation bricks is possible. It gives valuable product with compare able Physical and mechanical properties to the convectional insulation bricks. Utilization of PET plastic wastes as binder agent can be used as alternative to cement in production of insulation bricks and it can be potential input for construction sector and other engineering applications. Results from the feasibility study indicated that the proposed work was feasible with rate of investment (ROI) 14.27% and the payback period of the project is estimated to be 2years. The produced insulation bricks have light weight but better physio-mechanical properties compared to conventional insulation bricks.

7.2Recommendations

Due to the lack of temperature controlling tools for this research, the effect of temperature and cooling rate did not study. However, it may affect the physio-mechanical and chemical properties of the product. Hence, the author recommends the future researchers to consider them. To minimize effects due to molecular weight and melting temperature of the plastic wastes, the wastes from the same origins were used as much as possible. Before melting, plastic wastes have to be shredded into small flakes. But the availability of plastic shredder is less in Ethiopia. For this reason, the author used scissor to reduce the size of PET waste plastic. However, with the availability of shredder and molecular weight analyzer the future researcher can shredding in short time of PET plastic wastes from different packaging materials and apply it for large scale production. Sealing the internal part of the mold with aluminum foil during the production was used to simplify the discharging of the produced terrazzo tile. For large scale production, stainless steel mold is recommended. The heated and blended mixture of plastic, diatomite and sawdust can also be pelletized using granulator or pelletizing machine. The pellet can then be further processed to different products. The author recommends further researcher or the plastic and the insulation brick industries to incorporate hot pressing machine and model mold and also pelletizing plastic waste to different profiles. In order to minimize the slippery properties of the plastic, different patterns can be embossed on the surface of the insulation bricks. The outer surfaces can also be treated with additional diatomite and sawdust by using heat and pressure. Pressing the molded product by large stone is used to compacted and well shape of the insulator bricks. However, in large scale hydraulic pressure is recommended.

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