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Potential assessment and characterization of locally available material for production of refrigerator body in Ethiopia

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THERMAL STREAM

'Potential assessment and characterization of locally available material for production of refrigerator body in Ethiopia'

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Declaration

I hereby declare that the work which is being presented in this thesis entitled "**Potential assessment and characterization of locally available material for production of refrigerator body in Ethiopia**" is original work of my own, has not been presented for a degree of any other university and that all sources of material used for this thesis have been duly acknowledged.

____________________ ________________

Molla Tilahun Date

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

__________________________________ ____________________________

Yilma Tadesse **(PhD)** (Advisor) Date

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Very special tanks to Dr Tesfye Damma, Dr Abdulkader Amn, Dr Wondwossen Bogale, Dr Eddisa Dribssa,Dr.Berhanu Bekele, Mr. Hailelouel Sahle,Mr. Hiredin. and I would like to thank to my colleague Zekarias Moges and Gudeta Wegissa for their supports in this period.

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Abstract

Refrigerator and Air condition has become an important issue in Ethiopia as the advances in technology increased demand for creating comfort ability. The main scenario in refrigerator is importing complete unit or semi assembly and then distribute. Ethiopia has endogenous art to make good or building differently as renowned Lalibela, Axum and ancient coin are good examples. Using Bamboo product to build refrigerator body will be an alternative material.

The objective of this study is assess and characterize locally available material options in Ethiopia for production a refrigerator body by bench marking with an available commercial refrigerator body in the market to determine feasibility. Experimental approach is used to determine appropriate material for making refrigerator body among Bamboo, plywood, and fiberglass. Thermal conductivity and tensile strength of each material is the key parameter to compare and select material for body making.

Keywords: Refrigerator body, Experiment, Bamboo. Plywood, fiberglass, thermal conductivity and tensile strength.

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Chapter 1 : Introduction

1.1 Background

Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature. One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures [1]

The raw material in refrigerators today consists of several basic components: the exterior cabinet and door, the inner cabinet or liner, the insulation inserted between the two, the cooling system, the refrigerant, and the fixtures. The cabinet and door are made of aluminum or steel sheet metal that is sometimes painted and reshaped as per required. The inner cabinet is made of sheet metal, like the outer cabinet, or of plastic. The insulation that fills the gap between the inner and outer cabinets consists of fiber glass or poly foam. The components of the cooling system (compressor, condenser, coils, and fins) are made of aluminum, copper, or an alloy. Freon is most commonly used refrigerant, and almost all of the large interior fixtures (door and cabinet liners) are made from vacuum-formed plastic [2]

The purpose of a refrigerator cabinet is to allow as little heat transfer from the surroundings to the inside of the cabinet. In other words, it is to keep the inside of the cabinet as insulated as possible so that the refrigerator system does not have to do as much work. In its simplest form, a cabinet is an insulated volume. The amount of heat transferred to the cabinet dictates the amount of work a refrigerator will need to do and this in turn affects the size of the parts of the whole refrigerator. Heat is transferred through convection, conduction, and radiation; but radiation can typically be neglected. It is, therefore, important to choose an insulation material with a low conduction coefficient [3].

The task for this research is to asses and characterization of locally available material for manufacturing a refrigerator body in Ethiopia. Here we have wood and bamboo, Fiberglas, plastic material option to substitute for the construction of the body frame/casing outer cabin and insulation; In combination of products that will satisfy the design requirement at lowest total cost over the life it will depend on cost, availability or other consideration of materials options for production of a refrigerator body by testing material properties and bench mark with an available commercial refrigerator body in the market and asses its convenience for manufacturing a refrigerator body. It will save foreign exchange by substituting the current refrigerator body by locally available materials.

1.2 Statement of the Problem

Refrigerator consists of around 60 percent metal the bulk of the weight coming from iron and steel. Infarct the average refrigerator contains 123 pounds of steel and iron and cost of steel and iron is higher lead the overall cost of refrigerator became higher, and in Ethiopia the demand of refrigerator is meant entirely through import with higher price, which puts quite a dent in the country’s economy.

There are a lot of materials that are readily available in Ethiopia for manufacturing a refrigerator body such as bamboo, wood, and different plastic materials. In this study the choice is made with respect to their thermal properties, physical properties, manufacturability and cost so that if the country produce refrigerator body by locally available materials which save foreign exchange and are more lightweight than any other refrigeration system.

1.3 Objectives of the study

1.3.1 Main objectives

The main objective of this research is to assess and characterize locally available material options in Ethiopia for production a refrigerator body by bench marking with an available commercial refrigerator body in the market to determine feasibility.

1.3.2 Specific objectives

- Finding locally available material can be used for refrigerator body
- Test material properties for newly produced
- Test used refrigerator body

1.4 Significance of the study

Refrigerator is one of the most essential domestic equipment to keep perishable food items and cool for certain period of time so as to more hygienic and economical, hence the demand of the refrigerator in Ethiopia is met through import. The country imports a variety of refrigerators and freezers from various countries. According to the data obtained from the Ethiopia Customs Authority Trade Statistics shows an increasing trend for the resent years 2011-2015 benefit of this research is substituting the current refrigerator body by locally available material options like wood, bamboo and fiber glass rain forced plastic bench marking with an available commercial refrigerator body in the market to determine feasibility and also asses its convenience for manufacturing a refrigerator body. It will save foreign exchange by substituting the current refrigerator body by locally available materials.

1.5 Scope

In this research first of all assess and characterize locally available materials in Ethiopia to substitute the external shell of the a single structure cabinet that supports the inner food compartment liner, the door, and the refrigeration system and the materials used between the inner and outer walls of the cabinet insulation based on Design Requirements after that select materials from locally available option then doing experimental analyses after these investigate material according to design requirement and determine feasibility common Finally discuss manufacturing methods and tools used in the construction of body.

1.6 Limitation

Refrigerators today consist of several basic components: the exterior cabin and door ,the inner cabin or liner the insulation inserted between the inner cabin and exterior cabin, the refrigerant and the fixtures however, detail design of Refrigerator body and inner cabin or liner , the refrigerant and the fixtures, thermal load calculation, detail body design are not considered in this research.

1.7 Thesis Outline

The research is organized in six Chapters. The first chapter is the introduction part which clearly states the background of the research, statement of problem, and objective, scope and limitation of the study and benefits of the research.

Chapter two discusses literature review of the refrigerator body system. Definition, key points, models and analytical approaches will be discussed in this part of the study.

Chapter three discusses materials and methods.

Chapter four Experimental Methods.

In Chapter five , results and discussions which include possible design suggestion will be discussed.

The conclusions of this work are presented in Chapter six. In addition, possible improvements that can be made are discussed here as part of future works.

Chapter 2 : Review of Literature

2.1 Introduction

How did our ancestors live without refrigerators? People living in temperate zones soon realized that perishable foods kept much better in winter than in summer. The use of "natural refrigeration" began in the distant past and lasted a very long time: early in the 20^{th} century [4].

Historical Aspects according [5] they simply made use of natural ice, the trading of natural ice on a commercial scale was initiated by Frederic Tudor (1783-1864) who, in around 1806, cut ice from the Hudson River in the United States and sold it. At the beginning of the 20^{th}century wooden boxes insulated with various materials, including cork and sawdust were used to hold blocks of ice and refrigerate food.

Figure 2-1: ***20^{th} century wooden boxes used to hold blocks of ice and refrigerate food*** **[5]**

The first known attempt to develop an artificial refrigerator took place in Scotland at the University of Glasgow. There, in 1748, William Cullen revived the ancient Indian-Egyptian practice of freezing liquid by means of evaporation; although he accelerated the process by boiling ethyl ether into a partial vacuum (ethyl evaporates more quickly than water). Cullen attempted this merely as an experiment, as did American Oliver Evans, who designed another refrigerator in 1805. Evans's machine, based on a closed cycle of compressed ether, represented the first effort to use simple vapor instead of vaporizing a liquid. While Evans never developed his machine beyond the prototype stage, in 1844 an American doctor named John Gorrie actually built a very similar machine to provide ice for the hospital in which he worked. Gorrie's machine compressed air that was next cooled with water. The cooled air was then routed into an engine cylinder, and, as it re-expanded, its temperature dropped enough so that ice could be made [6].

At the beginning of the 20th century wooden boxes insulated with various materials, including cork and sawdust were used to hold blocks of ice and refrigerate food .First refrigerator cabinets were made in wood and cooled with ice blocks (Nickles, 2002). In 1923 the two Swedish students Baltzar von Platen and Carl Munters came up with a solution for how to use gas and an absorption technique in a refrigerator which could replace the blocks of ice [7].

The basic technical principle of a refrigerator figure 2.5 is rather simple and has not changed very much since the 50's, except from the development to be more energy efficient and the addition of some new functions (Carlberg, 2005; September, 2005). One important change made to improve the refrigerator sustainability were the prohibition of the toxic coolant gas earlier used, the CFCs (Freon's). Already in 1974 it was found that the CFCs destroyed the ozone in the Stratosphere, but not until 1992 the industrialized countries decided to cease the production of CFSs by 1995 (Diamond, 2005). In 1995 Electrolux had removed all Freon from their refrigerators (Grunewald, 1999) [7].

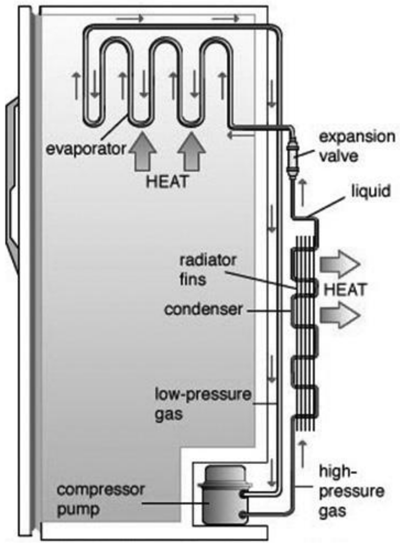

Figure 2-2: *Technical principle of a refrigerator with static condenser* [7]

Now day full-sized household refrigerators and freezer the most common of which are illustrated in Figure below.

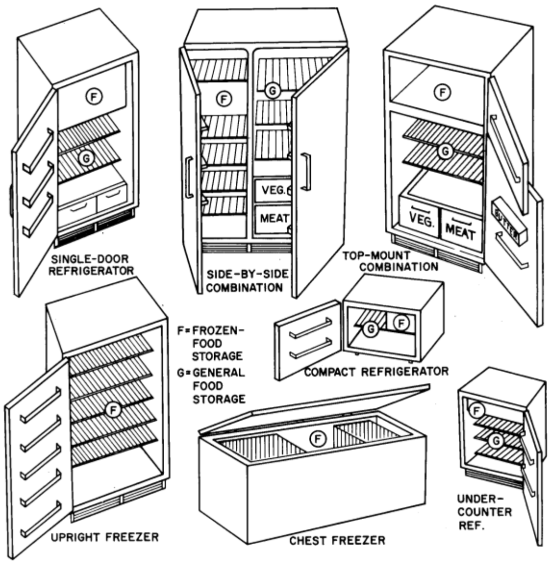

Figure 2-3 : Configurations of Contemporary Household Refrigerators and Freezers [8]

Within the frames of this thesis project no new technology is developed. The results should be based on technologies existing today, this research mainly focus on the substituting refrigerator outer cabin by locally available material and Choice of materials has been taken into consideration bench mark with an available commercial refrigerator this technological solutions included does not have to be in use or industrialized today, but be highly possible to use in 10 years' time. The proposed solutions should be realistic to produce and, manufacture in Ethiopia.

2.2 Historic Evolution of Design and Characteristics of refrigerator

The first household refrigerator was developed in 1803 by Thomas Moore, a farmer from Maryland (USA), and consisted of a box cooled by a mixture of salt and ice. In fact, domestic cooling capacities in the shape of iceboxes began to make frequent more than 20 years later. At that time, only cool larders were used for domestic food storage. In 1826, the Society encouragement pour la Industry proposed a prize of 2000 French Francs for the development of a proceeding to maintain as long as possible the ice stored in household iceboxes. At the same time in the United States, Frederic Tudor, from New York, proposed the use of natural ice in domestic iceboxes, which became a common practice during the next decades and lasted even well within the past century. Production of natural ice developed into an organized activity with standard ice block sizes, harvesting methods, and storage and distribution facilities, which concluded in the ice man that made the household distribution of ice pieces [9].

The true evolution of domestic refrigeration took place in the third and fourth decades of the twentieth century, helped by the design and development of fractional horsepower motors and with the introduction of fully sealed systems that eliminated the belts [10].

2.3 Historic Evolution of Design and Characteristics of refrigerator Materials

Many of the first designs had wooden cabinets and iron tubing, belt drivers, expansion valves, and other features that evolved within a short time toward the actual components of household appliances. The external surface of cabinets is normally made of steel in the shape of a structure that supports all the components of the appliance (door, refrigeration system, inner food compartments).The main evolution of refrigerator cabinets during the last 50 years has been on its shape and size, the introduction of different specialized compartments and best use of the available inner space. The continuous development in plastics enabled the inclusion of different compartments in the inner door liners, able to support thousands of door openings without breakage, even when heavily loaded, for example, with bottles of different drinks. In brief, domestic refrigerators changed considerably from their early designs during the first part of the second half of the twentieth century. Multiple compartments made them more complex, the design being refined to meet more stringent customer demands each time [11].

2.4 REFRIGERATOR DEMAND

There is no plant in the country that manufactures refrigerators. Hence, the demand for the item is met through import each year. During my visit to Beyo, some commercials are assembled in Legetafo city. ERCA Data indicated that importation of fridges trend starting from 2016 to 2019 is a good clue for the demand is under good conditions.
According to the data obtained from the Ethiopian Customs Authority Trade Statistics, the country imports a variety of refrigerators and freezers from various countries. These include:

- Combined refrigerators-freezers with separate external doors
- Compression type house hold refrigerators
- Absorption type house hold refrigerators
- Other types of house hold refrigerators

- Freezers of chest type with capacity of = < 800 liters and capacity of = < 900 liters
- Other refrigerating/freezing chests, cabinets and similar refrigerating furniture's and
- CFC free refrigerators and freezers.

Table 2-1 IMPORT OF REFRIGERATORS Source: - Ethiopian Revenues & Customs Authority

Year	Import (No.)	Value (Birr)
2000	18,082	49,967,605
2001	49,698	53,394,329
2002	187,826	65,874,152
2003	51,053	98,505,662
2004	55,717	78,345,536
2005	59,967	155,221,711
2006	75,029	189,979,441
2007	84,122	219,375,316
2008	2,884	10,484,478
2009	12,043	384,788,862
2010	111,435	336,678,709
2011	105,906	415,528,327
Total	813,762	2,058,144,128
Average	67,814	171,512,011

Chapter 3 Materials and methods

3.1 Introductions

The main parts of the refrigerator comprises of a box body, a door body, electrical system, compressor and refrigeration system and so on. The box body and the door body shell are made by vacuum plastic molding, whose intermediate foam material is made by foam molding. In recent years, since raw material prices continue to rise in national and international markets, reducing production costs and improving product quality are becoming means for a manufacturer to win in the pierce competition [12].

Many factors are considered in the design of the envelope of a refrigerated unit: extremes of exterior weather conditions, desired interior conditions, insulation properties, infiltration of air and moisture, tradeoffs between construction cost and operating costs and physical deterioration from shocks and vibrations.

Many cost reductions have been implemented over the years but never had there been a comprehensive attempt to optimize the overall structure [13] the research focused on typically, cost reductions of the cabinet's structural components have been accomplished as assess materials readily available in Ethiopia characterized tested and the results are compared to current production cabinets.

3.2 Data Source and Methods of Collection

3.2.1 Data and data sources

The first thing to do for the desired study is evaluating the resources that are available by searching the primary and secondary data from refrigerator assembling company and thesis, publications, and books.

3.2.2 Method of data collection

The Primary as well as secondary data which are needed for this study is collected using different data collection techniques. These are:

- By observing available materials choices in Ethiopia that replace commercial refrigerator body in the market predetermine, what contaminants could exist?
- By interviewing concerned bodies, consulting advisors and discussing with friends.
- Searching for thesis, publishing's, newspapers, books, etc. on different web sites which are helpful for meeting the general objective and the Specific objective as well.

3.2.3 Experiment

Material properties used to describe the density and material strength such as tensile strength of selected materials will be conducted.

3.3 Materials assessment

The industries continue to develop new materials to meet the increasing demand for specialized products like domestic refrigerator. This research focused typically on assess materials readily available in Ethiopia that would substitute current household refrigerators cabinets structural components available in market it helps cost reductions of the cabinet's structural this have been accomplished characterized the materials and test mechanical property and compare to current household refrigerators cabinets.

Normally, the choice of material is dictated by the design. But sometimes it is the other way round: the new product, or the evolution of the existing one, was suggested or made possible by the new material. The number of materials available the materials kingdom, is characterized by a set of attributes which include its mechanical, thermal, electrical and chemical properties, its processing characteristics, its cost and availability , and the environmental consequences of its use. We call this its property-profile. Selection involves seeking the best match between the property profile of materials in the kingdom and that required by the design [14].

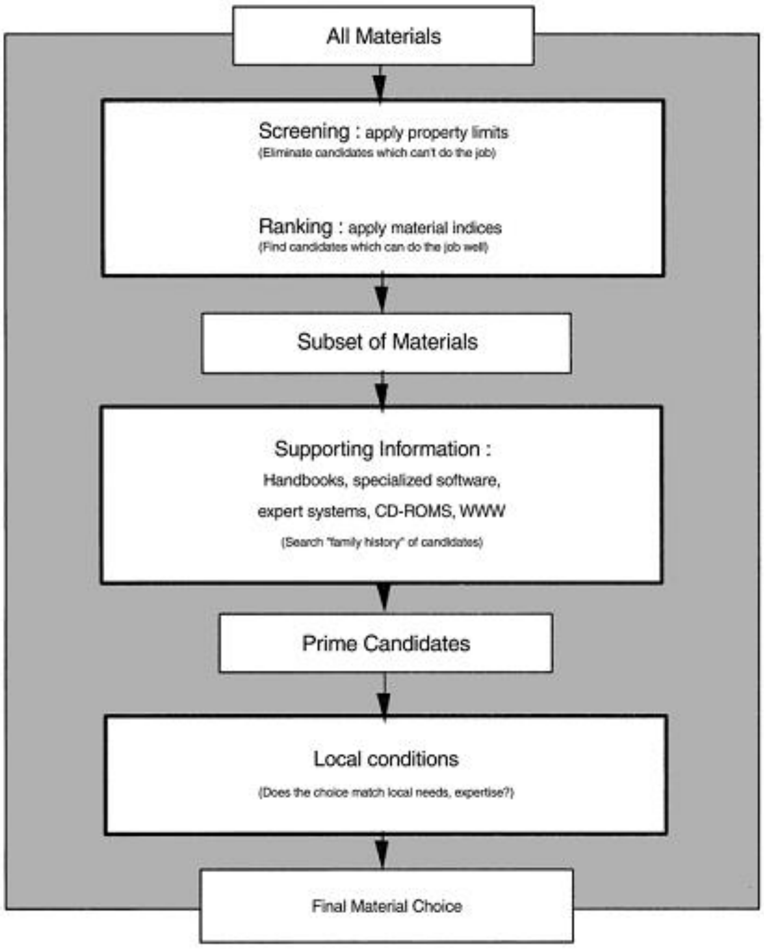

***Figure 3-1: the strategy for materials selection. The main steps are enclosed in bold boxes* [14].**

3.4 Raw Materials

Refrigerators today consist of several basic components: the exterior cabinet and door, the inner cabinet or liner, the insulation inserted between the two, the cooling system, the refrigerant, and the fixtures. The cabinet and door are made of aluminum or steel sheet metal that is sometimes painted then reshaped to the required design. The outer cabinet and door, made of sheet metal, are either welded or clinched together. While some manufacturers also use sheet metal for the inner cabinet, some manufacturers and some models use plastic for inner liners. The plastic liners are made by vacuum forming. In this process, a thick piece of plastic slightly larger than the finished part has its outer edges. The insulation that fills the gap between the inner and outer cabinets consists of fiberglass or poly foam [15].

3.5 Materials selection

When I assess materials readily available in Ethiopia that can replace current material of refrigerator exterior cabinet and door, the first step taken from a variety of materials was by carefully defining categorically the requirements of the desired components. This was followed by checking these requirements

1. The mechanisms can be characterized by either loads (or stress) related failure or structural (or materials) related the material can withstand the loads additional support is typically provided in must withstand the thermal stresses.
2. They must be unaffected by common contaminants encountered in a kitchen environment.
3. Materials possibly emerging trends in premium kitchens of today
4. Materials cost and manufacturability

Based on above requirement and availability in Ethiopia fiber glass, wood-based composite materials and bamboo are selected for the construction of the body frame/casing of refrigerator then we will discuss thermal, mechanical and physical property of selected materials below.

3.5.1 Physical and thermal properties of wood and wood panel materials

Wood is a fibrous rigid material of plant origin. It is broadly classified as hardwood and softwood. Hardwood is derived from angiosperm or broad-leaved trees and Softwood is obtained from coniferous trees, which have needle-like leaves [16] and [17].

The term composites used to describe any wood material bonded together with adhesives. Wood-based composites are used for a number of structural and nonstructural applications. Product lines include panels for both interior and exterior uses, furniture components, and support structures in buildings [16]. Wood-based composite materials which are available in Ethiopia is Plywood. It is one of the important wood-based composites produced from different tree species, and it has some superior advantages compared to solid wood. Physical properties are the quantitative characteristics of wood and its behavior to external influences other than applied forces. Familiarity with physical properties is important because they can significantly influence the performance and strength of wood used in structural applications [17].

The density of a hydroscopic material such as wood, density depends on two factors: the weight of the wood structure and moisture retained in the wood. Wood density at various moisture contents can vary significantly and must be given relative to a specific condition to have practical meaning [17].

This study focused on the thermal properties of solid wood, as used in framing, and several commonly used structural wood panel products. These include plywood.

[18] Concluded that the thermal conductivity of plywood was approximately the same as that of solid wood of that species. This conclusion has been echoed by others and is apparent in design values for thermal conductivity of plywood currently in use.

Thermal conductivity is the time indicator of constant flow of heat (W) through a homogeneous material with the thickness of 1 m, in the direction that is perpendicular to isothermal sheets, which is caused by the temperature difference (K) within the sample. Thermal conductivity, (λ) is expressed as $W \cdot m^{-1} \cdot K^{-1}$unit. Thermal conductivity directly depends on the temperature and moisture of the material. Thermal conductivity is the indicator of efficiency of any thermal insulation material. Thermal resistance is the indicator of the resistance of the material to heat transfer by inhibiting conductivity, convection and radiation. Thermal resistance is directly dependent on the thermal conductivity, thickness and density [19].

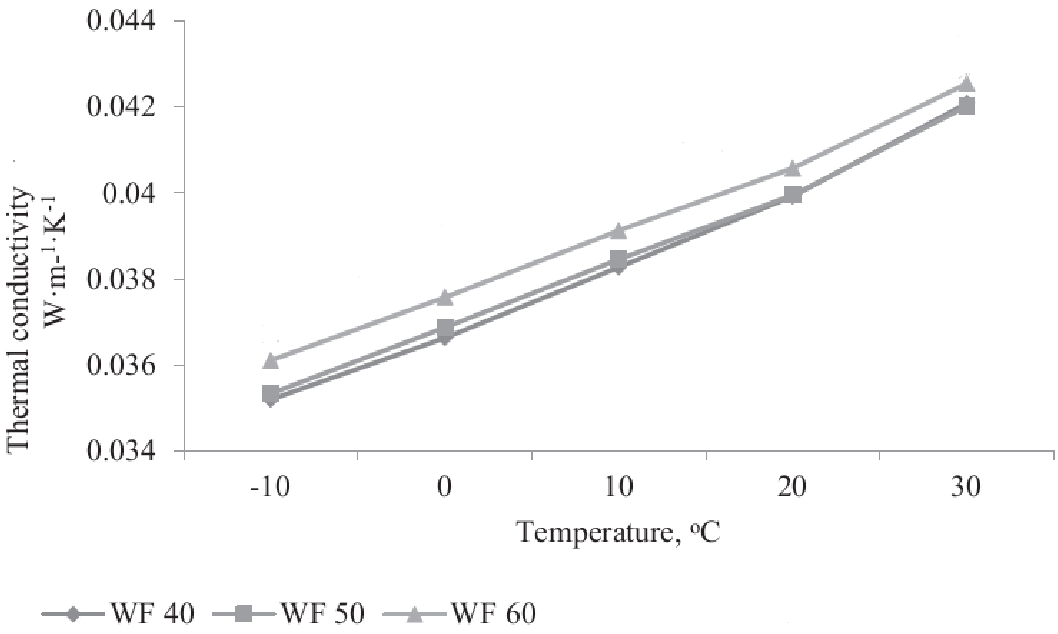

Figure 3-2 Thermal conductivity of materials depending on their density and temperature, WF – wood fiber **[19].**

Table 3-1Thermal conductivity of wood fiber material with density [19].

Density kg•m^{-3}	Thermal conductivity W•m^{-1}•K^{-1}
40	0.0383
50	0.0385
60	0.0391

Value of thermal conductivity of wood material is characteristic of organic thermal insulation materials and similar to commonly used nonorganic insulation materials. The advantages of plant-based fibers over traditional synthetic fillers are their light weight, low cost, specific mechanical properties and excellent biodegradable properties.

3.5.2 Physical and thermal properties of Bamboos

Bamboo is a rapid growing fibrous plant available in abundance on the earth. It has tremendous economic potential. Bamboo is one of the strongest building materials [20]. Ethiopia has the greatest bamboo resources in Africa representing a significant proportion of Africa's total bamboo resources. Ethiopia has more than 1 million hectares of bamboo which is 67% of African bamboo resources and more than 7% of the world total areas covered by bamboo are found in Ethiopia. Ethiopia has two bamboo species namely, Yushania alpine (highland bamboo) and Oxytenantheriaa byssinica (lowland bamboo) [21].

Specific gravity (SG) is a measure of the density of a substance. The specific gravity of a substance is a comparison of its density to that of water. The specific gravity of bamboo varies between 0.4 and 0.8 depending mainly on the anatomical structure and density varies from 0.56 gm/cc to 0.96 gm/cc. Minimum density is it can be seen that tensile strength is also less. Possibly this lower tensile strength can be correlated to lower density. The moisture content of bamboo varies vertically from the bottom to the top portions and horizontally from the outer layer to the inner layers. Bamboo possesses very high moisture content. Aging of a bamboo Culm influences physical, chemical and mechanical properties. The physical and mechanical properties of bamboo vary with the age of the bamboo and the height of the Culm [22].

Bamboo mat board (BM B) is a layered composite comprising several layers of woven mats. The decline in timber availability and the emergence of new technologies and product options have spurred interest in bamboo–based composites and wood substitutes. Bamboo mat board is gaining popularity as an alternative to other panel products such as plywood, particle board, etc., in housing applications due to its good strength properties and aesthetic value.

Thermal conductivity is the intrinsic property of a material which relates its ability to conduct heat. Heat transfers through a material at a specific rate and the rate which depends on the material itself. Some materials such as metals allow heat to transfer quickly through them, whereas some materials such as wood allow heat to transfer very slowly through them. Information on the thermal conductivity of any panel product is of importance for determining its heat insulating value for specialized uses [23].

***Table 3-2Thermal conductivity of bamboo mat boards with different thicknesses and densities* [23].**

Density, gm/cm^{-3}	Thickness, mm	Thermal conductivity, W/m-K
0.765	5	0.121
0.816	6	0.141
0.756	9	0.134
0.824	12	0.142
0.836	15	0.148
0.875	5	0.153
0.924	6	0.161
0.918	9	0.159
0.941	12	0.162
0.877	15	0.15
0.964	5	0.163
1.014	6	0.17
1.042	9	0.176
0.987	12	0.171
1.034	15	0.169
1.084	12	0.195
1.271	12	0.286
1.442	12	0.354
1.096	15	0.201
1.107	15	0.243

From table 3.2 we conclude that no considerable effect of thickness on thermal conductivity of bamboo mat boards (having same density) was observed.

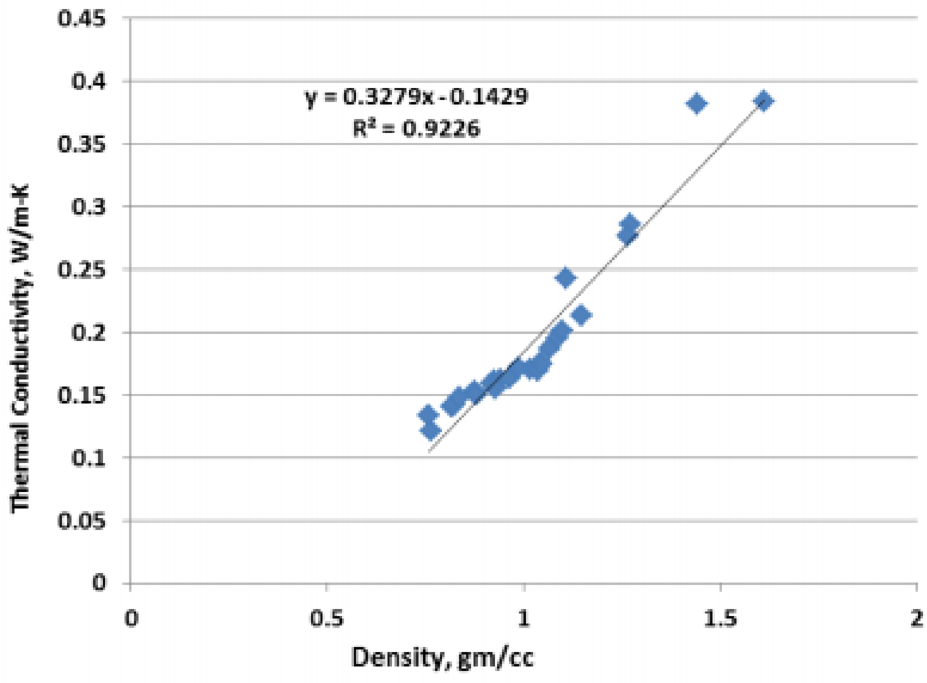

Figure 3-3 Effect of density on thermal conductivity of bamboo mat boards [23]**.**

From above figure, it is observed that the thermal conductivity of BM B varies from 0.12 to 0.38 W/m-K and it increases with increase in density, since it has lower thermal conductivity as compared to most of the other material which indicates that it allow heat to transfer very slowly and hence it can be a good alternative materials for refrigerator.

Refrigerators are in most commonly placed in the kitchen, that's why the kitchen environment was important to consider when developing a new refrigerator, premium kitchens of today natural materials like wood and bamboo sometimes even concrete.

3.5.3 Physical and thermal properties of fiber glass

A composite is commonly defined as a combination of two or more distinct materials, each of which retains its own distinctive properties, to create a new material with properties that cannot be achieved by any of the components acting alone. Using this definition, it can be determined that a wide range of engineering materials. Glass fibers, also known commercially as 'fiberglass', are most extensively use reinforcements for polymer matrix imbedded in glass fibers composites due to their combination of low cost, high strength and relatively low density. Thermal Conductivity Samples have a disc shape with (25 mm) diameter and (3 mm) thickness and Fourier equation applied to calculate thermal conductivity coefficient (k) in Thermal Conductivity [24].

$$Q = -KA\left(\frac{\Delta T}{\Delta X}\right)$$

Where

Q = heat passed per time (W).

k= thermal conductivity coefficient (W/mºC)

A = area (m^2)

$\left(\frac{\Delta T}{\Delta X}\right)$ = temperature gradient (ºC/m)

Glass fibers fall into two categories, low-cost general-purpose fibers and premium special-purpose fibers. Over 90% of all glass fibers are general-purpose products. These fibers are known by the designation E-glass. Special-purpose fibers, which are of commercial significance in the market today, include glass fibers with high corrosion resistance (ECR-glass), high strength (S-, R-, and Te-glass), with low dielectric constants (D-glass),high strength fibers, and pure silica or quartz fibers, which can be used at ultrahigh temperatures [25].

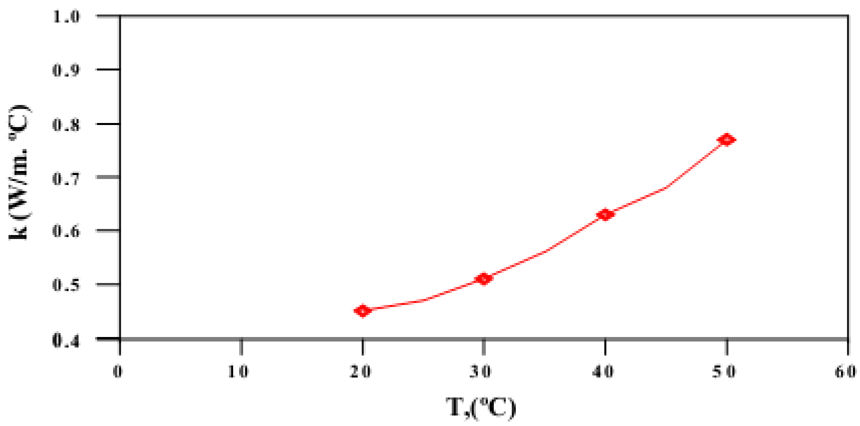

Figure 3-4reinforcing percentage (80% Resin+20% Fibers) **[25]**

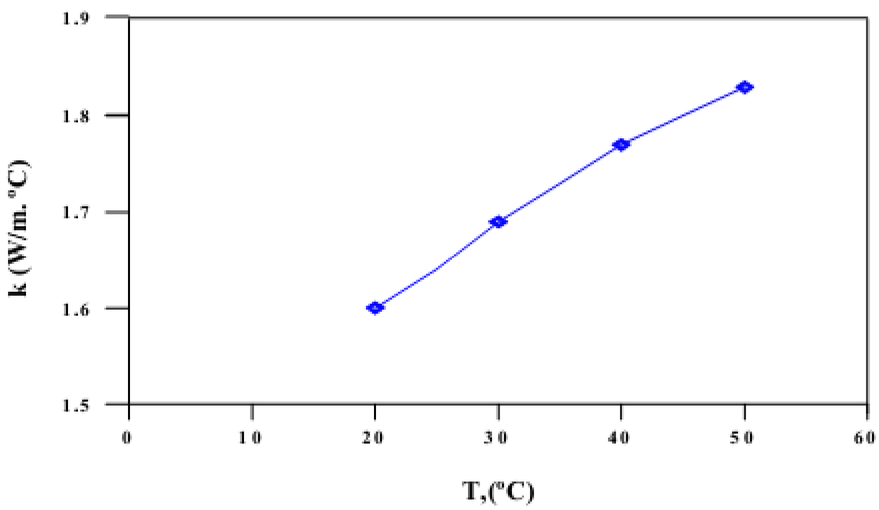

Figure 3-5 reinforcing percentage (60% Resin+40% Fibers) **[25]**

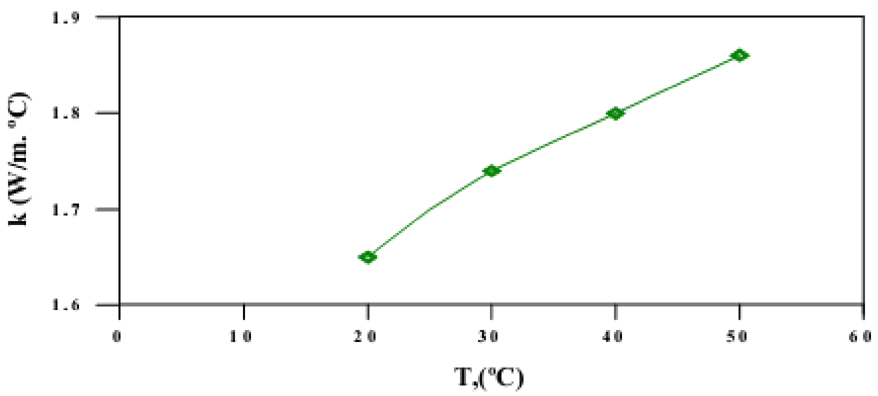

Figure 3-6 reinforcing percentage (40% Resin+60% Fibers) **[25]**

From figure 3.3 which represents the thermal conductivity with (80%) resin and (20%) glass fibers, we observed that increasing of (k) value when temperature increased due to good conducting ability of glass fibers compared with resins. figure 3.4 represents the thermal conductivity with (60%) resin and (40%) glass fibers ,thermal coefficient still increased with raising temperature, and we expect this increment because the high thermal coefficient of fibers . this behavior of increment will continue with (40%) resin and (60%) glass fibers as shown in figure 3.5improvement of thermal coefficient when reinforcing by fibers increasing thermal coefficient values with increased reinforcing percentage [25].

Chapter 4 : Experimental method

4.1 Sample preparation and Parameter selection

The bamboo, fiberglass and plywood species were obtained from Ethiopian manufacturers and they were machined and trimmed to the specimen standard. Determination of mechanical properties sample size of 10mm x 10mm x 300mm and three numbers of test samples were cut from each of the test samples after the mechanical tests. samples were prepared and conditioned at 27+2ºC experiment was laid out in Complete Block Design (CBD) and the samples were replicated three times [17] [18] [20].

Figure 4.1 ply wood sample

Figure 4.2 bamboo sample

Figure 4.3 fiberglass sample

4.2 Equipment used for the experiment

In these experiment I used different equipment's used to determine Physical Properties and tensile strength.

4.2.1 Equipment's used to determine Physical properties

Equipment's used in experiment to determine Physical Properties are a digital weighing balance, the veneer caliper used to measure longitudinal, radial and tangential axes and an oven used to dry the samples.

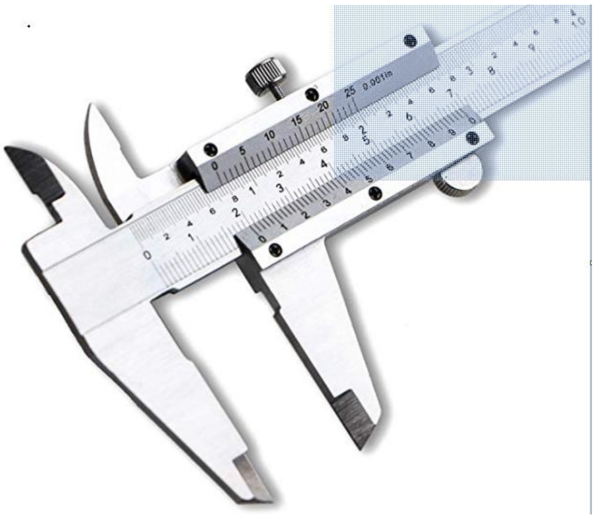

Figure 4.4 veneer caliper

Figure 4.5 an oven

4.2.2 Equipment's used to determine mechanical properties

Mechanical tests were performed on an improvised wood bending strength frame with digital dial gauge (Improvise Universal tensile testing Machine)

Figure 4.6 Universal tensile testing Machine

4.2.3 Test Methodology and Data Analysis

This section reviews some of the more important considerations involved in tensile testing. These include:

- Sample preparation
- Test set-up
- Test procedure
- Data recording and analysis
- Reporting

The sample to be tested must fairly represent the body of material in question. In other words, it must be from the same source and have undergone the same processing steps. It should be remembered that a "sample" is a quantity of material that represents a larger lot. The sample usually is made into multiple “specimens” for testing. Test samples must be prepared properly to achieve accurate results

First, as each sample is obtained, it should be identified as to material description, source, location and orientation with respect to the body of material, processing status at the time of sampling, and the data and time of day that the sample was obtained.

Second requires that equipment be properly matched to the test at hand. There are three requirements of the testing machine: force capacity sufficient to break the specimens to be tested; control of test speed (or strain rate or load rate), as required by the test specification; and precision and accuracy sufficient to obtain and record properly the load and extension information generated by the test.

Finally test result recording and analysis.

Chapter 5 : Results and Discussion

5.1 Introduction

The mechanical strength test on bamboo, plywood and fiber glass experimental conducted was executed in Ethiopia conformity assessment enterprise three times and comparison with renown brands such as WestPoint fridge and Samsung fridge.

5.2 Discussion and conclusion

5.2.1 Discussion

In Ethiopia the demand of refrigerator is meant entirely through import with higher price but there are some manufacturers which assemble refrigerator one of them is Beyo refrigerator assembling company for the help of these study I visit how they assemble refrigerator body before selecting material readily available in Ethiopia can be characterized by either loads (or stress) related failure or structural (or materials) related the material can withstand the loads additionally support is typically provided in must withstand the stresses based on these criteria bamboo, plywood and fiber glass are selected and conduct tensile strength test compare the result with Samsung fridge body and west point fridge body.

5.2.2 Mechanical test result

The tensile test of each sample conducted three times the result is as follow

I. BAMBOO

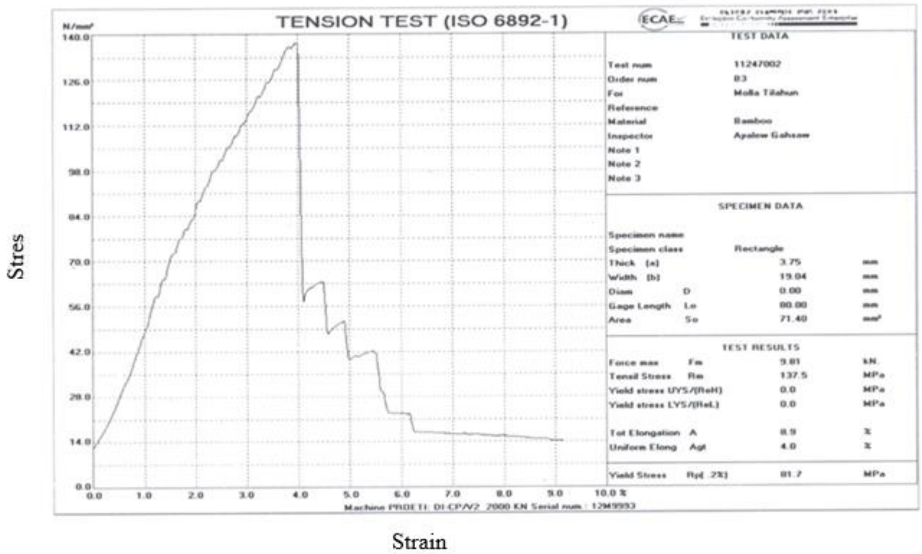

Figure 5-1: Tensile test result of sample 1

We prepare bamboo sample one with spacemen size of width 19.04mm and thickness of 3.75mm with total area of 71.4mm^2 finally Tensile strength result shows 137.5Mpa and test elongation of 0.9% by applying 9.01KN.

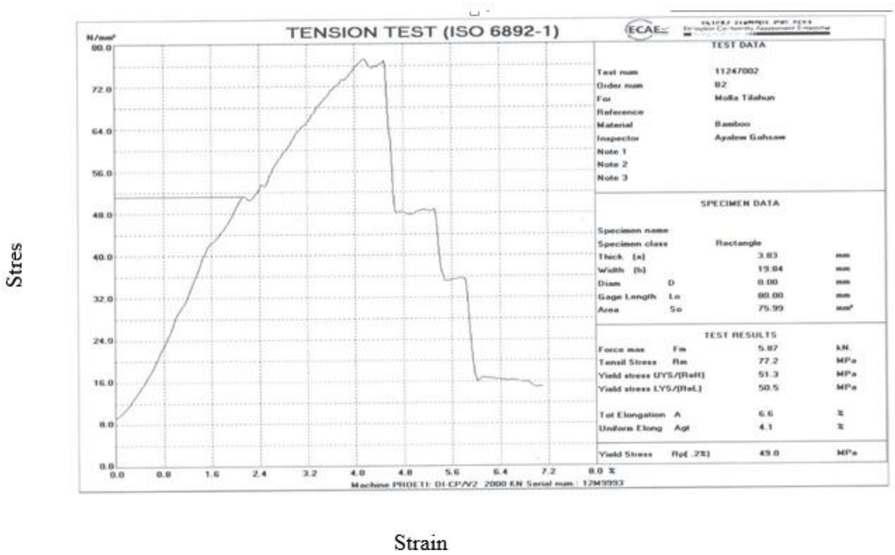

Figure 5-2: Tensile test result of sample 2

We prepare bamboo sample two with spacemen size of width 19.04mm and thickness of 3.83mm with total area of 75.9 mm^2 finally Tensile strength result shows 77.2Mpa and test elongation of 6.6% by applying 5.87 KN.

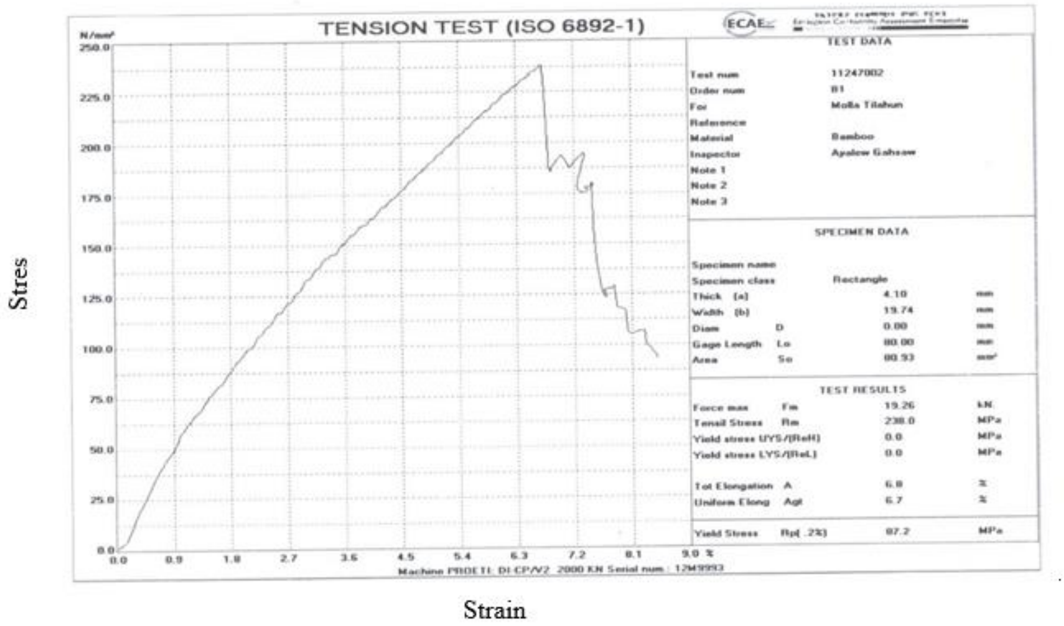

Figure 5-3: Tensile test result of sample 3

We prepare bamboo sample three with spacemen size of width 19.74mm and thickness of 4.10mm with total area of 80.93mm^2 finally Tensile strength result shows 238.0Mpa and test elongation of 6.9% by applying 19.26KN.

Table 5-1 Tensile test result of bamboo

Bamboo	Sample size	Force	Tensile Strength	Test elongation
Sample one	19.04×3.75	9.01KN	137.5Mpa	0.9%
Sample two	19.04×3.83	5.85KN	77.2 Mpa	6.6%
Sample three	19.74×4.10	19.26KN	238.0Mpa	6.95%

II. PLYWOOD

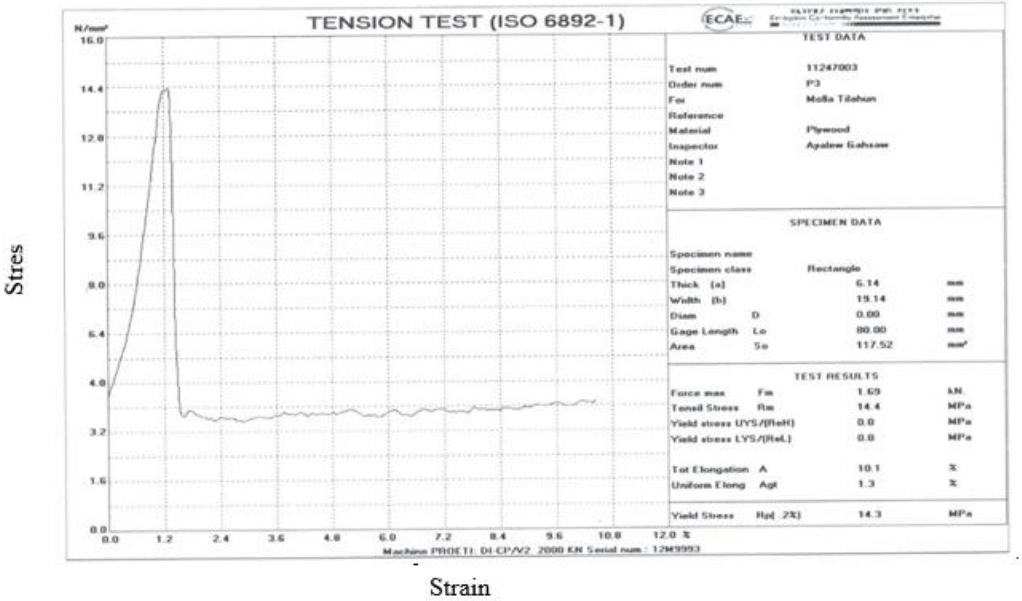

Figure 5-4: Tensile test result of sample 1

We prepare ply wood sample one with spacemen size of width 19.14mm and thickness of 6.14mm with total area of 117.52mm^2 finally Tensile strength result shows 14.40Mpa and test elongation of 10.1% by applying 1.69KN.

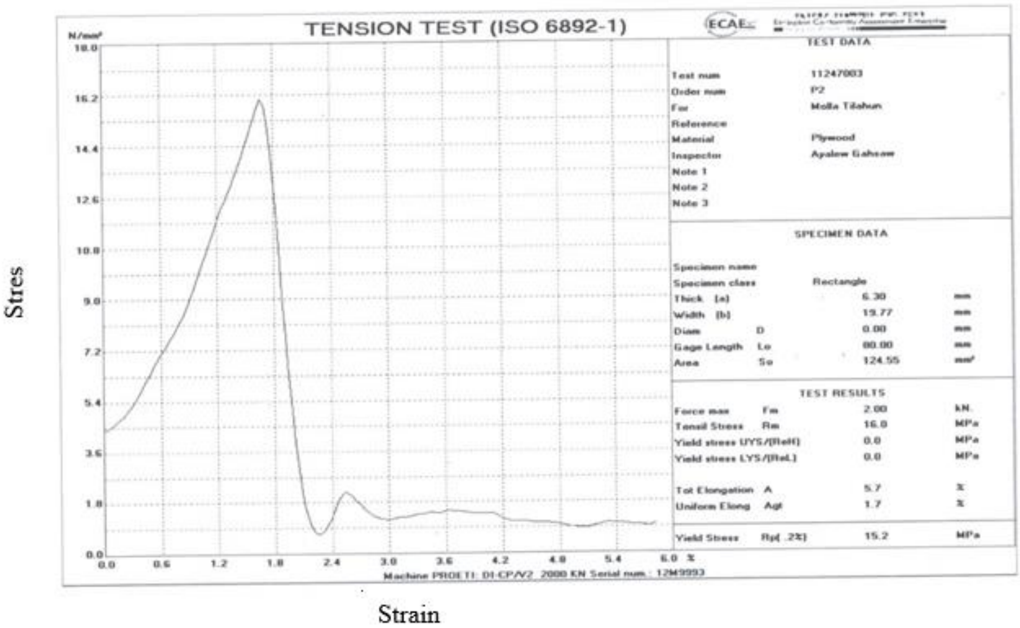

Figure 5-5: Tensile test result of sample 2

We prepare ply wood sample two with spacemen size of width 19.77mm and thickness of 6.30mm with total area of 124.55mm^2 finally Tensile strength result shows 16.0Mpa and test elongation of 5.7% by applying 2.00KN.

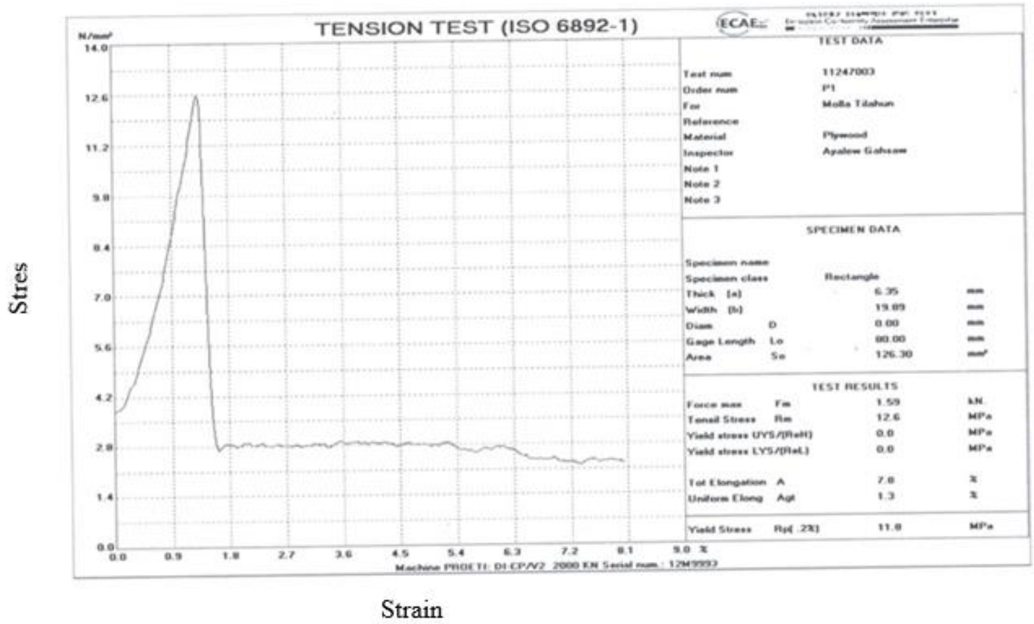

Figure 5-6: Tensile test result of sample 3

We prepare ply wood sample three with spacemen size of width 19.09mm and thickness of 6.35mm with total area of 126.30mm^2 finally Tensile strength result shows 12.60Mpa and test elongation of 7.0% by applying 1.59KN.

Table 5-2 Tensile test result of ply wood

Ply wood	Sample size	Force	Tensile Strength	Test elongation
Sample one	19.14×6.14	1.69KN	14.4Mpa	10.1%
Sample two	19.77×6.30	2.00KN	16.0Mpa	5.7%
Sample three	19.09×6.35	1.59KN	12.6Mpa	7.0%

III. FIBER GLASS

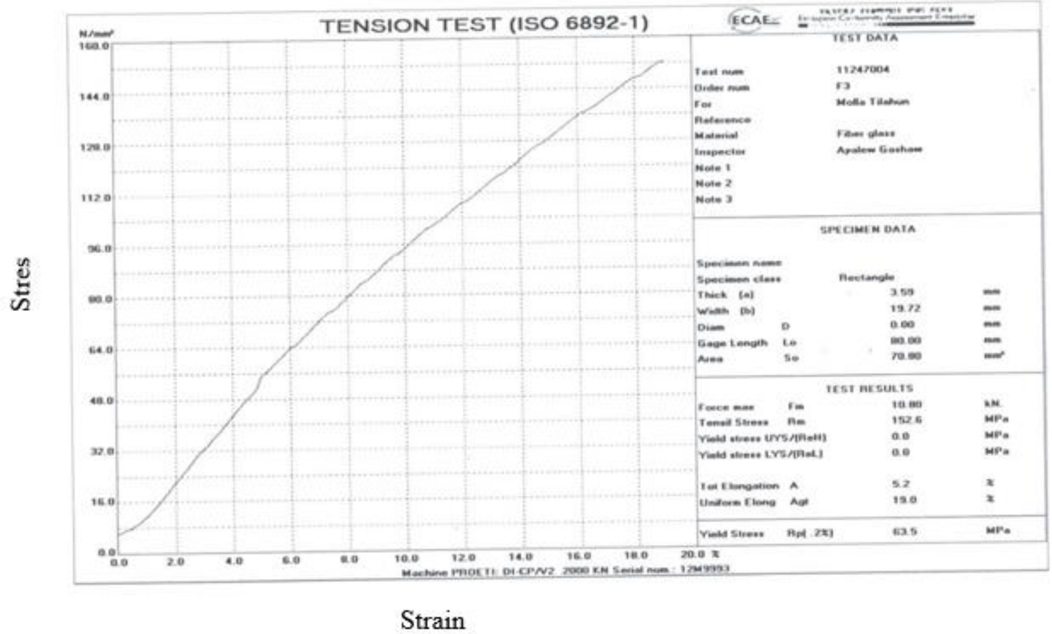

Figure 5-7: Tensile test result of sample 1

We prepare fiber glass sample one with spacemen size of width 19.72mm and thickness of 3.59mm with total area of 70.80mm^2 finally Tensile strength result shows 152.60Mpa and test elongation of 5.2% by applying 10.80KN.

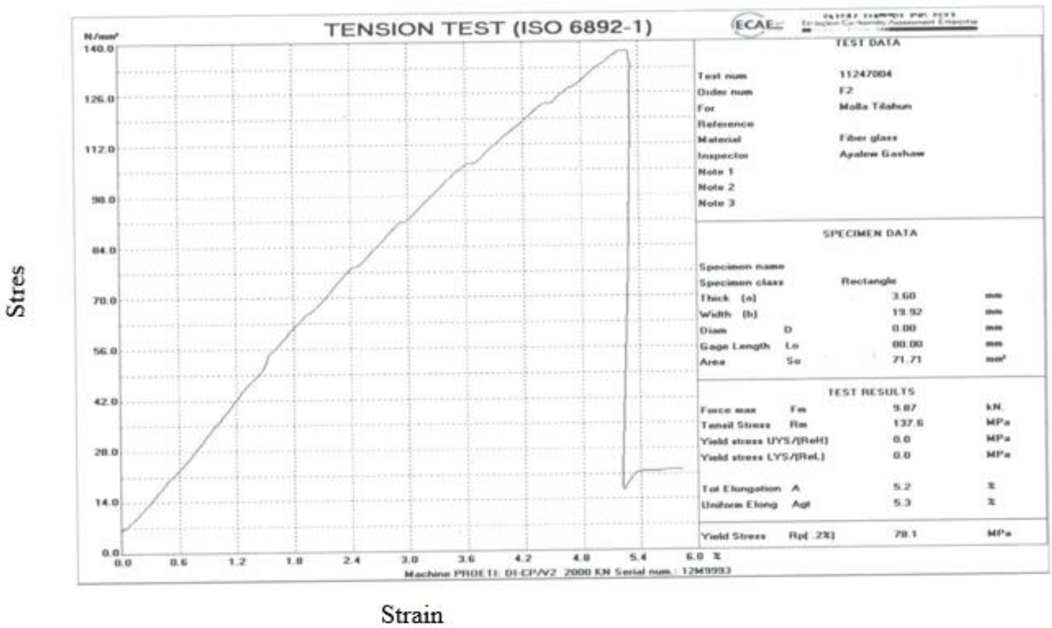

Figure 5-8: Tensile test result of sample 2

We prepare fiber glass sample two with spacemen size of width 19.92mm and thickness of 3.6mm with total area of 71.71mm^2 finally Tensile strength result shows 137.6Mpa and test elongation of 5.2% by applying 9.87KN.

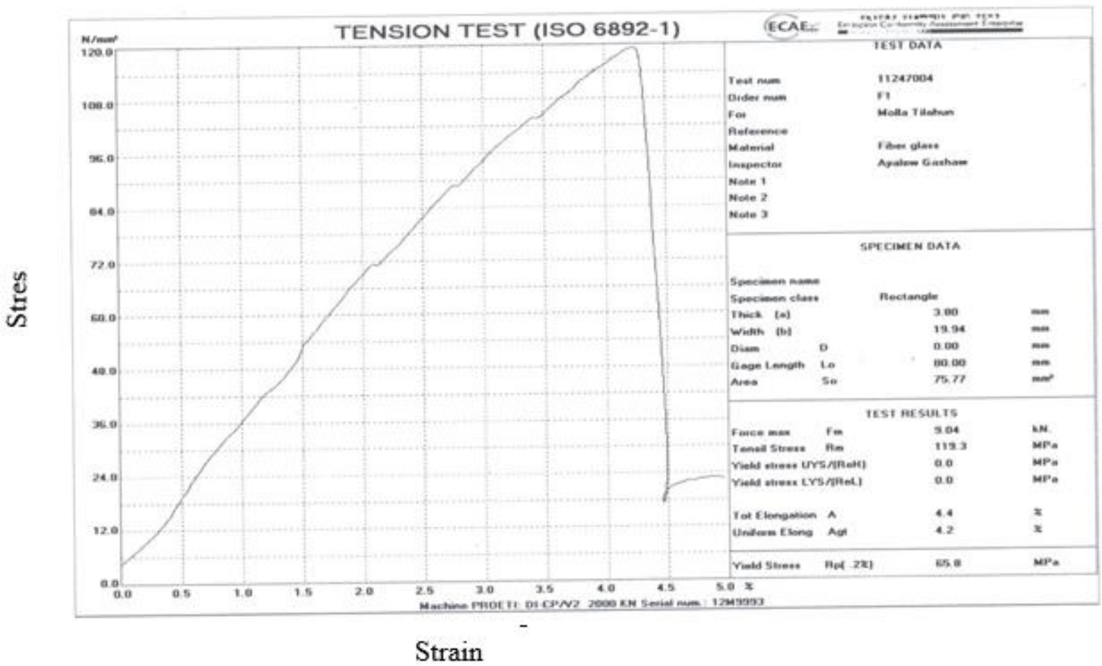

Figure 5-9: Tensile test result of sample 3

We prepare fiber glass sample three with spacemen size of width 19.94mm and thickness of 3.80mm with total area of 75.77mm^2 finally Tensile strength result shows 119.3Mpa and test elongation of 4.4% by applying 9.04KN.

Table 5-3 Tensile test result of fiber glass

Fiber glass	Sample size	Force	Tensile Strength	Test elongation
Sample one	19.72×3.59	10.80KN	152.6Mpa	5.2%
Sample two	19.92×3.6	9.87KN	137.6Mpa	5.2%
Sample three	19.94×3.80	9.04KN	119.3Mpa	4.4%

IV. WEST POINT FRIDGE

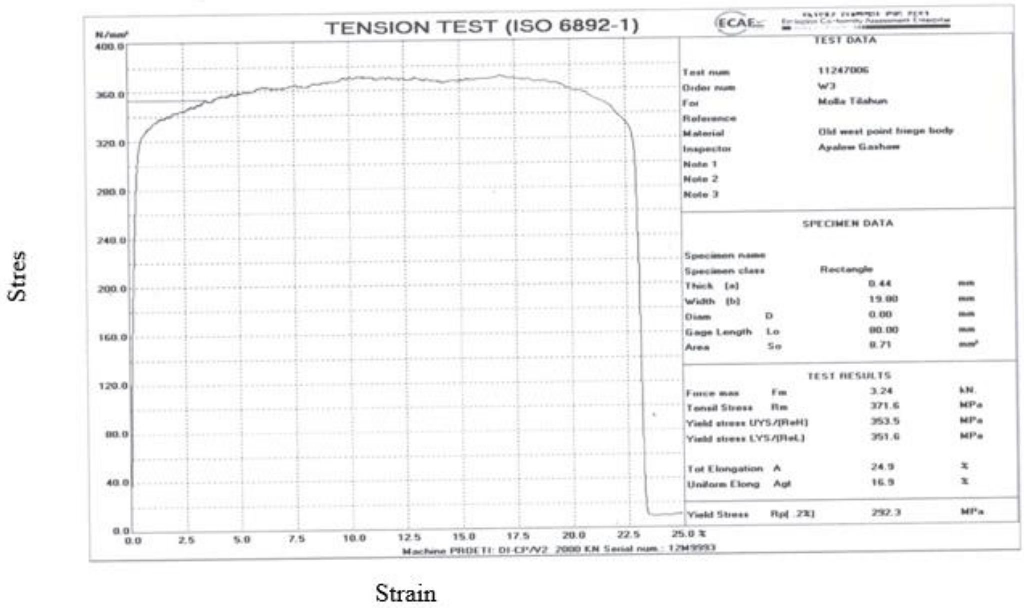

Figure 5-10: Tensile test result of sample 1

We prepare west point fridge sample one with spacemen size of width 19.80mm and thickness of 0.44mm with total area of 8.71mm^2 finally Tensile strength result shows 371.6Mpa and test elongation of 24.9% by applying 3.24KN.

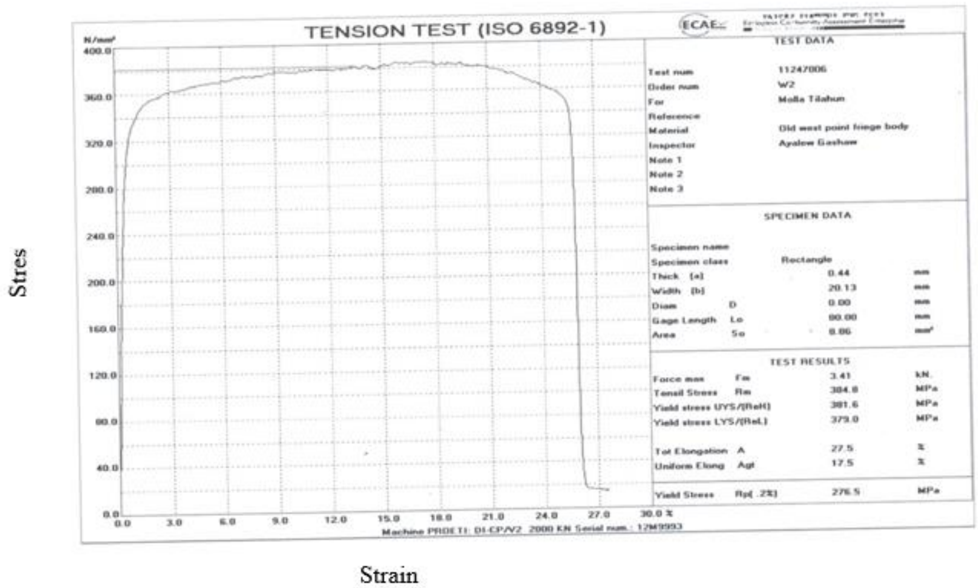

Figure 5-11: Tensile test result of sample 2

We prepare west point fridge sample two with spacemen size of width 20.16mm and thickness of 0.44mm with total area of 8.06mm^2 finally Tensile strength result shows 384.8Mpa and test elongation of 27.8% by applying 3.14KN.

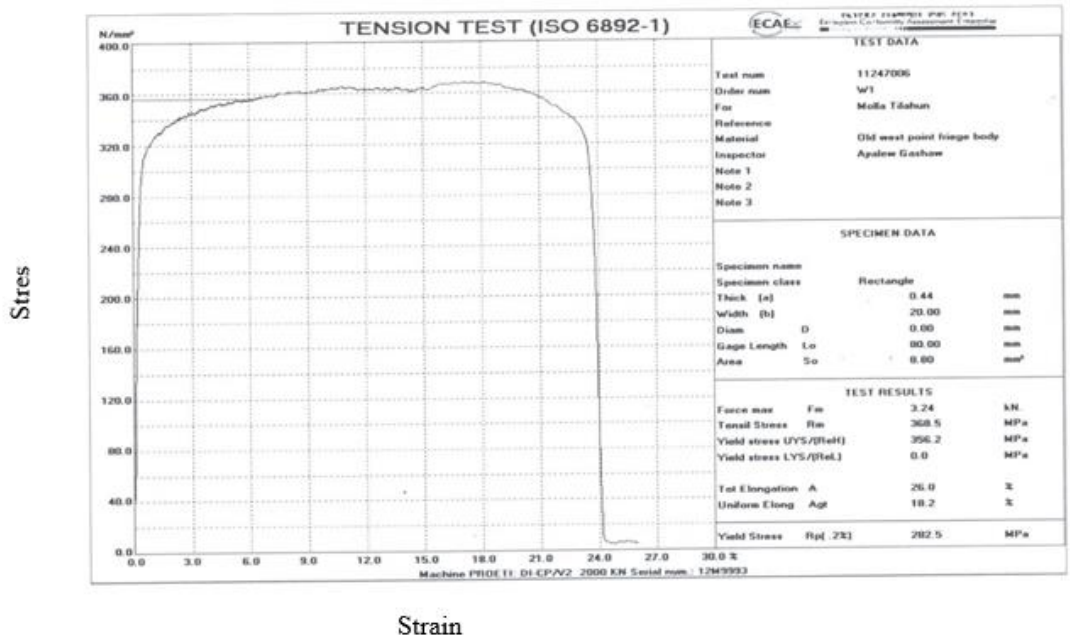

Figure 5-12: Tensile test result of sample 3

We prepare west point fridge sample two with spacemen size of width 20.0mm and thickness of 0.44mm with total area of 8.06mm^2 finally Tensile strength result shows 368.8Mpa and test elongation of 26.0% by applying 3.24KN.

Table 5-4 Tensile test result of west point fridge

west point fridge	**Sample size**	**Force**	**Tensile Strength**	**Test elongation**
Sample one	19.0×0.44	3.74KN	371.6Mpa	24.9%
Sample two	20.13×0.44	3.14KN	384.8Mpa	27.5%
Sample three	20.0×0.44	3.24KN	360.3Mpa	26.0%

V. SAMSUNG FRIDGE BODY

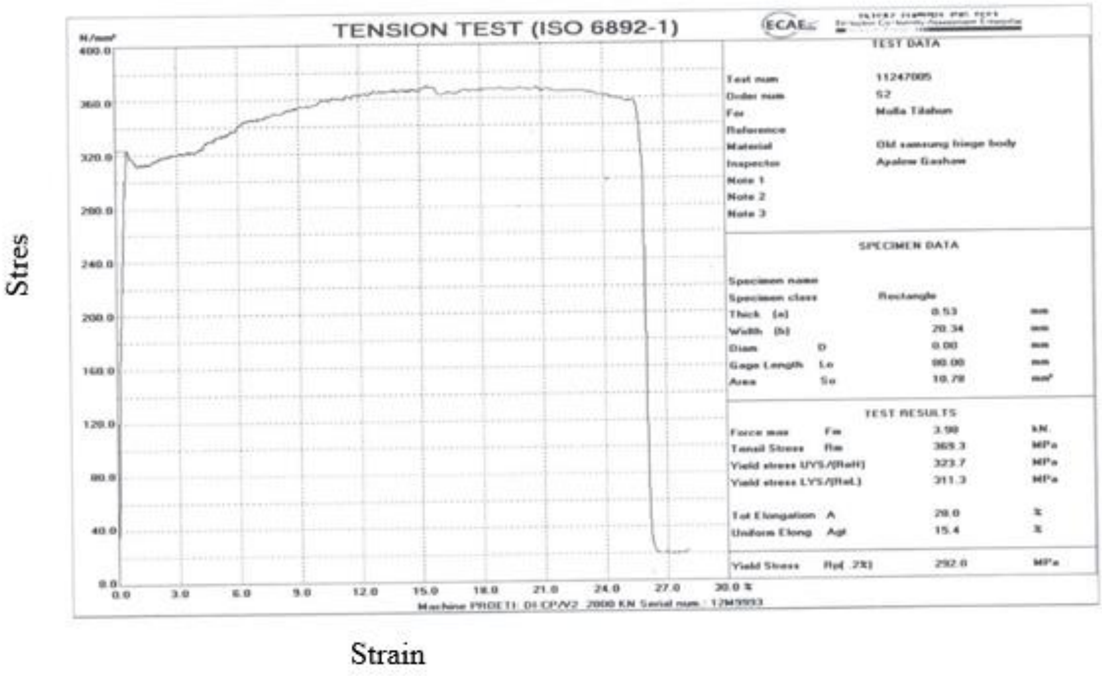

Figure 5-13: Tensile test result of sample 1

We prepare Samsung fridge body sample one with spacemen size of width 20.34mm and thickness of 0.53mm with total area of10.76mm^2 finally Tensile strength result shows 363.3Mpa and test elongation of 29.0% by applying 3.90KN.

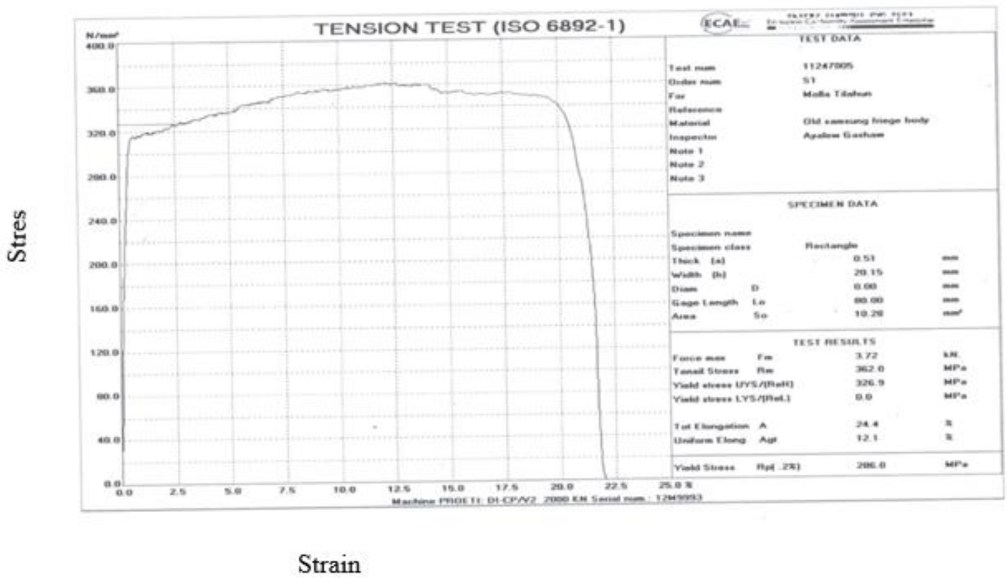

Figure 5-14: Tensile test result of sample 2

We prepare Samsung fridge body sample two with spacemen size of width 21.5mm and thickness of 0.51mm with total area of10.29mm^2 finally Tensile strength result shows 363.3Mpa and test elongation of 24.4% by applying 3.72KN.

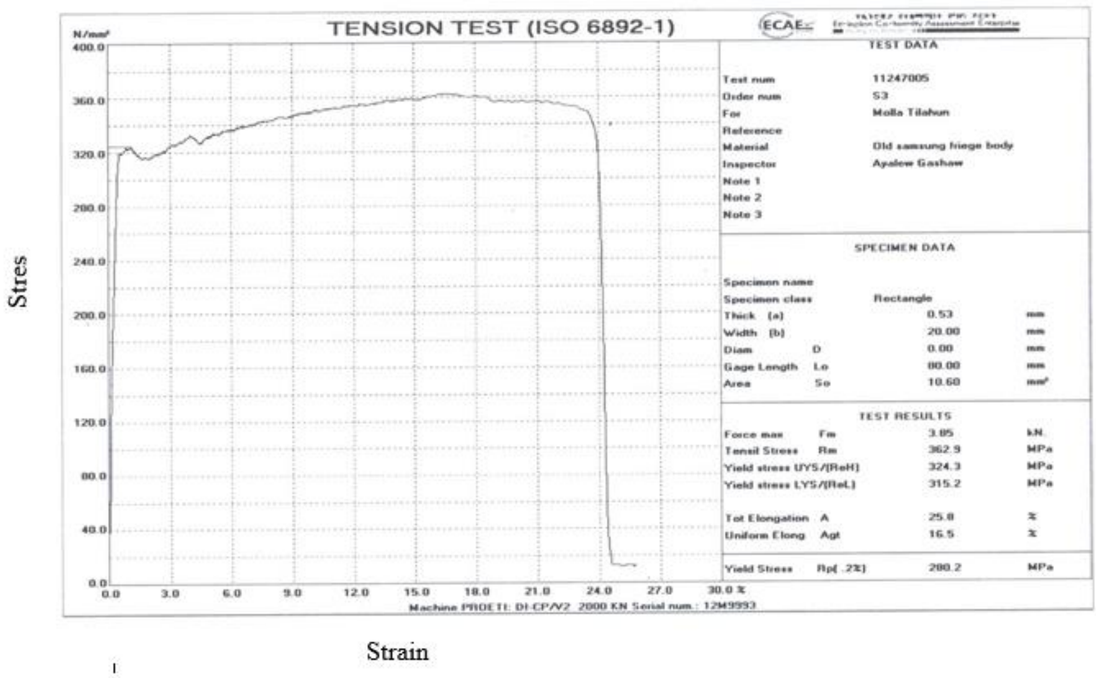

Figure 5-15: tensile test result of sample 3

We prepare Samsung fridge body sample three with spacemen size of width 20.0mm and thickness of 0.53mm with total area of10.60mm^2 finally Tensile strength result shows 362.9Mpa and test elongation of 25.8% by applying 3.85KN.

Table 5-5 tensile test result of Samsung fridge

Samsung fridge	Sample size	Force	Tensile Strength	Test elongation
Sample one	20.3×0.53	3.9KN	363.3Mpa	29.0%
Sample two	20.13×0.5	3.72KN	362.9Mpa	24.2%
Sample three	20×0.53	3.85KN	362.9Mpa	25.0%

Table 5-6 average tensile strength of material

MATERIAL	AVERAGE TENSILE STRENGTH
bamboo	140Mpa
fiber glass	126Mpa
plywood	14Mpa
Samsung fridge body	317Mpa
west point fridge body	318Mpa

In this study, on experiment mechanical properties of bamboo, plywood and fiber glass as mechanical test result shows that bamboo have higher tensile strength of the other two but fiber glass have relatively the second when we compare with Samsung and west point fridge body they have much less tensile strength

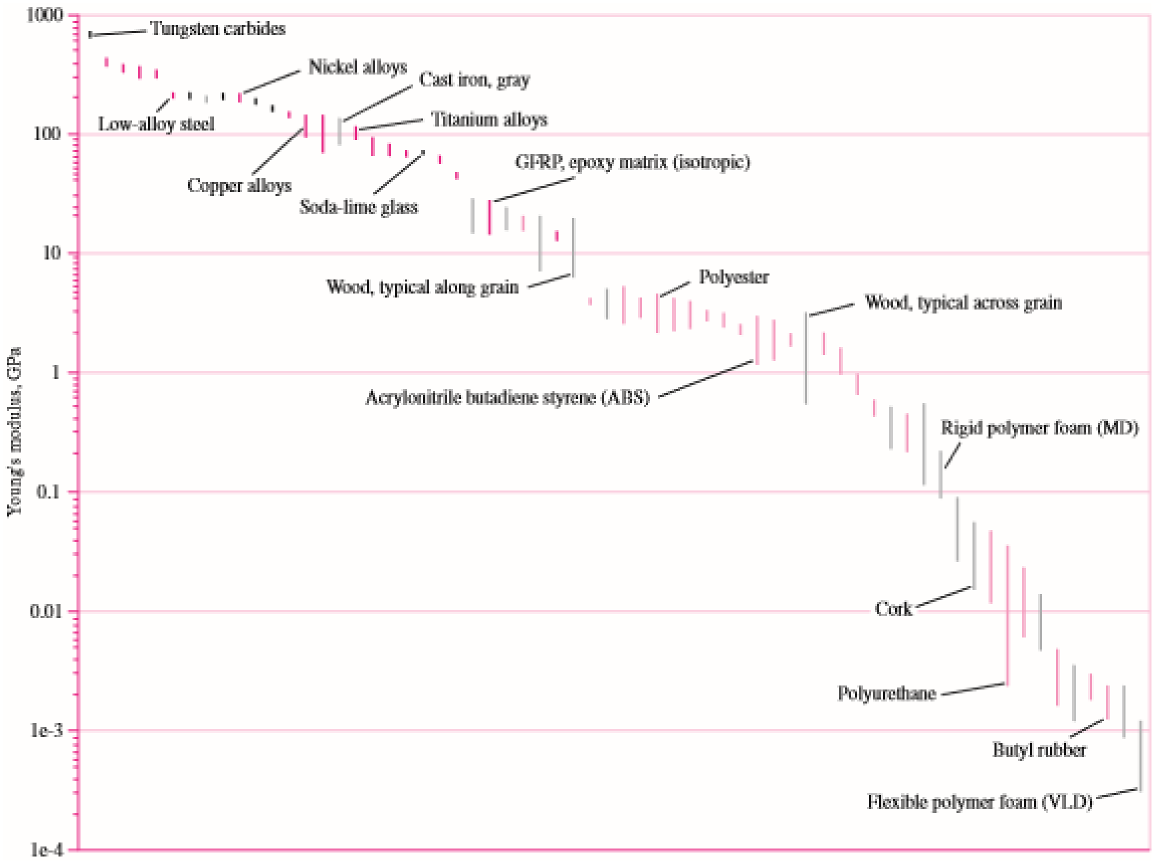

Figure 5-16: Young's modulus E for various materials. (Figure courtesy of Prof. Mike Ashby, Granta Design, Cambridge, U.K.)

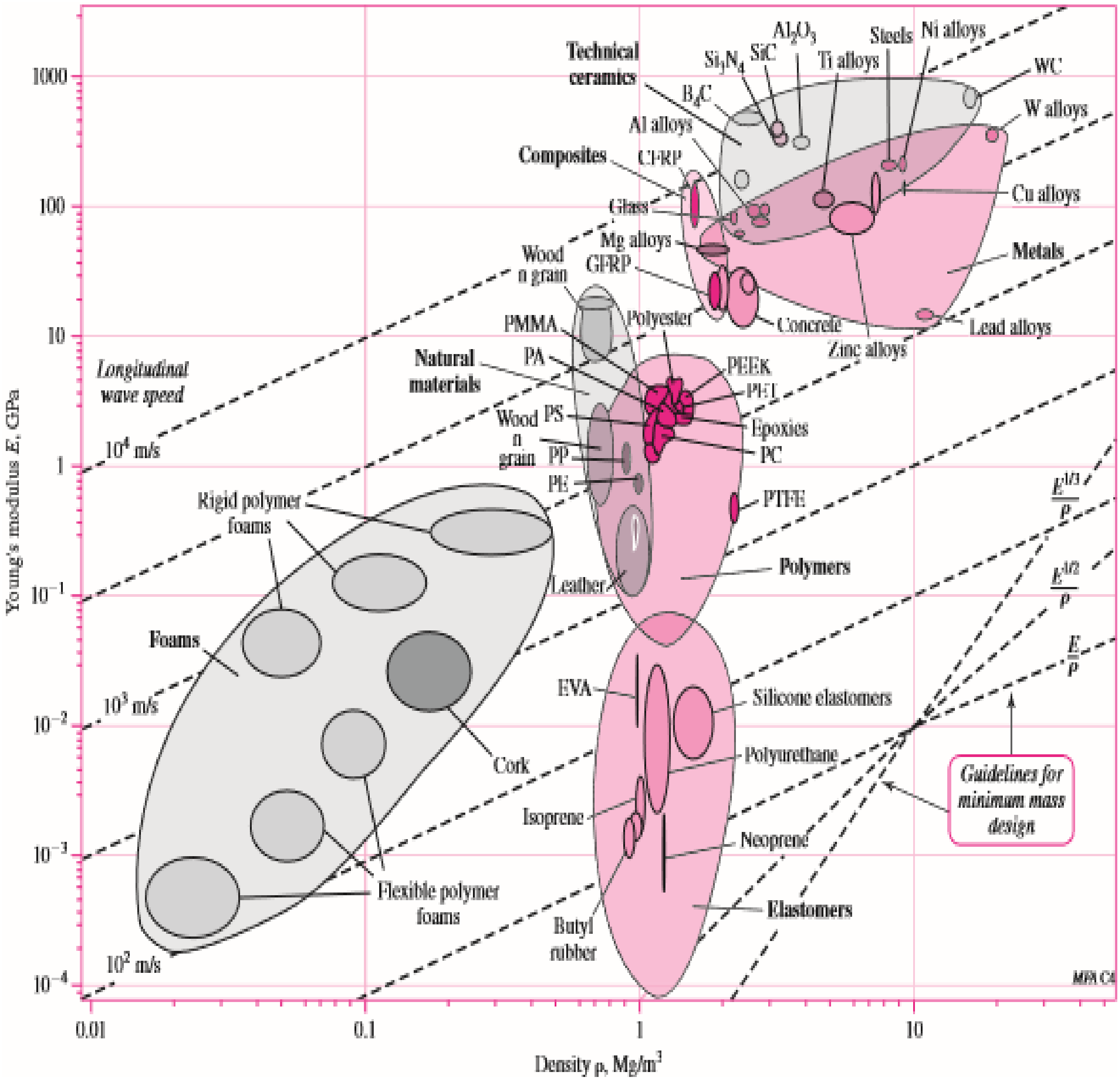

Figure 5-17: Young's modulus E versus density ρ for various materials. (Figure courtesy of Prof. Mike Ashby, Granta Design, Cambridge, U.K.)

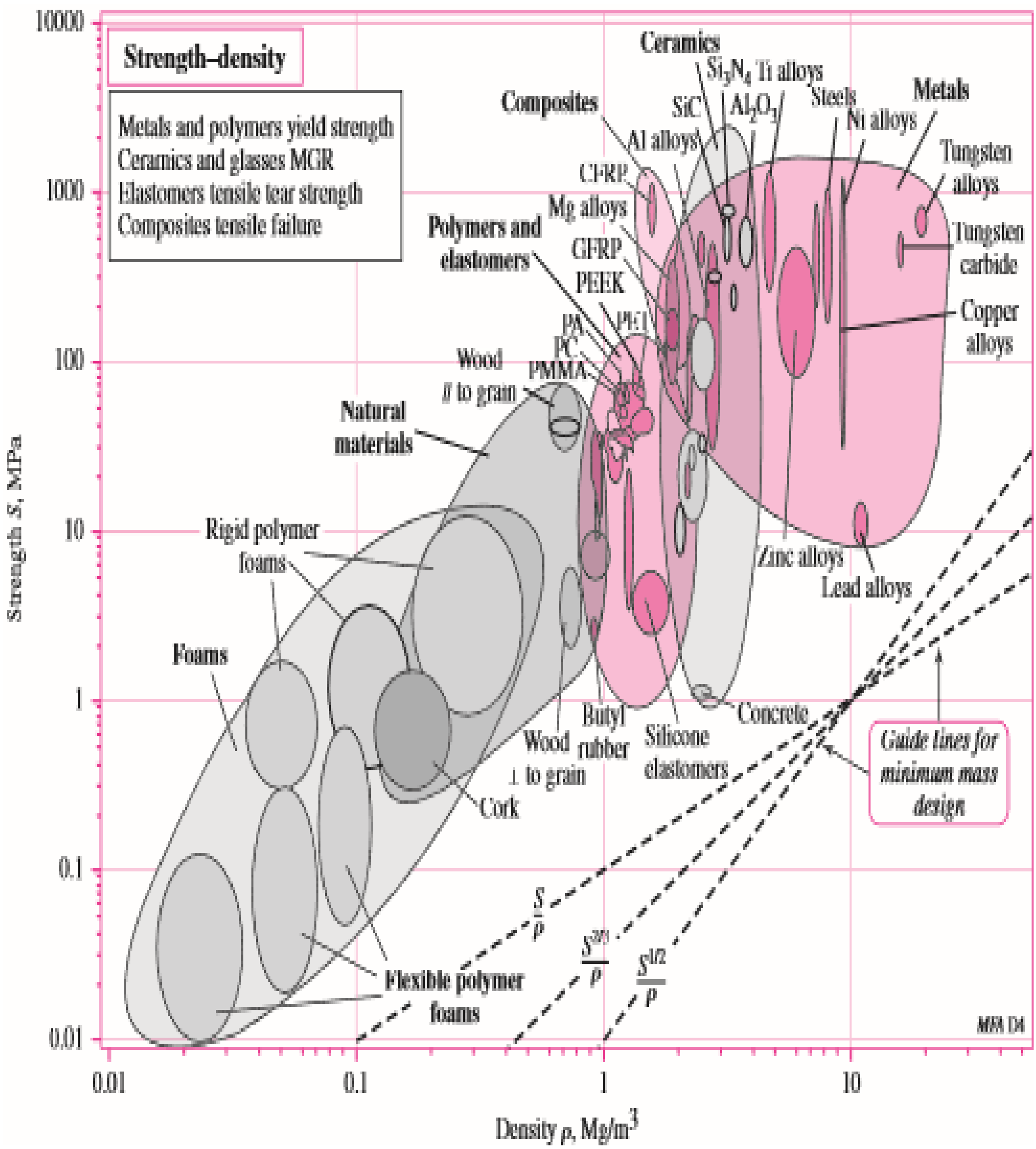

Figure 5-18: Strength S versus density ρ for various materials [26].
For metals, S is the 0.2 percent offset yield strength. For polymers, S is the 1 percent yield strength. For ceramics and glasses, S is the compressive crushing strength. For composites, S is the tensile strength. For elastomers, S is the tear strength. (Figure courtesy of Prof. Mike Ashby, Granta Design, Cambridge, U.K.)

In this study, on experiment mechanical properties of bamboo, plywood and fiber glass as mechanical test result shows that bamboo have higher tensile strength of the other two but fiber glass have relatively the second when we compare with Samsung and west point fridge body they have much less tensile strength from figure 5.17 The Young's modulus (GPa) of selected materials are Bamboo 8 GPa, Plywood 1 GPa, fiber glass 0.3 GPa.

The external shell of the cabinet is usually a single structure that supports the inner food compartment liner, the door, and the refrigeration system. As result shows bamboo have higher mechanical strength therefore we can bamboo is possible to do an attractive cold food preservation product be designed with a meaningful added value, where the good usability makes the user easer

5.2.3 Strength calculations

Mechanical test result shows that bamboo and fiber glass have higher tensile strength of the other two but The refrigerator should have to design and considered as unique to be attractive to the target user in the kitchen environment so that bamboo mat boards is selecting the materials for the final product with dimension of 500×500×800 (L×W×H)mm^3 and some mechanical calculations were made in the most critical parts of the refrigerator or the parts that suffer more load; that means the shelves. The shelves are usually where most of the dishes and heavy objects are stored therefore the deformation of the shelves were analyzed. In both cases the load applied was300N since in the product specifications was determined that the shelves must support a mass of 30 kg. So, the load is obtained by multiplying the mass by the gravity (10 m/s^2).

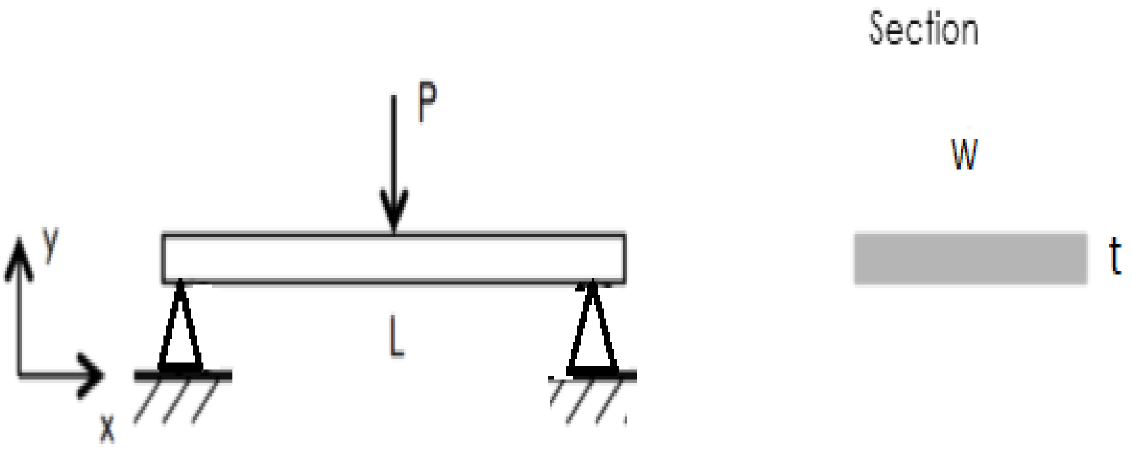

Figure 5-19 Deformation diagram steady shelf

Material: bamboo mat boards

From figure 5 -16: Young's modulus of bamboo is 8Gpa

Dimensions: L = 500 mm

w = 500 mm

t = 3 mm

The load p is 300N

The moment of inertia of body at bottom

$$I = \frac{W \times t^3}{12}$$

$$I = \frac{500 \times 3^3}{12}$$

$$I = 1.2 \times 10^{-9} m^4$$

The deformation

$$Y_{MAX} = \frac{-P \times L^3}{48 \times E \times I}$$

$$Y_{MAX} = \frac{-300 \times 500^3}{48 \times 8 \times 10^6 \times 1.2 \times 10^{-9}}$$

$$Y_{MAX} = 0.0082\text{m}$$

From the strength calculations it was conclude that after applying a load of 300 N in the most critical point of each shelf, the deformation of both the foldable shelf and the steady shelf was acceptable (less than 8 mm)

Chapter 6 : Conclusion and Recommendation

In order to make a good conclusion of this project it is important to go back to the objectives that were considered at the beginning of the project and check if all of them were accomplished First of all, the objectives concerning to assess and characterize locally available material options in Ethiopia and based on the material can withstand the loads additional, materials possibly emerging trends in premium kitchens of today. In this study select bamboo, plywood and fiber glass and conduct mechanical test result shows that bamboo have higher tensile strength of the other two but fiber glass have relatively the second when we compare with Samsung and west point fridge body they have much less tensile strength but from the strength calculations it was conclude that after applying a load of 300 N in the most critical point of each shelf, the deformation of both the foldable shelf and the steady shelf was acceptable (less than 7 mm) and according to refrigerated body storage cabinet specification (LEEC) of dimension 500×500×800 (L×W×H)mm^3 domestic refrigerators load bearing capacity of up to 30 KN/m^2 therefore it is possible to use bamboo for refrigerator the external shell of the cabinet by changing Product architecture the idea of having the top surface of the product in line with a standard kitchen workbench and minimizing stored food load it’s possible to use bamboo.

6.1 Recommendation for Future Work

As the time is limited, and the project can always be improved there are several aspects that can be develop more in detail in the future. One of them is to do thermal analyses and design a mechanism or a new way to have the possibility of adjusting the shelves vertically. It also would be interesting to create a standard inner liner to fix all the possible combinations of the different items in the interior of the refrigerator.

APPENDIX

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Ethiopia Conformity Assessment Enterprise

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ለሞላ ጥላሁን መታፈሪያ

<u>አዲስ አበባ</u>

ግንቦት 07 ቀን 2011 ዓ.ም በአገልግሎት መጠየቂያ ቅጽ የBamboo፣ Plywood፣ Fiberglass፣ Old Samsung fridge body እና Old West Point fridge body ናሙናዎች እንዲፈተሽላችሁ መጠየቃችሁ ይታወሳል።

ስለሆነም በጥያቄው መሠረት ፍተሻው ተካሂዶ 5 ገጽ የፍተሻ ውጤት በዚህ ደብዳቤ ሸኝነት የላክን መሆኑን እንገልፃለን።

ከሠላምታ ጋር

<u>አባሪ</u>፡ 5 ገጽ የፍተሻ ውጤት MTR/1996-2000/11

<u>ግልባጭ</u>፣

በኢትዮጵያ የተስማሚነት ምዘና ድርጅት

- ለደንበኞች አገልግሎት

<u>አዲስ አበባ</u>

ወደ ላቀ ብቃት የሚያደርስ!
Moving you forward!

ECAE ኢተምድ	የኢትዮጵያ የተስማሚነት ምዘና ድርጅት Ethiopian Conformity Assessment Enterprise	Document No: TLD/F5.10-1 Copy No: - / Rev No: 1
Title:	TEST REPORT ይህ የናሙና ፍተሻ ሪፖርት እንጂ ሰርተፍኬት አይደለም	Page No: 1 of 1 / Effective Date: 1Jan 13

Report No: MTR/1996/11
Test order No: ---

1	Name and address of client	Mola Tilahun Metaferia Tel: +251-913-03-65-36, Addis Ababa
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	15/05/2019
5	Client's sample code	-
6	Laboratory designated sample No.	11247002
7	Type of sample	Bamboo
8	Test method	As per client's agreement
9	Test date(s)	17/05/2019
10	Date of Submission of test report	17/05/2019

L.D.S No.	Test No.	Test Result Tensile strength (Mpa)
11247002	1	222
	2	126
	3	71
Average		140

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Habtamu Mihret Position Analyst III Sign.______

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Report No: MTR/1997/11
Test order No: ---

1	Name and address of client	Mola Tilahun Metaferia Tel: +251-913-03-65-36, Addis Ababa
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	15/05/2019
5	Client's sample code	-
6	Laboratory designated sample No.	11247003
7	Type of sample	Plywood
8	Test method	As per client's agreement
9	Test date(s)	17/05/2019
10	Date of Submission of test report	17/05/2019

L.D.S No.	Test No.	Test Result Tensile strength (Mpa)
11247003	1	13
	2	16
	3	14
Average		14

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Habtamu Mihret Position Analyst III Sign.______

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Report No: MTR/1998/11
Test order No: ---

1	Name and address of client	Mola Tilahun Metaferia Tel: +251-913-03-65-36, Addis Ababa
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	15/05/2019
5	Client's sample code	-
6	Laboratory designated sample No.	11247004
7	Type of sample	Fiberglass
8	Test method	As per client's agreement
9	Test date(s)	17/05/2019
10	Date of Submission of test report	17/05/2019

L.D.S No.	Test No.	Test Result Tensile strength (Mpa)
11247004	1	109
	2	126
	3	142
Average		126

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Habtamu Mihret Position Analyst III Sign.________

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Report No: MTR/1999/11
Test order No: ---

1	Name and address of client	Mola Tilahun Metaferia Tel: +251-913-03-65-36, Addis Ababa
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	15/05/2019
5	Client's sample code	-
6	Laboratory designated sample No.	11247005
7	Type of sample	Old Samsung fridge body
8	Test method	As per client's agreement
9	Test date(s)	17/05/2019
10	Date of Submission of test report	17/05/2019

L.D.S No.	Test No.	Test Result Tensile strength (Mpa)
11247005	1	313
	2	322
	3	316
Average		317

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Habtamu Mihret Position Analyst III Sign.

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Report No: MTR/2000/11
Test order No: ----

1	Name and address of client	Mola Tilahun Metaferia Tel: +251-913-03-65-36, Addis Ababa
2	Date and place of sampling	Not Specified
3	Sampled and submitted by	Client
4	Date sample received	15/05/2019
5	Client's sample code	-
6	Laboratory designated sample No.	11247006
7	Type of sample	Old West point fridge body
8	Test method	As per client's agreement
9	Test date(s)	17/05/2019
10	Date of Submission of test report	17/05/2019

L.D.S No.	Test No.	Test Result Tensile strength (Mpa)
11247006	1	311
	2	328
	3	315
Average		318

Remark:

1. This test report relates only to the specific sample product which has been tested by ECAE testing laboratory
2. Sample prepared and submitted by customer.

Test report authorized by, Name Habtamu Mihret Position Analyst III Sign.________

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