Manufacturing and study of sand-LDPE composite as an alternative building material for pollution control

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I hereby declare that the work which is being presented in this thesis entitle "**Manufacturing and study of sand-LDPE composite as an alternative building material for pollution control**" is my original work and has not been presented for a diploma / degree of any other Institution/University and I have acknowledged and referenced all materials used in this work.

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LIST OF ABBREVIATIONS AND NOTATIONS

ASTM	American Society for Tasting and Measuring
ASTU	Adama Science and Technology University
A	Area
C^0	Degree centigrade
D	Diameter
d_i	Inner diameter
d_o	Outer diameter
DFA	Design for Assembly
DFM	Design for Manufacturing
E	Elastic modulus
EC	European Commission
F	Force
H	Height
HDPE	High Density Polyethylene
I	Moment of inertia
K	Bulk modulus
L	Length
LDPE	Low-Density Polyethylene
MSW	Municipal Solid Waste

M_b	Mass of brick
M_p	Mass of plastic
M_s	Mass of sand
n	Factor of safety
P	Pressure
PE	Polyethylene
PET	Polyethylene Teraphthalate
PP	Poly propylene
PPI	Plastic Pipe Institute
PVC	Poly Vinyl chloride
SPC	Sand-Plastic Composite
SPI	Plastic Industry trade Association
SWM	Solid Waste Management
USMSW	Unite State Municipal Solid Waste
Z	Modulus of elasticity

ABSTRACT

Plastic wastes are the most environment polluting wastes and mainly end up on landfill sites where they take around 1000 years to photo degrade. They break down into tiny toxic particles that contaminate the soil and water ways and enter the food chain when animals accidentally ingest them. Plastic wastes like plastic carrier bags carrying advertising logos, pack in bags and a variety of other forms are all polluting our environment. Just when take a look around as Plastic bags can be seen hanging from the branches of trees, flying in the air on windy days, settled amongst bushes and floating on rivers. They block gutters and drains causing water and sewage to overflow and become the breeding grounds of germs and bacteria that cause disease, so plastic waste conversion to use full product is one of the current a major environmental concerns in our country. The main aim of this research is to prepare and Study sand-LDPE waste plastic composite as an alternative building material to reduce the LDPE plastic waste that cause environmental pollution. In this research first manually operated compression molding machine was designed using CATIA V5 software and manufactured. Then Sand reinforced waste plastic composites (SPC) containing different concentration of plastic (LDPE) with respect to the mass of sand was prepared by melt blending and compression molding. The plastic waste was mixed with sand at three mass percent of 50%, 55%, and 60% for the experiments. Then, different mechanical and physical properties were evaluated including compressive strength, Density and water absorption. The obtained results indicated that the mechanical properties of the sand-LDPE composite brick with 50 % plastic was higher than the other mass ratios of plastic. The compression strength of 50% sand-LDPE brick was increased by 34.2 % (1.2N/mm^2) as compared to minimum requirement of standard *cement brick, and has density of 1.12 g/cm^3 which confirm with* desirable limit of a hollow cement brick*, and also water absorption is decreased as percent of the LDPE content increases compared to conventional cement brick. Therefore, the paper was concluded that the manufactured 50% and 55% by mass plastic composite brick is applicable in civil engineering applications as alternative building material for construction of* partitions, fence, panel walks, parapet, and balcony railings *and, as a result large mass percent of waste plastic is removed from environment with manufacturing of 50% to 55% sand-LDPE composite brick.*

Keywords: *Molding machine, Building material, SPC brick, plastic waste, LDPE*

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 Introduction

Worldwide, waste management is still a challenge brought about by urbanization, population increase, and industrial growth. The conventional methods of disposing of solid wastes are landfill, burning and recycling. However, landfill spaces are reducing, burning process emits hazardous gases, and recycling seem to be expensive and laborious [1].The current sustainable approaches for waste management are reducing, reuse and recycle However; it does not address properly the abandoned waste which pollutes the environment.

Figure 1.1: Image of waste plastic taken from ASTU waste disposal area

Plastic Industry trade Association (SPI) classifies plastic as follow [2]:

1. Polyethylene Terephthalate (PET),
2. High-Density Polyethylene (HDPE),
3. Polyvinyl Chloride (PVC),
4. Low-Density Polyethylene (LDPE),
5. Polypropylene (PP)
6. Polystyrene (PS), and
7. Others (like polyester, polyamides, and polycarbonate).

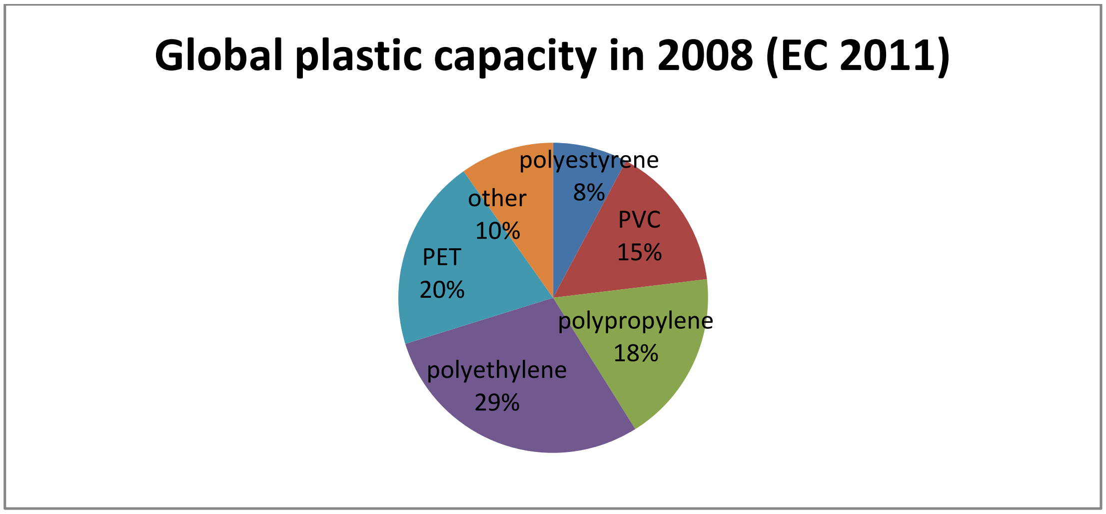


Figure 1.2: Global plastic capacity in 2008 [4]

Sectors that use plastic are packaging, automotive, agriculture, furniture, sport, electrical and electronics, health and safety, building and construction, and consumer and household appliances [3,4]. Increase in plastic products has resulted in an increase in plastic waste, which is a challenge to waste management authorities. Plastic waste recycling benefits the society, economy and environment [5]. However, there is highlights the demerit of plastic waste as being non-biodegradable, cause a health risk, and difficult to reuse or recycle in practice.

Due to urbanization and modernity, civil engineering structures like roads, railways, dams, retaining walls and buildings are on demand. The demand for good quality construction material and other alternative building materials is high. In Ethiopia, adequate shelter is a main problem in most part of the country. And, soil is widely used in the traditional construction of mud house. Unfortunately, the traditional building techniques which are practiced in most part of Ethiopia for mud house construction have serious defects and consumes natural resource such as woods, which accelerates deforestation. In some places natural construction materials are depleted and importing it from long distances is costly and time-consuming. And also conventional cement construction materials are so expensive for low income people. Therefore, economic and environmental challenges have stimulated researchers to study on waste plastic composite as alternative building materials.

1.2 Research Questions

This research prepares and study the mechanical behavior of sand reinforced with LDPE plastic waste. Research questions related to the study included but not limited to the following:

1. Does sand- LDPE plastic waste composite can use as alternative construction material?
2. What percentage of LDPE plastic waste (by weight of sand) is optimum to prepare the proposed alternative building material?
3. How is sand- LDPE plastic waste composite prepared?
4. What laboratory experiments are required/carried out on sand- LDPE plastic waste composite?
5. What are the applications of sand-LDPE plastic wastes composite in construction field?

1.3 Research Objectives

The main objective of the research was to prepare and study the mechanical performance of sand-LDPE plastic waste composite brick as alternative building material. However, the following are the specific objectives formulated with the goal of achieving the main objective:

- To design and manufacture manually operated compression molding machine
- To produce sand - LDPE plastic composite brick with different concentration of sand and LDPE
- To test the compressive strength, density and water absorption of SPC brick.
- To obtain the best possible mixture that enhances good mechanical property of SPC

1.4 Statement of the problem

Currently the amount of garbage or waste is increasing day after day as the world's population increases. If we see closely, most of the wastes are from the things that we used daily such as plastic and paper. Due to the increasing number of mankind in the world, more products have to be manufactured to supply the needs of every human being. These cause municipal wastes such as plastic carrier bags, plastic advertising logos, cleared pack in bags and a variety of other forms of plastic waste to increase fast. Due to these deterioration of natural beauty of an environment, death of domestic and wild animals, Blockage of sewerage systems which in turn, creates foul smells and favorable habitats for mosquitoes and other vectors that could spread a large number of diseases will occurs. Therefore, to reduce plastic bags disposing in to land fill and in order to protect environmental pollution, there is a need of methods and technology that economically processing waste plastic into useful product. Realizing this, study of sand-LDPE waste plastic composite as an alternative Building material for waste plastic pollution control is introduced in this thesis as a way to curb the problems that arise.

Furthermore, hundred years ago, there were a lot of forests, which were our main material resources for building constructions [6]. However, nowadays, our forests are almost gone, and woods for constructions are rare. This is because of rapidly increasing population and their construction material demand. Currently, the majority of developing countries are faced with a problem of providing adequate construction material for housing. In the last few decades, shelter conditions have been worsening: resources have remained scarce, housing demand has risen and the urgency to provide immediate practical solutions has become more sensitive. Adequate shelter is one of the most important basic human needs. [7]. In Ethiopia, adequate shelter is a main problem in most part of the country. And, soil is widely used in the traditional construction of mud houses called "Chika bet''. Unfortunately, the traditional building techniques which are practiced in most part of Ethiopia for mud house construction have serious defects. The main defects are: walls can easily be eroded by rain and suffer from extended shrinkage cracks, the construction consumes natural resource such as woods, its external and internal appearance is not much attractive, the house suffer from health related problems, and the mud walls require a regular repairs (wastage of material and energy regularly). And also conventional cement construction materials are so expensive for low income people.

Figure: 1.3 Traditional houses building in Ethiopia [6]

Additionally, the traditional building requires a lot of woods for the construction of walls and fence. However, this accelerates deforestation. A long time back in history, some parts of Northern Ethiopia, which are today suffering from conditions caused by land degradation, were covered with forests. In present day Ethiopia, however, forests are being destroyed at a shocking rate and the area covered by forests at present is only 2.4 % compared to the estimated 40 % initial coverage [8]. The primary causes of forest destruction are increasing of the demand for construction material. Reducing and monitoring deforestation is a vital issue at this time. There are different methods which are appropriate and reliable for monitoring deforestation. One of these methods is minimizing consumption of materials that have direct contact with forests or using alternative building materials. In order to tackle the problem, sand-LDPE composite brick was developed in this thesis as alternative building material. So, the other aim of this thesis is to replacing wooden mud wall houses and fence by sand-LDPE composite brick, which would help to restore the ecological balance and to build a house wall and fence with good quality and with fair price. Sand-LDPE composite brick technology is not commonly practices in Ethiopia. So, this opens ways for small-scale entrepreneurs.

1.5 Significance of the Thesis

Findings of the research study have extended literature and data regarding reinforcing sand with LDPE plastic waste. Furthermore, reduce the challenges faced by waste management and alternative building material.

The significances of the project are as follows:

- Reduce environmental pollution and health problem caused by plastic waste
- Reduce the solid waste management (SWM) cost
- Help to manufacture SPC brick from sand and locally available waste plastic bag
- Provide alternative building material for construction
- Present an effective low cost compression molding machine which can also capable of manufacturing other type of brick such as soil, WPC and compressed mud block.
- Helps small scale microenterprises and individuals to start their own business through use of the machine and manufacturing of SPC.
- Contribute to literature gaps by efforts made in the areas of study and analysis of the impact of parameters (plastic waste and sand) on properties of the SPC compressive strength, density and water absorption.

1.6 Beneficiaries:

The sectors to benefit from this research include but are not limited to:

i. Waste management field will benefit by the reduction of LDPE plastic waste which is normally taken to landfills if not recycled and hinders the proper flow of water which leads to poor drainage.
ii. Civil engineering field will benefit by development of the alternative building material which can be used in the construction of civil engineering structures.

1.7 Research Scope

This research considered preparation and study of the mechanical behavior of sand- LDPE plastic waste composite brick. The research scope included the following:

i. Local fine sand obtained from brick manufacturing micro enterprise in Bishoftu town was used as a representative of river sand.
ii. LDPE plastic waste from garbage waste was used in varying proportions.
iii. Laboratory experiments on the sand- LDPE plastic waste composite specimens have been carried out to determine its engineering mechanical and physical properties. These tests include compression strength test, density and water absorption tests.
iv. Design of compression molding machine is based on existing manual brick molding machine with modification of internal molding chamber.
v. Manufacturing of compression molding machine is carried out at Tsedeke, Wendmu and his family metal work micro enterprise,

1.8 Research Limitations

Some of the experiments on LDPE (like tensile strength at break and melting point) were not conducted. Therefore, data regarding properties of LDPE is taken from available published data. Furthermore, some experimental data used for comparative purpose on conventional concrete brick (like compressive strength and water absorption) were collected from conducted experiment and from available published standard data. During laboratory experimenting, specimens of sand-LDPE plastic waste composite were prepared with 50%, 55% and 60% by mass of plastic content as compared to sand content and cement brick of 1:11 ratio of cement to aggregate by weight was prepared with accordance to mix specification of Standards [9] and test for comparative purpose with sand-LDPE plastic waste composite brick.

1.9 Layout of the Thesis

Chapter 1: Research Introduction and Background

The first chapter outlines the research background, problem statement, research questions, and research objectives, significance of the research, research scope, and limitations among others.

Chapter 2: Literature Review

The second chapter presents previous publications of different researchers on the area under discussion.

Chapter 3: Materials and methodology

This chapter is discussed under four broad sub topics as following:-

3.1: Design and material selection for compression molding machine

This sub topic introduces the design analysis and material selection of critical components for manual operated compression molding machine.

3.2: Manufacturing process, assembly and maintenance

This sub topic addressed the process and Operation sheet for critical components and Procedures of assembling components of the project.

3.3: Cost analysis for compression molding machine

This sub topic computes the total cost by adding costs of raw materials and standard items, labor cost for manufacturing and assembling components , and Machine Depreciation Cost to manufacture parts required for compression molding Machine

3.4: Preparation and testing of sand –LDPE plastic composite brick

The adopted research methods and the laboratory investigation are outlined in this sub topic. Moreover, different procedures followed while conducting this research are presented.

Chapter 4: Results and Discussions

The test results and discussion of research findings are presented in this chapter.

Chapter 5: Conclusions and Recommendations

This chapter brings out the general conclusions of the study and provides recommendations

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter looks at previous publications of different researchers on the area under discussion. More, this chapter presents an overview of plastics, LDPE, Impacts of plastic wastes and studies on Converting waste plastic in to useful product. Furthermore, the chapter highlights the performance of plastic composite and Lastly, a summary and conclusions discussed in this chapter are listed.

2.2 River sand

River Sand is a naturally occurring granular material composed of rock and mineral particles. The composition of sand is highly variable, but the most common constituent of sand is silica (silicon dioxide, or SiO_2). In terms of particle size as used by geologists, sand particles range in diameter from 0.0625 mm (or 1⁄16 mm) to 2 mm. An individual particle in this range size is termed a sand grain. There are many types of sand in the world, natural sand is choosing for this research. Natural sand is the sand that is commonly used for construction. It has high melting temperature and high hardness. Besides, it is very easy to get around river side.

Figure 2.1: River sand

The particles which make up sand are different for each type of sand and they depend on where and how the sand was formed. Some of the most common minerals are listed below.

1. Quartz (silica): This is the main component of most sand. The grains are hard and glassy and vary in color from white to clear to rusty-red. (Figure 2.1)
2. Mica: This is a shiny mineral which may be black or white. It breaks easily and forms very small particles in most sand deposits and it is a flat.
3. Feldspar: This is a milky white to pink mineral. It is not as hard as quartz, so will form smaller grains or be worn away more quickly.
4. Dark black and green minerals: Many of the minerals on the earth's crust are dark in color. The harder ones will remain as grains in sand, softer ones will be more worn down.
5. Calcite: Calcium carbonate is most commonly found in bones and shells of living organisms. When these are broken down they may form small fragments which can be part of the sand. Calcium carbonate can be dissolved in rain water which contains carbonic acid and can also form clear or milky white crystals. It is soft and easily worn away.

Table 2.1: Property of silica sand [11]

Sr. No	Characteristics silica sand	value
1	Grain shape	Round
2	Specific gravity	2.65
3	Bulk density(kg/m^3)	1490
4	Thermal expansion (20-1200C^0)	1.9%
5	Water absorption	4%
6	Application	General

2.3 Plastics

2.3.1 Introduction to plastics

Plastics are polymers that have been synthesized from petroleum or natural gas derivatives [12]. The term plastics encompasses a wide variety of resins each offering unique properties and functions. In addition, the properties of each resin can be modified by additives. Different combinations of resins and additives have allowed the creation of a wide range of products meeting a wide variety of specifications[13]. Polymers are chemically inert large molecules made up of repeating chemical units (monomers) that bind together to form long chains or polymers [14]. Polymers are pure materials formed by the process of polymerization; additives are added to form plastics. These additives include: antistatic agents, coupling agents, fillers, flame retardants, lubricants, pigments, plasticizers, reinforcements, and stabilizers [15]. Pure polymer may include silk, bitumen, wool, leather, rubber, wood, cotton and cellulose. Plastic production and use has grown because of many advantages plastics offer over other more traditional materials. A few of the attractive basic properties of plastics include [12]:

i. Design flexibility – plastics can be modified for a wide variety of end use,
ii. High resistance to corrosion,
iii. Low weight, and
iv. Break resistance.

2.3.2 Categories of plastic

The Plastic Industry Trade Association (SPI), identifies plastic into seven (11) broad categories. Table 2.2 summarizes their detailed identification and respective applications

Table 2.2: Plastic identification and applications [2]

Plastic ID#	Plastic ID code	Plastic	Application
1	1 PET	Polyethylene Terephthalate	• Make bottles for water, beverage, oil, medicine products, peanut butter, cleaning products, and lubricants. • PET plastic waste can be recycled into tote bags, carpets, fleece jackets, luggage, clothing, erosion blankets
2	2 HDPE	High Density Polyethylene	• Make bottles for dairy products, juice, lubricants, detergents, bleaches, shampoos, and conditioners. • Make caps and closures of bottles, jars, pots, and cartons • HDPE plastic waste can be recycled into plastic buckets, recycling containers and flower pots

3	3 PVC	Polyvinyl Chloride	• Make trays for salads, desserts and meat • PVC plastic waste can be recycled into mobile homes, cassette trays and traffic cones.
4	4 LDPE	Low Density Polyethylene	• Make caps and closures of bottles, jars and pots • Make squeezable bottles • Make carrier bags, garbage bags, and sandwich bags • LDPE plastic waste can be recycled into garbage cans, floor tiles landscape board
5	5 PP	Polypropylene	• Make trays for vegetables, dairy products, and soups • PP plastic waste can be recycled into brooms, brushes, trays, and automobile battery cases
6	6 PS	Polystyrene	• Make disposable coffee cups, plastic food boxes, pots and tubs • PS plastic waste can be recycled into thermal insulation, light switch plates
7	7 O	Others like: Polyester, Polyamides, Polycarbonate,	• Polycarbonate plastic is used to make baby bottles, water tanks, compact discs and medical storage containers • Polycarbonate plastic waste can be recycled into plastic lumber.

2.3.3 Applications of plastic in construction

Plastic has numerous applications in the different sectors like: construction, automotive, furniture, sports, electrical and electronics, health and safety, consumer and household appliances. In the construction engineering field, plastic is used as components in the construction of bridges, buildings, roads and highway, railroads, landscaping, landfills, water retaining structures [16]. The plastic components that are used in the construction industry include: sound barriers, guide rails/guard rails, railroad ties, pallets, curbs/wheel stops, docks, board walks and walkways, bicycle racks, erosion control, and construction materials separations. In construction engineering for a material to qualify as a good construction material it should be durable, strong, ductile, easy to install, fire resistant, and inexpensive. However, Table 2.3 shows the characteristics of plastic compared with other construction materials, and since this research focused on reinforced LDPE plastic waste with sand, its properties are outlined in Table 2.4.Furthermore, the following are the qualities of construction plastics [17].

- Plastics are strong, and can resist knocking and scratching.
- Plastics are durable, making them withstand harsh weather.
- Plastics are easy to install and move around.
- Plastics offer design freedom in that it can be turned into any shape, and plastic products can be colored, opaque, or transparent, rigid or flexible.
- Plastics promote energy efficiency in buildings since they are low conductors of heat, and can achieve a tight seal.
- Plastic products have low maintenance cost and do not need painting.
- Plastic building products can be recycled with low energy input.
- Constructing using plastic products is cost effective since plastic is durable, of good quality, have low maintenance cost and saves labor.

Table 2.3: Characteristics of plastic with other construction materials [16]

	Plastic	Steel	Concrete	Wood
Ultraviolet resistance	Excellent (with stabilizers)	Excellent	Excellent	Excellent
Abrasion resistance	Excellent	Excellent	Good	Poor
Chemical resistance	Excellent	Fair	Good	Good
Fabrication	woodworking tools	Specialized Equipment	Formwork	Hand tools
Ozone resistance	Excellent	Excellent	Excellent	Excellent
Fire resistance	Requires frame source	Noncombustible	Noncombustible	Combustible
Stress crack performance	Excellent	Excellent	Poor	Poor
Decay potential	Non-Biodegradable	Will corrode	Degrades	Biodegradab le
Resistance to marine borers	Excellent	Excellent	Excellent	Poor
Fastening materials	Metal fasteners	Bolts/welds	Casting/inserts	Metal Fasteners

2.3.4 Impacts of LDPE plastic wastes

Accumulation of plastic bag wastes causes environmental pollution that can be manifested in number of ways. One of the problems is deterioration of natural beauty of an environment [12].

Figure 2.2: Deterioration of natural beauty of environment

Another common problem associated with these wastes is death of domestic and wild animals. This necessitates for proactive measures in order to safeguard animal species against extinction. Blockage of sewerage systems is also becoming a common problem in cities. Different report showed that plastic bags are still causing severe environmental pollutions and also human and animal health damages in urban and rural areas of the country.

Figure 2.3: Death of domestic and wild animals by ingesting plastic waste

Figure 2.4: Blockage of sewerage systems (photo taken from Adama city around bus station)

2.3.5 Management of plastic wastes

Solid waste management refers to all activities concern to the control of generation, storage, collection, transfer and transport, treatment and processing, and disposal of solid wastes in accordance with the best principles of public health, economics, engineering, and other environmental considerations [18]. Waste is an item (plastic, food, paper, and etc) rejected for being of no use or value to the owner after its intended application. All wastes excluding liquid and gases are termed as solid waste. Commercial solid wastes and household solid wastes together form the municipal solid waste (MSW). The MSW include plastics, organic, metals, papers, glass. MSW are usually mixed together, hence it is laborious to manage while disposing. Solid waste management is the process of safely disposing of MSW through recycling, burning, and landfill to turn away polluting humans and environment.

Most of the post-consumer plastic waste is land filled along with municipal solid waste [12]. Plastic waste account for a large and growing portion of the municipal solid waste stream. LDPE Plastics are about 7 percent of municipal solid waste and a large percentage plastic waste by volume estimated to be in the range of 14 to 21 percent of the waste stream [12]. Considering the trend, the amount of plastic waste is predicted to increase.

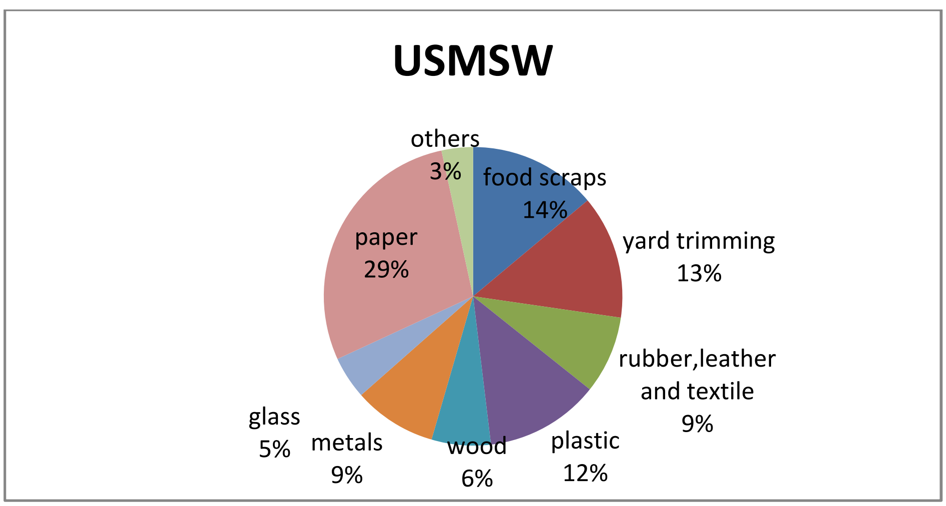


Figure 2.5: The composition of the USMSW stream

Out of 250 million tons generated in the year 2010 source [19]

Management of plastics in a landfill

Plastics are non-degradable and do not affect the structural integrity of a landfill. However, plastic wastes do affect the landfill capacity due to their large numbers and continued plastics production.

Management of plastics in burn up

Plastics contribute significantly to the heating value of municipal solid waste, with a heating value of three times that of typical municipal waste [13]. Burning alternatives were rejected by several countries due to their potential danger to the environment either by polluting air or land [20].

Methods for reducing impacts of plastic wastes

Source Reduction

Source reduction aims at reducing generated plastic waste amount or toxicity [12]. Source reduction processes are as follows:

i. Modifying design of product or package to decrease the amount of material used,
ii. Making materials more durable so that it may be reused, and
iii. Substitute away for toxic constituents in products and packaging.

Recycling

Recycling is the process of converting waste materials into reusable products, and it is important to say that plastic recycling is in its immaturity stage. Despite the seven (7) SPI plastic identifications (Table 2.2), most of the recycling companies concentrate on PET and HDPE plastic waste [26]. These plastic wastes makes only 5% of the postconsumer plastic waste stream and the rest is either burn up or put in landfill or dumped in open space [12,19]. There are two type of recycling technology, single homogeneous resins and a mixture of plastic resins recycling technologies.

1) Recycling PET and HDPE plastic waste is an example of homogenous resin, which yields to products similar in quality to those of virgin resins. PET and HDPE plastic waste can be recycled over and over again, hence reducing the need for PET and HDPE disposal [12].
2) Considering plastic identification according to SPI as seen in Table 2.2, in this case plastic wastes can be mixed and recycled into new low cost construction building materials which can compete with wood and concrete [12]. In this case, the recycling process becomes simple as sorting of different types of plastic waste is eliminated.

2.4 Low Density Polyethylene (LDPE)

2.4.1 Manufacture of LDPE

There are three main polymerization reactions used to make the different types of polyethylene. The first is a free radical polymerization; this type of polymerization is used to make the highly branched LDPE. The manufacture of LDPE using this method is done when ethylene is heated at high pressures (up to 3,000 bar) and temperatures of 100 to 300 C in the presence of a free essential initiator, the polymer known as low density polyethylene (LDPE) is produced.

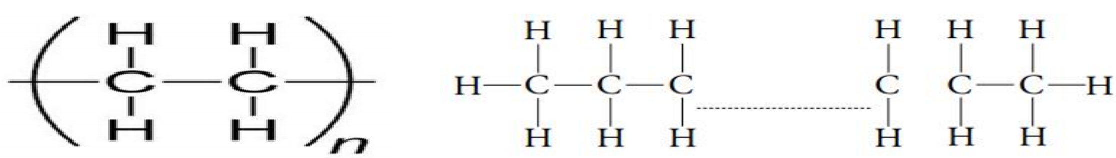


Figure 2.6: Structure and Molecular Chain of Polyethylene [2]

This is a semi-crystalline thermoplastic material which is transparent only in thin section can be cooled quickly. Otherwise its natural color is an opaque, milky white. It is flexible and has a soft, wax-like feel. The polymers have densities from 0.915 - 0.940 g/cm3 depending on the extent of branching which in turn depends on the polymerization conditions. This material is tough but only has moderate tensile strength and suffers from creep. On the other hand the impact resistance, chemical resistance and electrical insulation properties are excellent. LDPE is more permeable to gases and vapors than HDPE.

2.4.2 General uses and properties of LDPE

LDPE is soft and is waxy, smooth to touch, and has a shinny appearance. It is normally used in garbage bags, cling wrap, sandwich bags, and squeezable bottles. LDPE has very low water absorption. Even after one year at 20 C the increase in weight is less than 0.2%. When this material (LDPE) is heated in a flame then it ignites easily and burns with a yellow tipped flame giving off only a little smoke. It forms burning drops and when the flame is extinguished gives off a smell like candle grease. LDPE has a melting point of 110 - 125 C. When heated in the absence of a flame the material will soften and melt to give a clear liquid.

Table 2.4: Typical LDPE property [21]

Property	Test Method	Unit	LDPE
Physical			
Density	ASTM D-792	g/cm^3	0.9
Water Absorption	ASTM D-570	%	Slight
Mechanical			
Yield point	ASTM D-638	Psi	1,363
Tensile Break	ASTM D-638	Psi	1,943
Elongation at Break	ASTM D-638	%	515
Tensile modulus	ASTM D-638	Psi	41,615
Flexural modulus	ASTM D-790	Psi	28,565
Flexural strength	ASTM D-790	Psi	1,175
Hardness	ASTM D-2240	Shore D	55
Thermal			
Melt point	ASTM D-3417	^0F	230
Heat deflection	ASTM D-668	^0F	98-110

2.5 Composites

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials.

Typical engineered composite materials include:

1. Composite building materials such as cements, concrete
2. Reinforced plastics such as fiber-reinforced polymer
3. Metal Composites
4. Ceramic Composites (composite ceramic and metal matrices) [22]

Composite fabrication usually involves wetting, mixing or saturating the reinforcement with the matrix, and then causing the matrix to bind together (with heat or a chemical reaction) into a rigid structure. The operation is usually done in an open or closed forming mold, but the order and ways of introducing the ingredients varies considerably [22]. Within a mold, the reinforcing and matrix materials are combined, compacted, and cured (processed) to undergo a melding or blending event. For a thermosetting polymeric matrix material, the melding event is a curing reaction that is initiated by the application of additional heat or chemical reactivity such as organic peroxide. For a thermoplastic polymeric matrix material, the melding event is solidification from the melted state [22].

2.5.1 Advantages of Composites

In today's world, there are three main reasons for using composites. One is financial, translating ultimately to profit. This may come through a performance improvement which makes a product more attractive or economic to own, or when a service becomes cheaper to deliver (or more profitable). The second is legislative, driven by environmental protection factors. The third reason is, simply, because there is no alternative . All the technological advantages fall under one of these three categories - economic, legal or 'no alternative'. Again, the advantages of using composite materials are the following:

[1] The fatigue strength of composite materials is also very high

[2] Composite materials also offer high corrosion resistance.

[3] Composite materials offer increased amounts of design flexibility

[4] Complex parts and special contours which are sometimes not possible with metals can be fabricated using composite materials.

[5] Composite materials offer greater feasibility for employing design for manufacturing (DFM) and design for assembly (DFA) techniques. These techniques help minimize the number of parts in a product and thus reduce the assembly and joining time.

[6] Composites offer good impact properties.

[7] The cost of tooling required for composites processing is much lower than that for metals processing because of lower pressure and temperature requirements.

2.5.2 Previous studies related to using recycled plastic as building materials

The earliest example of composite is the bricks made from clay reinforced with straw by the Egyptians in the third millennium BC [23]. Recently composite materials have been of interest because of their wide applications in many fields such as civil, industrial, military, space craft, automobiles, packaging and biomedical applications mainly because of their excellent thermo mechanical properties [24]. By variation and combination of various fibers and polymers, a wide range of composite, having unique properties for versatile applications as alternative to conventional materials like metals, wood etc. have been prepared [1]. Composites are materials that comprise strong load carrying material known as reinforcement imbedded in weaker material known as matrix [25]. Reinforcement provides strength and rigidity, helping to support structural load. The matrix o r binder maintains the position and orientation of the reinforcement. The reinforcement may be particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material. Polyester matrices have been in use for the longest period in the widest range of structures because of easy handling, balanced mechanical and chemical characteristics and a cheap price.

Ohemeng studied the feasibility of using low linear density polyethylene as partial replacement for sand in the production of concrete pavement blocks. The plastic material was ground and used together with cement, sand and coarse aggregate in a mix ratio of 1:1.5:3 (cement, sand, coarse aggregate). It was observed that as the plastic content increased, the density, compressive strength, flexural strength and splitting tensile strength decreased [26].

Denish.S and Kirubakaran investigated utilization of waste plastic in manufacturing of bricks and paver blocks. They investigated utilization of HDPE and PET in brick and paver block production. The mix proportion were in the ratio of (1:2, 1:3, 1:4, 1:5, 1:6 by weight) plastic to river sand respectively. The authors found increase in compressive strength when the sand content increases. The compressive strength increase from 4.65N/mm^2 to 5.12N/mm^2 for mix ratio of plastic to sand 1:2 to 1:4 and compressive strength decrease from 5.12N/mm^2 to 3.17N/mm^2 for mix ratio of 1:4 to 1:6 plastic to sand, and also from water absorption test average water absorption of plastic composite brick is observed that 1.10 %. The researchers concluded that the Plastic sand bricks possess more advantages which include Cost efficiency , removal of waste products thus abolished the land requirement problem for dumping plastic. The natural resources consumed for the manufacturing of Plastic sand bricks and Paver blocks are very much less when compared to its counterpart [27].

Kalu worked on finding an alternate source of building materials by using laterite (red hard sand). In their work, laterite was reinforced with plastic particulates obtained from plastic wastes, and rubber to improve flexural and compressive strength respectively. He found out that 20% volume fraction of fine grain plastic particulates mixed with matrix (60% laterite + 20% cement) had a better flexural and compressive strength respectively and such could be used as an alternate source of building material in rural areas. By this a very good use is found for plastic waste [28].

Raji and Oluokum partially replaced cement with polyethylene water sachet. They found out that as the percentage of polyethylene water sachet was being increased, the weight of the molded cubes as well as the compressive strength of the molded cube decreased. In effect, the greater the percentage of the polyethylene water sachet used, the lower the weight of the block and the lower the compressive strength [29].

Ismail and Al-Hashmi presented the possibility of using various plastic wastes, containing approximately 80% polyethylene and 20% polystyrene, as fine aggregates, up to 4.75 mm in concrete. By increasing the plastic waste content, the compressive tests showed the tendency for compressive strength values of plastic waste concrete to decrease below the reference concrete at each curing age. The concrete with 10% of plastic waste displayed the lowest compressive strength at 28 days curing age, about 30%lower than that of the reference concrete mixture. Also the study found 5%, 7%, and 8.7% lower densities of concrete mix containing 10%, 15%, and 20% plastic aggregates respectively [30].

Al-Manaseer and Dalal, investigated the effect of plastic aggregates on the bulk density of concrete. For this purpose, they made 12 concrete mixes with different w/c percentages varying (0%, 10%, 30%, and 50%) of plastic aggregates. Angular post-consumer plastic aggregates having a maximum size of 13 mm were used. They concluded that: (i) bulk density of concrete decreased with the increase in plastic aggregates content; (ii) reduction in bulk density was directly proportional to the plastic aggregates content; and (iii) density of concrete was reduced by 2.5%, 6%, and 13% for concrete containing 10%, 30%, and 50% plastic aggregates, respectively. Reduction in density was attributed to the lower unit weight of the plastics [31].

Marzouk reported the bulk density of cement mortar mixes prepared by replacing 0–100% in volume of sand by two different sizes of PET aggregates. Their results showed that the reduction of bulk density remained small when the volume occupied by aggregates varies between 0% and 30%, regardless of their size. However, when this volume exceeded 50%, the composite bulk densities started to decrease until reaching a value 1000 kg/m^3. They also found that for the same volumetric percentage of substitution the bulk density decreased with decreasing particle size [32].

Akinpelu and Bamidel investigated the effects of polyethylene modified bitumen on the properties of hot mix asphalt. The polyethylene was added in a grinded state as a binder modifier. The polyethylene was introduced to the mixture by melting it in bitumen used in preparing asphalt concrete mix. They found out that the modifier increases the stability, reduces the density and slightly reduces the flow of the asphalt concrete. Again, the polyethylene modifiers offers better engineering properties and its usage as a bitumen modifier could serve as a means of managing the waste menace [33].

Consoli studied the engineering behavior of sand reinforced with plastic waste. The materials used in the study included uniform fine sand; Polyethylene Terephthalate (PET) fiber of length up to 36mm and content up to 0.9% by weight of sand; and rapid hardening Portland cement with content ranging from 0% to 7% by weight of sand. Unconfined compression tests, splitting tensile tests, saturated drained tri-axial compression tests with local strain measurement were carried to evaluate the benefit of utilizing randomly distributed PET fibers alone or combined with rapid hardening Portland cement to improve the engineering behavior of a uniform sand. Test results showed that PET fiber reinforcement improved the peak and ultimate strength of both cemented and un cemented soil, and reduced the brittleness of the cemented sand [34].

Hannawi and Bermand investigated the effect of using Non-biodegradable plastic aggregates made of polycarbonate (PC) and polyethylene terephthalate (PET) waste as partial replacement of natural aggregates in mortar. Various volume fractions of sand 3%, 10%, 20% and 50% are replaced by the same volume of plastic. The authors found a decrease in compressive strength when the plastic aggregates content increases. The drop in compressive strength seems to be not proportional to the volume fraction of sand replaced by plastic aggregates. a decrease of 9.8%, 30.5%, 47.1% and 69% for mixtures with, respectively, 3%, 10%, 20% and 50% of PET-aggregates, and of 6.8%, 27.2%, 46.1% and 63.9% for mixtures containing, respectively,3%, 10%, 20% and 50% of PC aggregates is observed. According to authors the drop in compressive strengths due to the addition of plastic aggregates can be attributed mainly to the poor bond between the matrix and plastic aggregates. The study presented the variations in the flexural strength of different mixtures as a function of the percentage of sand (in volume) replaced by the same volume of plastic aggregate. By comparing to control mixture, no significant changes are observed for mixtures containing up to 10% of PET-aggregates and up to 20% of polycarbonate (PC) aggregates. According to the authors, a decrease of 9.5% and 17.9% for mixtures with, respectively, 20% and 50% of PET-aggregates is observed. For mixtures with 50% of PC aggregates, a decrease of 32.8% is measured. The authors found that the calculated flexural toughness factors increase significantly with increasing volume fraction of PET and PC aggregates. Thus, addition of PC and PET plastic aggregates in cementations materials can give a good energy absorbing material which is very interesting for several civil engineering applications like structures subjected to dynamic or impact [35].

The previous studies showed that lot of efforts done for investigating the effect of using waste plastic materials as a component in the concrete mix, but all of them are trying to use waste plastics such as HDPE, PET and low linear density polyethylene in concrete mix in different mix ratio by volume and mass . This research aims to implement a similar task but with applying the available locally used materials specially using melted LDPE plastic bag as matrix material in higher percentage and river sand as reinforcing material for production of sand-LDPE composite interlocking brick for alternative building material. From the literature review, percentage of polymer used in manufacturing composite in small percentage by weight percent of the sand or other aggregate (0% to 7%) and 30% to 50% by volume. But, manufacturing of composite with higher percentages of LDPE plastic waste ranging above 50% by mass of fine aggregate is not considered by the literature. Therefore this thesis consider manufacturing of composite with higher percentages of LDPE plastic waste ranging above 50% by mass content for alternative non load bearing building material and which can remove plastic waste channeled into the landfills in higher percentages. Therefore, use of higher percentage of LDPE plastic waste to manufacture composite is seen as advance measure to solve the challenges facing the alternative building material and waste management fields.

Furthermore, the published literature did not deal with equipment and machineries used for manufacturing the composite. The manufacturing process and machines used for manufacturing composites is core in the sustainability of LDPE plastic waste management. Due to this gap in the published literature, this research discussed the design and manufacturing of compression molding machine which produce interlocking brick in Chapter three.

2.6 Compression molding machine

Plastic is one of the daily increasing useful as well as a hazardous material. At the time of need plastic is found to be very useful, but after its use, it is simply thrown away, creating all kinds of hazards. Plastic is not bio degradable, so it will continue to be hazardous for more than centuries. In addition to manufacturing sand-LDPE plastic composite brick the idea of this paper is to design and manufacture manual inter locking brick manufacturing machine. Since, there is literature gap regarding design and manufacturing of machine which produce a brick from sand and waste plastic this paper will fill the gap and will sustain waste plastic management. The machine parts is made of mild steel, because of its availability and versatile machine ability. The machine is capable of producing one inter locking brick at a time using the specifically designed mold. The economic realities in many developing countries like ours call for development of least-cost brick making techniques, which will be readily available for both in rural and urban areas. In addition, the shortage in power supply in most of these countries makes the manual machine more appropriate. The detail design and manufacturing of the compression molding machine is given chapter three.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Design and material selection

3.1.1 Introduction

No construction is possible without bricks. Since many centuries brick making has been practiced by human beings. Presently, bricks are easily made by using machines using new technologies. Generally two types of bricks are manufactured by using machines that are concrete block machines and clay brick machines. Different types of automatic machines use different techniques to make bricks. The raw materials used by the machines for making interlocking bricks are fly ash and sand lime but, in this thesis sand-LDPE plastic waste inter-locking brick is manufactured.

The focus of this thesis is on the production of sand-LDPE plastic waste inter-locking brick, specifically interlocking bricks which offer cost effective, environmentally sound alternative to conventional walling materials. It is an effective means of utilizing waste plastic generated by house hold, company and agricultural wastes. The new technique in producing this sand-LDPE plastic waste inter-locking brick can generate a highly profitable business for micro and small scale building material producers . The market for this type of brick is not yet growing, even though there are demands for alternative building material. This is due to absence of cost effective interlocking brick manufacturing machine.

- **Interlocking Brick Specification**

The interlocking bricks are different from other normal bricks as it requires no mortar or cement for brickwork. This bricks interlocked with each other by means of positives and negative frogs on the top and bottom of the bricks which disallow the horizontal movement of bricks. There are various applications of this bricks namely; internal partition wall, paving, decking, fencing and other small load applications. The specifications and the characteristics of this brick depend on the machine used to manufacture it.

The size of brick is 300 x 150 x 100 (+20) mm (+20mm is flexibility of height change during compression molding of brick).The basic raw material is LDPE plastic waste and sand. Weight of bricks manufactured is based on percentage of plastic used to manufacture the brick.

L=300mm=30cm

W=150mm=15cm

H=100mm=10(+2) cm

Where: - L is length of brick H = height of brick

W = width of brick

Volume of brick (V_b) = $L \times W \times H + 2(l_1 \times w_1 \times h_1) - (l_2 \times w_2 \times h_2)$

$= 30 \times 15 \times 10\,(+2) + 2(7 \times 7 \times 7) - 2\,(8 \times 8 \times 8)$

$= \underline{\underline{5062cm^3}}$

Where: - L= 30, W=15, H=10 (+2)

l_1=7, w_1=7, h_1= 7

l_2=8, w_2=8, h_2=8,

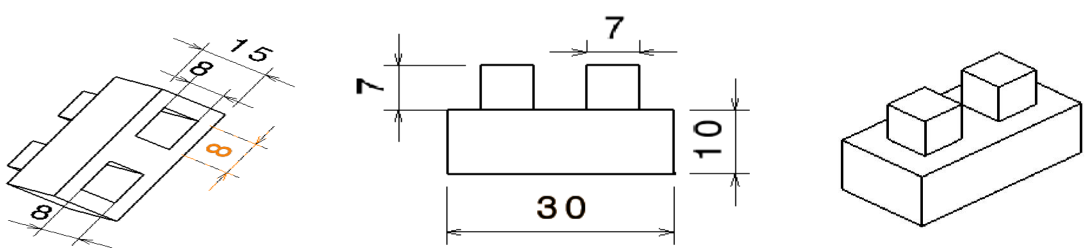


Figure 3.1: Sand-LDPE plastic composite interlocking Brick dimension

❖ Production of Interlocking Brick Process

Current process of producing the interlocking brick is produced using a semi mechanized stationary type machine. The other production systems are manual moulds that require hand tamping, a mobile semi-mechanized egg-laying machine and fully mechanized system that combines compression and manual concrete filling in mould.

The designed machine compact the sand and molten waste plastic mix manually at designed force to required shape so that the bricks are uniform in size and attain desired physical properties. The bricks are not required long curing period, they are ready to use after three hour.

❖ Types of Interlocking Bricks

There are various types of interlocking bricks [36]. The most commonly used cement interlocking bricks are;

i. Regular Shaped Brick
ii. Half Size Brick
iii. U-Shaped Brick

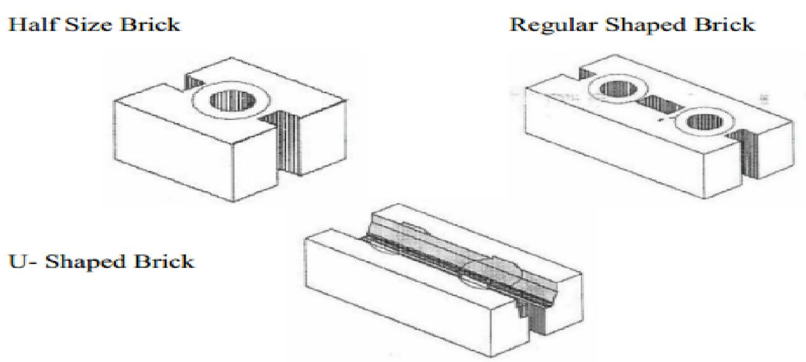


Figure 3.2: Type of Interlocking Brick [36]

In these thesis a new interlocking brick shape is manufactured based on the ease of inter locking and edge alignment of sand-LDPE plastic waste composite brick in different direction

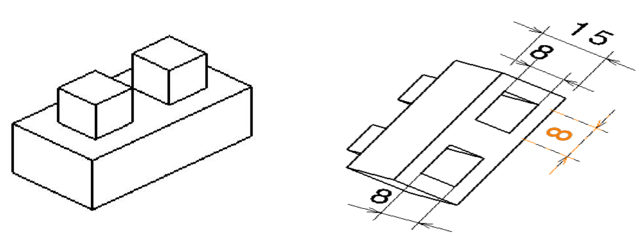


Figure 3.3: new sand-LDPE plastic composite interlocking Brick

3.1.2 Design of compression molding machine

From the study of existing ideas, a new idea has to be conceived. The idea is then studied keeping in mind and given shape and form in the form of drawings. In the preparation of these drawings, care must be taken of the availability of resources about money, men and materials required for the successful completion of the new idea into an actual reality. In designing a machine component, it is necessary to have a good knowledge of many subjects such as Mathematics, Engineering Mechanics, Strength of Materials, Theory of Machines, Workshop Processes and Engineering Drawing.

General Considerations in Design

- ✓ Type of load and stresses caused by the load
- ✓ Motion of the parts or kinematics of the machine;
- ✓ Selection of materials;
- ✓ Form and size of the parts;
- ✓ Use of standard parts and safety operations; etc.

This designs of manually operated compression molding machine is Starting from the idea of design principles and functional requirements, the researchers designed the parts of the machine based on the design procedures [37].

❖ Design of Critical Components

The main parts of this machine includes lever arm, housing, top plate, molding plate, compressing frame, bottom plate and lifting support.

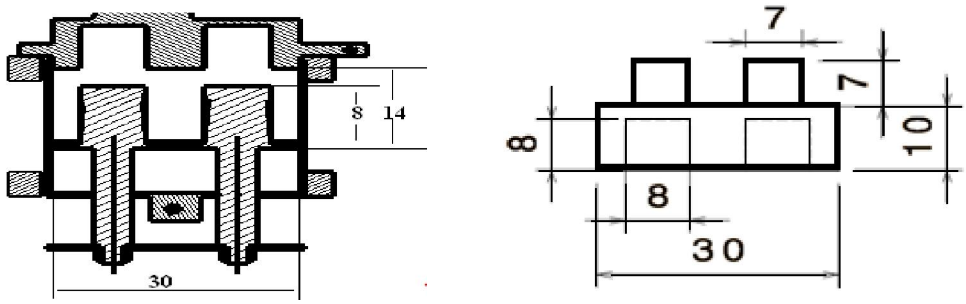
<u>Power source</u>

This project is designed to produce sand plastic composite brick of length 300mm, width of 150mm and height of 100mm. The design dimensions are usually obtained by considering maximum force a man can exert rather than the load actually necessary to be resisted. So the researcher recommends the consumption of power to be approximate manual force in "N" taken as given in text book of machine design for lever arm mechanism [38, 39]. The values of standard manual force are shown in Table 3.2. So the assumed value of manual force used for this design is selected from the table.

Table 3.1: maximum load can be applied by man [38]

Name of operation	Continuous	Intermittent	Instantaneous
Hand operation	70-100	200-250	350-400
Foot operation	150-200	400-500	700-800

- **Force required for compressing the brick into required shape**



(a), Volume of filled composition (b), volume of extremely compacted brick

Figure 3.4: Volume of filled and extremely compacted brick

Volume of filled composition (before compression)

$$V_1 = 14 \times 30 \times 15 - 2(8 \times 8 \times 8) = \underline{\underline{5276\ cm^3}}$$

Volume after compression (volume of extremely compacted brick)

$$V_2 = 10\,(+2) \times 30 \times 15 + 2\,(7 \times 7 \times 7) - 2\,(8 \times 8 \times 8) = \underline{\underline{5062cm^3}}$$

- Therefore, Change in volume (ΔV) due to compression pressure (P) is

$$\Delta V = V_2 - V_1$$

$$= 5062cm^3 - 5276\ cm^3 = \underline{\underline{-\ 214\ cm^3}}$$

- Height compressed to form the brick is obtained from change in volume

$$\Delta V = L \times W \times H = 214\ cm^3 \qquad \text{but,}\ \ L = 30,\ W = 15$$

$$H = {}^{214cm3}/_{30cmx15cm} = \underline{\underline{0.5cm}}$$

Poison’s ratio is related to the compressibility of the material. Since poisons ratio of reinforced thermoplastic is not known, the Poison’s ratio used for this design is the Poison’s ratio of plastic exclusively from reinforced sand to calculate the pressure required to compress the brick in to required shape [38, 36].

The bulk modulus (k) also called the modulus of compressibility is the ratio of compressive pressure (p) needed for a unit relative decrease in volume (ΔV/v) [38].

$$K = -P \text{ x } \frac{v}{\Delta V} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: - k = compressibility

P = compressive pressure

ΔV = change in volume due to compression

V= unit volume

For isotropic materials the bulk modulus is related to the elastic modulus and poison’s ratios as [38].

$$K = \frac{E}{3\,(1-2\Upsilon)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where: - E is elastic modulus of plastic = $1.4 \text{ x } 10^9 \text{ N/m}^2$ see appendix “B3”

Υ is poisons ratio of plastic = 0.3 see appendix “B5”

From equation (2) it is possible to evaluate compressibility (k)

$$K = \frac{E}{3\,(1-2\Upsilon)} = \frac{1.4 \text{ x } 10^9 \text{ N/m}^2}{3\,(1-2(0.3))}$$

$$= \underline{\underline{1.16 \text{ x } 10^9 \text{ N/m}^2}}$$

Therefore the pressure required to compress and produce the brick into required shape is evaluated from modulus of compressibility “k” from equation (1) as following

$K = -P \text{ x } \frac{v}{\Delta V}$ But, $\Delta V = -214\text{cm}^3 = -0.214 \text{ x } 10^{-3}\text{m}^3$

$$P = -k \text{ x } \frac{\Delta V}{v} = -1.16 \text{ x } 10^9 \text{ N/m}^2 \text{ x } \frac{-0.214 \text{ x } 10^{-3} \text{ m}^3}{1\text{m}^3} = \underline{\underline{0.24 \text{ x } 10^6 \text{ N/m}^2}}$$

$$P=F/A \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3)$$

$$A=L \times W = 30cm \times 15cm = 450\ cm^2 = \underline{\underline{0.045\ m^2}}$$

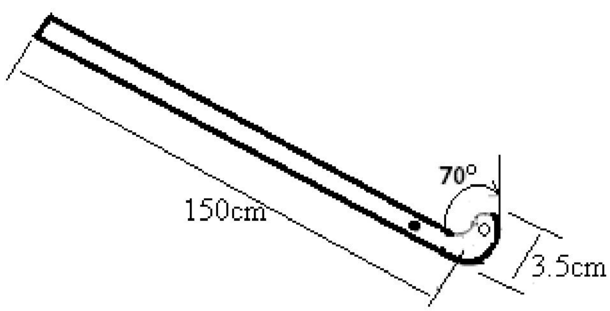
$F= P \times A$

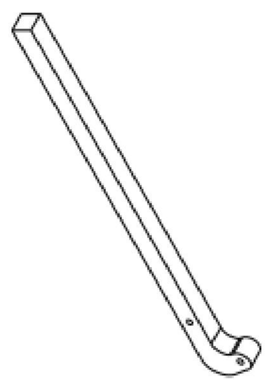
$= 0.24 \times 10^6\ N/m^2 \times 0.045\ m^2$

$= \underline{\underline{10.8\ k\ N}}$ (force required to compress the brick in to required shape)

❖ Design of lever arm

Liver arm mechanism is a mechanism used to get mechanical advantage [38] and it is means to raise a load with less effort, or sometimes it is simply facilitate the application of force in a desired direction. A lever may be straight or curved. The lever mechanism used in these design is curved lever type for raising load of compressing.





(a), Lever arm dimension (a), Isomeric view of the lever arm

Figure 3.5: dimension and isomeric view of the lever arm

Material to be selected for the lever arm should satisfy the following requirements. These are:

- Moderate weight
- Should be local
- Less cost
- Have a moderate strength
- Easily manufactured

Candidate materials to manufacture the lever arm are Aluminum, wood, Cast iron and steel. Mild steel is moderate in weight, can be easily machined , available on market and possesses moderated strength and also comparatively it is cheaper than aluminum. Since the compression force on the lever arm can easily break the wood and the aluminum may have weldablity problem and it is expensive, the selected material for the lever arm is mild steel. The forces applied by the lever may be parallel or may be inclined to one another in these case the force applied is inclined to another at right angle to plane of application.

Design assumptions

- For this project the assumed (considered) force 'F_1' a man can exert is 250 N intermittent forces since the machine works in the stopping and starting interval manner.
- The other assumption is the length of the lever arm is assumed to be 1.5m from fulcrum point to applied force (F_1) and 3.5 cm from fulcrum to load going to be lifted (F_2).
- Each load F_1 and F_2 are acts at right angle to the lever arm and the included angle (θ) between the arms is 70^0.
- For the case of this design, it is decided to have maximum mechanical advantage

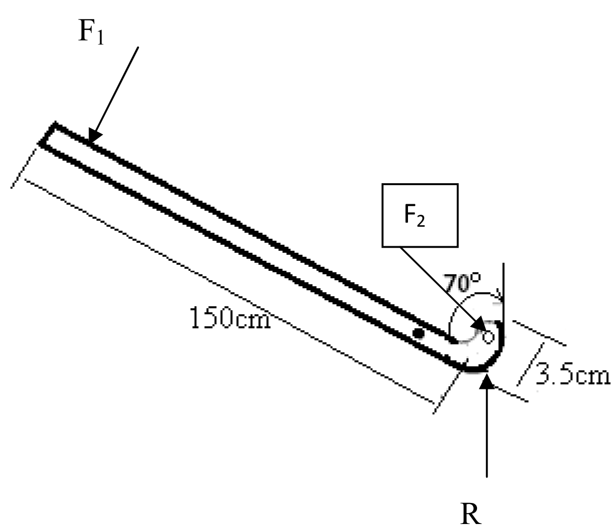


Figure 3.6: Lever arm dimension with applied load

Now from the selected manual force and assumed dimension of lever arm, it is possible calculate the maximum force required to lift the load (F_2). From FBD in figure (3.6) we can find maximum load lifted by mechanism of the liver using moment principle as following:- Taking moment about fulcrum neglecting weight of member

F_1 x 1.5m – F_2 x 0.03 m = 0 but, from assumption F_1=250N

$$F_2 = \frac{250N\ x\ 1.5m}{0.03m} = \underline{\underline{12.5\ KN}}\ \text{(maximum force required to lift the load)}$$

Since $\mathbf{F_2 > F}$ (force required to compress the brick) the design is safe

The reaction "R" at the fulcrum point will depend upon that how "F_1"and "F_2" are acting. When the two forces "F_1" and "F_2" are act at right angles to two arms of lever, which included angle "θ" in between two arms, then the reaction at the fulcrum can be obtained by relation given below [38].

$$R = \frac{\sqrt{F1^2+F2^2-2F1\ X\ F2\ COS\theta}}{1} \text{.................................... [4]}$$

Therefore the reaction force (R) at fulcrum from equation (10) will be as follow

$$R = \frac{\sqrt{F1^2+F2^2-2F1\ X\ F2\ COS\theta}}{1} = \frac{\sqrt{(250N)^2+(12.5kN)^2-2X250N\ X\ 12.5kNXCOS\ 70}}{1}$$

$$=\underline{\underline{12.42kN}}$$

Determining thickness of the lever arm

For any type of lever arm it is always desirable to know the thickness of the lever arm material if the material is hollow rectangular bar or hollow square bar. It will be required to protect the lever arm from failure due to bending force. 20mm x 40mm hollow bar is used for lever arm in this design. The appropriate thickness of the bar is determined using maximum load to be lifted from the following equation [38].

$F=Ax\ \sigma_b$.. (5)

Where: - F = the maximum load to be lifted = F_2= 12.5kN from equation (3)

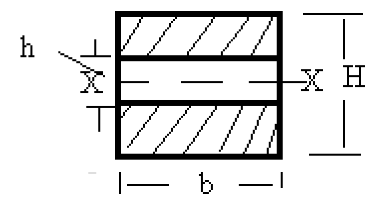
σ_b= allowable bending stress of the material of the lever arm

The material selected for lever arm is low Carbone steel (mild steel) for this project. Using factor of safety (F_{sy}) of steel and ultimate tensile stress of steel given in appendix 'B'.

σ_b= allowable bending stress of mild steel = $\frac{tensile\ \ stress}{factor\ of\ safety}$

$= 420/6 \underline{\underline{=70\ N/mm^2}}$

A = cross sectional area of hollow rectangle = Hb – hb



So, from equation (5)

$$F= A \times \sigma_b = (Hb – hb) \times \sigma_b = b (H -h) \times \sigma_b$$

$$12.5\ KN = 20 (40 -h) \times 70\ N/mm^2$$

$$h=31.5mm \approx \underline{\underline{32mm}}$$

Therefore, the thickness of mild steel bar is

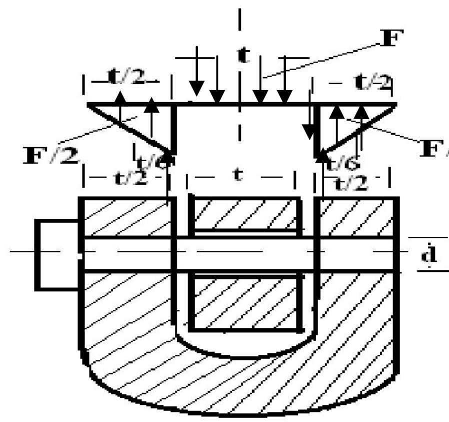
$$t = \frac{H-h}{2} = \frac{40-32}{2} = \underline{\underline{4mm}}$$

Design of the end connection of lever arm

The end of lever arm should be checked for shear force if the load at the end is applied by forked connection, and then the dimension of the lever at that end can be proportioned as a knuckle joint. Therefore the knuckle joint bolt is designed for bearing and bending consideration with a proper check for shear and deflection also. Bending of bolt in the fork may take place in different ways of force distribution on the bolt, according to fig. (3.7). In these design force distribution on the bolt is a bolt supported in fork type fig. (3.7). for the bolt supported in fork, the stress distribution is assumed to be zero at outside and maximum at the inside, the effect of clearance is neglected. The assumptions are:-

- There is no stress concentration

- The load is uniformly distributed over each component.
- The load (F) and efforts (P) are acting in tension at 70^0 to each other at axis of joint
- Materials of all components are the same having tensile, compressive, and shear stress of (σ_t), (σ_c) and (τ_s) respectively.



Bolt supported in fork

Figure 3.7: Distribution of force on bolt [40]

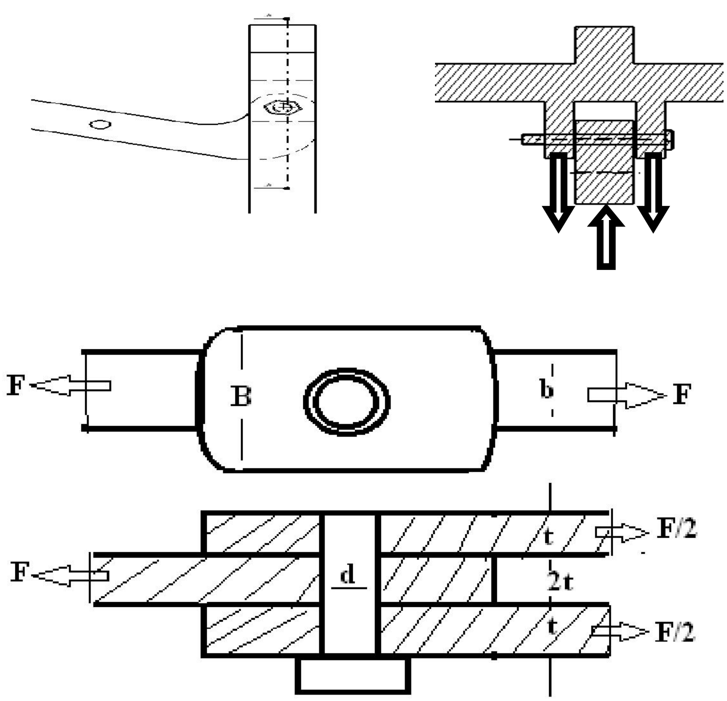


Figure 3.8: Link mechanism of eye end lever arm and fork end of lifting frame [38]

In this design of joint link mechanism used in lifting load, thickness of fork end of lifting frame is assumed to have thickness t=20mm and assume that lifting frame material and bolt are made of the same material with permissible stress values in tension, compression, and shear stress of the same value of 60N/mm^2, 80N/mm^2, and 45N/mm^2 respectively using factor of safety of steel in appendix –'B4' the design of joint is calculated.

- Considering tension failure of the fork end of lifting frame across the width (b)

F= A x σ_t ……………………………………………………… (6)

12.4 kN = 2 (bt – ht) x σ_t = 2t (b -h) x σ_t

12.4kN = 2x20mm (40mm-h) x 60N/mm^2

h=34.8≈35

Therefore the thickness of fork end material of lifting frame is given by

t= H-h=40-38=2mm

- Considering shear failure of the bolt, which is under double shear

$F= \frac{2\pi d2}{4} \times \tau$ ………………………………………………… (7)

$12.4kN = \frac{2\pi d2}{4} \times 45N/mm^2$

d^2=175.424mm^2

d= 13.2mm ≈ 15mm diameter bolt

- Neglecting stress concentration effect

B= b+d = 40mm +15mm =55mm

- Thickness of the eye end of lever arm is =2t =2x20mm= 40mm

- Considering crushing between the bolt and eye end of lever arm

F=2t x d x σ_c ……………………………………………………….. (8)

12.4kN=2(20mm) x 15mm x σ_c

$\sigma_c = \underline{\underline{20.6 N/mm^2}}$

(As crushing stress induced is less than the allowable crushing stress of the material the design of joint is safe)

❖ **Design of lifting frame**

The lifting frame is made from 20x40 hollow steel bars and transmits compressing force of brick. Tensile force F_1 is developed on each side of compressing frame due to compressive load F, come from lever arm and molding plate as figure bellow

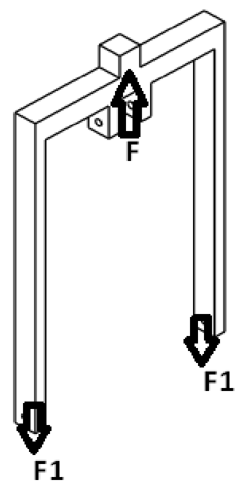


Figure 3.9: lifting frame

$F=2F_1\cos\theta$ ………………………………………………………… (9)

Where: - F = Force developed at fork end of compressing frame due to lever arm.

F_1= Tensile force developed on each side compressing frame

Θ = Angle between F and F_1

From above equation

$12.4kN = 2F_1\cos(180)$

$F_1 = \underline{\underline{-6.2kN}}$

Since, the compressing frame is made from 20mmx40mm hollow mild steel bar and since , lifting element have two resisting area, tensile load F_1 can be expressed as equation be low

$F_1 = 2A \times \sigma_t$……………………………………………. (10)

Where: - A = cross sectional area of the compressing frame members

σ_t = Allowable tensile stress of the compressing frame material

A = cross sectional area of hollow rectangle

And considering factor of safety of steel (6) and maximum yielding stress of steel $\sigma_y = 360N/mm^2$ from table of steel property in appendix

We have allowable stress = maximum yielding stress/factor of safety

$$\sigma_t = 360N/mm^2/6 = 60\ N/mm^2$$

$F_1 = 6.2kN$ and $\sigma_t = 60\ N/mm^2$

So, from equation (16) we have

$$6.2kN = 2A\,\sigma_t$$

$$6.2kN = 2(Hb - hb) \times \sigma_t = 2b\,(H - h) \times \sigma_t$$

$$6.2kN = 2 \times 20\,(40 - h) \times 60\ N/mm^2$$

$$h = \underline{\underline{37.78mm}} \approx \underline{\underline{38mm}}$$

Therefore, the allowable thickness of mild steel bar is

$$t = (H-h)/2 = (40-38) = \underline{\underline{2mm}}$$

Eye end design for lifting frame

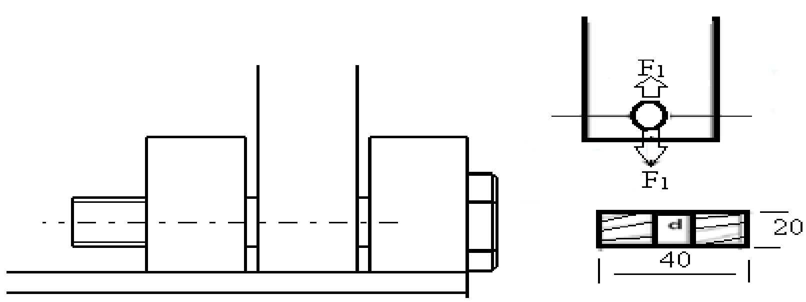


Figure 3.10: Eye end of lifting frame

The eye end of compressing frame will fail due to tensile load (F_1) across the hole. Therefore permissible hole diameter which resist the load F_1 will obtained by considering tensile failure of the plate across the hole

$$F=A \times \sigma_t$$

$$6.2\ kN = (40x20-dx20) \times 60N/mm^2$$

$$\underline{d=34mm} \text{ (diameter of the hole)}$$

Failure of comprising frame bolt

Check for Failure of bolt

The bolt will fail in double shear. The induced shear stress can be checked by relation in equation (6) as following

$$F= \frac{2\pi d2}{4} \times \tau_s \text{...} (11)$$

$$6.2kN= \frac{2\pi\ (34mm)\ 2}{4} \times \tau_s$$

Gives, $\underline{\tau_s=3.41N/mm^2}$ which is much less than the allowable shear stress of $\underline{45N/mm^2}$, hence the design is safe.

In above case there is no clearance between the pin and the mating component. But, in practice the components are assumed with sufficient clearance to permit angular movement of one with respect to the other. Once, there is clearance between the components and the bolt, the bolt will be subjected to bending. The induced bending stress can be checked by relation in equation (7) as following.

Assuming the load to be uniformly distributed on the pin in the fork and from zero at the outside to maximum at the inside, the loading of the bolt is shown in figure 3.11[38].

Maximum Bending moment (M_b) $=F/2[(t_1/3 + t_2/2)- t_2/4]$

$$= F/2[t_2/4+ t_1/3]$$

Now from relation of equation (5) we have

$$M_b = Z \times \sigma_b$$

$$F/2[t_2/4 + t_1/3] = \pi/32 \times (d_1^3) \times \sigma_b \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \text{(12)}$$

$$F/2[20/4 + 20/3] = \pi/32 \times (d_1^3) \times \sigma_b$$

$$6.2kN/2[20/4 + 20/3] = \pi/32 \times (34mm^3) \times \sigma_b$$

Gives, $\underline{\sigma_b = 9.7 N/mm^2}$ which is much less than the allowable bending stress of $\underline{70 N/mm^2}$, hence the design is safe.

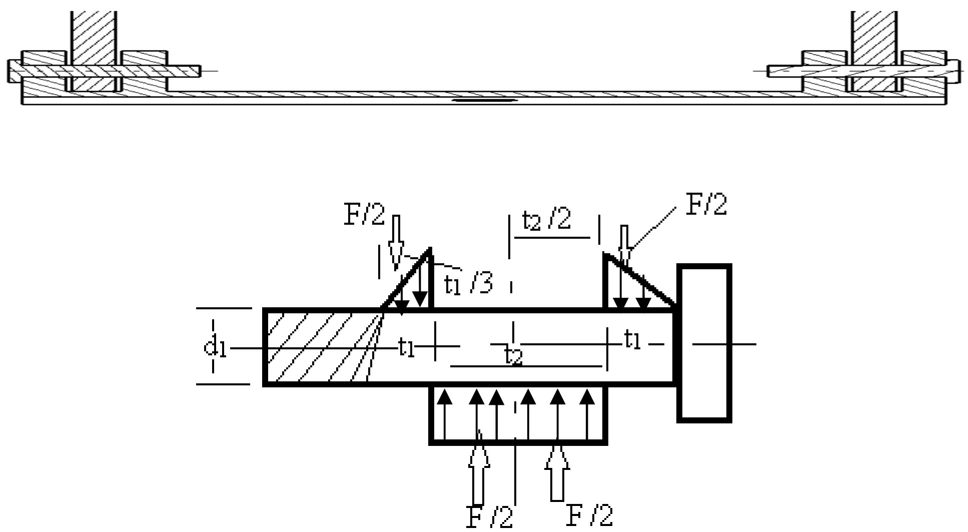


Figure 3.11: bending of bolt

- **Design of top plate**

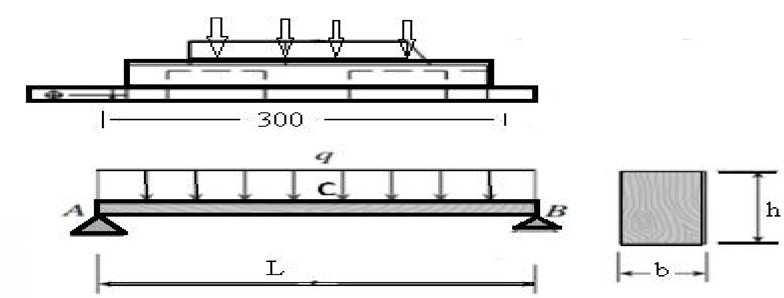


Figure 3.12: Bending of top plate

Top plate is designed for resisting compressive force (F) acting at fulcrum which required to lift load (P) the top plate designed based on reaction force at fulcrum to protect the bending failure of top plate. Assuming the top plate as simple supported beam and the thickness of the plate is uniform across the length. Thickness of the top plate material which resists compressive force (F) acting on top plate by fulcrum of the lever arm without deflection is obtained by:-

Let, t=is thickness of the plate

R_1 and R_2 reaction at the supports

Taking moment about 'A' the left support

12.4kN 150 –R_2 x 300=0

R_2=6.2kN and R_1=6.2kN

Bending moment at 'C' (at centre of beam)

M_c =150mm xR_2 = 150mm x 6.2kN = 930kNmm

Therefore maximum bending moment

$M_b = \sigma_b \times Z$

$M_b = \sigma_b \times I/y$

Where: -

M_b= maximum bending moment

σ_b =allowable bending stress of top pla

Z= modulus of elasticity rectangular cross section=I/y

I=moment of inertia=$bh^3/12$

Y= distance from neutral axis=h/2

b= depth of plate=150

h=thickness of the plate

$M_b = \sigma_b \times Z = \sigma_b \times I/y$

930kNmm= 70N/mm^2 x 1/6 x (300mm) x h^2

$h^2 = \sqrt{531.4}$ = h= 23mm≈30mm

- **Design of bottom plate**

The loads developed on the bottom plate are external loads, which are line of action parallel but don't concede with the central axis of the bottom plate. Those loads are eccentric loads**.**

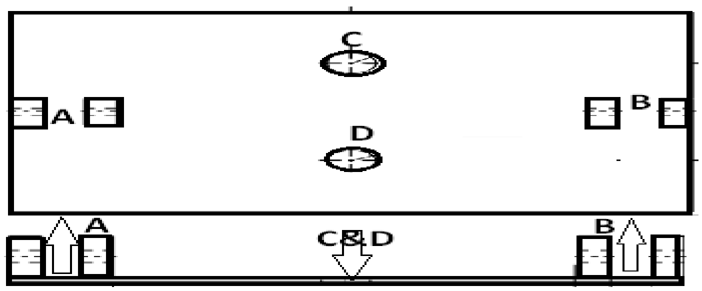


Figure 3.13: force distribution on bottom plate

The bottom plate is made from mild steel of length 400mm and 300mm width plate, and the plate is subjected to down ward compressing force come from molding plate and side bending force com from lifting frame. So the plate must design for resisting those forces without failure with factor of safety (4) with respect to the developed critical load.

So the required thickness of plate for resisting this force is determined as following

$P_{cr} = \pi^2 \text{ x E x I}/L^2$……………………….……………. (13)

Where: - P_{cr} = critical load on the plate

E = modulus of elasticity of plate material (mild steel) =200Gpa

I = moment of inertia of rectangular cross section

L = length of plate=400

P_{cr} =factor of safety (n) x load transmit to bottom plate (F) = 4 x 12.4 kN = 49.6kN

From equation (19) we have

$P_{cr} = \pi^2 \text{ x E x I}/L^2$

$49.6\text{kN} = \pi^2 \text{ x 200Gpa x I}/ (400\text{mm})^2$

$I=49.6\text{x}10^3 \text{ N x 16 0000mm}^2/ (1973.92 \text{ x } 10^9 \text{ N/m}^2)$

$= \underline{\underline{4.020 \text{ x } 10^{-9}\text{m}^4}} = \underline{\underline{4020\text{mm}^4}}$

But, moment of inertia is given by

$$I = b\,t^3/12$$

$$4020 = (300\text{mm})\,t^3/12$$

$$\underline{\underline{t = 4\text{mm}}}$$

Compressive (downward) force at the center of the bottom plate is given by

$$F_y = R_1 + R_2 = 5.4\text{kN} + 5.4\text{kN} = \underline{\underline{10.8\text{kN}}}$$

Bending moment about center of the plate is given by

$$M_b = F_1 \times 200\text{mm} - F_2 \times 200\text{mm} = 6.2\text{kN} \times 200\text{mm} - 6.2\text{kN} \times 200\text{mm} = \underline{\underline{0\ \text{Nm}}}$$

The above result show no bending moment is developed at the center bottom plate instead of bending compression stress is developed at the center of bottom plate. The compressive stress developed at the center of the bottom plate is given by

$$\sigma_c = F_y/A + M_b\,(t/2)/I = 10.8\text{kN}/(300\text{mm}\times 4\text{mm}) + 0\ \text{Nm}\,(4\text{mm}/2)/4020\text{mm}^4 = \underline{\underline{9\ \text{N/mm}^2}}$$

Since, compressive stress developed at center of bottom plate is much less than allowable compressive stress of the bottom plate material ($\sigma_c < \sigma_a$) the design is safe.

- **Design of housing**

In a rectangular or cylindrical containers subjected to internal pressure, the following stress are induced

I) Tangential stress
II) Longitudinal stress
III) Radial stress

However, radial stress is small compared to the other two and usually neglected. The following modes of failure are considered for the design of container.

i) Rupturing along a longitudinal section and

ii) Failure across a transverse section

The housing is design based on considering failure mode of rupturing along longitudinal section in this design

Pressure developed in housing (molding chamber) is a pressure required to mold the brick

$P= 0.24 \times 10^6\ N/m^2$……………………..from equation (2 & 3)

Therefore, external force acting the wall of housing is given by

External force acting on wall of housing = brick molding pressure x surface area of housing

$F= P \times A$ …………………….from equation (3)

$= 0.24 \times 10^6\ N/m^2 \times 0.045\ m^2 = \underline{\underline{10.8\ k\ N}}$

Considering factor of safety of (6) for external force to design the housing, the critical load (F_{cr}) will be

F_{cr} =factor of safety x F = $6 \times 10.8kN = \underline{\underline{64.8\ kN}}$

The resisting force, offered by housing wall = $2t \times L \times \sigma_t$

Where: - t=thickness of hosing plate

L=length of housing plate

σ_t =allowable tensile stress of housing plate material (mild steel) $=60N/mm^2$

Now equating the above two equations we have the thickness of hosing wall that resisting external force of molding pressure (F_{cr})

$F_{cr} = 2t \times L \times \sigma_t$ .... (14)

$t = F/ (2 \times L \times \sigma_t) = 64.8kN/2 \times 400mm \times 60N/mm^2 = \underline{\underline{1.45mm}}$

But, for more safety purpose $\underline{\underline{t=4mm}}$ mild steel plate is used to construct the housing of in this design project.

- **Design of molding plate**

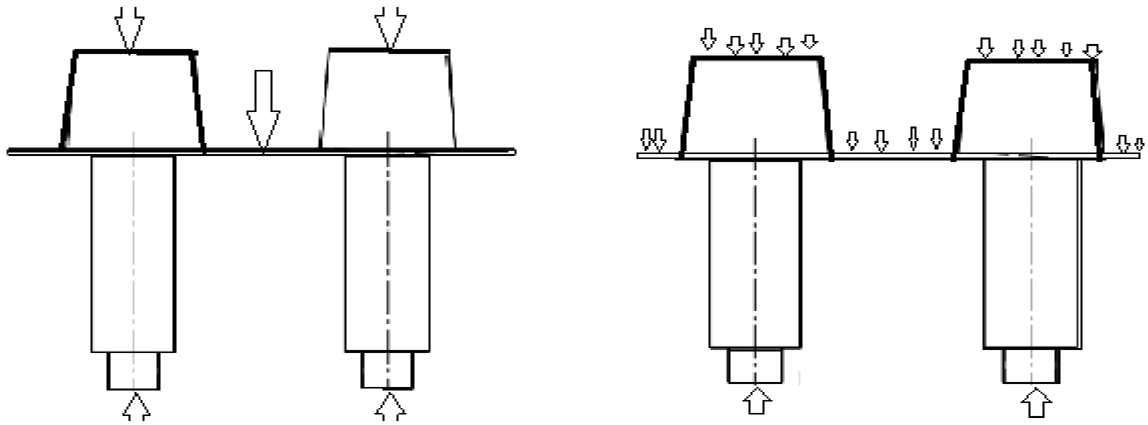


Figure 3.14: force distribution on molding plate

Molding plate is designed for resisting Compressive load developed on the molding plate surface which results in deflection molding plate legs due to compressive load. To determine Thickness of the hollow circular tube that can resist compressive stress developed on the legs of molding plate, first it is necessary to determine the distributed load over the top plate of molding plate by assuming that top of molding plate as simple supported beam and the legs of the molding plate as one end fixed and other end free moving column.

From equation (3) we have

P= F/A

Where: - p= pressure required to compress and produce the brick in N/m^2

F=compressive force in N

A= area of compression in m^2

Therefore the pressure required to compress and produce the brick into required shape is evaluated from modulus of compressibility "k" from equation (1) as following

$K= -P/\Delta V/v = -P \times v / \Delta V$ $\quad\quad$ $\Delta V = -214cm^3 = -0.214 \times 10^{-3}m^3$

$$P = -k \times \Delta V / v = \frac{-1.16 \times 109\frac{N}{m2} \ \times -0.214 \times 10-3 \ m3}{1m3} = \underline{\underline{0.24 \times 10^6 \ N/m^2}}$$

$A = L \times W = 30cm \times 15cm = 450 \ cm^2 = \underline{\underline{0.045 \ m^2}}$

But, $P = F/A$

$F = P \times A = 0.24 \times 10^6 \ N/m^2 \times 0.045 \ m^2 = \underline{\underline{10.8 \ k \ N}}$ (Distributed force over the top of molding plate)

Reaction force developed at the leg is

$R_1 = F/2 = 10.8kN/2 = \underline{\underline{5.4kN}}$

$R_2 = F/2 = 10.8kN/2 = \underline{\underline{5.4kN}}$

Therefore, compressive force over the two legs of the molding plate is

$F_1 = -R_1 = -\underline{\underline{5.4kN}}$ and $F_2 = -R_2 = -\underline{\underline{5.4kN}}$

Now, using the Rankine-Gordon formula of column design [38], internal diameter of hollow circular bar used for legs of molding plate can be determined

$F_1 = \sigma_c \times A / (1 + a\,(l/d_0)^2)$…………………….…………… (15)

Where:-F=load on the legs of molding plate in N

A=area of hollow rod in $m^2 = \pi/4 \times (d_0^2 - d_i^2)$

σ_c= allowable compressive stress of rode material in N/mm^2 (wrought iron)

a=constant=1/9000 for wrought iron

d_0=outer diameter of the rode in mm=50mm

l=length of legs in mm=300mm

$5.4kN = 342MN/m^2 \times \pi/4 \times (50^2 - d_i^2) / (1 + 1/900(l/50)^2)$

$$(5.4kN \times 1.004)/ (342MN/m^2 \times 0.785) = (2500 - d_i^2)$$

$$d_i^2 = 2500mm^2 - 20.2mm^2$$

$d_i = \underline{\underline{49}}$ but, it is possible to take $d_i = \underline{\underline{48}}$ for more safe condition Therefore, the thickness of wrought iron rode required for molding plate is

$$t = d_0 - d_i = (50mm - 48) = \underline{\underline{2mm}}$$

Table 3.2: Wrought iron property [38]

Material	Ultimate compressive stress In N/mm^2	The constant (a)
Cast iron	570.0	1/1500
Wrought iron	342.0	1/9000
Medium steel	420.0	1/7500
Hard steel	535.0	1/5000

Check for Failure of mouding plate legs

The failure of the moulding plate legs can be checked under compresive stress

$$\sigma_c = F/A = F/ (\pi/4 \times (d_0^2 - d_i^2)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(16)$$

where:- σ_c = compressive stress developed on molding plate legs in N/mm^2

F = compressive force in N

A=crossectional area of molding platelegs

$$\sigma_c = F/A = 5.4kN/ (\pi/4 \times (50^2 - 48^2) = 5.4kN/153.9mm^2$$

$$\underline{\underline{\sigma_c = 35N/mm^2}}$$

Gives, $\underline{\underline{\sigma_c = 35N/mm^2}}$ which is much less than the allowable compressive stress of $\underline{\underline{342N/mm^2}}$ hence the design is safe.

Molding plate and bottom plate joint design

Molding plate is connected to bottom plate with ISO metric screw thread of M50 x 1.25. the head of the bolt is welded to the end of molding plate of 50mm diameter wrought iron rode.

The stresses induce in the bolt under the load of compression are

1) Stress due to initial tightening of the nut

When a bolt is tightened by a nut initially the following stresses are induced tensile stress (stretching of the bolt), compressive stress (on the tread of the bolt) and shear stress across the tread. Therefore tensile force in the bolt due to initial tightening is given by [according to stress in screwed fastener]

$\mathbf{F_1}$ =2840d………………………………………………… (17)

Where: - $\mathbf{F_1}$ =tension force in the bolt

d = nominal diameter of the bolt=d_c/0.88(for fine tread)

= d_c/0.84(for coarse tread)

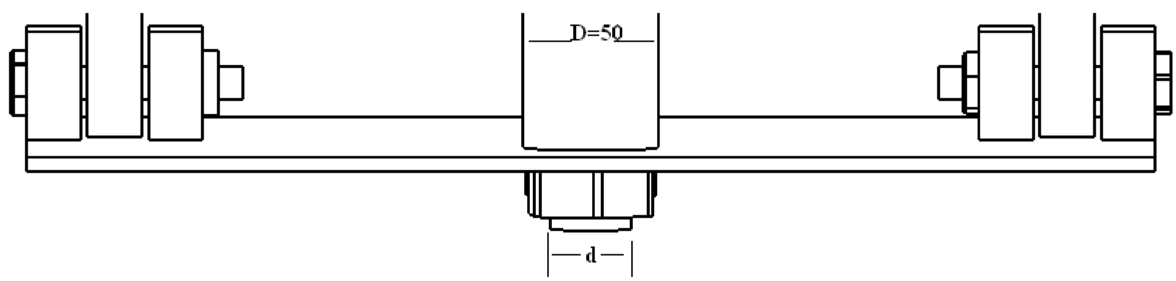


Figure 3.15: molding plate and bottom plate joint

2) Stress due to external load

A bolt can also subjected to external load of tension which is given by

$F_2 = \pi d_c^2/4 \times \sigma_t$ ………………………………………….. (18)

Since the external load, (F_2) is resisted by two bolt

$F_2 = 2\pi d_c^2/4 \text{ x } \sigma_t$

Where: - $\mathbf{F_2}$ =external tension force in the bolt

d_c = core diameter of the bolt

σ_t =permissible tensile stress in the bolt material (similar to molding plate material which is wrought iron)

3) Stress due to combined load

It is the combination of the above two load acting on the bolt. Tightening load exists if there is elastic material between bolt connected parts. Therefore in this case the two connected parts are molding plate , bottom plate and hard cupper washer , that is metal to metal connection in which stiffness constant (k) for the connected part is equal to 0.25 (k=0.25)

Therefore, maximum resultant force on the bolt is given by

$F= F_1 + kF_2$……………………………………………………………. (19)

Compressive load developed over molding plate is 10.8kN but, the force is distributed over each leg of compression molding plate which are $F=R_1= R_1= -5.4KN$ (downward). So, considering factor of safety of (6) and from equation (19) and combining equation (25) & (24) we have.

F_{cr} =factor of safety x F= 6 x 5.4kN= 32.5kN

$F= F_1 + F_2= 2840d + 2\pi d_c^2/4 \text{ x } \sigma_t =2840d + 2\pi\ (0.84d)^2/4 \text{ x } \sigma_t$

$32.5kN =2840d + 2\pi\ (0.84d)^2/4 \text{ x } 70N/mm^2$

$77.58d^2 + 2840d - 32500mm^2 = 0$

$$d= \frac{-2840+\sqrt{2840^2-(4x77.58x-32500)}}{2 \text{ x } 77.58} = 9.15mm \text{ (minimum diameter of the bolt)}$$

but the size of the legs of the molding plate are designed to 50mm outer diameter, therefore the bolt diameter (d) is required to be 33mm in order to weld the bolt head to leg end of the molding plate. Diameter –pitch combination for ISO metric tread is given in appendix ‘B’.

❖ Design of lifting support

Considering the lifting support as cantilever beam supporting lifting force of (f), the maximum diameter of lifting support rode is obtained from maximum moment at support neglecting weight of the rod. Therefore, maximum bending moment at the support considering critical load (F_{cr}) with factor of safety six (n=6) is obtained as following

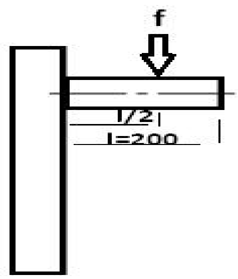


Figure 3.16 Lifting support

$M_b = F_{cr}$ x L ……………………………………………. (20)

Where: - M_b= bending moment about the support

L= distance between support and point of lifting force application=100mm

F_{cr} = n x f =6 x 77.17N= 463N

$M_b = F_{cr}$ x L/2=463Nx100mm =46300Nmm

But, bending moment can be as following

M_b= Z X f_b …………………………………………….. (21)

Where: - M_b =bending moment in Nm

- $M_b = F_{cr}$ x L=463Nx100mm=46300Nmm…………… from equation (3)

Z =section of modulus in m^3

- Z= I/y = $2\pi/64$ X (d_0^3)

I= moment of inertia of the cross section in m^4 = $\pi/64$ X (d_0^4)

Y=distance from neutral surface in m = $d_0/2$

σ_b= bending stress in N/m^2

- The material selected for lifting is low Carbone steel (mild steel) for this project

Therefore, σ_b = bending stress of mild steel =70 N/mm^2 see appendix-B

d_0= outer diameter of hollow circular rode of (see appendix 'B6')

Therefore, using equation above it is possible to determine outer diameter of steel bar and then internal diameter, which intern used to determine thickness of steel rode required for lifting support.

$$M_b = \sigma_b \text{ x } z$$

$$M_b = \sigma_b \text{ x } 2\pi/64 \text{ x } (d_0^3)$$

$$d_0^3 = M_b \text{ x } 64/2\pi \text{ x } \sigma_b \quad = 46300Nmm \text{ x } 64/2\pi \text{ x } 70\ N/mm^2 = 6737mm^3$$

$$d_0 = 19.88 \approx \underline{\underline{20mm}}$$

Internal diameter (d_i) is determined equating the tensile (bending resistance of the rod to the load (F_{cr}) as following :-

$$F = A \text{ x } \sigma_b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ (22)}$$

Where: - $A = \pi/4 \text{ x } (d_0^2 - d_i^2)$ and σ_b =70 N/mm^2, F_{cr} = 463kN and d_0=38mm

$$F = \pi/4 \text{ x } (d_0^2 - d_i^2) \text{ x } \sigma_b$$

$$463kN = \pi/4 \text{ x } (20mm^2 - d_i^2) \text{ x } 70\ N/mm^2$$

d_1=$\underline{19mm}$ it is better to take$\underline{\underline{18mm}}$

Therefore, the thickness of mild steel rode required for lifting support is

$$t = d_0 - d_i = (20mm-18mm) = \underline{\underline{2mm}}$$

3.1.3 Material selection

Material selection is a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals. Systematic selection of the best material for a given application begins with properties and cost of candidate materials. The selection of materials and the processes used in fabrication are integral parts of the design of a machine component. The characteristics that are usually considered when selecting a material for a given application can be classified into the following categories:-

1. Mechanical behavior including shear strength, yield strength, tensile strength, elongation percent, reduction in area percent, hardness, toughness, fatigue strength and stiffness resistance to abrasion and erosion are also related to mechanical behavior;
2. Chemical properties which include corrosion and oxidation resistance.
3. Physical characteristics including electrical, magnetic and thermal properties. Density is also included in this category;
4. Process ability which includes castability, workability, weldability and machinability.

In selecting materials for a given application it is useful to classify them according to the major function they are expected to perform in service. The selection of proper materials for engineering purpose is one of the most difficult problems for the designer. The best material is one which services the desired objectives at the minimum cost and the following factors should be consider while selecting material.

- Availability of the material in the form and shape desired
- Total cost of the material including initial and future cost;
- Material properties as they relate to service performance requirements;
- Suitability of material for working condition in service;
- Substitutability of the materials; and
- The processing of the material into a finished part.

The design of this project is performed by considering the above factors

3.2 Manufacturing process, Assembly and Maintenance

This sub topic addressed the process and Operation sheet for critical components and Procedures of assembling components of the project.

3.2.1 Manufacturing process

Each part or component of a product must be designed so that it is not only meets design requirements and specifications, but also can be manufactured economically and with relative cost. Manufacturing process is the part of the production process which is directly concerned with the change of form or dimensions of the part being produced. It is usually carried out as a unit operation, which means that it is a single step in the sequence of steps required to transform the starting material into a final product.

The broad categories of processing methods for materials are:

- Casting (expansion mold and permanent mold)
- Forming and Shaping (rolling, extrusion, drawing, sheet forming, powder metallurgy, and molding)
- Machining (turning, boring, drilling, milling, and so on)
- Joining (welding, soldering and mechanical joining)
- Finishing operations (polishing, burnishing, honing, surface treating, coating, and painting)

Selection of a particular manufacturing process depends not only on the shape to be produced but also on a large number of other factors.

General steps to manufacture components of the machine:-

- ✓ Take the material for the component according to the design parameters.
- ✓ check the selected diameter (dimension) to assure by proper measuring tool
- ✓ Mark the selected material to the recommended dimensions.(Layout)
- ✓ Select the appropriate machine or tool for cutting the material to prepare the rough dimension.

- ✓ Hold the selected material in the selected machine or tool to make the rough dimensions.
- ✓ Perform the operation within the recommended and measured dimension on the marked line with allowance.

Figure 3.17 performing operation with appropriate material and equipment

- ✓ Perform the joining operation (welding, bolt & nut, …)
- ✓ Finishing operation to the recommended exact dimension.

Figure 3.18 Joining, grinding and painting operation

❖ Manufacturing operation

It is series of operation in which components are manufactured in their sequential order. Manufacturing operations can be divided into two basic types:-

1) Processing operations and
2) Assembly operations

A processing operation transforms a work material from one state of completion to a more advanced state that is closer to the final desired product . It adds value by changing the geometry, properties, or appearance of the starting material. In general, processing operations are performed on work-parts, but certain processing operations are also applicable to assembled items (e.g., painting a spot-welded car body).

Processing operation is done by using operation sheet which is the best & simplest way of showing how the part is manufacture through different steps to complete the work. Therefore process operation of this project is explained by using operation sheet.

An assembly operation joins two or more components to create a new entity, called an assembly, subassembly, or some other term that refers to the joining process (e.g., a welded assembly is called a weldment [38].

Note: *The reader should refer to the detailed drawings in Appendix (A) for information regarding shapes and sizes in the operations sheets.*

- ### Operation sheet for critical parts

Operation sheet for Frame

It is a 20 x 40 mm rectangular hollow bar of 2mm thickness used to hold all molding and lifting parts together such as housing, molding plate, lifting frame etc... It is connected with bolts to the components.

Material------------FeE250 rectangular rode

Blank size---------8300 mm

Quantity------------1

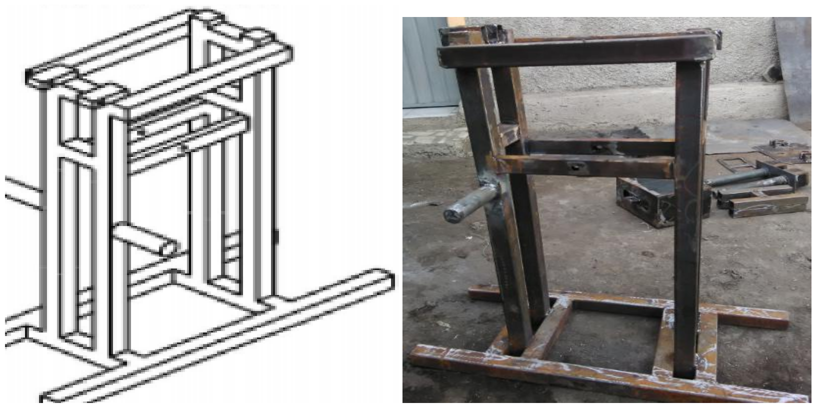


Figure 3.19 Frame

Table 3.3 Operation sheet for Frame

No.	Operation	Machine used	Tools and Equipments used	dimension	Qnt.
1	Measuring and cutting to size	Cutter disk and grinder	Steel rule and pensile	L=862mm L=322mm L=802mm L=302mm L=42mm	4 6 2 4 2
2	Side grinding	Grinding cutter And grinder	Bench support	L=860mm L=320mm L=800mm L=300mm L=40mm	
3	Drilling	Drilling machine	Drill bit	Hole =12mm diameter	4
4	Welding	Arc welding machine	Welding electrode		18
5	Grinding and painting	Grinding machine	Grinding disk , antirust and brush		

Operation sheet for housing

It is the main component of the compression molding machine which is made from mild steel plate with 4mm thickness. It is a machine element used as a chamber for molding the brick.

Material------------FeE250 plate

Blank size---------1310mm x 1285mm x 4mm

Quantity------------01

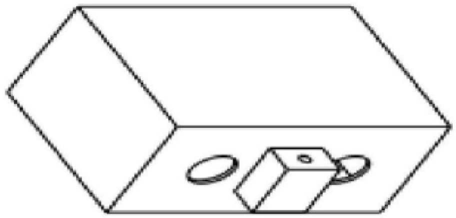
 

Figure 3.20 Housing

Table 3.4 Operation sheet for Housing

No.	Operation	Machine used	Tools and Equipments used	dimension	Quant.
1	Measuring and cutting to size	Cutter disk and grinder	Steel rule and pensile	L=302mm W=227mm L=162mm W=227mm L=302mm W=227 L=80mm	2 2 1 1
2	Side grinding	Grinding cutter And grinder	Bench support	L=300mm W=225mm L=160mm W=300mm L=300mm W=225	2 2 1
3	Drilling	Drilling machine	Drill bit	Hole =45mm diameter Hole =12mm diameter	2 1
4	Welding	Arc welding machine	Welding electrode		6
5	Grinding and painting	Grinding machine	Grinding disk , antirust and brush		

Operation sheet for lifting Frame

It is a 20 x 40 mm rectangular hollow bar of 2mm thickness used to hold molding plate and bottom plate parts together and used to compress the brick. Joined to lever arm by bolt

Material------------FeE250 rectangular rode

Blank size---------1660 mm

Quantity------------1

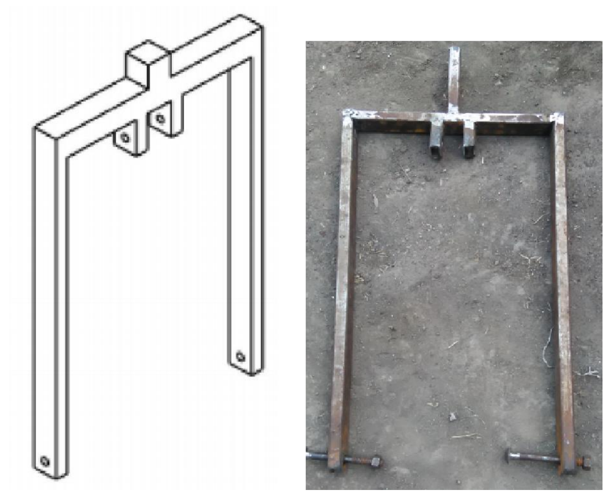


Figure 3.21 Lifting Frame

Table 3.5 Operation sheet for lifting Frame

No.	Operation	Machine used	Tools and Equipments used	Dimension	Qnt.
1	Measuring and cutting to size	Cutter disk and grinder	Steel rule and pensile	L=567mm L=333mm L=62mm	2 1 3
2	Side grinding	Grinding cutter And grinder	Bench support	L=565mm L=331mm L=60mm	2 1 3
3	Drilling	Drilling machine	Drill bit	Hole =12mm diameter	4
4	Welding	Arc welding machine	Welding electrode		6
5	Grinding and painting	Grinding machine	Grinding disk , antirust and brush		

Operation sheet for molding plate

Molding plate is made from 4mm thickness steel plate and 30mm outer diameter of hollow wrought iron rode. It is used to mold the brick in to required brick size and joined to bottom plate by bolt and nut.

Material------------FeE250 plate and Ø50 x 220 mm wrought iron rod

Blank size---------830mm x 830mm x 4 mm and Ø50 x 220 mm

Quantity------------1

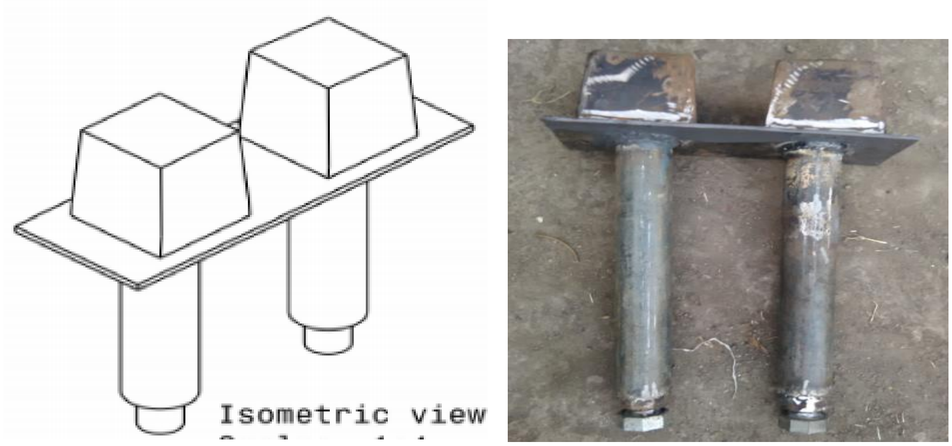


Figure 3.22 molding plate

Table 3.6 Operation sheet for molding plate

No.	Operation	Machine used	Tools and Equipments used	Dimension	Qnt.
1	Measuring and cutting to size	Cutter disk and grinder	Steel rule and pensile, Venire caliper	L=82mm W=82mm L=212mm Ø=52mm	10 2
2	Side grinding	Grinding cutter And grinder	Bench support	L=80mm W=80mm L=210mm Ø=50mm	2 1 3
4	Welding	Arc welding machine	Welding electrode		12
5	Grinding and painting	Grinding machine	Grinding disk , antirust and brush		

Operation sheet for Bottom plate

It is the main component of the compression molding machine which is made from mild steel plate with 4mm thickness and 20x40mm hollow steel bar of thickness 2mm. It is a machine element used to join lifting frame and molding plate mechanism

Material------------FeE250 plate and bar

Blank size---------420mm x320mm x 4mm and 250mm bar

Quantity------------01

Figure 3.23 Bottom plate

Table 3.7 Operation for Bottom plate

No.	Operation	Machine used	Tools and Equipments used	Dimension	Quant.
1	Measuring and cutting to size	Cutter disk and grinder	Steel rule and pensile	L=418mm W=312mm L=50mm	1 4
2	Side grinding	Grinding cutter And grinder	Bench support	L=416mm W=310mm L=45mm	1 4
3	Drilling	Drilling machine	Drill bit	Hole =30mm diameter Hole =12mm diameter	2 4
4	Welding	Arc welding machine	Welding electrode		4
5	Grinding and painting	Grinding machine	Grinding disk , antirust and brush		

Operation sheet for Lever arm

It is a 20 x 40 mm rectangular hollow bar of 2mm thickness used to develop mechanical advantage to compress brick in to required shape by transferring human force in to maximum compressive force.

Material------------FeE250 rectangular rode

Blank size---------1010mm length

Quantity------------1

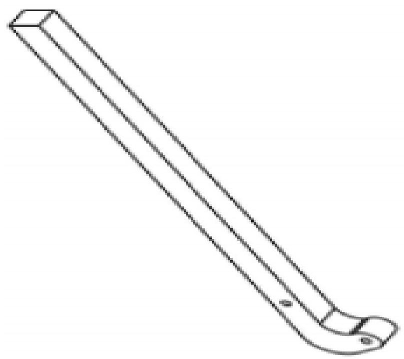


Figure 3.24 Lever arm

Table 3.8 Operation sheet Lever arm

No.	Operation	Machine used	Tools and Equipments used	dimension	Qnt.
1	Measuring and cutting to size	Cutter disk and grinder	Steel rule and pensile	L=1002mm	1
2	Side grinding	Grinding cutter And grinder	Bench support	L=1000mm	2
3	Drilling	Drilling machine	Drill bit	Hole =12mm diameter Hole =10mm diameter	1 1
4	bending	Bending machine		70^0	
5	Grinding and painting	Grinding machine	Grinding disk , antirust and brush		

Operation sheet for top plate

Top plate is made from 4mm thickness steel plate and 20x40mm hollow steel bar of 2mm thickness. It is used to support lever arm while compression and also used for covering the housing to protect outflow of the brick while composition.

Material------------FeE250 plate and 50

Blank size---------960 mm x 940 x 4 mm and 530mm

Quantity------------1

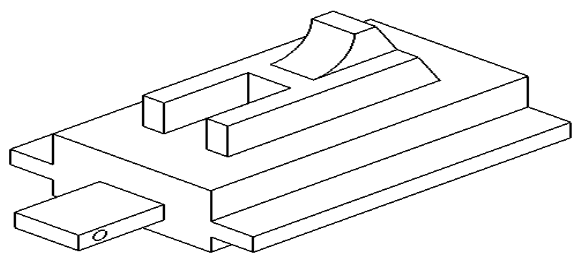


Figure 3.25 Top plate

Table 3.9 Operation for Top plate

No.	Operation	Machine used	Tools and Equipments used	Dimension	Quant.
1	Measuring and cutting to size	Cutter disk and grinder	Steel rule and pensile, Venire caliper	L=302mm W=227mm L=82mm W=82mm L=202mm L=62mm	1 8 2 2
2	Side grinding	Grinding cutter And grinder	Bench support	L=300mm W=225mm L=82mm W=82mm L=200mm L=60mm	1 8 2 2
4	Welding	Arc welding machine	Welding electrode		12
5	Grinding and painting	Grinding machine	Grinding disk , antirust and brush		

Note: The operation sheet for other parts like holding plate and holding plate support is similar to the operation sheet of parts mentioned above based on size, operation, tools and machines required and their operation sequences are explained in Labor cost for manufacturing components in the following sub topic 3.3.

3.2.2 Procedures of assembling components

Now all the parts needed for making the machine are manufactured and prepared as necessary. Then the next step is assembling of manufactured components in their correct place for making the project functional.

Therefore assembling of components with their step is as follows

1. Assembly of housing with frame by press fit and bolt…… 01

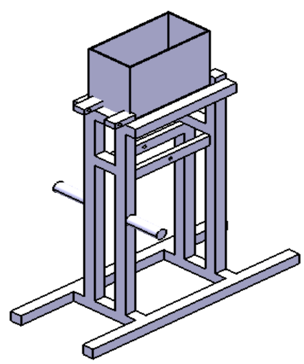


Figure 3.26 housing and frame (support)

2. Assembling of molding plate with assembly 01 by press fit….. Sub-assembly-02

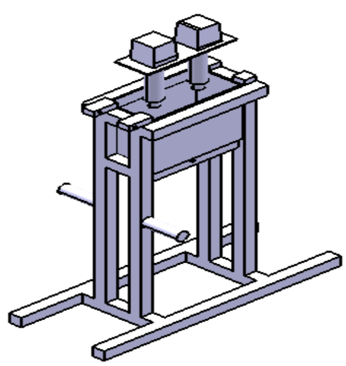


Figure 3.27 molding plate and housing

3. Assembling of lifting plate with sub-assembly-02 ………. Sub-assembly-03

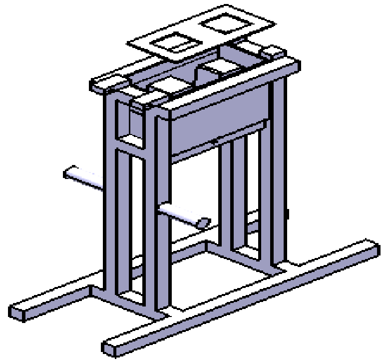


Figure 3.28 Lifting plate and housing

4. Assembling of bottom plate with Sub-assembly-03…Sub-assembly-04

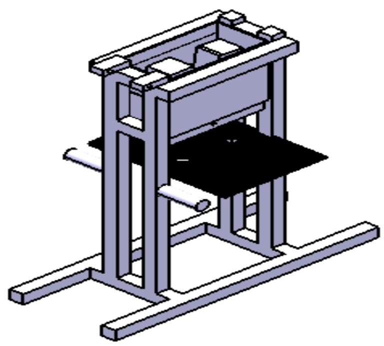


Figure 3.29 Bottom plate assemblies

5. Assembling of top plate, lifting frame, lever arm, and lifting connector with sub-assembly-04 ….. 05

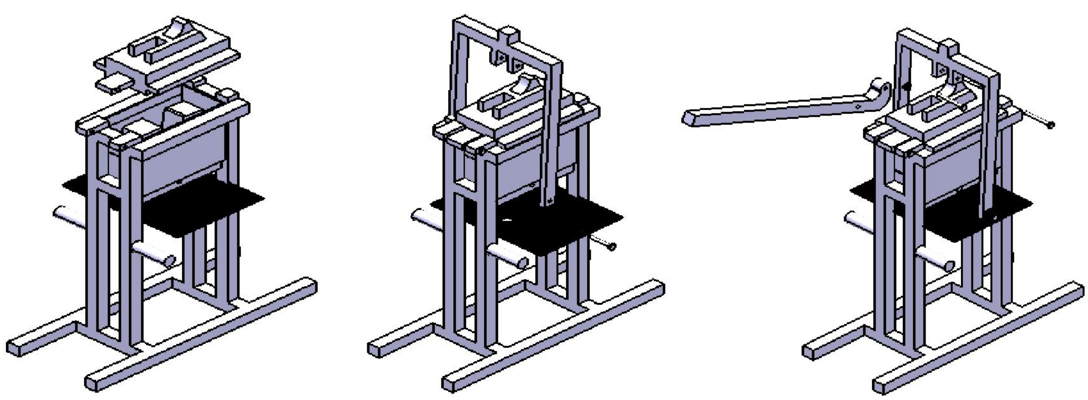


Figure 3.30 assembling the components

6. Final assembly of the project ….. 10

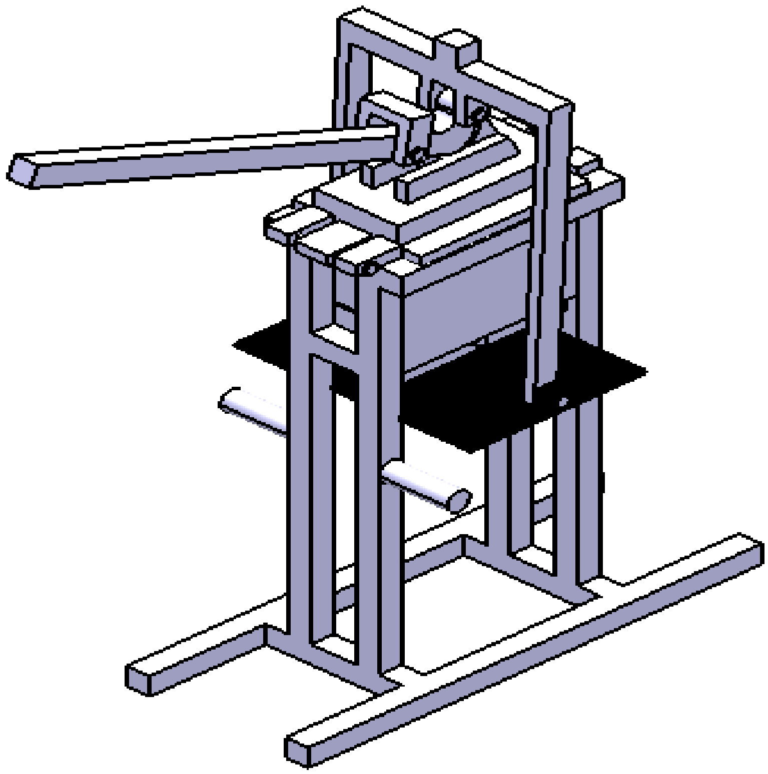


Figure 3.31 compression molding machine

7. Finishing, painting and testing of the machine to be functional.

3.2.3 Maintenance

Maintenance is "the work of keeping machine in proper condition or upkeep." This would imply that maintenance should be actions taken to prevent a device or component from failing or to repair normal equipment degradation experienced with the operation of the device to keep it in proper working.

❖ **The expecting problems in the machine and Maintenance**

The main expected problems in the operations of Manual compression molding machine and the elements that will require maintenance activities are: -

- Bolt and nuts are loosen or easily damaged or broken;

Bolts, nuts and other components of the machine are must be inspected for failure or breakage before using the machine in order to take action of maintenance by substitution for failed bolts and nuts or weld if parts of machine such as molding plate, housing, and lever arm etc. are fail.

- During the operation, vibration might be observed;

In order to reduce the vibration of machine during operation, first cause of vibration must inspect, the vibration may be caused due to loosely tighten bolt and nut, standing surface of the machine or due lack of lubricant. Therefore, machine component should be tightened correctly and machine should be placed on the flat horizontal surface and also each component of machine requiring lubrication must lubricated with right type of lubricant at the right time, at right place and in right quantity.

- Most parts of the machine might be corroded easily;

Corrosion reduce machine operation life therefore continuous inspection is necessary for the machine component in order to take preventive maintenance, it is essential to paint the machine even if the machine is not corrode ,every 240 working hours. Due to the above problems operator must be informed of the maintenance measures required and the operating instructions. The maintenance should be applied during working regularly.

3.3 Cost analysis of compression molding machine

This chapter computes the total cost by adding costs of raw materials and standard items, labor cost for manufacturing and assembling components , and Machine Depreciation Cost to manufactured parts required for compression molding Machine and also result and discussion is included.

3.3.1 Cost Analysis

❖ **Elements of cost established selling price**

Design and manufacture a product according to a certain specification by minimizing total cost and maximizing efficiency of the product or machine to meet service requirements is only one aspect of production. Based on these the design and manufacture of certain brick molding machine analysis should be done in order to be competitive. The way element of cost builds up to establish a selling price is shown on figure below

				Profit	Selling price
			Sales expense	Total cost	
		General expense	Manufacturing cost		
	Factory expense	Factory cost			
Material cost	Prime cost				
Labor cost					

Figure 3.32: Establishing of selling price [38]

The chief cost elements of direct material cost and direct labor cost determines prime cost. The factory expense such as power, maintenance, supply plus prime cost gives factory cost. The general expense such as marketing and sales cost, legal expense, and security cost, financial, and administrative plus factory cost gives manufacturing cost. The sales expense such as taxes, office stuff, and purchasing plus manufacturing cost gives total cost. (Total cost=manufacturing cost + sales expense). Finally the selling price established by adding a profit to the total cost for a business.

- **The costs of raw materials and the cost of standard items**

The material costs are refer to those materials which are consumed to produce a real components of our machine and the standard item costs are those costs which is purchased from a local markets/they are a finished product.

Table 3.10: costs of raw materials

No	Material Description	Size required	Unit	Qty	Unit price		Total price	
					Birr	Cent	Birr	Cent
1	Mild steel flat bar	150x85x10mm	pcs	1	3000	00	2000	00
2	Round bar	Dia. 50x180mm	pcs	4	300	00	1200	00
3	Round Bar	Dia. 30x38mm	pcs	1	1500	00	1500	00
4	Mild steel sheet metal	$60000mm^2$x4mm thick	pcs	5	600	00	3000	00
5	Mild steel sheet metal	300x200x3mm thick	pcs	3	600	00	1800	00
6	Mild steel hollow square bar	40x40mmx3mm thick and 8m long	pcs	3	550	00	1650	00
6	Mild steel hollow square bar	40x20mmx3mm thick and 3m long	pcs	1	550	00	550	00
Total cost							9900	00

Total Materials Cost = Cost of raw materials + Cost of Standard items

= 9990 Birr + 1164 Birr

➡ Total material Cost = <u>11,154 Birr</u>

Table 3.11: costs of standard item

No	Material Description	Size required	Unit	Qty	Unit price		Total price	
					Birr	cent	Birr	Cent
1	Hexagonal head screw	M6x30	Pcs	10	10	00	100	00
2	Hexagonal bolt with nut	M8x40	Pcs	4	8	00	32	00
4	Anti rust	Litter	Pcs	1	120	00	120	00
5	Drill bit	Dia. 6	Pcs	2	20	00	40	00
5	Drill bit	Dia. 8.5	Pcs	2	25	00	50	00
6	Brush	Big one	Pcs	2	50	00	100	00
7	Electrode	Dia. 2.5	Pcs	10	30	00	300	00
Total cost							1164	00

❖ Labour cost for manufacturing

It is the cost of the worker spend and making a product. The cost includes all the labor from the time materials are first handle to the time the product is finished.

Note:-I agreed about a labor cost will have paid 25.00 Birr per hour. For all components, I estimated the project labor cost as follows.

Table 3.12 Manufacturing Labor cost

No	Part name to be made	Qty	Operation	Working time in hr	Payment per hr	Labor cost price	Total cost of part
1	Housing	1	Measuring &cutting to size	1	25	25	100
			Lay out for drilling holes	0:30	25	12.5	
			Drilling	0:30	25	12.5	
			Welding	2	25	50	
2	Top plate And bottom plate	2	Measuring &cutting to size	2	25	50	200
			Lay out for drilling holes	1	25	25	

			Drilling	1	25	25	
			Welding	4	25	100	
3	Molding plate	1	Measuring &cutting to size	2	25	50	150
			Welding	4	25	100	
4	Compressing frame	1	Measuring &cutting to size	1	25	25	150
			Lay out for drilling holes	1	25	25	
			Drilling	1	25	25	
			Welding	3	25	75	
5	Handle	1	Measuring &cutting to size	1	25	25	125
			Lay out for drilling holes	1	25	25	
			Drilling	1	25	25	
			Welding	2	25	50	
6	Lifting connector	1	Measuring &cutting to size	0:30	25	12.5	50
			Lay out for drilling holes	0:30	25	12.5	
			Drilling	0:30	25	12.5	
			Welding	0:30	25	12.5	
7	Frame		Measuring &cutting to size	4	25	100	350
			Lay out for drilling holes	0:30	25	12.5	
			Drilling	0:30	25	12.5	
			Welding	8	25	200	
						Total	1125

❖ Labour cost for assembling components

Labor cost for assembling components

- Detail assembling of manufacturing components is indicated in section manufacturing process.
- To the total cost of labor, we should calculate the time spend for manufacturing & assembling of parts (components) of the project.
- The time needed for assembling components of our project is indicated as follows: -

Table 3.13: Assembling labor cost

No.	Type of assembly	Method of assembly	Working time in hr	Payment per hr	Labor cost price in birr
1	Assembly of housing with molding plate	Manual	1	25	25
2	Assembly of frame with sub assembly 1	Manual	1	25	25
3	Assembly of sub assembly 1 molding plate with bottom plate	Bolting	1	25	25
4	Assembly of top plate with frame	Bolting	1	25	25
5	Assembly of lifting frame with sub assembly 3 bottom plate	Bolting	1	25	25
6	Assembly of handle with sub assembly 5 lifting frame	Bolting	1	25	25
7	Assembly of lifting connecter with sub assembly 6 handle	Bolting	1	25	25
				Total	175

Total Labor Cost = Labor cost for manufacturing components + Labor cost for assembling

= 1125 Birr + 175 Birr

➡ Total Labor Cost = 1300 Birr

❖ Electrical power consumption cost

It is the cost of electric power needed to machine and weld parts of the project. Electric power is expressed (measured) by a unit watt (w) or kilo watt (Kw).The cost of electric power is expressed in birr per KWH. The electrical machines used and time consumed is indicated below:-

Table 3.14 Electrical power consumption hour

No.	Manufactured part	Qty.	Type of machines and their machining time in hour		
			Arc welding machine	Portable hand grinder	Drilling machine
1	Frame	1	3	3	0.30
2	Housing	1	1	0.30	0.30
3	Molding plate	1	2	1	0
4	Compressing frame	1	0.30	0.30	0.30
5	Bottom plate	1	1	0.30	1
6	Lever arm	1	0.30	0.30	0.30
7	Top plate	1	0.30	0.30	0.30
Total time			8.30	6.30	3.30

Now let's calculate the energy used for each machine multiplying their power rating with their machining time.

Note: - Power rating of each machine is taken from their life history card

Example-1 Power hack saw

Power rating (p) =0.75KW

Working time (t) =5:45hr

Energy consumed (E) =?

E=P x t= (0.75 x 5) + (0.75 x 0.45)

E=3.75KWH + 0.5625KWH

Energy consumed (E) = <u>4.3125KWH</u>

Example-2 Lathe machine

power rating (p) =2.2KW

working time (t) =19:10hr

Energy consumed (E) =?

E=P x t= (2.2x19) + (2.2 x 0.10)

E=26.4KWH + 1.833KWH

Energy consumed (E) =<u>42.167KWH</u>

Note: - the energy consumed for each machine is done with the same procedure of the above two examples

Note: - the electrical power cost for 1KWH is 0.70 Birr, source from EELPA

Table 3.15 Electrical power consumption cost

No.	Machine type	Power rating of the machine	Total machining Time in hour	Energy consumed In KWH	Payment for 1KWH in birr	Total payment In birr
1	Arc welding machine	4.9kW	8.30	40.67 KWH	0.70	28.469
2	Portable hand grinder	2kW	6.30	12.6KWH	0.70	8.82
3	Drilling machine	1.3kW	3.30	4.29KWH	0.70	3
Total cost						40.28

❖ Machine Depreciation Cost

Depreciation is defined as the reduction in value of the machine over time as it is working g at a specific task. Depreciation occurs due to wear that gradually declines the capacity of the piece of equipment to perform its function. The objective of the depreciation schedule is to recover the initial investment cost of equipment each year over its economic life .Straight-line method assumes that the value of the equipment reduces at a constant rate for each year over its economic life. The straight-line method is the simplest way for estimating depreciation costs and may be most preferable method to calculate equipment cost per unit of time. The mathematical formula for the yearly depreciation charge using the straight-line method is [38, 39]

$$D = (p-s)/N$$

Where, D = Depreciation charge

P = Initial purchase price (actual price)

S = Salvage value (take average 30% initial price P

N = Economic life (in year or scheduled machine hours)

Example: For this project the depreciation cost of power drilling machine is calculated as follows and the same is done for other machines

$$D= (p-s)/N$$

Where, D = Depreciation charge

P = 100,000

S = 30% 100,000=30,000

N = 10yrs

$$D= (p-s)/N = (100,000-30,000)/10yr =7000birr/yr$$

In one year we have 12 months, and the depreciation cost for a month, 7000/12 = 583.33Birr/month since there are 4 weeks in a month, the depreciation cost for a week=583.33/4= 145.833 Birr /week. In a week we have 5 working days the depreciation cost per day =145.833/5= 29.166 Birr/day. Further we have 8 working hours in a day so the depreciation cost per hour= 29.166/8= 3.65 Birr/hr.

Therefore the time period over which hourly depreciation of the machine that we have used to manufacture our product is already calculated. Therefore, we can take the depreciation of those machines from the university scheduled data. Therefore by summing up all the time for machining from the operation sheet we can calculate the total depreciation of these machines by multiplying the time we operated them and the hourly depreciation

Table 3.16 Depreciation cost of different machines

No.	Machine type	Life span in years	Machine price	Depreciations Values/hr		Usage time	Total Depreciations Values
				Birr	Cent		
1	Arc welding machine	5	30,000	2	19	8.30	18.17
2	Portable hand grinder	3	2000	0	24	6.30	1.50
3	Drilling machine	10	100,000	3	65	3.30	12.04
Total cost							31.70

3.3.2 Total cost of compression molding machine

- **Manufacturing cost**:-
  - Material cost ----------------------- = 11154 Birr
  - Labor cost ------------------------- = 1300 Birr
  - Electric power consumption cost = 40.28 Birr
  - Machine depreciation cost ------- = 31.70Birr

Manufacturing cost = 12525.98 Birr

- **Contingencies:** - it is compensation due to some errors and unexpected failure of time in this project it is usually taken as 10% of the manufacturing cost.

Contingency = 10% x 12525.98 Birr

=0.1 x 12525.98 Birr

Contingency = 1252.598 Birr

- **Total manufacturing cost** = Manufacturing cost + Contingency

= 12525.98 Birr + 1252.598 Birr

= 13778.60 Birr

- **Profit:** - it is usually taken as20% of the total cost.

Profit =0.2 x 13778.60 Birr

Profit = 2755.70 Birr

- **Selling price** = Profit + Total manufacturing cost
  = 2755.70 + 13778.60 Birr
  = 16534.30 Birr

Compression molding Machine useful life and depreciation cost

Depreciation occurs due to wear that gradually declines the capacity of the piece of equipment to perform its function. The objective of the depreciation schedule is to recover the initial investment cost of equipment each year over its economic life. It is not necessary that each individuals use a single method of computing depreciation for all depreciable assets. The four methods used most often are straight-line, unit of production, declining balance, and sum of the year digits. The unit of production method yields a depreciation charge that varies with the amount of asset usage [41]. The unit of production method is selected for estimating depreciation costs of compression molding machine. To apply this method the length of life of the machine is expressed in terms of productive hours. For Compression molding machine estimated operation hour is estimated to be 1100hr and estimated Residual value at the time retired from service is estimated to be 30% of selling price of the machine.

$$\text{Residual value} = \frac{30 \ \text{X}\ 16534.30}{100} = \mathbf{4960.30}\ \text{birr}$$

The mathematical formula for the hourly depreciation charge using the unit of production method is [41]

$$\text{Hourly depreciation} = \frac{\text{Celling price} - \text{Estimated residual value}}{\text{Estimated opration hours}}$$

$$= \frac{16534.30\ \text{birr} - 4960.30\ \text{birr}}{11000\text{hrs}} = \mathbf{1}\,\text{birr/hr}$$

Therefore hourly depreciation of compression molding machine is 1 birr/hr

3.4 Preparation and testing of sand- LDPE plastic composite brick

3.4.1 Introduction

The content in this Chapter evolve around the experimental work carried out to achieve the aims of the study. This Chapter first elaborates on the research materials and equipment used to conduct this research. Thereafter, it describes the methodology followed to prepare sand-LDPE plastic waste composite. Furthermore, it gives an introduction to test performed, sample preparation and test procedure to follow while performing test of the samples.

3.4.2 Materials

❖ **Waste plastic material**

Waste plastic bag were collected, washed and dried in the sun to remove the water and odors and then stored. The waste plastic (LDPE) have density of 0.901g/cm^3 from density test result of waste plastic given in appendix ‘C’.

(a), collected LDPE (b), washed LDPE (c), dried LDPE

Figure: 3.33 waste plastic material

- **River sand**

The fine aggregate which is used in this composition is the river sand which was obtained from brick manufacturing micro enterprise in Bishoftu town. The maximum size of sand is a size of sand passing through 1.18mm standard sieve. Test result of physical properties of the sand used is given in table 6.1 bellow.

Table 3.17: Physical properties of the sand used

No.	Property	Value
1	bulk density	1.6 g/cm^3
2	Sieve analysis	
	(a) size of Sand passing 1.18mm sieve	61.19%
	(b) size of sand >1.18 mm sieve	38.81%

- **Cement**

Normal Derban cement grade 32.5N obtained from local market is used at constant dosage as the chemical stabilizer for conventional cement brick used for comparison.

- **Water**

Water was used to do water absorption test of the SPC brick and conventional cement brick in 7 days and 28 days and used for mixing cement and coarse sand to produce cement brick.

3.4.3 Equipment

Some of the equipment used in the work includes the following

1. Balance for weighing the mass of sand and the waste plastic material

2. Electric oven (heater) for heating LDPE to form paste
3. Compression molding machine
4. Aluminum plate for melting in heater
5. Hydraulic compressive strength testing machine
6. Thermometer to measure temperature output range of thermostat connected to heater

(a), Electric oven (heater) (b), Compression molding machine (c), Strength testing machine

Figure 3.34: Equipments

3.4.4 Preparation of waste plastic and sand

The waste plastic bags were sundried in the open and batching by mass is done in 1:1, 1:1.2 and 1:1.5 ratios for sand and plastic respectively. All mixing ratio of sand to plastic by mass and respective mass percentage is shown in table below.

Table 3.18: Composition ratio of brick by mass

Brick Mix sample	Sand to plastic mix Ratio	% of Sand by mass	% of plastic by mass	Sand mass in kg	Plastic mass in kg	Total mass
M1	1:1	$X_1 = 50\%$	$X_2 = 50\%$	4kg	4kg	8kg
M2	1:1.2	$X_1 = 45\%$	$X_2 = 55\%$	4.4kg	3.6kg	8kg
M3	1:1.5	$X_1 = 40\%$	$X_2 = 60\%$	3.2kg	4.8kg	8kg

X_2 is the percentage of plastic within the mix by mass. It is composed of shredded plastic waste obtained from garbage. The utilization of this type of plastic would save the environment as these bags are non biodegradable materials which are mostly thrown away in a dumpsite; therefore, it is a costless unutilized resource calling for investment. X_2 was utilized in this thesis with percentages varying from 50% to 60% (table 6.2). The higher Percentage of X_2 was decided based on trial experimentations. When the percentage exceeded 60%, extremely low compressive strength and low density product is resulted. Therefore, it was decided afterwards not to increase the amount of plastic more than 60%. On the other hand, the minimum Percentage of X_2 (50%) was decided based on the objective of the thesis to remove waste plastic in the environment in high percentage using it as alternative building material. X_1 is river sand obtained from brick manufacturing micro enterprise in Bishoftu town. The maximum size of sand is a size of sand passing through 1.18mm standard sieve.

❖ Sand-LDPE composite preparation Processes In Brief

The processes start by draying the sample sand in an oven for 1 hour to eliminate the moisture within sand particles setting the oven temperature at $110C^0$. The drayed sand is then taken to be sieved into required size using sieve of sizes 1.18 mm to avoid more coarse sand and obtain a relatively homogenous sand particles. After sieving takes place, the sand is then batched in mass as given in table 6.2 by weighting the sand for each brick composition, and similarly the waste plastic is batched in mass as given in the table above for each brick composition.

After batching in mass is takes place the waste plastic is melted using an electric heater with appropriate mass proportion. The heater power control is set to (5) scale which gives temperatures of about $200C^0$ and complete melt of waste plastic is obtained after about few time (melting time is depend on weight of waste plastic). After the melt is formed, respective mass percent of sand is poured into the waste plastic bag melt. The mixture is manually stirred with a wooden stirrer till a homogenous mixture of the sand and waste plastic bag paste is formed.

The composite paste is then instantaneously taken into the molding machine to be pressed to prevent early hardening of the composite upon removal from the heater. Finally, storing and curing of brick are done to make the product ready for testing in accordance with the requirements of the testing standards.

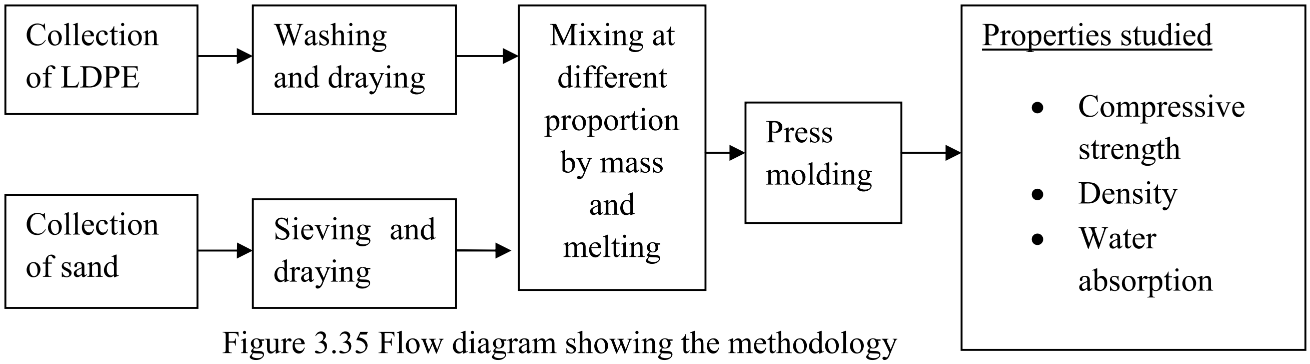


Figure 3.35 Flow diagram showing the methodology

❖ Sand-LDPE composite preparation Processes in Details

➢ Sand sieving

The fine aggregate which is used in this composition is the river sand which was obtained from brick manufacturing micro enterprise in Bishoftu town. The maximum size of sand used is a size of sand passing through 1.18mm standard sieve. Based on literature, the common adopted sizes of sand utilized for the production of composite range from 0.05mm to 1mm; where increasing particle size results in better flow of molten composite and lower mold shrinkage [42]. In other words, better properties are obtained when the size of particle increase. Based on this claim, it was decided to use all particles passing through 1.18mm standard sieves size.

➢ Sand draying

The heater used was set at 110 C^0 then the sand is left for 1 hour in the oven to get rid of the moisture. It was assured that the moisture was totally eliminated through a test that was done. The test includes taking all grain sizes of sand and left in oven for half hour then weight. It was weighed after each half hour. At the 3^{rd} and 4^{th} half hour the weight was not changed. Therefore, it was concluded that 1hours was sufficient to dry the sand appendix ‘C’ contains the weights of sand with each draying minutes and percent of water lost. Then, take all drayed sand passing through 1.18mm sieve, and weighs it in all proportion given in table 6.2.

- **Melting of plastic**

The plastic used are 50 %, 55 % and 60 % by mass percent for each sample proportion. At the beginning, a warm up period for the heaters for about 3 minute was prerequisite to set the heater body and aluminum pan at similar temperature of $200C^0 \pm 5C^0$ by setting thermostat scale of the heater on maximum scale 5. This is done using thermostat scale knob of the heater which have five scales of temperature. The thermostat scale and their measured corresponding temperature are given in appendix 'C'. The waste plastic is then loaded on aluminum pan turn by turn in mass percent of each sample proportion and the process starts by putting in the heater (figure 6.5). Setting the heaters temperature at $200C^0$, 3.6kg and 4kg plastic is melt totally within about 22min and 27min respectively, and 4.8kg plastic is melt within about 30min. When the temperature was dropped much less than 200Cº the plastic will not melt quickly therefore, consume more time to melt completely. Therefore the temperature of 200 Cº ± 5Cº is maximum temperature of this heater to get good melt in short time. The temperature was decided based on trial test aimed at forming a complete melt in short time.

Figure 3.36: Loading of waste plastic on the Aluminum plate

Figure 3.37 putting the waste plastic in heater

Figure 3.38: Regulating heating temperature

Figure 3.39: The final paste of the composite

- **Compression molding**

Before casting, the compression molding machine components were cleaned and the bolts were tightened then, sand waste plastic composite was transferred to the compression molding machine and compression molding chamber was filled with the composite paste and then, compression pressure was applied using lever arm of the machine till the pressure limit of the machine is reached (molding plate lift up and start to come down) to mold the composite in to required inter locking brick size. Then brick was removed from the moulds and stored for further testing after 7 days and 28 days as seen in figure 6.8 (a and b).

(a) Molding & removing

(b) storing for 7 days and 28 days

Figure 3.40: Molding and curing of SPC brick and cement brick for 7 and 28 days

3.4.5 Preparation of cement interlocking brick

The interlocking blocks of cement brick were produced using compression molding machine with size of 300mm x 150mm x 100mm. The materials used for the production of cement brick were measured by weight batching by 1:11 ratio of cement to aggregate in accordance to IS 2572 (2005): Construction of hollow and solid concrete block masonry [43, 44]. The mixing was done on an impermeable surface made free from all harmful materials which could alter the properties of the mix. The measured sand aggregate was spread using a shovel to large surface area. Cement was then spread evenly on the sand and thoroughly mixed with the shovel. The dry mixture was spread again to receive water which was added gradually while mixing, until the optimum moisture content of the mixture was attained. The wet mixture was filled into the compression molding machine and then compacted manually using the machine. Then, removing the brick from the machine, first allowed to air dry under a shade for 24 hours. Thereafter, curing was continued by sprinkling water morning and evening for 28 day then made ready for compressive strength test and water absorption test.

3.4.6 Testing Methods and procedures

In order to evaluate the performance of sand-LDPE composite brick, the following tests shown in Table 6.3 were conducted, details of which are given in the following sections.

Table 3.19 Tests conducted

No.	Tests conducted	Reference Standards
1	Compressive strength	IS : 3495, (Part I) 1976
2	Brick dry density	BIS 1725 , 1982
3	Water absorption	IS 3495 (Part II) 1976

❖ Compressive Strength Test

This test is done to know the compressive strength of brick. Compressive strength test is done in compression testing machine. The brick is placed between the jaws and load is applied gradually. Precaution is taken allow that load would be applied to all surface portion of the brick, by removing inter locking portion of the brick. Gradual load is applied over the complete area till the failure occurs and notes the maximum load at failure (figure 3.41). The load at failure shall be the maximum load at which the specimen fails to produces any further increase in indicator reading on compression testing machine. Two specimens of bricks were taken to laboratory for testing for each proportion of LDPE and cement brick, and tested one by one. Compressive strength test were carried out on 300 mm X 150mm X 100mm specimen. The compression test of brick is conducted as per specification Indian standards IS 3495:1976 [40]. Specimen is tested after 7 and 28 days.

Procedure:

1) Two composite bricks for each proportions of LDPE and two cement bricks were manufactured.
2) Each brick was placed in the test area in the ascending order of plastic content.
3) Load was applied until the brick broke.
4) The maximum load at crushing in kN was noted

Compressive strength = Maximum load at failure / Avg. area at bed face

(a) Interlocking Bricks

(b) Testing   Procedure   (c) compressive Testing

Figure 3.41: compressive Testing

❖ Water Absorption Test

Water absorption is the measure of the amount of water the brick unit absorbs when placed in water for 24 hours. It is conducted as per Indian Standard IS 3495:1976 [40]. The dry weight of sample is found and it then immersed in water bath for 24 hours. Then the sample is taken out, wiped with dry cloth and its wet weight is found. The water absorption percent is calculated by dividing the gain in weight by dry weight of brick and multiplying with hundred. Bricks have pores in them. Due to porosity, the dry bricks when come into contact with water absorb water through these pores. Smaller the porosity; lesser is the absorption. In this test, bricks are weighed in dry condition and let them immersed in fresh water for 24 hours. After 24 hours of immersion, those are taken out from water and wipe out with cloth. Then, brick is weighed in wet condition. The difference between weights is the water absorbed by brick. The percentage of water absorption is then calculated. The less water absorbed by brick the greater its quality. Good quality brick doesn't absorb more than 20% water of its own weight.

Procedure:-

1) Dry the specimen in a ventilated area till it attains considerably constant mass
2) Obtain specimen mass (M_1)
3) Immerse completely dried specimen in clean water at room temperature for 24 hours
4) Remove the specimen and wipe out any traces of water with damp cloth and weigh the specimen after it has been removed from water (M_2).
5) Calculate Water absorption % after 24 hours immersion in water using bellow formula.

Percent of water absorption of brick = $\frac{(\text{Mass of wet brick} - \text{Mass of dray brick})}{\text{Mass of dray brick}} X100$

❖ Density Test

Dry density of samples with different composition of LDPE is determined as per Indian Standard IS 1725 (1982) [45]. The results are analyzed for the effect of LDPE content.

Procedure:-

1) Dry the specimen in a ventilated area till it attains considerably constant mass
2) Obtain specimen mass (M)
3) Obtain specimen volume (V)
4) Determine dray density of the specimen using bellow formula.

$$\text{Dray density } (\rho) = \frac{M}{V}$$

Where: - ρ is dray density, M is mass of specimen and V is volume of specimen

CHAPTER FOUR

TEST RESULTS AND DISCUSSION

4.1 Introduction

The property of the sand-LDPE plastic waste composite was examined by focusing on the influence of percentage of LDPE plastic waste to the sand. Based on the experiments elaborated in Chapter 3, this Chapter presents the test results, analysis and discussions of Compression tests, water absorption test and tensile strength test and density test performed on sand-LDPE plastic waste composite brick.

4.2 Effect of percentage of waste plastic on compressive strength

As defined earlier in Chapter 3 the compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. Compressive strength test is carried out on sand-LDPE plastic waste composite brick and conventional cement brick and the average result is given in table 4.1 and table 4.2 for 7 and 28 days.

Table 4.1: compressive strength test results of 7 days Brick

Percentage of waste plastic by mass	Area of brick In (mm^2)	Load (kN)	Compressive strength in (N/mm^2)	Average Compressive strength in (N/mm^2)
		7days		7days
50% (1:1 ratio)	$44872mm^2$	213	4.74	4.7
		211.9	4.72	
55%(1:1.2 ratio)	$44872mm^2$	198.3	4.41	4.4
		198.9	4.43	
60%(1:1.5 ratio)	$44872mm^2$	194.5	4.33	4.3
		197	4.39	
Cement brick by 1:11 ratio of cement to aggregate	$44872mm^2$	94.4	2.10	2.1
		97.5	2.17	

Table 4.2: compressive strength test results of 28 day Brick

Percentage of waste plastic by mass	Area of brick In (mm^2)	Load (kN)	Compressive strength in (N/mm^2)	Average Compressive strength in (N/mm^2)
		28days		
50%(1:1 ratio)	44872mm^2	214	4.76	4.7
		211	4.70	
55%(1:1.2 ratio)	44872mm^2	198	4.41	4.4
		198	4.41	
60%(1:1.5 ratio)	44872mm^2	195.4	4.35	4.3
		198	4.41	
Cement brick by 1:11 ratio of cement to aggregate	44872mm^2	179	3.98	3.99
		180	4	
standard requirement of compressive strength [44,46]	For hollow brick of grade 'A'			3.5-12
	For hollow brick of grade 'B'			3.5-5
	For hollow brick of grade 'C'			Not less than 2.5 N/mm^2

As shown in table 4.2, 50% LDPE waste plastic has an average compressive strength of 4.7 N/mm^2, 55% LDPE waste plastic has average compressive strength of 4.4 N/mm^2; and 60% LDPE waste plastic has compressive strength of 4.3 N/mm^2 and also, the prepared cement concrete brick strength is 3.99 N/mm^2. From the test conducted it can be observed that as the percentage of waste plastic increases, the compressive strength of the brick decreases for both 7 days and 28 days brick. This fall in compressive strength is due to the increase in plastic loading without reinforcing sand in proportion to plastic, when waste plastic is reinforced with more amount of sand the composite result in higher compressive strength due to strengthening effect of sand in polymer matrix. The decrease in compressive strength is also due to flexibility property of composite brick is increased as percentage of plastic is increasing more than sand content; this result in easily yielding and cracking when subjected to compressive load.

The failure of conventional cement brick was very quick during compression test, in contrast to the compression test of sand-LDPE composite brick where, the deformation of the brick still continued, even after the ultimate load, and fine cracks were seen on the specimens. From the figure 4.1 it can be seen that the compressive strength of the composite is similar as the days increase from 7 days to 28 days. But, compressive strength of conventional cement brick is increase as days increase from 7 days to 28 days. For sand-LDPE composite brick waste plastic percentage dependence is significantly stronger than the aging dependence therefore, Sand-LDPE plastic composite brick is preferable than conventional cement brick since, can be available for use in few day after manufactured unlike concrete brick which require aging time of 28 days.

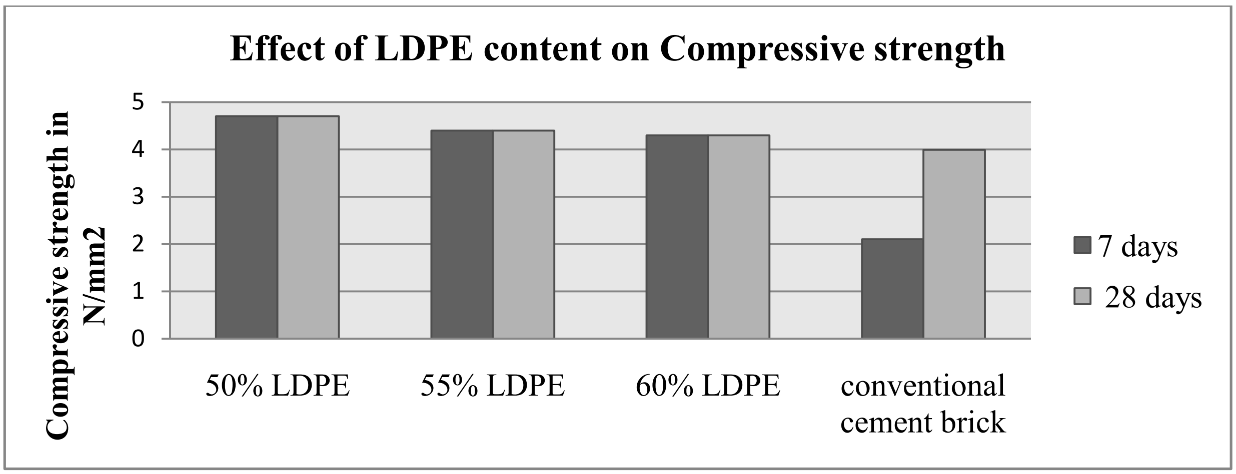


Figure 4.1: Effect of LDPE content on Compressive Strength

Based on the results obtained in this test, it was found that the three brick mix (M1,M2 and M3) at age 7 and 28 days have compressive strengths meets the standard strength values of hollow brick as Indian Standard (IS IS 2185-1 (2005))[46]. Compared to minimum requirement of 'A' grade standard hollow cement brick of Indian Standard (IS IS 2185-1) [46] , the sand-LDPE composite brick have shown an increase of 34.5 %, 25.7% and 22.8% in Compressive strength for 50%, 55% and 60% waste plastic content respectively. The maximum quantity of LDPE must be used for production of sand-LDPE composite brick is concluded to be limited to 60% plastic content by mass, considering the maximum mass percentage LDPE removed from environment, strength and density.

As per IS 2185 (part 1)-2005 [46] the brick which are to be used in general building construction when tested in accordance with the procedure laid in the standard IS 3495 (Part I), 1976 [40] shall have a minimum average Compressive strength of not less than 4N/mm^2 for grade 'A', 3.5 N/mm^2 for grade 'B' and 2.5 N/mm^2 for grade 'C'. Sand-LDPE composite brick have compressive strength of 4.7N/mm^2, 4.4N/mm^2, and 4.3N/mm^2 for 50%, 55% and 60% plastic content respectively which is higher than minimum requirement. Therefore sand-LDPE composite brick can be used for general building construction like fence, non load bearing partition wall and as paving brick in the garden [46].

4.3 Effect of LDPE content on Water Absorption

As mentioned in Chapter 6 bricks those of 28 day were undergone water absorption test. Bricks have pores in them. Due to porosity, the dry bricks when come into contact with water absorb water through these pores. Smaller the porosity; lesser is the absorption. The less water absorbed by brick the greater its quality. Good quality brick doesn't absorb more than 20% of water of its own weight. The test result is given in table 4.3.

Water absorption affects the bond strength and durability of bricks. In addition to that, higher value of water absorption causes cracks on plasters (gesso) as well as damage to the wall finish. Table 4.3 shows that the water absorption of 50%, 55% and 60% plastic brick is 2.23%, 1.99% and 0.99% respectively, this satisfies the criteria of maximum limit of 20% of its own weight specified in IS 2185 (part 1)-2005 [46]. The values of water absorption for standard hollow cement brick of grade 'A' and 'B' are represent in table 4.3. It has been observed that both cement bricks are highly water absorbent material. Therefore, cement brick tends to have higher water absorption value than plastic composite brick.

Table 4.3: Effect of LDPE content on Water Absorption

Percentage of waste plastic	% of water absorption		
	28 days brick		
	Dray weight in (g)	Wet weight in (g)	% of Water Absorbed
50%	5686	5813	2.23
55%	5573	5684	1.99
60%	5246	5298	0.99
Cement brick by 1:11 ratio of cement to aggregate	5980	6705	12.12
Water absorption of standard Hollow cement brick [44,46]	Grade	A	Max 16
		B	Max 20

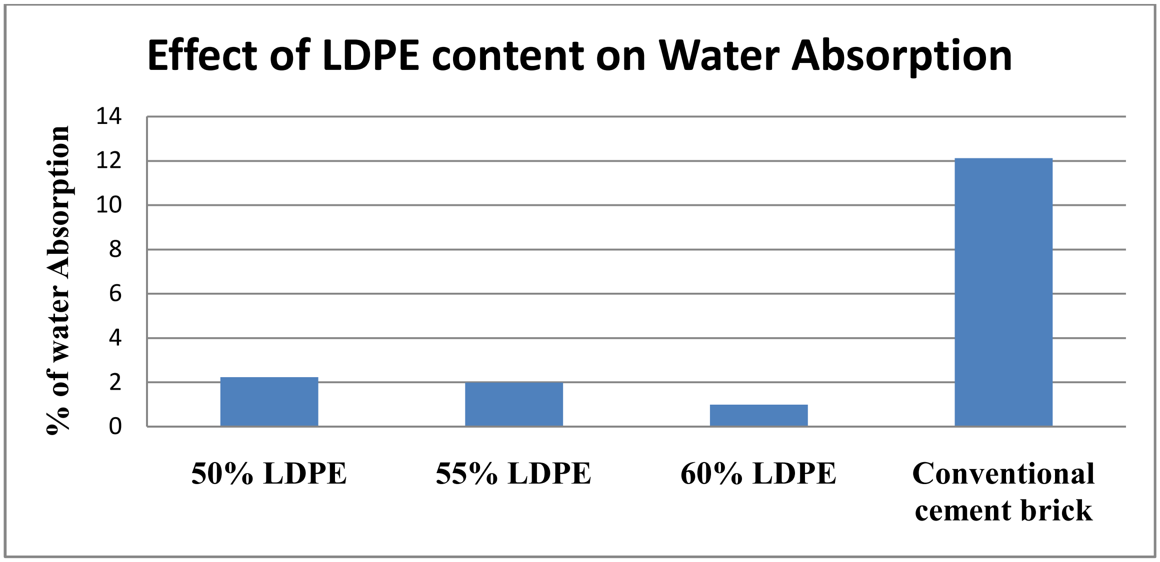


Figure 4.2: Effect of LDPE content on Water Absorption

Generally, as per IS 2185 (part 1)-2005 [46] the brick which are to be used in general building construction when tested in accordance with the procedure laid in the standard BIS 3495 (Part I), 1976 [40] shall have a maximum water absorption of not more than 16% for grade 'A', 20% for grade 'B'. Sand-LDPE composite brick have water absorption less than the permissible value of 20% by weight as per IS 2185 (part 1)-2005, Therefore sand-LDPE composite brick satisfies the criteria of maximum limit of water absorption value of the standard hence, it can be used for general building purpose like outdoor construction which has harsh environment condition requiring expose to water and decaying.

4.4 Effect of LDPE content on Density

Dry density of samples with different mass composition of LDPE was determined. The result is analyzed for the effect of LDPE content as described below. Table 4.5 and Fig 4.4 show the effect of LDPE content on the density. The density of the sand-LDPE composite brick samples are decreasing with every increase in percent of LDPE content. The density of the sample decreasing from 1.12 g/cm^3 for 50% LDPE to 1.02 g/cm^3 for the 60% LDPE. The decrease in density is due to low bulk density of LDPE. However, except for 60% LDPE composite brick, These values are between the desirable limit of a hollow cement brick of grade 'B' which is specified as 1.1g/cm^3 to 1.5 g/cm^3 in IS 2185 (part 1) 2005 [46]. Therefore, sand-LDPE composite brick can be used for applications related to grade ‘B’ bricks like non load bearing constructions, fence wall building and partition wall building [46].

Table 4.4: Effect of LDPE content on density

Percentage of waste plastic	Dray weight in (g)	Volume in (cm^3)	Density (g/cm^3)	Average Density in (g/cm^3)
50%	5686	5062	1.12	1.12
	5740		1.13	
55%	5573	5062	1.10	1.10
	5600		1.11	
60%	5246	5062	1.03	1.02
	5166		1.02	
Cement brick by 1:11 ratio of cement to aggregate	5980	5062	1.18	1.18
	5976		1.18	
standard requirement of density [44,46]	For hollow brick of grade ‘A’			1.5
	For hollow brick of grade ‘B’			1.1 to 1.5

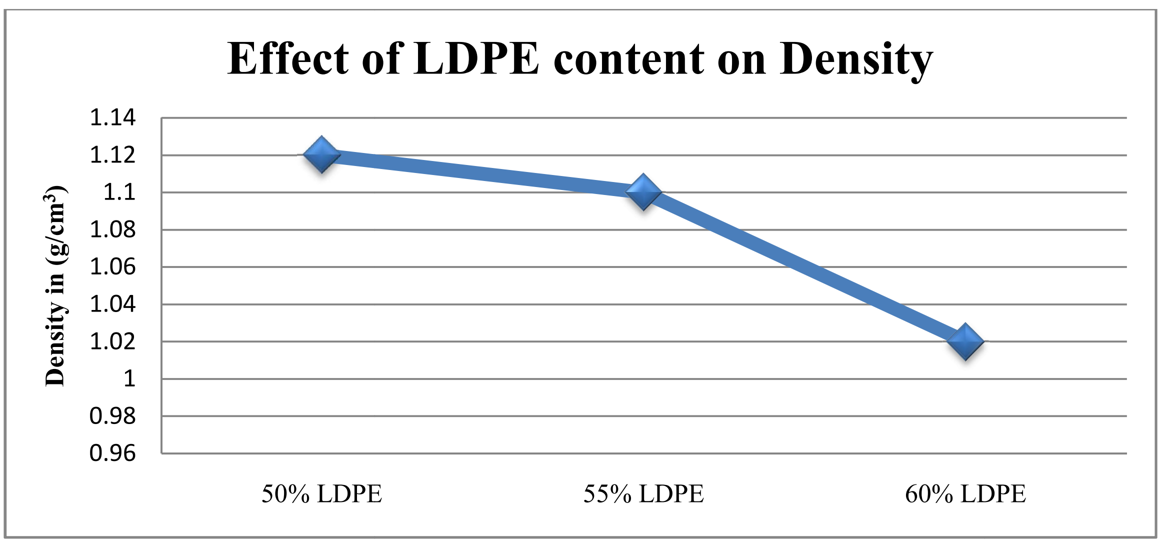


Figure 4.3: Effect of LDPE content on density

4.5 Cost comparison Analysis of Composite brick and Concrete brick

The unit cost of the cement interlocking brick and sand-LDPE composite interlocking bricks were calculated as follows.

➢ Unit cost of cement interlocking brick

Mix Ratio = 1:11 (that is 1kg of ordinary cement to 11kg of sand aggregate). This translates to one bag of ordinary cement to 550kg of sand aggregate, since one bag of ordinary cement is equal to 50kg of cement. The cost of one bag of ordinary cement is 120 birr and cost of 50kg of sand aggregate is 40 birr at the time of carrying out the research.

11kg of sand aggregate @ 0.8 birr ……………………………………= 8.80 birr

1 kg cement @ 2.4 birr ………………………………………………. = 2.4 birr

Total …………………………………………….....= 11.2 birr

For 6kg cement brick, 11.2 birr material produced 2 bricks.

Cost of materials for producing 1 unit of 6kg cement brick…………… = 5.6 birr

Assume 10% for labor cost…………………………………..……… = 0.56 birr

Assume also 20% for plant and others ………………………………..= 1.2 birr

Total cost incurred in producing one unit of 6kg cement brick …………. = 7.30 birr

➢ Unit cost of 50% sand-LDPE composite interlocking brick

Mix Ratio = 1:1 (that is 50% by mass of sand to 50% of LDPE plastic waste by mass). This translates to 3kg of sand to 3kg of LDPE plastic waste for 6kg composite brick. The cost of LDPE plastic waste is waste plastic collection cost which is 20 birr (researchers' assumption) for 50kg waste plastic and cost of 50kg of sand aggregate is 40 birr at the time of carrying out the research.

3kg of LDPE @ 0.4 birr ………………………………………….... = 1.20 birr

3kg of sand @ 0.8 birr ……………………………….………..………. = 2.40 birr

Total…………………………………..………. = 3.60 birr

Cost of materials for producing 1 unit of 6kg composite brick is …………....= 3.60 birr

Assume 10% for labor cost ……………………………………..…….……= 0.36 birr

Assume also 20% for plant and others……………………………………….. = 0.72 birr

Power rating of heater used for melting LDPE plastic waste is (p) = 2KW & melting time for 3.5kg, 4kg, and 4.8kg plastic is about 22, 27 and 30minutes respectively.

Energy consumed (E) = P x t= 2KW x 0.36hr = 0.72KWH ...= 0.72X0.70 birr=0.50 birr

(The electrical power cost for 1KWH is 0.70 Birr, source from EELPA)

Total cost incurred in producing 50% sand-LDPE composite brick ………...= 5.18 birr

➢ Unit cost of 55% sand-LDPE composite interlocking brick

Mix Ratio = 1:1.2 (that is 45% by mass of sand to 55% of LDPE plastic waste by mass). This translates to 2.7 kg of sand to 3.3kg of LDPE plastic waste for 6kg composite brick.

3.3kg of LDPE @ 0.4 birr ………………………………………….... = 1.32 birr

2.7kg of sand @ 0.8 birr …………………………….……..………. = 2.16 birr

Total…………………………………..………. = 3.48 birr

Cost of materials for producing 1 unit of 6kg composite brick………....= 3.48 birr

Assume 10% for labor cost ……………………………………..…= 0.34 birr

Assume also 20% for plant and others…………….……..…………… = 0.69 birr

Energy consumed (E) = P x t= 2KW x 0.36hr = 0.72KWH ...= 0.72X0.70 birr=0.50 birr

Total cost incurred in producing 55% sand-LDPE composite brick = 5 birr

➢ Unit cost of 60% sand-LDPE composite interlocking brick

Mix Ratio = 1:1.5 (that is 40% by mass of sand to 60% of LDPE plastic waste by mass). This translates to 2.4kg of sand to 3.6kg of LDPE plastic waste for 6kg composite brick.

3.6kg of LDPE @ 0.4 birr …………………………………………..... = 1.44 birr

2.4kg of sand @ 0.8 birr ……………………………..……..………. = 1.92 birr

Total…………………………………..………. = <u>3.36 birr</u>

Cost of materials for producing 1 unit of 6kg composite brick…………….= 3.36 birr

Assume 10% for labor cost ……………………………………………………= 0.33 birr

Assume also 20% for plant and others………………………..………………. = 0.67 birr

Energy consumed (E) =P x t= 2KW x 0.45hr = 0.9KWH = 0.9X 0.70 birr = 0.63 birr

Total cost incurred in producing 60% sand-LDPE composite brick………...= <u>4.93 birr</u>

The unit cost of sand-LDPE composite inter locking brick and cement inter locking brick are 7.30 birr, 5.18 birr, 5 birr and 4.93 birr for cement, 50%, 55% and 60% sand-LDPE composite brick respectively. These show that cost comparison between cement brick and 50%, 55% and 60% sand-LDPE composite brick have difference of 2.12, 2.30 and 2.37 birr respectively. The reason for this is that, sand-LDPE composite inter locking brick is manufactured from waste plastic which is available in environment without cost (very low cost) and substitute the expense of cement which rise the cost of cement brick. Composite inter locking brick is cheaper in unit cost than cement brick. Therefore san-LDPE composite inter locking brick can be used as alternative for construction of inexpensive building.

4.6 Application of Sand-LDPE composite brick

- Sand-LDPE composite brick of 50 % and 55% LDPE content have average compressive strength of 4.7 N/mm^2 and 4.4 N/mm^2 respectively; this strength serves mostly for non-load bearing building elements such as exterior and interior constructions such as partition, panel walks and fence walls construction confirming IS 2185 (part 1) 2005 which is standard hollow brick of grade ‘B’ with compressive strength between 3.5 N/mm^2 & 5 N/mm^2.

- Sand-LDPE composite brick behaves more ductile and can store more elastic energy compared to conventional cement brick. This renders it more resistance to earthquake force and used for inhibition of large crack propagation after initial formation during failure of brick; which is one of the major advantages of sand-LDPE composite brick.
- Sand-LDPE composite brick have water absorption of 2.23%, 1.99%, and 0.99% for 50%, 55% and 60% plastic content respectively which is less than the permissible value of 20% by weight as per IS 2185 (part 1) 2005. Therefore sand-LDPE composite brick can be used for general building purpose like outdoor construction which has harsh environment condition requiring expose to water and decaying.
- Sand-LDPE composite brick of 50 % and 55% LDPE content have average density of 1.1g/cc; this density serves mostly for non-load bearing building elements such as balcony railings, partitions, parapet and fence walls as IS:2185 (part 1) 2005 standard hollow brick of grade 'B' and density between 1.1g/cc & 1.5g/cc.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The main conclusions arising out of this research work are summarized as following:-

- Compared to minimum requirement of standard hollow cement brick, sand-LDPE composite brick have shown an increase of 34.5 %, 25.7% and 22.8% in Compressive strength for 50%, 55% and 60% LDPE content respectively. The maximum quantity of LDPE is considered to be limited to 55% by mass, considering maximum volume of LDPE removed from environment, Strength, density and the cost.
- Water absorption reduces from 2.23% to 0.99 % when the LDPE content is increased from 50% to 60%. In any case, the water absorption of samples with 50% to 60% LDPE was less than the specified value of 20% and satisfied standard requirement of IS: 2185-2005: Specifications for cement bricks used for general building construction.
- Measured density of the specimens was decreased from 1.12 g/cc to 1.02g/cc for 50% to 60% LDPE composite brick. Except for 60% LDPE composite brick; these values are in range of desirable limit of 'B' grade cement hollow brick which is specified as 1.1 to 1.5 g/cc according to IS:2185.The decrease in the density is due to low bulk density of LDPE.
- The unit cost of sand-LDPE composite inter locking brick are 5.18 birr, 5 birr and 4.93 birr for 50%, 55% and 60% LDPE respectively, while that of conventional cement brick is 7.30 birr. It was concluded that unit cost of sand-LDPE composite interlocking bricks are cheaper than conventional cement hollow brick.
- Sand-LDPE composite bricks are applicable for non-load bearing building elements such as partition wall, panel walks, fence wall construction, balcony railings and parapet construction depending on the compressive strength, density and water absorption property of the composite

5.2 RECOMMENDATIONS

From this work and its findings the following recommendations are suggested for future work

- The composite mixers used in mixing the content to give it a uniform mix should be considered in the future. The manual stirring using the rod could not ensure a uniform mixture of the composites as was required.
- Electrical properties, flexural strength and chemical test of waste plastic composites can be evaluated to further understand the behavior of the composite
- The thermal properties of the composite should be investigated and worked on in future work
- The current study is limited to compression, density and water abrasion properties only. It can be extended to other tests like flammability and life time tests.
- Particle size of the material used should be considered as a parameter in future studies.

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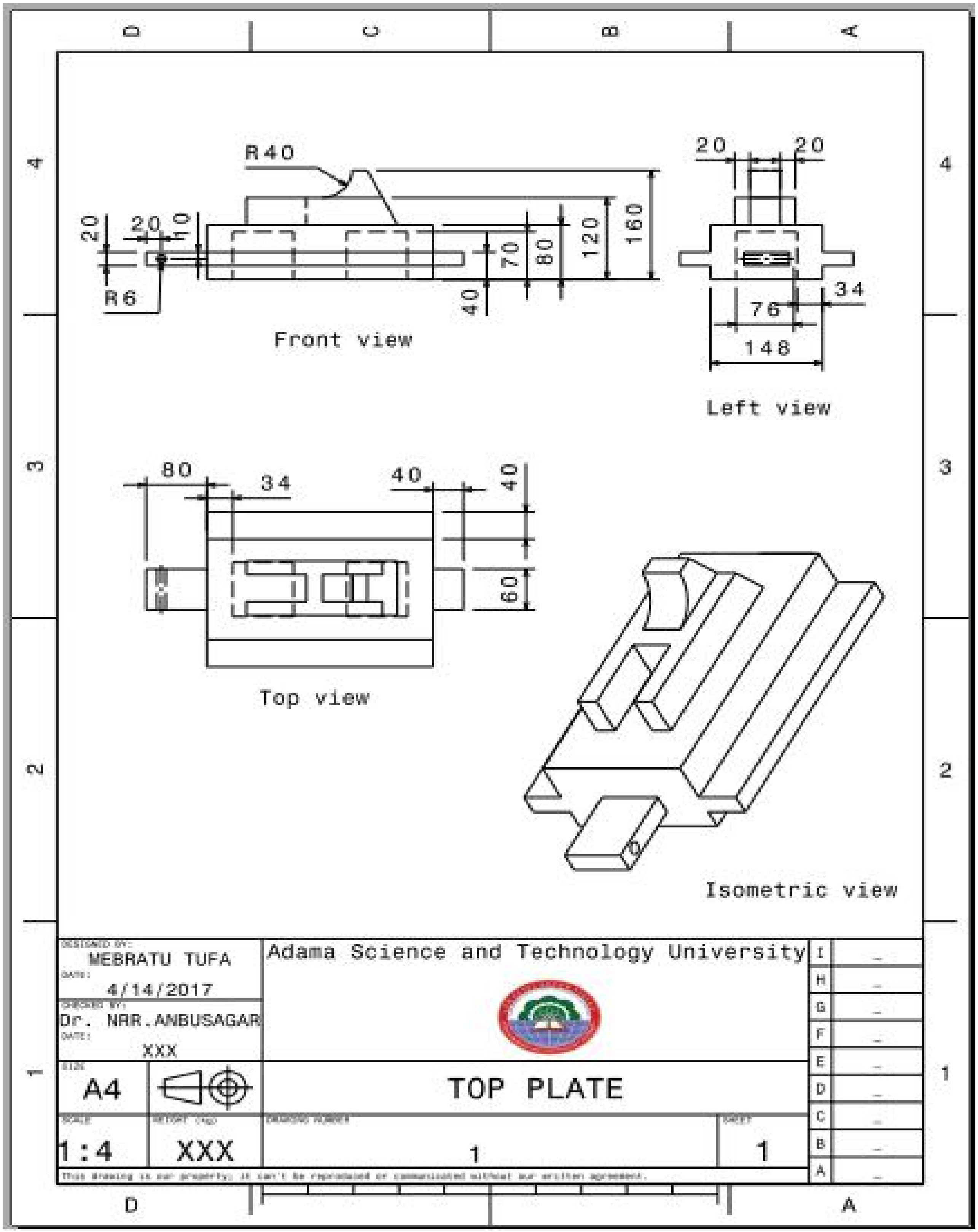
APPENDIX

APPENDIX A

Detail and assembly drawing

Detail drawing shows each and individual part drawing of the project or machine. The parts are drawn with appropriate scale whereas assembly drawing shows the overall view of the project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160
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R6
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34
76
148
Left view
80
34
40
40
60
Top view
Isometric view
DESIGNED BY:
MEBRATU TUFA
DATE:
4/14/2017
CHECKED BY:
Dr. NRR.ANBUSAGAR
DATE:
XXX
Adama Science and Technology University
SIZE
A4
TOP PLATE
SCALE
1:4
WEIGHT (kg)
XXX
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SHEET
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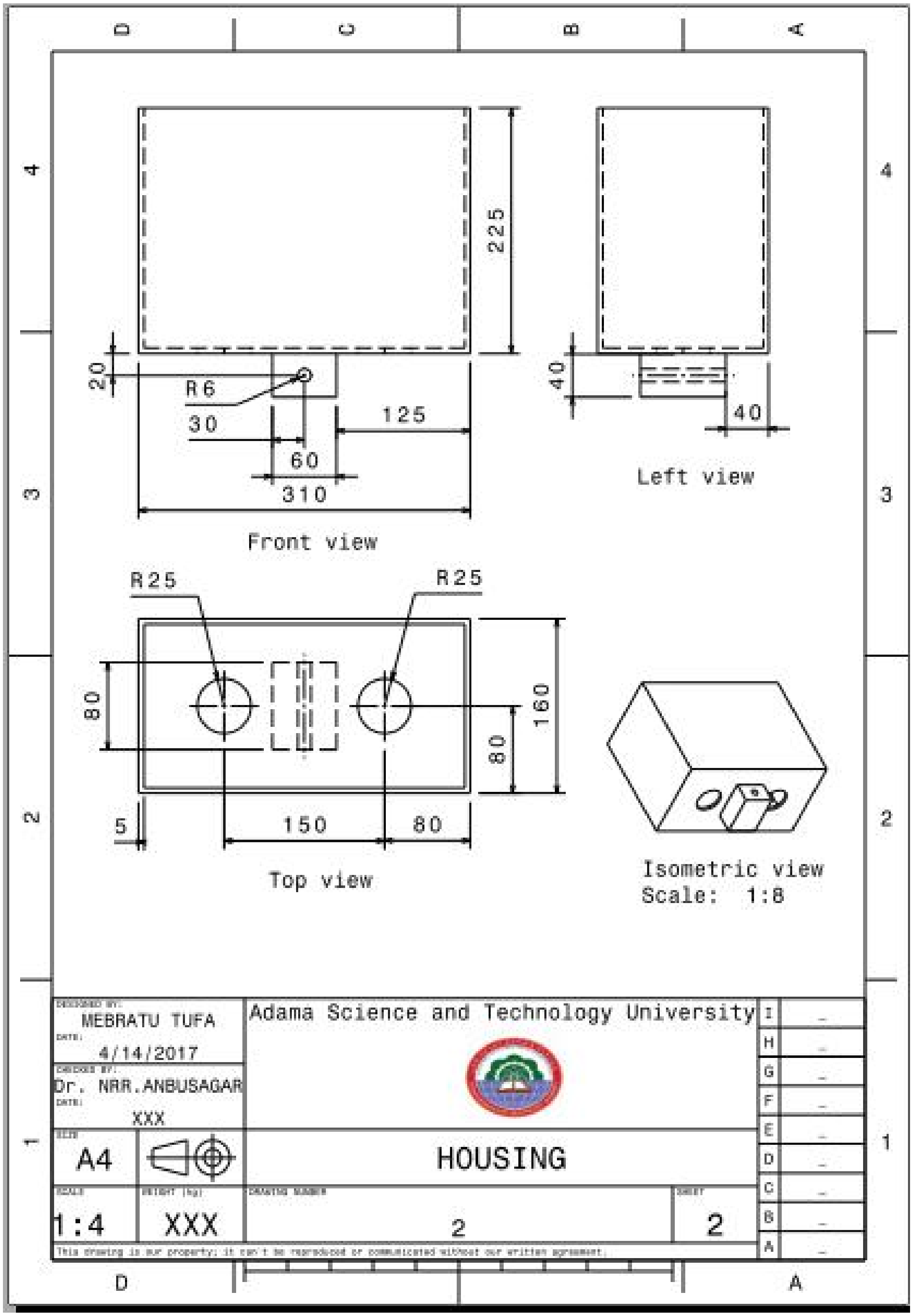
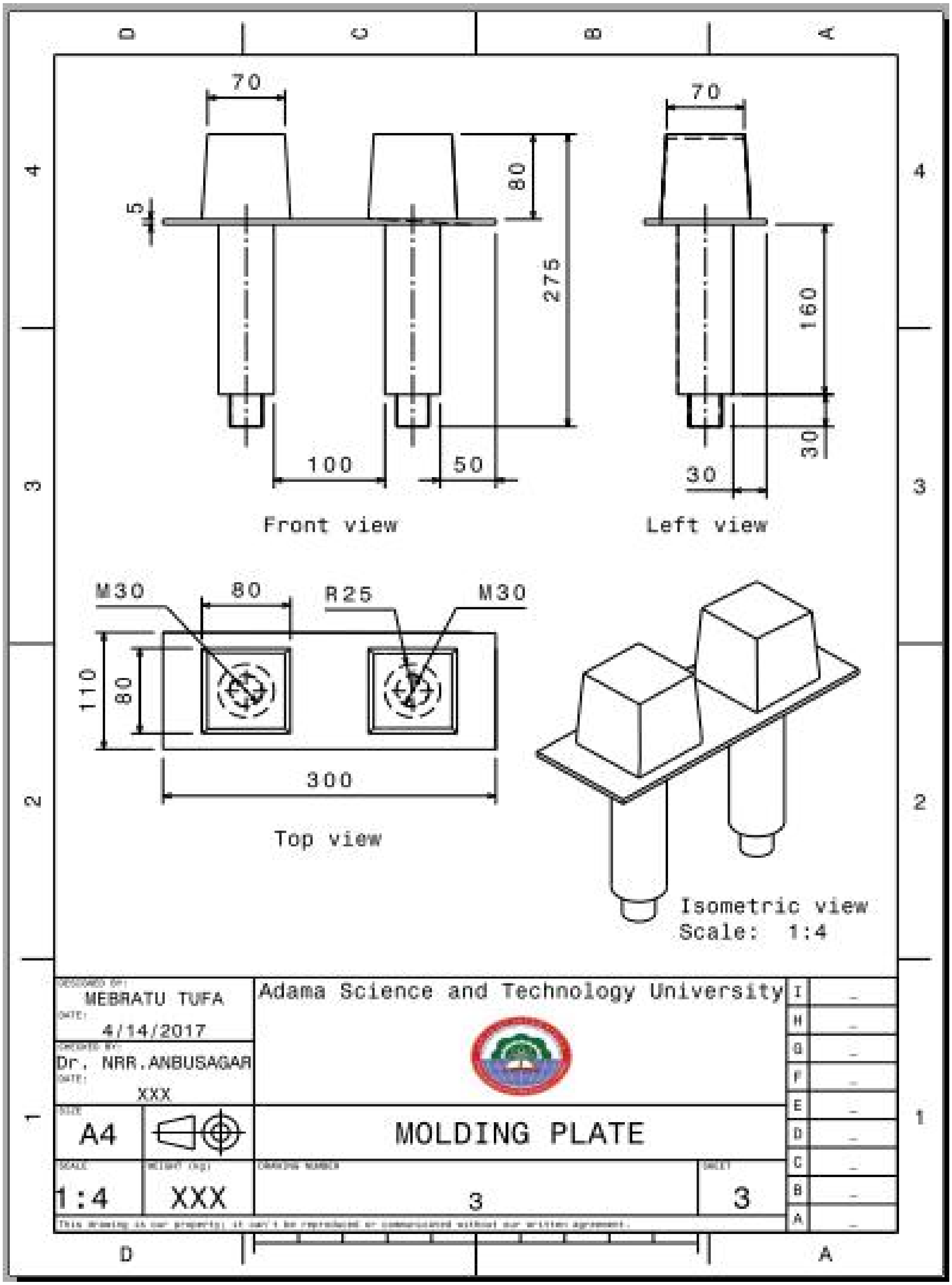


225
20
R6
30
125
60
310
Front view
40
40
Left view
R25
R25
80
160
80
5
150
80
Top view
Isometric view
Scale: 1:8
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
XXX
Adama Science and Technology University
A4
HOUSING
1:4
XXX
2
2



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80
5
275
100
50
Front view
70
160
30
30
Left view
M30
80
R25
M30
110
80
300
Top view
Isometric view
Scale: 1:4
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
XXX
Adama Science and Technology University
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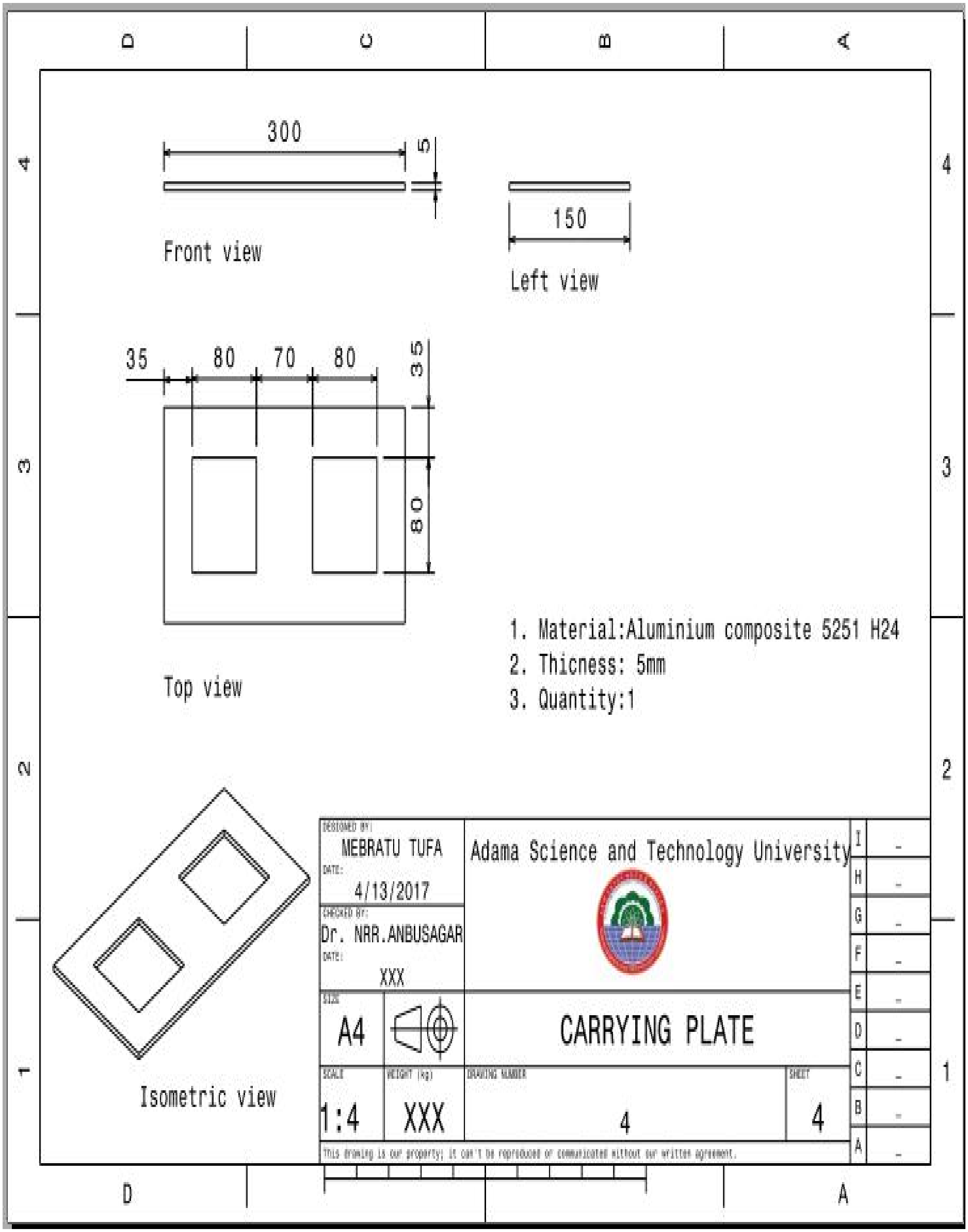
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Left view
35
80
70
80
35
80
Top view
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3. Quantity:1
Isometric view
DESIGNED BY:
MEBRATU TUFA
DATE:
4/13/2017
CHECKED BY:
Dr. NRR.ANBUSAGAR
DATE:
XXX
Adama Science and Technology University
SIZE
A4
CARRYING PLATE
SCALE
1:4
WEIGHT (kg)
XXX
DRAWING NUMBER
4
SHEET
4
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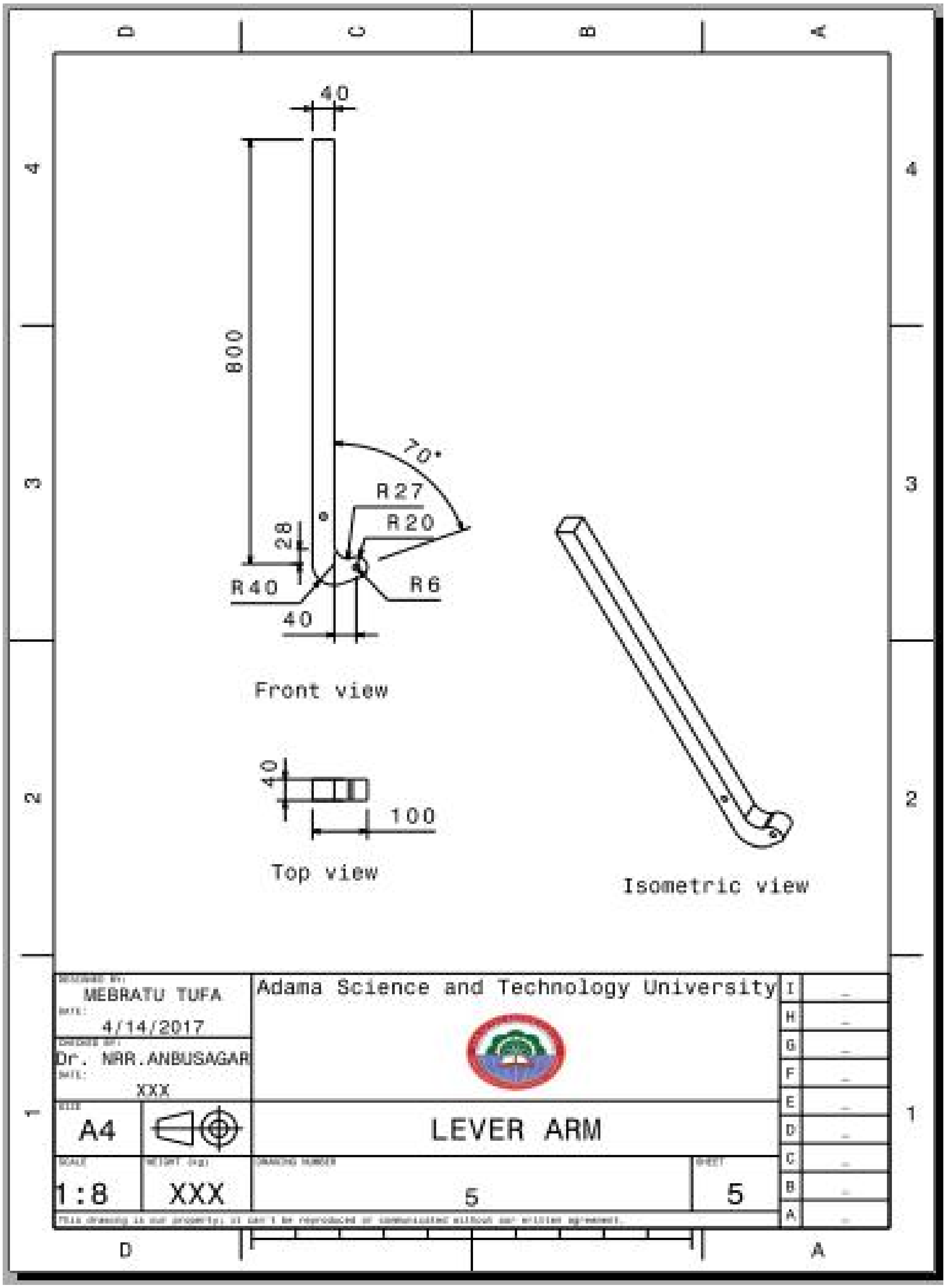
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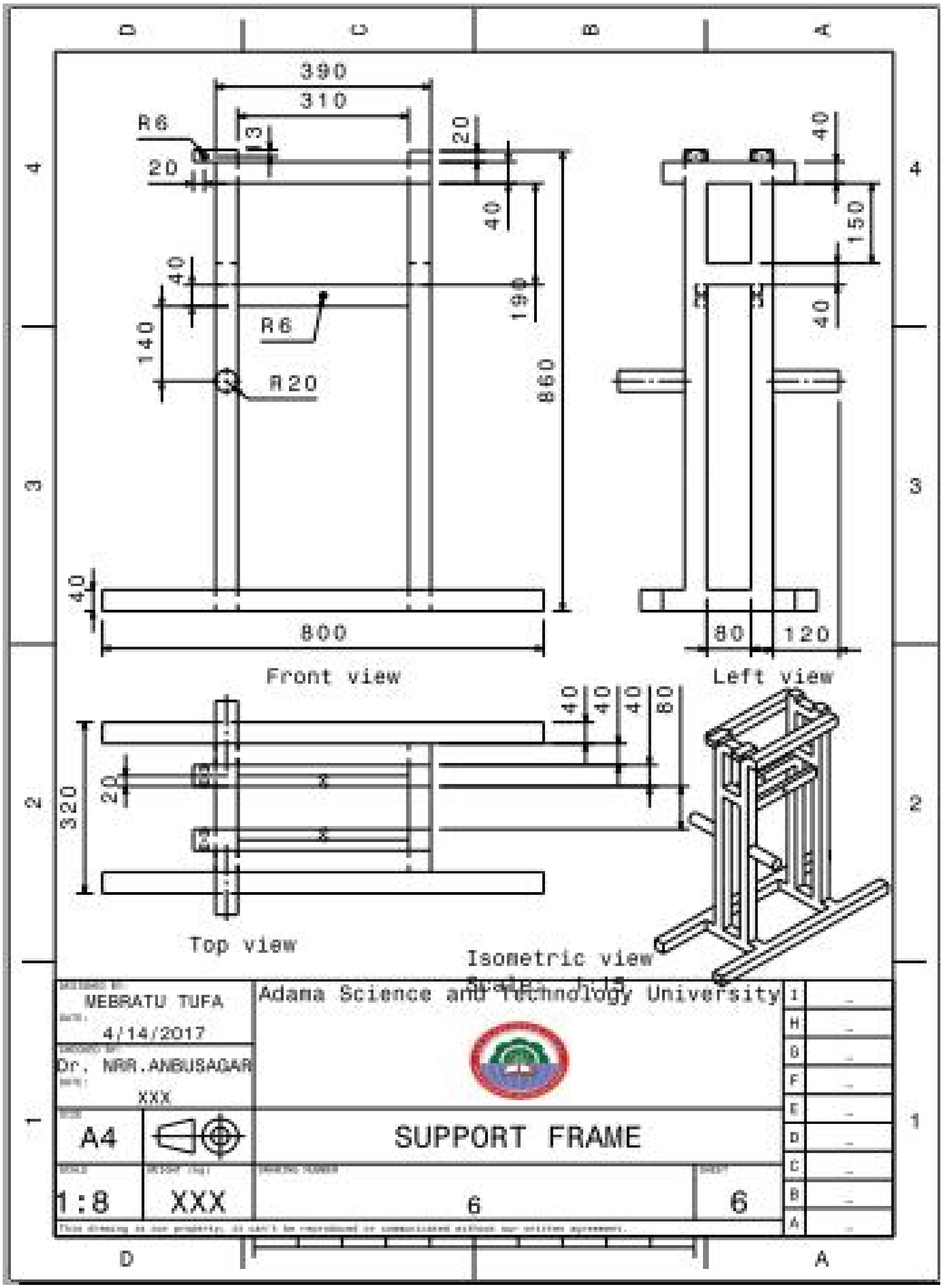
800
70°
R27
R20
28
R40
R6
40
Front view
40
100
Top view
Isometric view
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
XXX
Adama Science and Technology University
A4
LEVER ARM
1:8
XXX
5
5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80
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Left view
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40
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80
320
20
Top view
Isometric view
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
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Adama Science and Technology University
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6
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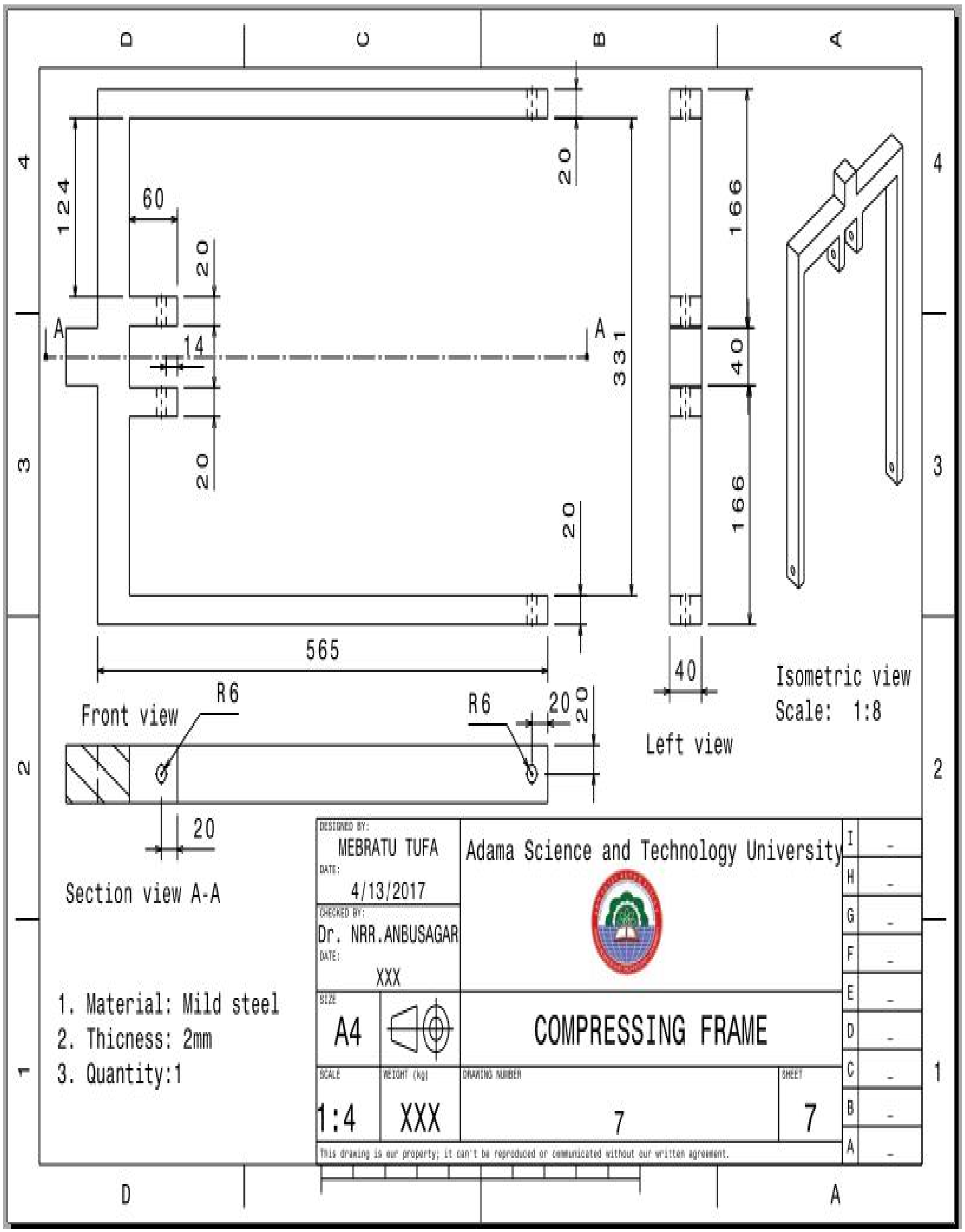
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Section view A-A
Left view
Isometric view
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3. Quantity:1
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DATE: 4/13/2017
CHECKED BY: Dr. NRR.ANBUSAGAR
DATE: XXX
Adama Science and Technology University
SIZE A4
COMPRESSING FRAME
SCALE 1:4
WEIGHT (kg) XXX
DRAWING NUMBER 7
SHEET 7
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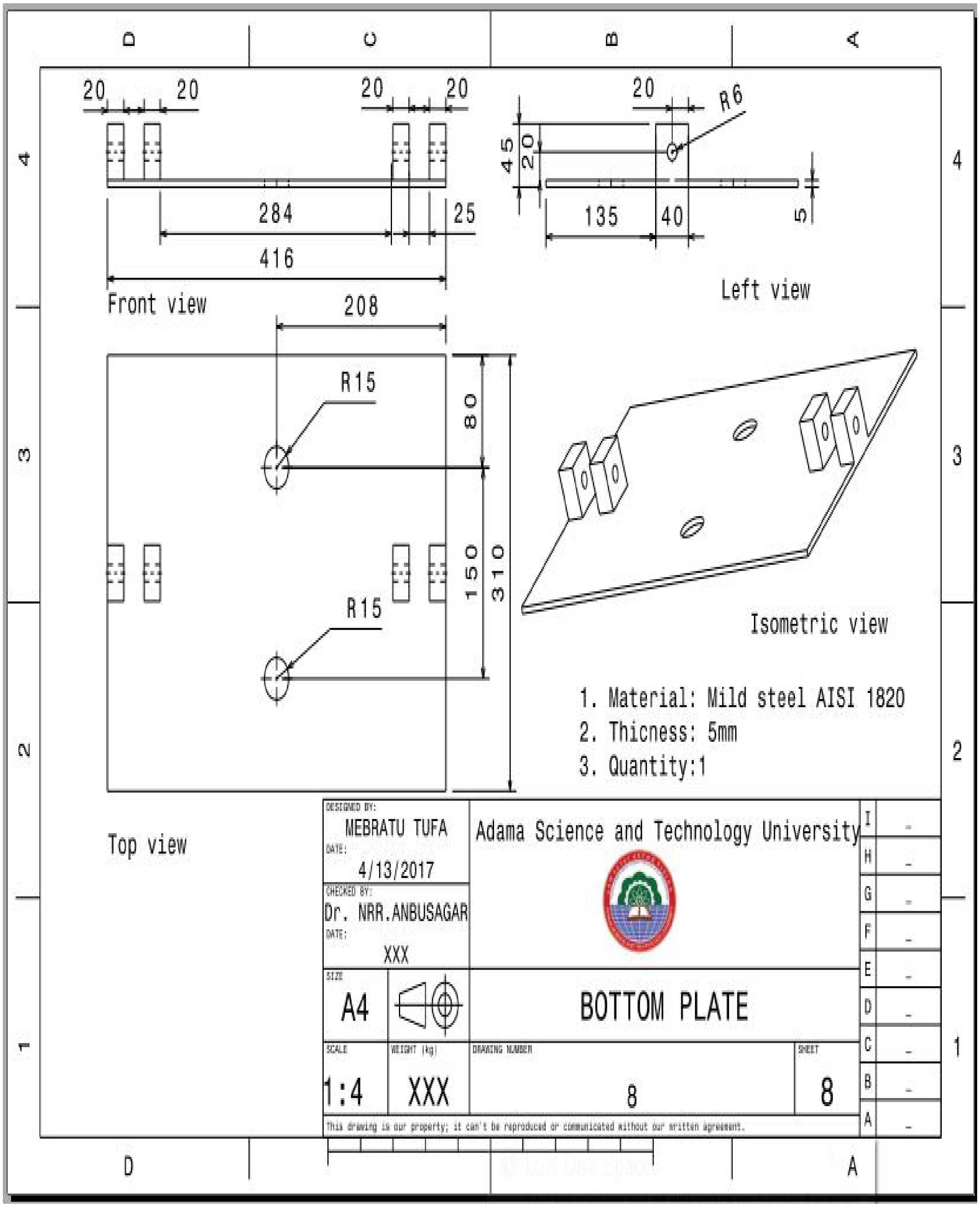
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Left view
Top view
Isometric view
R15
R15
R6
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2. Thicness: 5mm
3. Quantity:1
DESIGNED BY:
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DATE:
4/13/2017
CHECKED BY:
Dr. NRR.ANBUSAGAR
DATE:
XXX
Adama Science and Technology University
SIZE
A4
BOTTOM PLATE
SCALE
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WEIGHT (kg)
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8
SHEET
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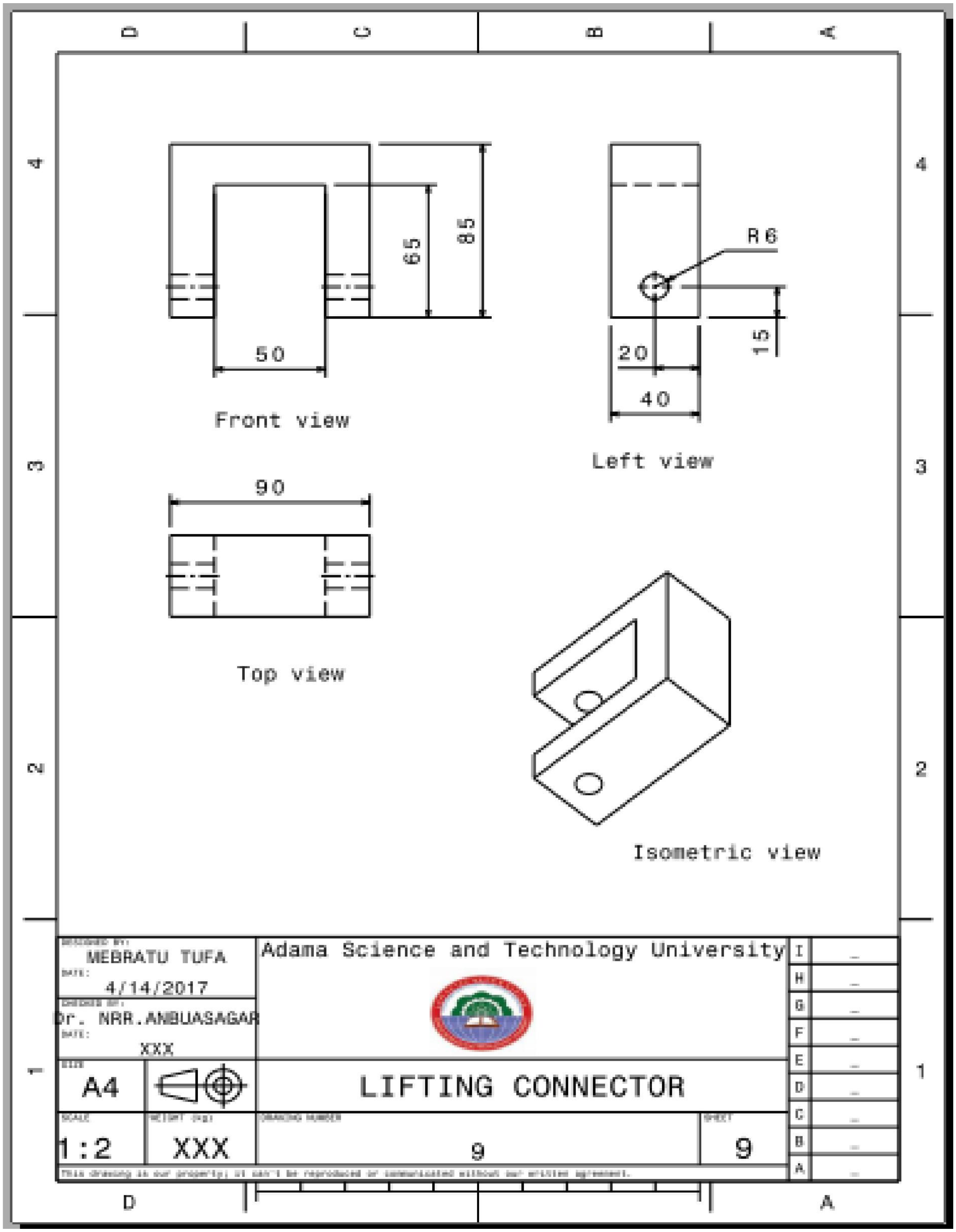
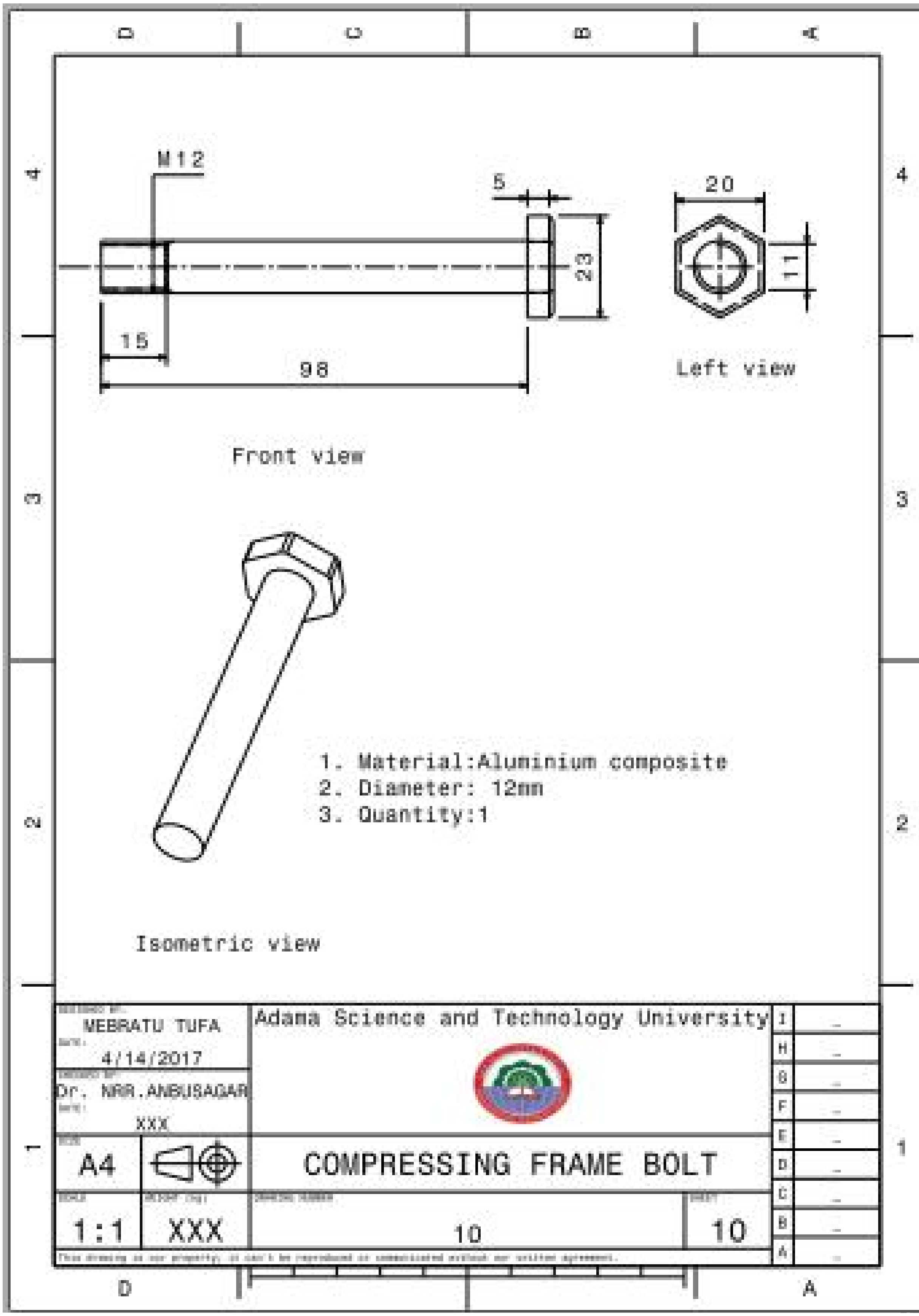


D
C
B
A
4
3
2
1
85
65
50
Front view
R6
20
40
15
Left view
90
Top view
Isometric view
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUASAGAR
XXX
Adama Science and Technology University
A4
LIFTING CONNECTOR
1:2
XXX
9
9
I
H
G
F
E
D
C
B
A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Front view
Left view
Isometric view
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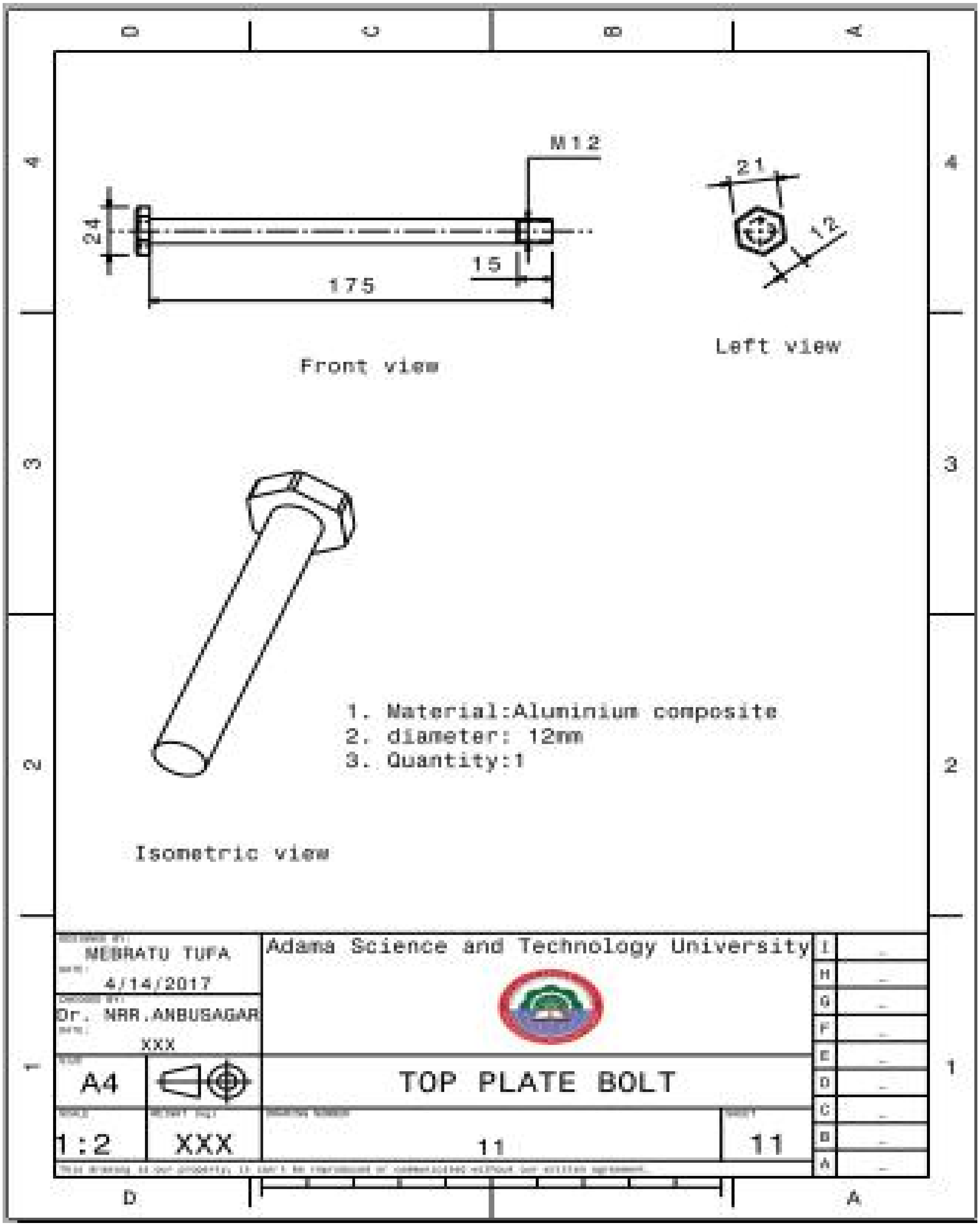
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
XXX
Adama Science and Technology University
A4
COMPRESSING FRAME BOLT
1:1
XXX
10
10



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Front view
Left view
Isometric view
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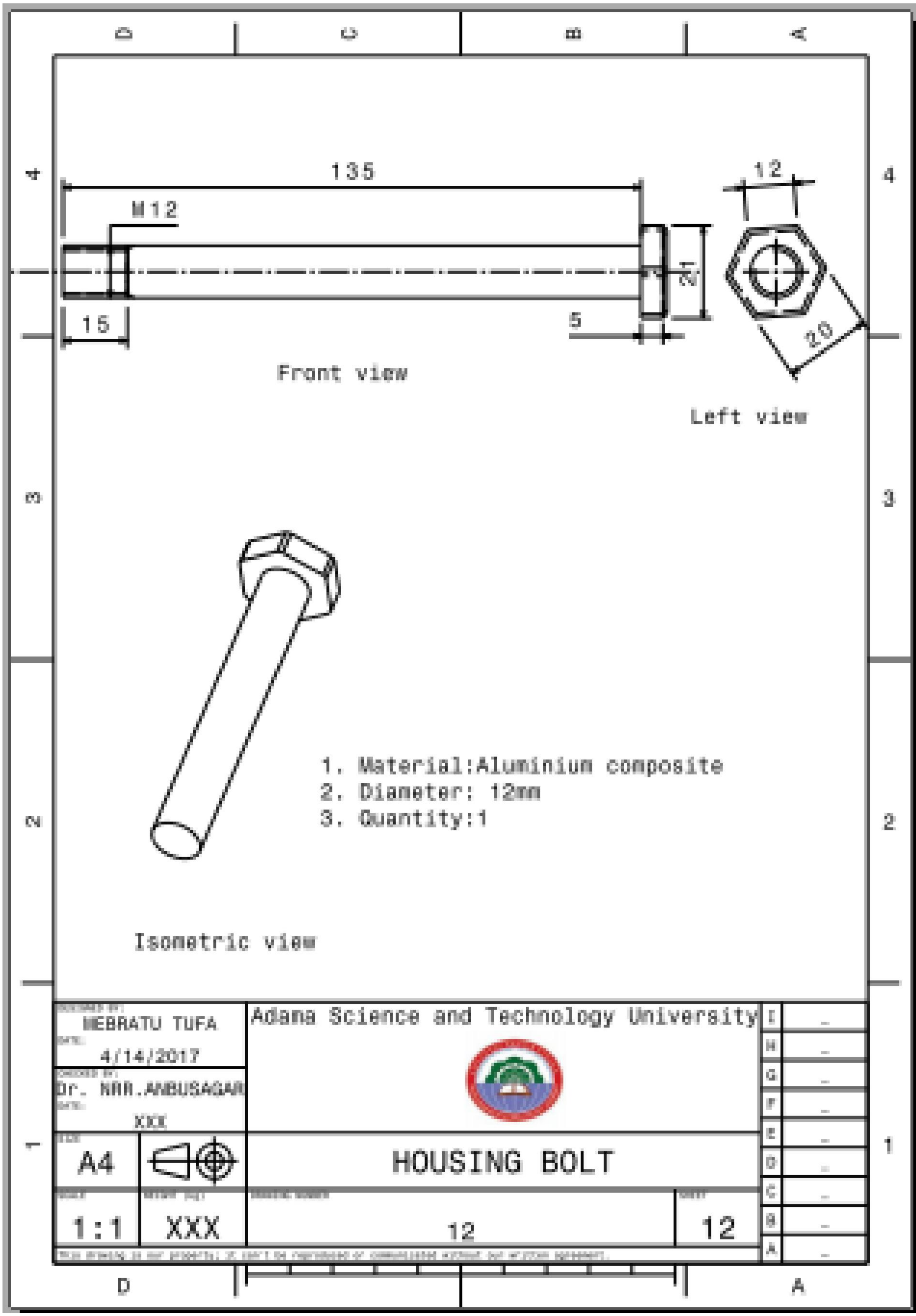
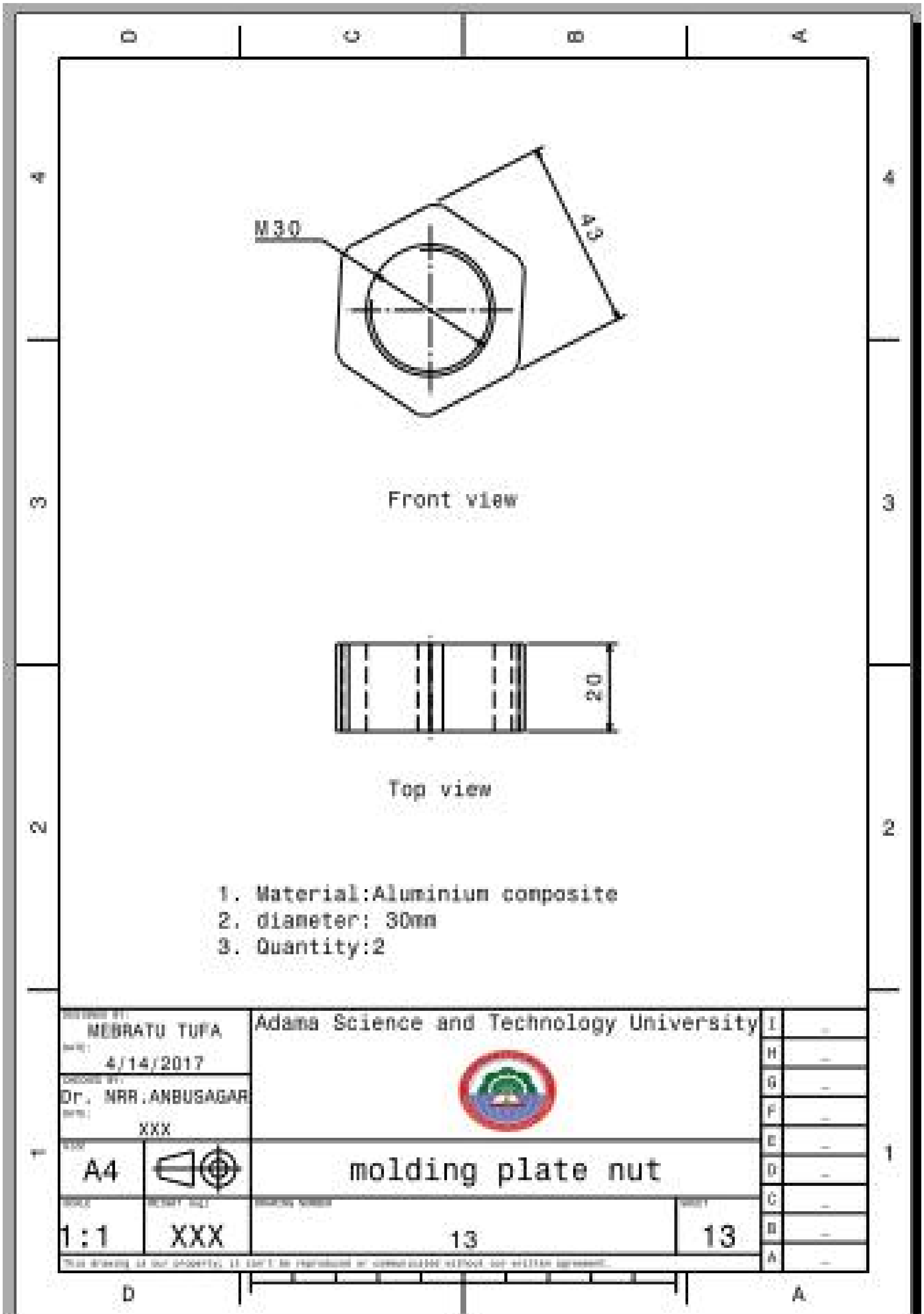
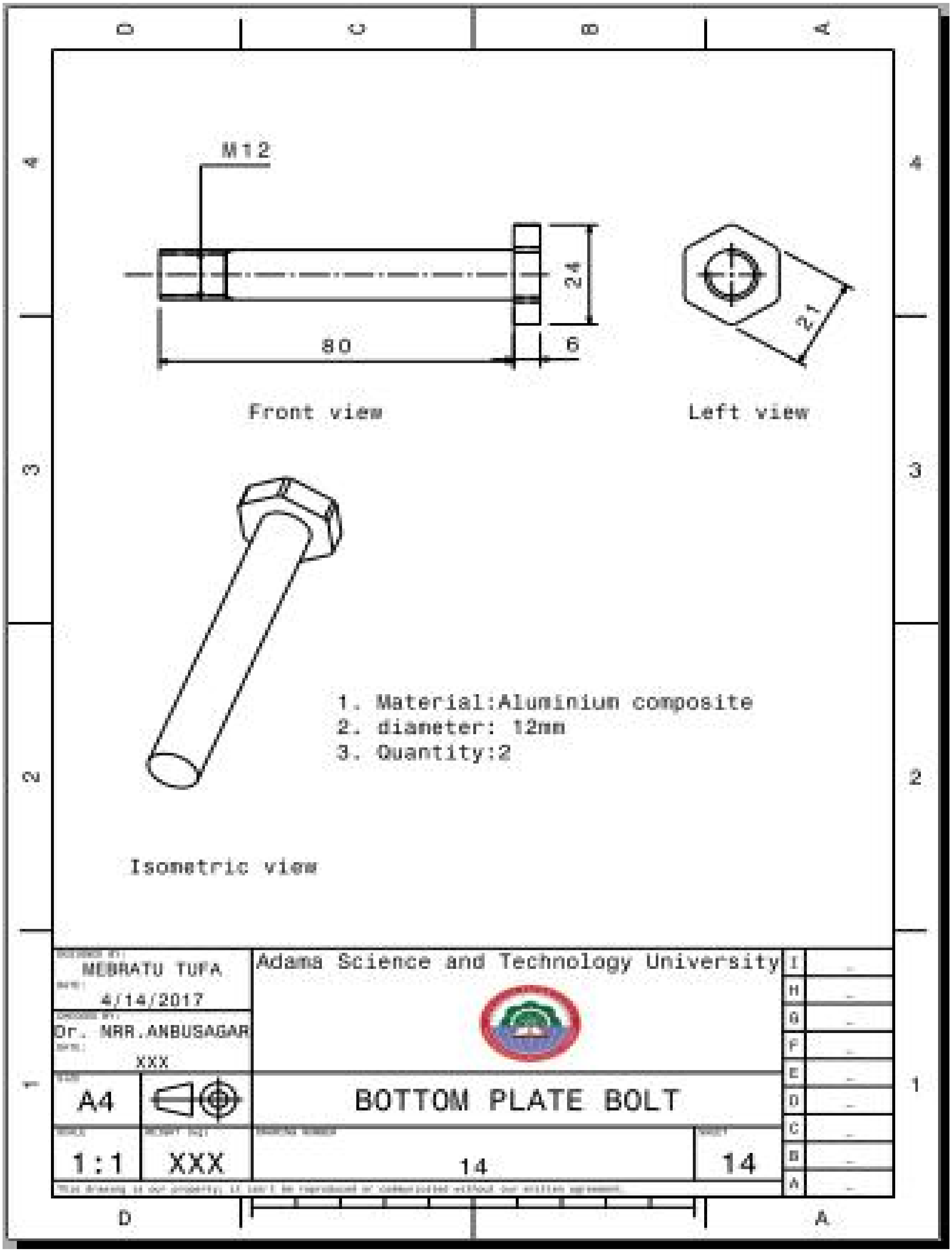
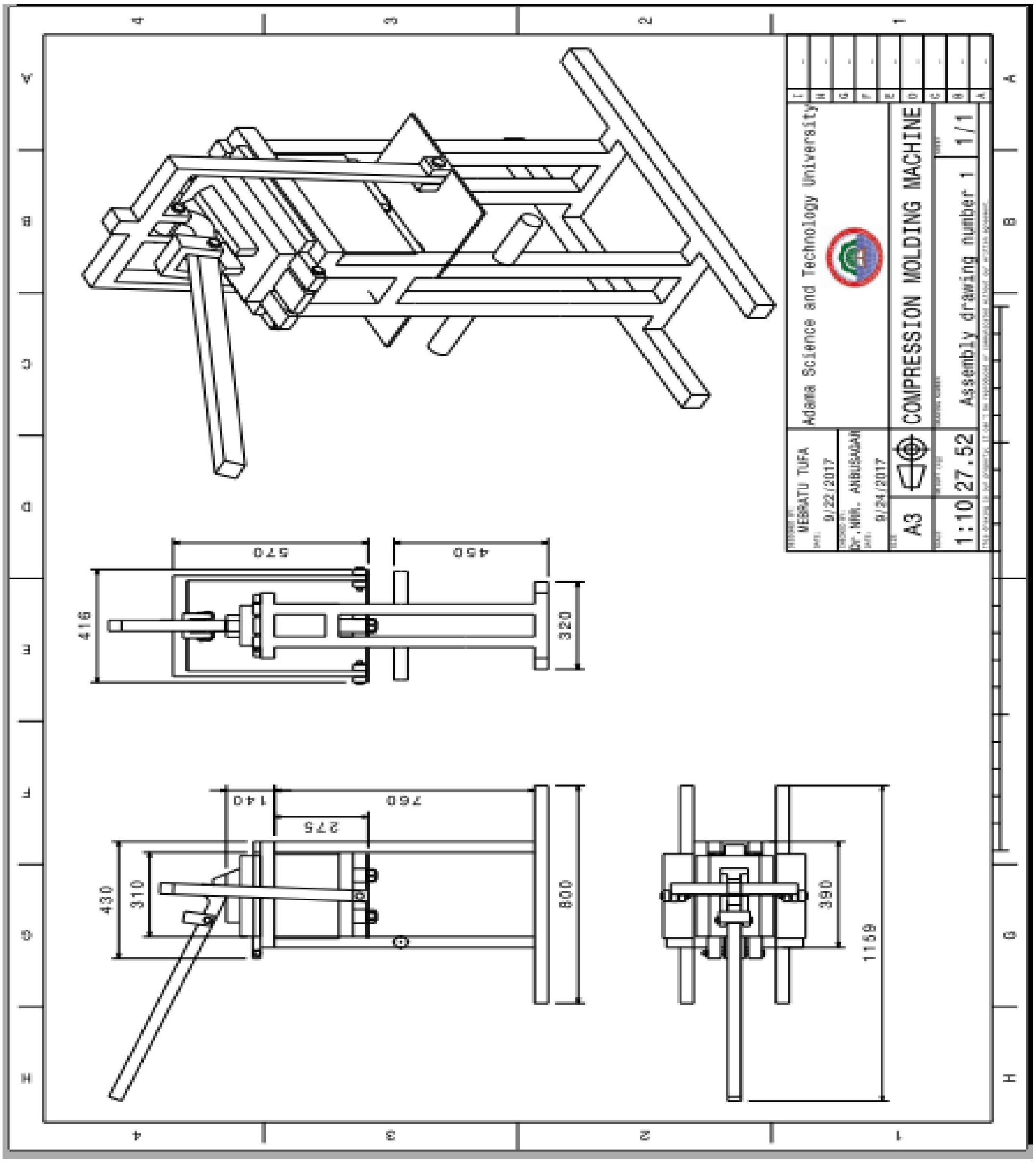
2. diameter: 12mm
3. Quantity:1
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
XXX
Adama Science and Technology University
A4
TOP PLATE BOLT
1:2
XXX
11
11



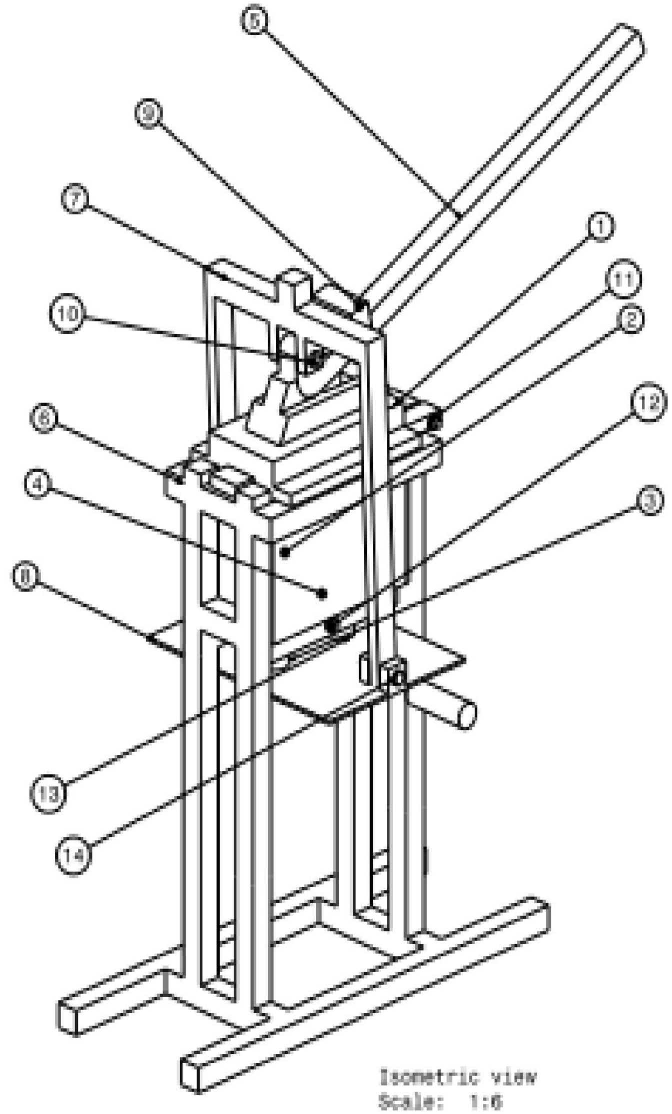
135
M12
15
5
21
12
20
Front view
Left view
Isometric view
1. Material:Aluminium composite
2. Diameter: 12mm
3. Quantity:1
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
XXX
Adama Science and Technology University
A4
HOUSING BOLT
1:1
XXX
12
12


M30
45
Front view
20
Top view
1. Material:Aluminium composite
2. diameter: 30mm
3. Quantity:2
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
XXX
Adama Science and Technology University
A4
molding plate nut
1:1
XXX
13
13


M12
24
21
80
6
Front view
Left view
Isometric view
1. Material:Aluminium composite
2. diameter: 12mm
3. Quantity:2
MEBRATU TUFA
4/14/2017
Dr. NRR.ANBUSAGAR
XXX
Adama Science and Technology University
A4
BOTTOM PLATE BOLT
1:1
XXX
14
14



Adama Science and Technology University
COMPRESSION MOLDING MACHINE
Assembly drawing number 1
MEBRATU TUFA
9/23/2017
Dr.MRR. ANBUSAGAR
9/24/2017
A3
1:10
27.52
1/1



Bill of Material: COMPRESSION MOLDING MACHINE

Quantity	Part Number	Material	Part name
1	part no. 1	Mild steel	TOP PLATE
1	part no. 2	Mild steel	HOUSING
1	part no. 3	Mild steel	MOLDING PLATE
1	part no. 4	Mild steel	CARRYING PLATE
1	part no. 5	Mild steel	LEVER ARM
1	part no. 6	Mild steel	SUPPORT FRAME
1	part no. 7	Mild steel	COMPRESSING FRAME
1	part no. 8	Mild steel	BOTTOM PLATE
1	part no. 9	Mild steel	LIFTING CONNECTOR
1	part no. 10	aluminium composite	COMPRESSING FRAME BOLT
1	part no.11	Auminium composite	TOP PLATE BOLT
1	part no.12	Auminium composite	HOUSING BOLT
2	part no.13	Auminium composite	MOLDING PLATE NUT
2	part no. 14	Auminium composite	BOTTOM PLATE BOLT

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9/21/2017
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9/24/2017

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A3

COMPRESSION MOLDING MACHINE

1:6 | 27.5KG | Assembly drawing number 2 | 1/1

APPENDIX-B

Table B1 property of materials

Material	Mass density(kg/m^3)	Material	Mass density(kg/m^3)
Cast iron	7250	Zink	7200
Wrought iron	7780	Lead	11400
Steel	7850	Tin	7400
Brass	8450	Aluminium	2700
Copper	8900	Nickel	8900
Cobalt	8850	Monel metal	8600
Bronze	8730	Molybdenum	10200
Tungsten	19300	vanadium	6000

Table B2 Indian standard designation of steel according to IS: 1871 (Part I)-1987 (Reaffirmed 1993).

Indian standard designation	Tensile Strength (minimum) N/mm^2	Yield stress (minimum) N/mm^2	Minimum Percentage elongation
Fe 290	290	170	27
Fe E 220	290	220	27
Fe 310	310	180	26
Fe E 230	310	230	26
Fe 330	330	200	26
Fe E 250	330	250	26
Fe 360	360	220	25
Fe E 270	360	270	25
Fe 410	410	250	23
Fe E 310	410	310	23
Fe 490	490	290	21
Fe E 370	490	370	21

Table B3 Values of E for the commonly used engineering materials

Material	Modulus of elasticity (E) in Gpa i.e. GN/m^2 or kN/mm^2
Steel and Nickel	200 to 220
Wrought iron	190 to 200
Cast iron	100 to 160
Copper	90 to 110
Brass	80 to 90
Aluminium	60 to 80
Timber	10
Plastic	1.4

Table B4 Values of factor of safety

Material	Steady load	Live load	Shock load
Cast iron	5 to 6	8 to 12	16 to 20
Wrought iron	4	7	10 to 15
Steel	4	8	12 to 16
Soft material and Alloy	6	9	15
Leather	9	12	15
Timber	7	10 to 15	20

Table B5 Values of Poisson's ratio for commonly used materials

S.No	Material	Poisson's ratio (l/m or μ)
1	Steel	0.25 to 0.33
2	Cast iron	0.23 to 0.27
3	Copper	0.31 to 0.34
4	Brass	0.32 to 0.42
5	Aluminum	0.32 to 0.36
6	Concrete	0.08 to 0.18
7	Rubber	0.45 to 0.50

Table B6: diameter –pitch combination for ISO metric tread [38]

Nominal diameter		Pitch			
First choice	Second choice	Coarse	Fine		
			1	2	3
4	-	0.7		-	-
-	4.5	0.75	0.5	-	-
5	-	0.8	0.5	-	-
6	-	1	0.5	0.5	-
8	-	1.25	0.75	0.75	-
10	-	1.5	1	1	0.75
12	-	1.75	1.25	1.25	-
16	14	2	1.5	1	-
20	18,22	2.5	1.5	1.5	1
24	27	3	2	1.5	1
30	33	3.5	2	1.5	1
36	39	4	2	2	1.5
42	45	4.5	3	3	2
48	52	5	4	3	2
56	60	5.5	4	3	2

Result of test carried out by construction technology management department at ASTU on Compressive strength of solid and hollow concrete brick

Table B7: For hollow brick

Class	Average of 6 units	Individual units
	N/mm^2	N/mm^2
A	4.2	3.8
B	3.5	3.2
C	2.0	1.8

Table B8: For solid block

Class	Average of 6 units	Individual units
	N/mm^2	N/mm^2
AA	12	
AAA	8.5	

Table B9: Energy use for polymer production in Europe [47]

Monomer type	Energy (GJ/t product)	Tones co_2 (fossil/t product)
LDPE	78	1.8
HDPE	80	1.7
PP	111	3.4
PVC	57	2
PS	87	2.6
PET	78	2.3
Amino	60	2.9
PUR	105	3.9
OTHERS	117	5.1

Table B10: Mix proportions in mass of concrete brick [9]

Cement: aggregate ratio	Materials		
	Cement	Coarse sand	Fine sand
1:11	1.00	5.17	4.18
1:9	1.00	4.23	3.72
1:7	1.00	3.29	3.26

Appendix C

Sand draying

Select sampling mass 10000g in this case. Dry the test sample in a suitable pan to constant mass at a temperature of 110C^0. Dry the sample for a minimum of 1 hour at 110C^0. Record the weight of the sample at each 30 minute. Continue drying and weighing until the weight does not change at drying intervals of a minimum of 30 minutes.

Table C1: Sand draying time

Time	minutes in oven	Weight in (g)	Percentage of water lost (drying)
9:00 AM	0	10000	0
9:30 AM	30	9900	1
10:00 AM	30	9870	0.3
10:30 AM	30	9870	0
11:00 AM	30	9870	0

Sand Sieve analysis

Weigh out 500 grams of oven-dried sand and transfer the dried sand to the top sieve of a stacked set of sieves of the following mesh sizes: 1180 µm 1000 µm; 500 µm, 250 µm,0 µm bottoms. Sieve for 10 minutes on the sieving machine and empty each sieve into a weighing dish by tapping it upside down. Weight with 0.01 g accuracy.

Sand (< 250 µm) = 4.95g

Sand (250-500 µm) = 20.05g

Sand (500-1000 µm) = 100.45g

Sand (1000-1810 µm) = 180.50g

Sand (> 1810 µm) = 194.05g

Sample weight = 4.95g + 20.05g + 100.45g +180.50g + 194.05g =500g

The proportional amounts of the fractions can now be calculated by:

Percent of sand retained on sieve = $\frac{\textit{weight of sand retained on sieve}}{\textit{weight of sample}}$ X100

Table C2: percent of sand retained on sieve

Sieve size	Mass of sand Retained (g)	Percent of sand retained
1180 µm	194.05	38.81%
1000 µm	180.50	36.10 %
500 µm	100.45	20.09 %
250 µm	20.05	4.01%
0 µm	4.95	0.99%
Total	500	100%

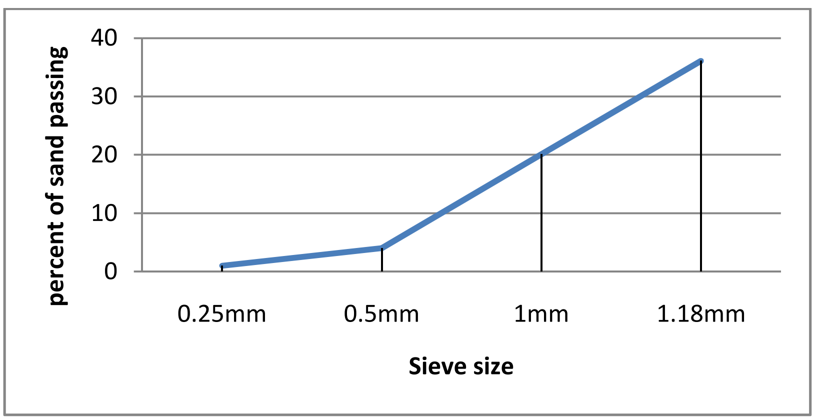

Figure C: Sieve Analysis of sand

Free Bulk density of sand

Tools for measuring bulk density

- Graduated cylinder of 500cm^3.
- Calculator
- Balance

Sample oven dry natural sand is introduced freely into Graduated cylinder of 500cm^3 that firmly stand on a smooth surface. Fill the cylinder until completely fill with sand to level of 500mL.

Then remove the sand from the cylinder and measure the mass of sand (M) and calculate the free bulk density of dry sand [48, 49]

Sand volume = Graduated cylinder volume

Cylinder volume = $500cm^3$

Mass of the sand = 788.50g

Dray density of the sand =$788.50g/500cm^3$ = $\underline{\underline{1.577g/cm^3}}$

Compacted bulk density of sand

The sand material, previously drayed out, is introduced into a determination vessel of known mass (M_1) and known volume (V_1), in three successive layers, after each one, the vessel being bitted 50 times by the table. For compacting of the last layer, a prolong is added to the vessel; after compacting being finished, the prolong is taken away and the filled in vessel is weighted (M_2) this test is carried out as per soil bulk density analysis methods [48, 50]

Compacted bulk density = $(M_2\text{-}M_1)/(V_1)$

Sand volume= vessel volume (V_1) =$500cm^3$

Mass of the vessel (M_1) = 125g

M_2= Mass of the sand + mass of vessel = 925g

Dray density of the sand = $(M_2\text{-}M_1)/(V_1)$

= $(925\text{-}125)/(500cm^3)$

= $\underline{\underline{1.60g/cm^3}}$

Density of plastic

Tools for measuring bulk density

- Graduated cylinder of $500cm^3$ and $1000cm^3$
- Calculator
- Balance

First mass of 243g of melt casted waste plastic bag is determined, and then volume of water in graduated cylinder is determined since, in case of small samples with irregular shapes, the volume determination is made by help of a graduated cylinder. For this, a liquid volume of (V_1=500cm^3) is determined. Then the sample (243g casted plastic) is carefully introduced to the other graduated cylinder of 1 liter (V_2=1000cm^3) and then 500cm^3 water poured into the graduated cylinder of 1000cm^3, the water level was rise up to the level V_3=770cm^3 in the graduated cylinder. The rising of water level equals to volume of the sample denoted by 'V' [48].

$$V = V_3 - V_1 = 770cm^3 - 500cm^3 = \underline{\underline{270cm^3}}$$

$$\text{Density of the plastic} = \text{mass of plastic}/\text{volume of plastic}$$

$$= 243g/270cm^3 = \underline{\underline{0.90\ g/cm^3}}$$

Method for the determination of density of Composite brick

Tools for measuring density

- Graduated cylinder of 1000cm^3
- Calculator
- Balance

First mass of 250g sand-LDPE composite brick sample is determined for each 50%, 55% and 60% LDPE composition , and then volume of water in graduated cylinder is determined since, in case of small samples with irregular shapes, the volume determination is made by help of a graduated cylinder. For this, a liquid volume of (V_1=500cm^3) is determined. Then the sample (250g samples of sand-LDPE composite brick for each composition) is carefully introduced to graduated cylinder containing 500cm^3 of water and then water level was rise up to the level (V_2) in the graduated cylinder. The rising of water level equals to volume of the sample denoted by (V). The step is repeated for each composition.

$$V = V_2 - V_1$$

$$\text{Density of the composite} = \text{mass of composite}/\text{volume of composite}$$

Percentage of waste plastic	samples	Dray weight in (g)	Volume (V) in (cm^3)	Density (g/cm^3)	Average Density in (g/cm^3)
50%	S1	250	720-500=220	1.13	1.12
	S2	250	723-500=223	1.12	
55%	S1	250	727-500=227	1.10	1.10
	S2	250	725-500=225	1.11	
60%	S1	250	731-500=231	1.08	1.07
	S2	250	733-500=233	1.07	

Table C3: Thermostat grade of heater and measured corresponding temperature range in C^0

Thermosetting grade	Corresponding Temperature range in C^0
1	$105C^0 \pm 5\ C^0$
2	$125C^0 \pm 5C^0$
3	$150C^0 \pm 5C^0$
4	$175C^0 \pm 5\ C^0$
5	$200C^0 \pm 5\ C^0$

Table C4: Specification of heater used for melting LDPE

Voltage	220-240V
Current	8A
Power	2kW