FABRICATION OF ROOFING SHEETS USING AGRICULTURAL WASTE MATERIALS

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Degree of Master of Science

Department of Materials Science and Engineering

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Thesis submitted in partial fulfillment of the

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DECLARATION

"I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text".

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The above candidate has carried out research for the Masters Dissertation under my supervision.

Name of the supervisor: Mr. A.M.P.B. Samarasekara

Signature of the supervisor: Date:

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ABSTRACT

Modern roofing products are very popular in various applications due to their specific features to satisfy the local and global demand. Asbestos roofing products are currently used as a roofing solution in very large scale worldwide due to its competitiveness. However, these products indicated some environmental and health problems during and after the usage.

The key objective of this research is to develop an environmentally friendly roofing product to cater local and global market based on locally available agricultural waste materials.

Since Sri Lanka is an agricultural based country, paddy cultivation is a key area of an agricultural sector. Large amount of waste materials generated after the paddy harvest. They are used in some of the applications but most of applications these waste create social and environmental issues. One of the key aspects of this research is to provide value addition to these locally available paddy wastes. The developed roofing product was a rice and paper waste based polymer product and it indicated low cost and biodegradable properties.

The replica and the mould were fabricated in accordance with the available roofing sheet standard. This developed roofing product displayed the minimum water permeability and water absorption features. Product provided the required loading bearing capacity. All produced product showed UV resistivity during the testing period without showing any appearance change on inner surface or outer surface. According to the experimental results, sample containing 65% dry rice husk and 35% paper satisfied the usage requirements successfully. These products can be used as environmentally friendly, low cost, decomposable substitute that can easily be manufactured using locally available agricultural waste and available technologies.

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CHAPTER ONE

FABRICATION OF ROOFING SHEETS USING AGRICULTURAL WASTE MATERIALS

1.1 Introduction

The need for a healthier environment is of paramount importance for living. In every second our environment is polluted without any perceptible symptoms, and may not come to light until it is too late. However it can be revealed only by studying statistics such as increase of diseases. Regarding the use of asbestos, world health organization has stated: "Once considered a miracle material it kills more than 107, 000 people in each year in the world" [1].

It can be clearly understood that use of asbestos could be a critical problem in the society [2]. Sri Lanka, being a third world country has not undertaken extensive of research on this subject due to lack of infrastructure, lab facilities, and funding. This research is intended to find a possibility of alternative solution to the use of asbestos.

1.2. Project Background

Asbestos roofing sheets are commonly used by the majority of the people in Sri Lankan society considering the trends, affordability, and various other factors to fulfill most of the roofing requirements in both rural and urban areas. Long-term effects are never considered, especially on the health aspect. [2- 3]

However, it can be seen that the majority of countries have abandoned their usage due to health concerns. Though the rules have been enforced for discontinuation, the production is still continuing to be exported to developing countries.

Further, upon understanding the potential consequences of use of the asbestos in long run, particularly the World Health Organization (WHO) has declared their recommendation through their journal stating that "WHO is committed to working with countries towards eliminating of asbestos-related diseases by recognizing that the

appropriate ways to eliminate asbestos-related diseases enabling to stop the use of all types of asbestos" [3].

Hence it would be prudent to replace these potentially harmful products from being used in our society. That could be done only by making a daily commitment in all aspects to fight against asbestos. Therefore it is considered the duty of students, researches, universities, administrative bodies, health sectors, and environmental authorities to stress the consequences of the usage of these products and to bring remedial actions sooner to protect the country as a healthier nation and to keep the name of the paradise of the Indian Ocean in time to come for generations.

On the other hand, the researchers are of the view that there should be substitutes as options in the market for replacement. However many industrialists do not care about the long term consequences or health matters but the profits in the silence of the Environmental Authorities as well as health sectors in Sri Lanka[3].

1.3 Problem Identification

Asbestos is an inorganic fibrous product and it is also a non-degradable. When it is inhaled or enters into the human body it remains in the lungs or where it accumulated. This may cause problems that in the human body, especially in the respiratory system and skin. Few of the identified diseases are Asbestosis, Silicosis, Codleworks, Neumeconisis & Beralisocis. Moreover, many other cancer-causing and skin related diseases are commonly reported in worldwide. Few skin related diseases are pulmonary fibrosis, Bronkiokainoma, & Misakilomia, which the diseases are created in the respiratory system, lungs, and abdomen systems [4]. To eradicate asbestos use from Sri Lanka, it is essential to find a viable replacement roofing material, which is the main objective of this study.

Table 1.1: Comparisons of the Asbestos & Commonly Used Substitutes

Substitutes Material	General Features
Clay tiles	Compared with asbestos but needs extra wood materials, time and cost for manpower in installation and maintenance. And suspect few on drizzle when rain. However, still considerable uses this for better cooling effects and healthier aspects.
Galvanized/Steel sheets	1. Cheap but Social aspect 2. High temperature penetration 3. Not good for corrosive environment 4. Affect for winds & other natural forces
Concrete	High cost and not suited for any types of roofing including when not permanent solution.
New decorated tiles Including micro concrete tiles	High installation cost for manpower and cost for structure, maintenance difficulties and temperature aspects.
Coconut leaves and other grass roofing products	Abandoned due to life span and other high maintenance cost including safety aspects on fire risks.

Apart from the above shortcomings in the substitutes despite the high heat transfer product of asbestos are still on the trend. Some aspects are the social level measuring aspect also included with this product. That is asbestos roofing becomes one of the standard scales of determinant by the national census department when evaluating the houses based on economical state.

This is an attempt to introduce polymer-based environmentally friendly roofing products incorporating degradable materials with low-cost, aiming to replace asbestos based roofing products.

1.4. Research Gap

The customer demand is not met with the products available at the market to seek as optional. That means there is a considerable gap or in other means an opportunity for the new product to come for fulfilling the actual vacuum and to replace asbestos products including flat sheets and corrugated sheets.

Secondly, it should be an organic-based product and have the characteristics of degradable features. Moreover, the product should have appropriate strengths compared with the products in the present market. Additionally, the planning product should addresses to following aspects sustain in the market and to defeat the desired outcome of replacing the asbestos roofing products from Sri Lanka.

i. Cost factor
ii. Appeal
iii. Mechanical characteristics
iv. Product Life
v. Production feasibility
vi. Aspects of maintenance
vii. Ease of Installation
viii. Acceptance by reputed authorities
ix. Standard etc..

1.5. Objective of The Project

Considering the above facts and understanding the resources available in Sri Lanka it is led to broaden this research project as fabrication of roofing sheet using agricultural waste materials and to introduce a product to Sri Lankan society aiming to introduce a healthier roofing solution and then eradicate asbestos from Sri Lanka because of its long term hazards impacts.

1.6. Proposed Solution

The proposed solution was to develop a corrugated roofing sheet using a polymer composite, where the matrix material would be a an agricultural waste product.

Figure 1.1: Trial product with rice husk-polyester composite

It is intended to develop this roofing product with basic technology by which a local traditional manufactures could initiate as a local industry with readily available raw materials aiming to minimize the hazardous effects of the asbestos roofing sheets and to provide eco-friendly product for a reasonable budget.

Moreover, based on the success of the project, it is invited to join hands with other communities who are in the trend of banning these hazardous products.

CHAPTER TWO

LITERATURE SURVEY

2.1. Introduction

It is identified that the specific areas which could be hazardous for human living and exposure and same demarcated for necessary future actions [5-6]. Further, based on the information and projection, it is estimated about 125 millions of people are exposed to asbestos in the world and more than 100 thousand people can affect every year from asbestos-related cancers due to asbestos exposure at home. Further, as per present records and reveals, most of the countries represented by Europe, the reason may be long term expose to asbestos. As Europe region, this had more exposure on to asbestos during last two decades over the other countries [6].

2.2. Asbestos

Asbestos is a natural mineral that contains several specific physical characteristics. Nearly about 130 years of history on manufacturing large scale of roofing products and it have comprehensive mechanical and chemical properties. Specially it can bear high temperatures and also resistant to high shock absorption qualities. Therefore it has been selected for many industries as raw material [7].

2.3. Types of Asbestos

There are three main types out of five asbestos commonly used as a raw material in the world. Those are White asbestos, Brown asbestos, and Blue asbestos. “Asbestos” is commercially identified name and is incorporated with many minerals. The basic classifications of asbestos are as follows.[8].

a. Chrysotile asbestos or (white asbestos)

Chrysotile asbestos could identify as one of the widely used asbestos product in the market. As this can be easily found in most of the roofing, ceilings, walls, floors of

homes in the majority of places as a and as well as in business. Further, automobiles manufacturers are also used these Chrysotile asbestos for various productions including break system components. While some used these raw materials to manufacturing brake system components, head gaskets, and certain boiler system components, whereas these products are in use for insulation for pipes, ducts, and appliances in the general industry

b. Amorite (brown asbestos)

Amorite asbestos are regularly used with pipe manufacturing field as well as in the building industry largely and while these asbestos can also be found in the production processes of insulating products manufacturing, ceiling and heat absorption applications product manufacturers in worldwide.

c. Crocidolite (blue asbestos)

This blue asbestos is widely used in the marine engineering field. Since these asbestos contents much high thermal & mechanical property, it has used on board exhaust systems and for various coatings.

d. Anthophyllite

This is also could use for numerous applications as insulation products and is commonly available in the market.

e. Tremolite asbestos and Actinolite asbestos

These products are rarely used and those products could use as Chrysotile asbestos but it has toxic effects. These two asbestos products are closely shows chemically similar minerals while these products are available in the market with different colors, commonly brown, white, green, gray, or transparent colors.[7-8].

2.4. Characteristics of Asbestos

Due to following main characteristics, the asbestos is attracted by many industries for the production of various manufacturing projects. Specially in electrical insulation products and roofing products [9].

Mechanical Characteristics

i. Withstanding capability for higher temperatures
ii. It has properties of insulating
iii. Probably mixing with other chemicals and ingredient
iv. Have high strength
v. Difficult to destroy and it takes a long time for degradation

Chemical Characteristics

i. High absorption power of other chemicals
ii. Not easily degradable
iii. Chemical component

Table 2.1: Forms of Asbestos Fibers

asbestos paper	asbestos friction materials	asbestos-cement product
vinyl asbestos floor tile	asbestos-reinforced plastics	asbestos coatings and sealants
asbestos gaskets	asbestos packing	asbestos textile

2.5. The Effects due to Asbestos Usage

a. Asbestos as hazardous material

Asbestos has been identified as one of utmost hazardous substances for the environment and it has been brought to the notice as "hazardous air pollutants." By the researches almost 50 years before in the year 1971, Environmental Protection Agency (EPA) was the first organization that initiated and addressed that the effects of dust particles of asbestos which haphazardly harming the respiratory system of

human. Further the comprehensive report brought with clear evidences for effects of asbestos dust upon inhale and the effects health of humans by National Emission Standard for Hazardous Air Pollutants (NESHAP) in the year 1973 and it was proposed implementation of certain regulation and the specific instructions for asbestos produces as well as asbestos related other product manufacturers in the world [9]. Moreover, it was alarmed the public and the workers those who were in the asbestos production and for the workers in the sites of demolition of structures that contain friable asbestos as well and additionally it was demarcate dparameters of asbestos content in many products, raw materials and for certain applications. Furthermore, it was declared as prohibited for certain products based on valid experiments (38 FR 22606) [10].

b. Asbestos attribute for lung cancers

The common belief in society, that the tobacco affects for lung cancers or problems related to lungs. Confirming above even the tobacco container specifically mentioned that the warning, however, it is not brought to the light the consequences of the effect of asbestos due to various reasons. But, As per the research conducted it has been proved hypothetically that both asbestos and /or tobacco inhalation is presumed to be the causes of many complications related to lungs and there are certain predictions more likelihood for asbestos dust over tobacco for the cause of lung cancer due to the contribution of asbestos and tobacco exposure[11].

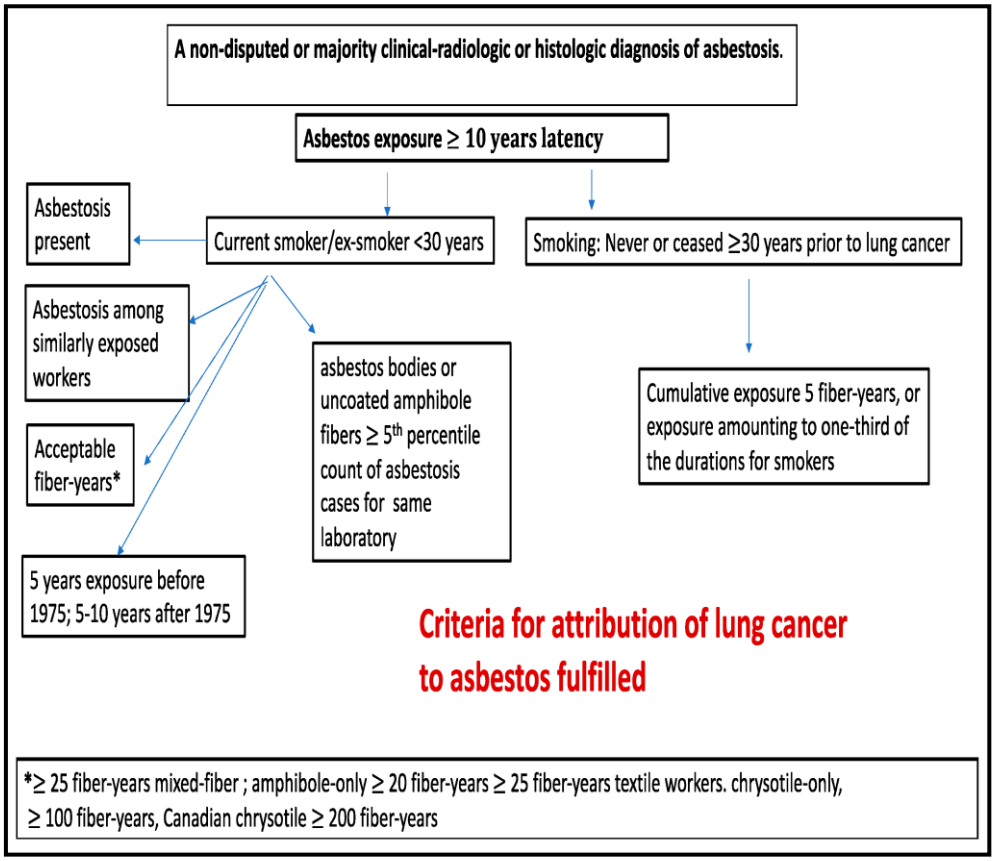

Figure 2.1: Asbestos Attribution On Lung Cancer

c. Asbestos related illnesses

As per statistics the use of asbestos in industrials and various manufacturers peaked during the period of 1960s to 1970s. The main reason behind asbestos was its attractive mechanical and thermal properties by which variety of products used these asbestos including cement pipes, flooring materials, thermal and electrical components, other various types of coatings, etc.. Due to these trends in that period the market almost filled with products that can products with asbestos and the cost of asbestos become high. However, by the year 2000 it was reported the real status of asbestos as there over 600 000 workers suffered with sicknesses and experiment reveals the causes are contributed with asbestos. At the same time that was affecting over 6000 businesses which was related with asbestos in USA. And that was the eye open point for consider the effect of asbestos over its advantages. As per the predictions it is Estimated total future costs to be borne by the affected community is vary from US$200 - US$265 billion [12]

Moreover, it is also revealed by the researches that the continuously expose for long duration of asbestos dust, that can cause many diseases specially in the respiratory system [12]. Aim of this research paper is also an attempt to show the requirement of finding a probable solution to eradicate asbestos considering such effects on human health. Further, there may be methods and procedures for safe handling too. However, there are possibilities to pollute environmental and thereby re-gain the exposure. Another study found that there are situations that affects for workers when inhale asbestos dust particles whilst work-related concentration activities, that does not show, occur or reported in short time basis but only on frequent examine it can reveal time of exposure and diagnosis aspects as none can predict or estimated level of effect of asbestos without proper investigation and selective examinations. However, based on continuous experiments it has established that the limits of minimum or maximum allowable levels and the safe working environment standard [13]. These levels are explained concerning the time of exposure:

(1) The sample contains 5 fibers longer than 5 micrometers per cubic centimeter of workplace air for time-weighted 8-hour exposure.

(2) The sample that contains 10 fibers longer than 5 micrometers per cubic centimeter of workplace air maximum peak concentration, generally measured over 15 minutes.

d. Asbestos contribute environmental pollution

Therefore, that can be arrived to conclude that the plain Asbestos-roofing sheets can carefully be handled under the adequate measures. but life span of the product and reaction with respect to the various environmental and uncontrolled heating condition management remain in doubt. Because the energy developed during the various processes and applications of machines that are in various cutting and other surface preparations is adequate to release considerable amount of asbestos-dust, which can harm for human health based on exposure time and quantity[2]. Moreover, when it compared with Sri Lankan society, it is prudent that many workers in the society have no concerns to use respirators and similar safety gears hardly find due to knowledge as well as various other factors such as cost of safety gears, poor concerns, reluctance

and the practices & habits of long term experiences. Hence, the aspects of passive inhale clusters under the inactive safety agencies and practices & concerns of the responsible parties are inevitable.

e. Asbestos treatment cost and its complexity

One of the attractive point in the aspect of its usage that helps for numerous application is; the asbestos has product diversity and that can have use for numerous applications due to its properties, since it has considerable mechanical properties such as high sound absorption, resistance to various environmental conditions, above average tensile strength, including high capacity for fire and heat aspects [10]. However, the hazardous aspect sthat cause serious health problems for human beings will make disadvantage over the advantage aspects. Many reports and studies confirms and concludes with newest technological evidences that the harmfulness [11,13]. However, it is understood that based on resources availability in Srilankan economy to exposure researches on these aspects are seldom, specially the cost of equipment is not bearable for many institutions in Sri Lanka, such as Phase Contrast Microscopy (PCM), Polarized Light Microscopy (PLM), Transmission Electron Microscopy (TEM) and Scanning electron microscopy (SEM). Moreover, the skills on expertness for analysis of a pattern of sample products also need considerable time upon access to above sophisticate and highly expensive equipment. Further, it is also a good example that the during the Covid 19 situation in Sri Lanka had the facility to undertake maximum of 1000 to 1500 PCR tests only, which is the capacity of the country, whereas USA carried out over 50,000 PCR tests daily.

Hence, it is appropriate to seeking environmentally friendly products to refrain from world-recognized diseases and moving for possible alternatives with economical researches. Generally, most the manufacturers will receive the basic asbestos fibers from a particular refine and that are used in variety of operations to produce the following products. Some examples of these manufactured materials include except roofing products.

2.6. Solutions Developed as Substitutes

Table 2.2: Usage of Asbestos In World Based On Industries

Sr.No	Field of construction	Usage
1	Building construction	Roofing sheet production
2	Electrical component manufacture	Electrical components
3	Steel construction	Heat isolation products
4	Machinery & Factories	As Insulators
5	Buildings on railways	High-temperature absorption areas and as resistance for shocks
6	Boiler industry	High-temperature absorption areas
7	Chemical industries	As insulating product and heat & chemical absorption product
8	Gas industry	As Heat protecting materials
9	Rubber mixed floor tiles industry	As for filling materials
10	Plastic mixed floor tiles industry	As for filling materials
11	Cushion mattress industry	As for filling materials
12	Automobile industry	As materials for Brake liners & clutch plates
13	Water Board & distributing industry	As production of water tanks & pipes
14	Shipping industry	As insulators
15	Garment industry	As production of heat resistant gloves and other heat resistant garments

As usual manner this is an environmental problem, which associates with asbestos and that makes the markets vulnerable to substitutes. It has been found that the trends with asbestos manufacturing companies, which they have been gradually replacing

numerous products that contain asbestos with substitute materials since market fragmentation.

Therefore as a solution various trends are in action, which includes re-engineering & re-designing old products to eliminate the need for asbestos, or de-signing new products with a new trend that require neither asbestos nor asbestos substitutes and while keeping the environmental aspects in tight. Meanwhile, it is important to consider main objectives of any projects, that the aspects of economy, environmental acceptance, re-engineering & manufacturing prospects, performance and/or technical difficulties if any well before asbestos is replaced with a substitute. Presently more than 3000 productions are made associated with asbestos in the world are identified and substitutes productions are in upcoming to replace of productions that are related to the following fields.

To have competitiveness over asbestos the proposing substitutes should withstand or fulfill certain mechanical, chemical and other core aspects including approaching to its strength, acceptance for inertness in chemically, anticipated shelf life or durability with certain environmental conditions, and cost-effectiveness over the asbestos. Examples of materials that has been substituted for asbestos include certain fiber products including ceramic fiber, cellulose fiber, carbon fiber, and fibrous glass and several varieties of organic fibers, moreover, it is found that there are 27 examples of alternative products which can be used as substitutes include aluminum, wood siding, vinyl, fiberglass sheet, asphalt coatings, ductile iron pipes, polyvinylchloride pipes, pre-stressed & reinforced pipes of concrete, and semi metallic pipes as substitutes.

Generally, it is true and confirmed without doubts that many asbestos-containing products have substitutes. Similarly, there are substitute for asbestos roofing too, but the trends and demand for asbestos roofing sheets remain in competitive stage basically due non availability of another competitive product and unaware of the hazarders aspects of asbestos. That can be the target or demarcated research gap of the future researches and innovators' goal.

2.6.1. Substitute Availability

As per the statistics that can take good example from the United States itself, USA has approx. 55 percent of total asbestos consumption during recent past period. However, with the certain trends it has observed out of above 55 percent 29 percent asbestos material used product replaced with other building materials and another, 30 percent has been replaced with organic felt, fiberglass or based on composite materials. Subsequently, the overall demand for asbestos product is questionable. While some products produced by asbestos will remain more inelastic, example of gasket materials. As there are few substitutes are in the market. While one of the highlighted aspects is substitutes for friction materials, as often that has been named as product of asbestos. However, there are substitution possibilities and some products are in the market today, that shows the possibility for substitutes. Similarly, Asbestos roofing sheets matter also may not be the longer case in a day to come with continuous experiments, researches as well as innovations compared with current trends for innovations. Undoubtedly, the processes of continuing exploration with the rapid expansion in the industry, it is seemed that a trend of changing asbestos-containing products by appropriate substitutes, while, appropriate fashions are within the cost-effective region. Presently, there is steady progress in these efforts and it is sure that further improvement in substitutes for overall asbestos consumption might be expected in the US as per assumptions and market evaluation.

2.7. Product Expansion or Diversification

With the development of technology there is always trend in developing products aiming many aspects matched with socio-economic aspects as well as learning the easiness and based on human behavior. At times it based on risk factor and another time it leads for improvement of certain qualities, safety and many more govern rules and even with the passions. Then it may happen as the result of one of the firm's desire to apply its existing capabilities to the creation of a new product pointing competitive advantages [14]. When these factors are focused towards the asbestos industry, most leading firms in the asbestos field may be attempt to diversification

based on consumer trends and may vary based on certain requirement and with the rise up of global environmental acts.

Currently, it is observed that firms those who are attempting to become more diversified rapidly due to the above reasons. Therefore now it is more focused on the environmental friendliness, feasible and cost-effective substitutes for replace these asbestos products. further, it is highly considered the degree of success to the return on investment as there are substitutes for every asbestos product in the world market except for few due to its high mechanical properties. Chinese substitutes are good examples. These examples prove the current trend on diversifying aspects of asbestos related substitutes. However, it is to understand that some relatively big money-maker in the field of asbestos product share still manufactured under the certain misuse of various powers and having poor sense on hazardous aspects and living exclusively on money over the other human aspects. As a result, asbestos productions processes are still in the production processes without trending in diversifying [15].

2.8. Proposals and Projections for Roofing Solutions

It is revealed that the trend on synthetic polymers in the recent era due to competitive advantages both in product capacity as well as its cost effectiveness. However, there are essential aspects too, when desiring for polymer or synthetic material usages, which is importantly the low biodegradability aspects. Hence that may remain as a environmental problem in time to come. As synthetic materials has good properties that may produce environmental pollutions, which on the other hand contribute disadvantages. Therefore, producing of roofing sheets or other competitive products or substitutes that having biodegradable materials are vital important and that have significant role in saving environment. Since, natural materials are biologically degraded by micro-organisms in the environment, which is the ultimate requirement as per present environmental regulations and requirement. Hence it is considered the responsibility of all of us to think, develop, support, and use environmentally friendly products in any field which automatically strengthens the environment and all living hoods.

Further, in many local researches, Sawmill waste is also identified as a wastes material and usually used as substances of burning materials in generally. Whereas, one of the researches was focused on these raw material or waste to produce biodegradable composite material and having cost-effectiveness for engineering applications by extracting cellulosic materials using these biodegradable materials of sawmill waste. The study concludes with the maximum percentage of cellulose and hemicellulose that can be achieved from these waste materials reach to 68. 7% and the extracted natural polymer were characterized upon analysis [16].

Moreover, in another study it was found that positive aspects on synthetic polymers or else plastics, which is one of the most expanded product and its multiple usage matching the correspondent properties to achieve targeted product with light weight and cool manufacturing processes while maintaining cost effectiveness and specific mechanical properties. However, similar to every product there are some disadvantage too such as low resistive temperature and low biodegradability aspects. In the meantime different types of clay tiles, Concrete slabs and Galvanize sheets are also playing a significant role in providing substitutes to replace these hazardous products manufactured by asbestos.[17]

2.9. Biodegradable Agricultural Waste Used Products

Since the main aim of this particular research work is also to produce a feasible roofing sheet product with the usage of biodegradable materials, it has found that there is a trend and many researches are being conducted based on biodegradable agricultural waste usage.

1) It was revealed that the Nigerian Building and Road Research Institute (NBRRI) has attempted to produce roofing sheets in 1978 with the use of Rice husks under the different concepts of mixing ratios and the usage of raw materials and under different treated conditions. The mixed ratio was waste paper, rice husk, and cement (1:3:16). Further, the development was carried out in par with British Standard (BS 690) and have made with close & homogeneous mixture consisting of suitable

inorganic binder of cement. The result was concluded that the possibility of developing roofing sheets with the above mixture, but also found certain drawbacks with the process and based on the results. It was also found that the appearance of cracks at the bottom side of the roofing sheet disqualified it as a final product as assumed [18].

Further, it was found that most the best alternative is to remove the fat and oil content in the husk without destroying the rice husk itself helps to develop more competitive products. Moreover, the results of data analysis and findings concluded that rice husk can be used in the production of corrugated sheets up to some extent and Rice husk roofing sheet provides a good alternative that does not pose any health hazard. And at resent in most parts of the western world asbestos roofing sheet is no longer being used in the roofing of houses. [19]

2) Another study carried out in recent past years and found there was a trend in usage of ordinary fibers with cement as substitutes for some material in the building construction field. This has showed positive trend in many developing countries and most significantly the mechanical and other properties had its attraction and trending features such as light weight and easy handling aspects on appearance while it has improved the environmental aspects including energy & thermal properties while maintaining economic benefits. With the innovations and development of natural fiber to usage and its tends to replace the use of products that contains asbestos is highly appreciated in order to insist other part of the world to confirm its opportunity.. Furthermore, that provides the best advantage for every community expected to achieve the economic returns while maintaining the stable environment impact [20].

3) Similarly another study was conducted particularly on biodegradable materials, since one of the waste used as raw material for the study. The possibilities of use of palm biomasses and some selected fruit bunches have used in this production and it was found these oil palm and other fruit branches are appropriate for furniture manufacturing, however, the procedures in details not published yet and is under testing level. So it gives an idea of trending in the society and it is essential

assistance for encouragement of similar research projects to improve the environment as well as communities in the world. Moreover, it is guaranteed the researchers and innovations will take necessary steps in near future.

4) It is also understood that fiber can be derived from natural fiber. Here it is the focus is on the vegetable (leaves, seeds, and grass fibers) &timber products that have been used as agricultures residues to produce natural fiber. The benefits of these fibers have many environmental benefited aspects over polymer as well as asbestos are specially the biodegradability, high strength and low specific gravity properties. Moreover it is also cost effective and could achieve waste management aspects too while the performance or the capacity handling depends on availability of waste. The selection criteria of natural fibers for buildings and roofing have been considered based on many experiments and evaluations by researches and interested groups including manufacturers. They found there are many opportunities in manufacturing substitutes using raw materials under cost effective manner will increase and improve the consistency of the development of many products and substitutes. [21]

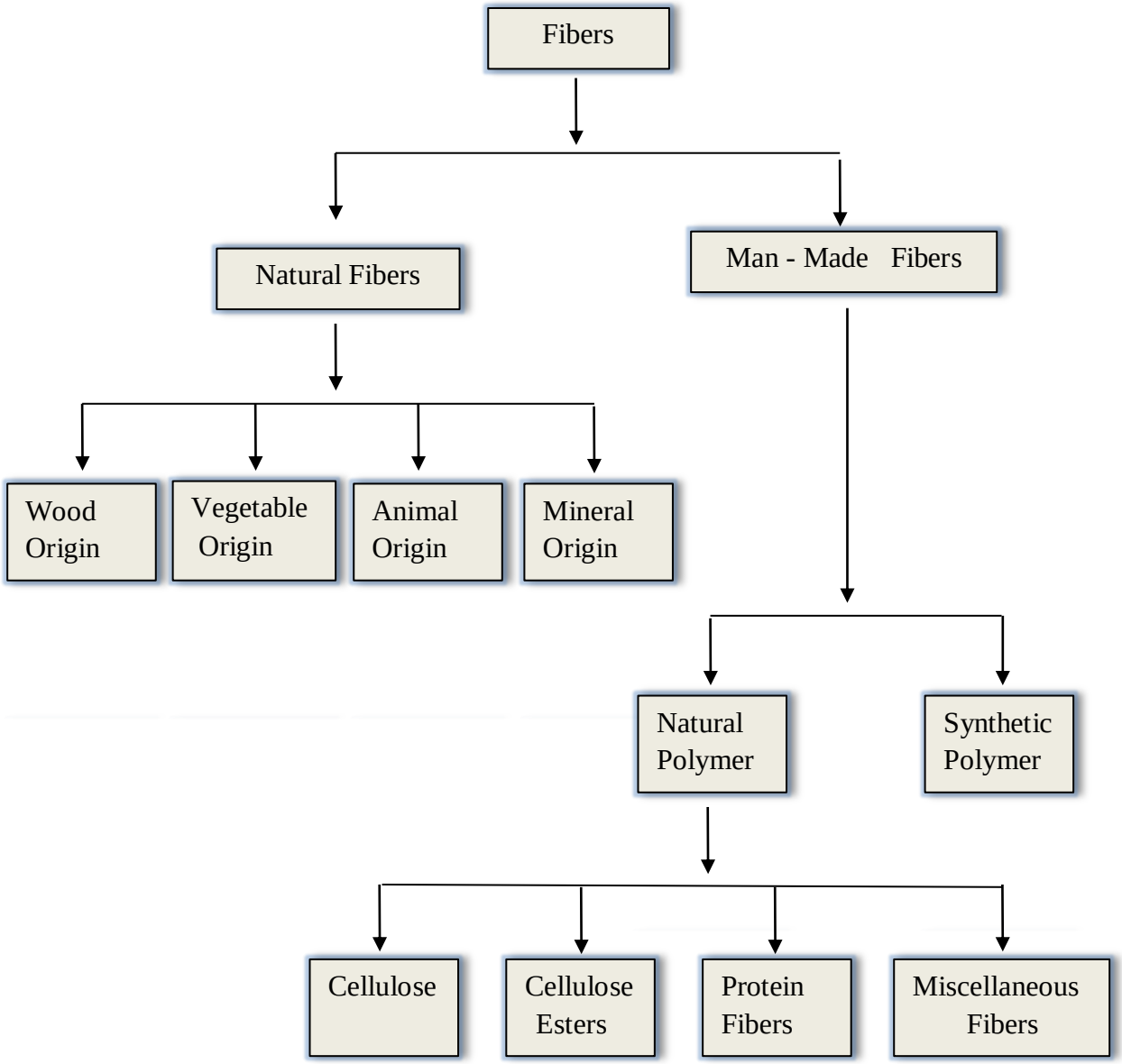

Figure 2.2: Types of Fibers

5). In another study it is found that agricultural residues used as raw materials in the process of manufacturing roofing tiles, with the raw material of sugar cane, biogases pulp fiber, water hyacinth, sisal, palm fruit bunch, and oil palm fiber. They were applied to use in the same way as wood but they have to be separated some impurities such as dust, sugar pits, and wax. As specified in the previous experiment. These are often barriers to bonding adhesive especially synthetic water-based solutions [22].

6). Similarly, one more study in Thailand reveals nowadays the demand for natural resources and energy conservation methods with other resource maintenance along with development in the country. Thereby the means and ways for different methods to manufacturing of roofing tiles can specify as a trending innovation aspect and at the same time it helps to economy of the country [23]. Further the raw material obtained from corn residues become an alternative to energy as well as environmental conservation while gaining the economy. Since Thailand is an agricultural country, it has plenty of crop residues such as straw, corncobs, bagasse pulp fiber, water hyacinth, sisal, palm fruit bunch, and oil palm fiber. Therefore, it is necessarily needed for continuous researches to investigate the use of recyclable raw materials of agricultural residue to replace the products or components made out of hazardous materials, and that helps to protect unpolluted environment as well as maintain healthier life cycle. [24]

7) The availability of raw material in production of corrugated roofing sheet in Sri Lanka can be illustrated with the figure 2.6 as it displays the area of paddy cultivation in the country When study the above experiments or the researches it can understand the significant trend and the feasibility of manufacturing the products, substitutes with natural fibers or combination with various types of waste to a valued products through proper study.

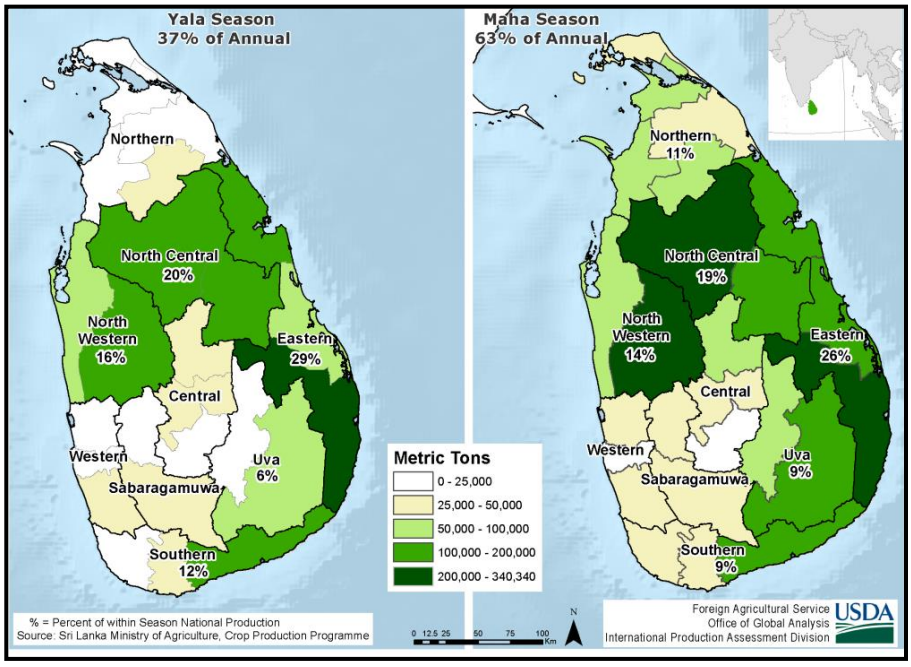

Figure 2.3: Production of Rice in Sri Lanka

Similarly, This research work also an attempt of fabricating a roofing sheet using rice straw, one of the waste material in Sri Lanka. The above picture indicates the availability of raw material of rice straw for production. This can clearly understand the availability of rice straw in Sri Lanka for production of any substitutes using rice straw. Usually most of the rice straw used as waste material. Since, it can utilize for the proposed project and that will help to improve the economy of the country, improvement of health aspects, occupations for labors, waste management and making a friendly environmental for nation.

CHAPTER THREE

METHODOLOGY

3.1. Guideline for Sampler Preparation and Testing

This chapter presents the design and the fabrication method of the proposed roofing sheet using the non-hazardous materials including agricultural waste materials. Further, the theories and adapted geometrical aspects usually used by the various leading asbestos sheet manufactures in the world.

For any project on product manufacturing, market domination is one of the key factors. Hence, similarly during in this project too its considered the most appropriate shape of the product and it is revealed most attractive shape of the roofing sheet in the market is as asbestos corrugated sheet, though the raw material in the product is not environmentally friendly. Thereby it is considered the maintaining the same geographical aspects in the product as per the commonly available standard since it will have the advantage for final users based on the success of the proposed project in the research. Additionally, there are added advantages to the end users which will be discussed and that will also be an added advantage to the project.

Moreover, the methodology adapted in this project can be sub categorized to as follows

a. Pattern and mould design
b. Raw material selection and mixing
c. Product development
d. Testing
e. Comparison the product with proved products

As per the literature and the market analysis in Sri Lanka, it is proven the Asbestos corrugated roofing sheets holding the market leader position continuously for a long period due its competitiveness features including strength and other mechanical

properties and characterization except its toxic material. Hence the project methodology aims to propose certain raw material for the new production and same planned to test under the asbestos production & testing criteria until newest criteria implemented. Flow chart of the process as follows.

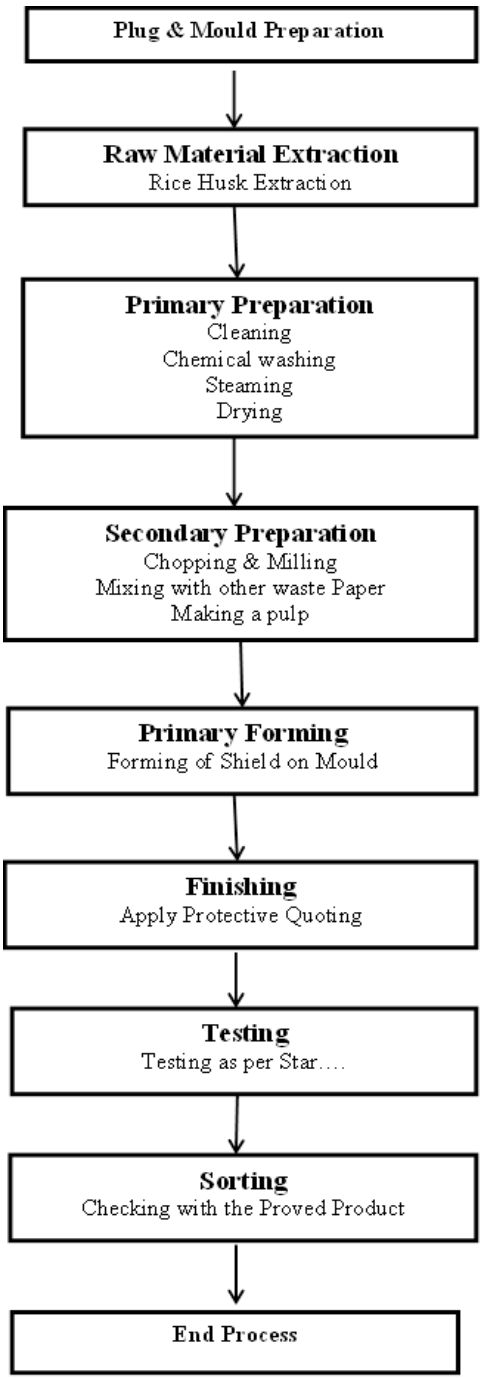

Figure 3.1: Flow chart of the process

3.2 Proposed Design

Based on the above discussed factors on asbestos roofing sheets, it is considered to proceed the project with the standard specified by the Sri Lanka Standard Institution (SLSI) under the Sri Lanka Standard 9: Part 2: 2001 (UDC691.328.5:692.4). That the standard developed for corrugated sheets of Asbestos has been made, assistance derived from various international standards specifically including the standardizations of British Standards Institution (BSI) and the Bureau of Indian Standard.

Since the planned project of manufacturing a corrugated roofing sheet with the use of polymer and natural waste materials, it is further intended to follow the main scope of production standard of asbestos corrugated roofing sheets. That is criteria for conformity on shape, finish and geometrical characteristics.

3.2.1 Pattern and Mould Design

Shape and finish

The sheet shall have a cross section consisting of regular corrugations defined by their pitch 'a' and their height 'h' where the inner radius 'R_I' and the outer radius 'R_o' do not differ, by more than 20 percent of 'R_o' (see Figure 3.1). The proposed surface to be used should be smooth finish and good surface appearance without affecting the appearance of the product. The sheet shall be reasonably straight and thee dges are straight, clean and square. The sheet thickness shall be uniform along the longitudinal and transverse directions.

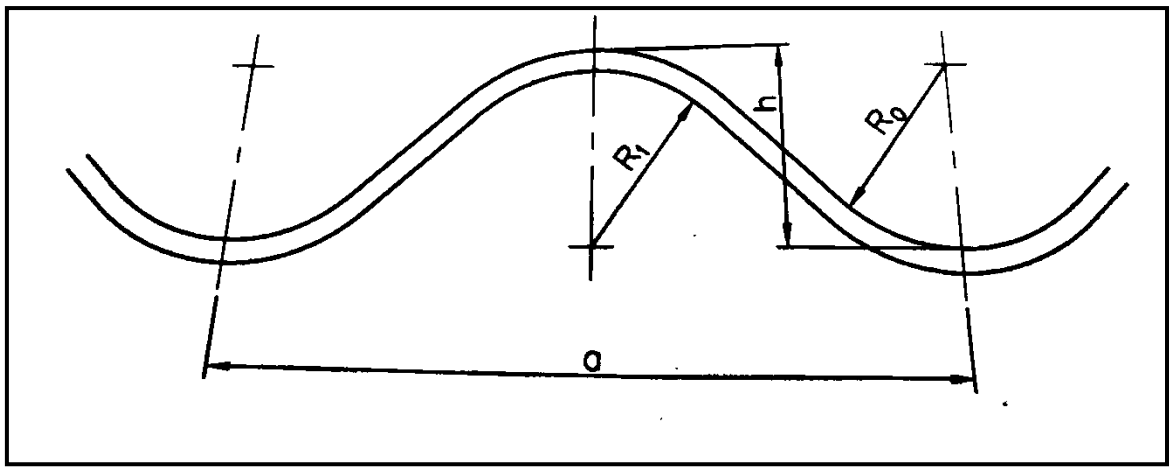

Figure 3.2: Shape of Corrugations

Geometrical Characteristics

General standard values of the geometrical characteristics shall be specified as follows.

a. Length

   The roofing sheet length approximately 0.5 m to 4 m depending on the requirement and application.

b. Width

   The overall width 1090 mm when measured as specified and the minimum would be 74 mm.

c. Thickness

   The mean thickness of the product shall be 6 mm when measured as per the specified in the Figure 3.2.

d. Pitch

   The pitch of produced sheet shall be 146 mm when measured as per the specified in the Figure 3.2.

e. Height

   The approximately height of the product shall be 48 mm when measured as per the specified in the Figure 3.2

f. Tolerance on the dimensions

The tolerance specified below shall apply to the nominal dimensions.

On pitch	: ± 2 mm
On the thickness	: ± 10 % with a maximum of 0.6 mm
On height of corrugation	: +3 mm /-4 mm
On the length	: ± 10 mm
On the Width	: + 10 mm /-5 mm
On squareness:	: 1 mm in 100 mm of width

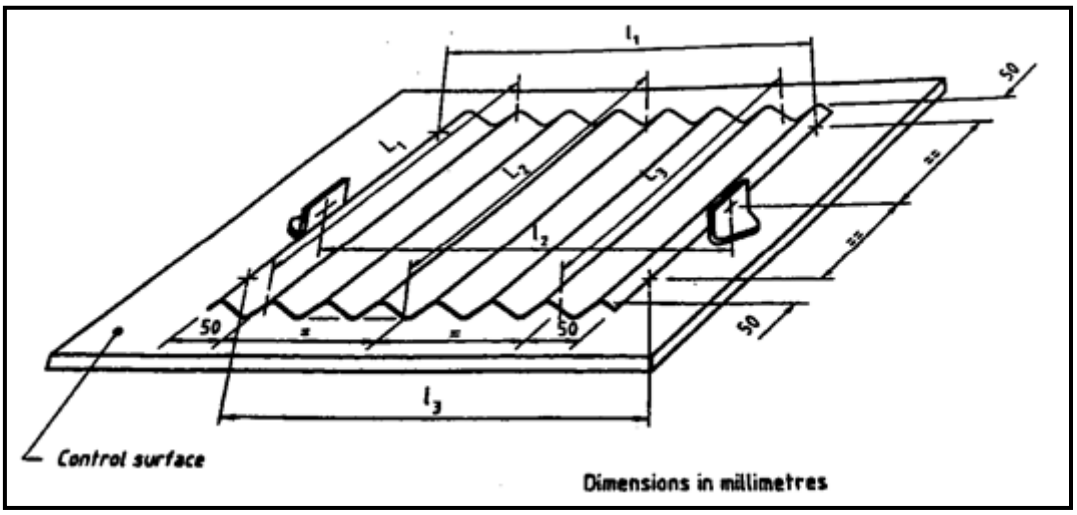

Figure 3.3: Locations for dimensional Measurements

3.2.2. Raw Material Selection and Mixing

As specified in the introduction and literature review, the material selection was carried out with the experiment results of relatively similar kind of research outcome. However the compositions of the raw material are different. Moreover, the proposed project is and the process of the project can sub divided to three segments based on raw material selection and mixing as follows.

Table 3.1: Mixing of raw materials

Material	Sample A	Sample B	Sample C	Sample D	Sample E
Clean dry rice husk	80%	75%	70%	65%	60%
Waste paper	20%	25%	30%	35%	40%
Chemical mixture	Used fiber resin as binding component				
Fiber resin coating	Coated with gel coat Use as coating component to the final roofing product				

Table 3.2: Pulp preparation

Material	Sample A	Sample B	Sample C	Sample D	Sample E
Clean dry rice husk	800 g	750 g	700 g	650 g	600 g
Waste paper	200 g	250 g	300 g	350 g	400 g

Table 3.3: Reparation of binding agent

Raw Materials	for 5 samples
Clean dry rice husk	0.02 m^3
Water	As required
Alum	600 g
Gum resin	1200 g
Soda ash	50 g
Resin	100 to 150 g
Waste paper	80 g to 640 g

3.2.3. Product Development

Product development proceeded with combination to standard method & extended with additional features. Basically its mixed raw materials as specified above send through mills to make smaller particle and then it was seen as a pulp and it contained main two types of raw materials that are dry rice husks and waste paper particles.

Then the raw material sample was projected to mould and arrange the proper layup with equally distributing and maintaining to achieve 5mm thickness throughout the sample before pressurized.

3.3. Testing of Product

a. Test for Breaking Load

A schematic diagram of a test bed is shown in Figure 3.4

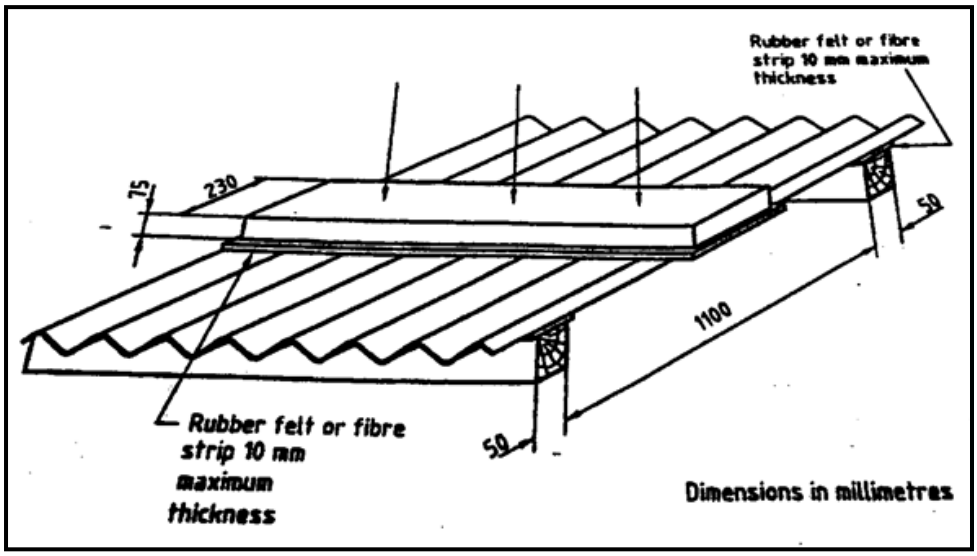

Figure 3.4: Placement for Load Testing

The whole sheet was used testing purpose. sample was immersed in water at ambient temperature for eighteen hours before testing as a preparation of the test specimen.

Testing procedure

Specimen was placed according to the Figure 3.3. Then load was applied at a rate of 100 N/s until the fracture or breaking. Breaking load was observed and recorded.

b. Test for Density

Specimen was prepared for the test by taking a piece of approximately 40 mm x 60 mm from the material as a specimen sheet. It was possible to utilise a portion from a sample that has been undergone the breaking load test.

Testing procedure

The mass of the test specimen in dry condition was ascertained by drying the test piece out in an oven at a temperature of 102.5±2.5 ^{0}C degree until the deviation between two successive weight measurements made at an interval 2.5 hours was constant.

Volume of the specimen was measured by submerging it in water and measuring the volume of the water displaced. Test specimen was saturated before determining the volume.

Calculation

Density was calculated using the following formula

$$\boldsymbol{\rho = 1000\frac{V}{m}}$$

Where,

ρ = the density, in kg/m^3

m = the mass of the test piece after drying, in 'g'

v = the volume of the test piece, in cm^3

When it was tested as described above, the density of a sheet shall not be less than 1200 kg/m^3 according to the tested standards.

c. Test for Water Absorption

Preparation of the test specimen

Specimens were prepared with 25mm x 25mm dimensions from the sheet previously tested for breaking load.

Procedure

i. Original Weight of the sample was measured as (m_0)

ii. The specimen was completely immersed in water at a temperature of 27 $\pm$ 3^0C for period of 24 hours.

iii. Then, specimen was removed weigh at room temperature. The mass (m_1) was recorded.

Water absorption was calculated as follows;

$$\textbf{Water absorption percentage} = \frac{m_1 - m_0}{m_0} \times 100$$

Where,

m_0 = mass, in 'g' of specimen

m_1 = mass, in 'g' of specimen after immersion

d. Test of Water Tightness

Apparatus and Material

Frame

As shown below in which the dimension (b) corresponds to the approximate value of the pitch of three full corrugations.

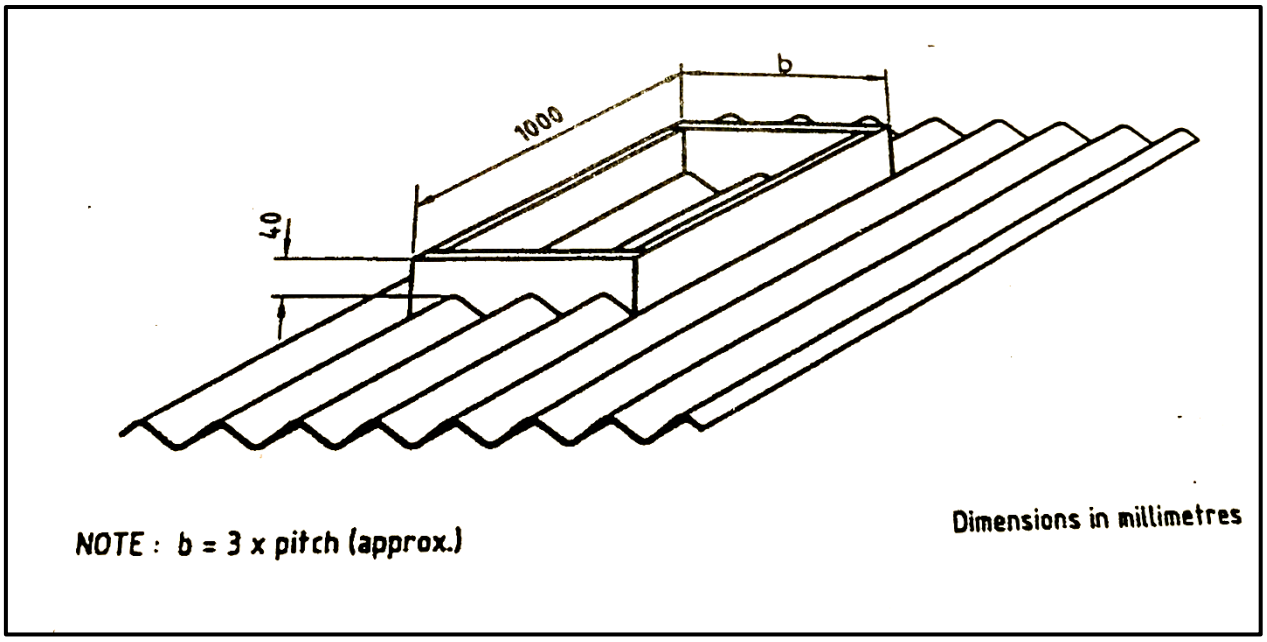

Figure 3.5: Placement for Measurement of Water Tightness

i. Sealant
ii. Preparation of test specimens
iii. Whole sheet was used for this purpose.

Procedure

i. Test was carried out at a temperature of 27 ± 3^0 C and relative humidity of 65 ± 5 percent.
ii. Frame was seal on to the test sheet, ensuring that the joints were watertight.
iii. Frame was filled with water to level of 20mm above the crowns of the corrugations.
iv. After the period of 24 hours the surface of the underside of the sheet specimen was examined for the presence of water droplets

e. Ultraviolet Exposure Test

All prepared samples were subjected to the UV exposure test as per ISO: 4582:1980 (E) standards. Five set of samples (Sample A, Sample B, Sample C, Sample D and Sample E) were removed from the UV chamber prescribed time sets as 24, 48, 72, 96, 120, 144 and 168 hours. Visual examination test was performed after above mentioned time period to evaluate the appearance change.

CHAPTER FOUR

RAW MATERIALS AND FABRICATION PROCEDURE ADAPTED

4.1. Introduction

It is intended to explain the entire processes involved during the fabrication of roofing sheet and used raw materials in detail. Furthermore, the mould preparation, pulp preparation and the procedure adapted during the experiment and testing of produced samples were also included with relevant pictures.

4.2. Raw Materials

a. For Mould

Table 4.1: Raw Materials used in Mould with Cost

Raw materials	Quantity	Approximate Cost (Rs)
Resin Polyester	7 kg	Rs. 2800.00
Polyurethane sheet (¾ inch)	1 Sq feet	Rs. 270.00
Mat 300 CSM	1 kg	Rs. 400.00
Mat 450 CSM	1.2 kg	Rs. 480.00
Mould wax	200 g	Rs. 600.00
Tooling gel	2 kg	Rs. 800.00
Polyurethane alcohol	100 ml	Rs. 70.00
Talk Powder	250 g	Rs. 20.00
Accelerator	10 ml	Rs. 40.00

b. **For Product**

Table 4.2: Raw Materials used in Product

Raw Materials	**For 5 Samples**	**Approximate Cost (Rs)**
Clean dry rice husk	0.02 m^3	No cost involvement
Water	As required	No cost involvement
Alum	600 g	Rs.60.00
Gum resin	1200 g	Rs. 960.00
Soda ash	50 g	Rs. 15.00
Resin polyester	600 to 1000 g	Rs. 450.00
Paper waste	80 g to 640 g	No cost involvement

4.3. Mould Preparation

A suitable plug was prepared using a piece of damaged asbestos sheet to the size of 60 cm into 90 cm. and then it was smoothened on the edges by the cutting/ polishing whilst taking the utmost precautions to minimize/refrain the inhalation of asbestos particles. Though spreading of tiny particles was experienced in the vicinity. So it was also a good experience to understand the possibility of spreading these harmful materials to the environment without notice by the general public or social livings.

Figure 4.1: Plug Preparation

A suitable mould was developed with the use of above mentioned materials in section 4.1 and mould piece was also built. The size of the mould projected area were 60 cm into 90 cm. the internal appearance of the mould is as follows.

Figure 4.2: Mould on Open View

Figure 4.3: Plug Preparation Complete

Suitable mould piece was made using the fiber materials where the plug piece was prepared with the help of commercially available asbestos corrugated sheet. Approximately dimensions of the mould were 60 cm into 90 cm while thickness was maintained as 6mm. moreover, it was integrated with 8 nuts and bolts to tighten the

upper and lower halves of the moulds aiming to remove the additional water content as well as to bring the shape to the sample product.

4.4. Preparation of Chemical Mixture

Figure 4.4: Chemical Mixture Compounds

600g of gum resin was used during the chemical mixture preparation, which was usually available as a solid pert very similar to a stone and that break into powder compound by hammering. Then it kept on a pan and provided heat source to reach it boiling. While heating the above gum resin, soda ash approx. 100g was poured by mixing with boiled water little by little (approx. 1000ml water was included during the process of compound). That the compound was called as Chemical mixture, which was used as binding agent to produce the sheets.

4.5. Preparation of Pulp

Table 4.3: The material used in the production of the rice husk roofing sheet

Material	Product A	Product B	Product C	Product D	Product E
Clean dry rice husk	80%	75%	70%	65%	60%
Paper	20%	25%	30%	35%	40%

The method applied here is action research. The material used in the production of the rice husk roofing sheet is as per the ratios of the above indicated. It is produced fine particles of rice husk, this is because it was revealed that the particle size of materials influences the strength and workability of the pulp [18], Which is obtained from the paddy field. Since this was a waste product of the paddy harvest. Then it was mixed with water to select the proper fiber to enrich particle by manual cleaning and Alum component was added (Mixing ratio is 30 gram of Alum for 1kg of rice husk), to ensure the cleanliness of the rice husk and cost-effectiveness during the sample preparation for small quantity.

Then the four out of five samples (A, B, C & D) products of rice husk were steamed by the water vapor up to the 100 ^{0}C using a domestic pan. The final sample called sample E was not treated and used as a control experiment. Then the steamed rice husk was mixed with the aforesaid chemical (Gum resin, Soda ash and water), blended paper particles, and water for a period of approx. 45 minutes and prepared the so-called pulp for fabrication.

Figure 4.5: Pulp Preparation

4.6. The Mixing Ratios of Raw Materials

As per previous research it was recorded that the mix proportion for the production of Asbestos roofing sheets as 15-25 percent Asbestos fiber and 75-85 percent of Portland cement [19]. Moreover, another research carried out much similar to the above and the mixing was used with rice husk, waste paper and portland cement for production of roofing sheets. The mixing ratio was 1:3:16 [15].

However, particularly, this research focus on use of local raw materials for construction of roofing sheets to improve the socio-economic aspect of general public in the country. Specifically, it is focused for locally available raw materials and technology that can often be used enhance the Sri Lanka's economic, social and environmental development as well as helping to develop our own industry while protecting the Sri Lankan society from the epidemic of asbestos based health issues.

Therefore, the mixing ratios of the roofing product were proposed based on the basic aspects of roofing sheets and the effects on the environment. The final coating was also selected based on the environmental friendly concept biodegradable aspects. It was beyond the concepts used in the previous researches and it was given more weightage to the primary component of rice husk over the usage of cement material taking special consideration to aspects of environmental friendliness, biodegradability, feasibility of production with simple mechanism, cost effectiveness and the use of waste product from the Sri Lankan agriculture process.

Table 4.4: Raw Materials used in mixing composition

Material	Sample A	Sample B	Sample C	Sample D	Sample E
Clean dry rice husk	80%	75%	70%	65%	60%
Waste paper	20%	25%	30%	35%	40%
Chemical mixture	Used above mentioned locally produced binding mixture.				
Fiber resin coating	Coated with gel coat on the final roofing product				

Moreover, above composition was selected also based on the results of haphazardly produce roofing sheet. Above product was made by the researcher to look forward the matter on experiment basis. The maiden product was produced as mentioned under the Figure 4.6.

Figure 4.6: The maiden product

4.7. Procedure of Rice Husk Sheet Preparation

a. Manual cleaning

The collected rice husks from the paddy fields were carefully examine and removed the foreign particles from the rice husks. This was the main basic raw material of the product. It was also noted that very much essential to collect fresh rice husks early from the paddy field before them become deteriorated condition.

b. Cleaning

Then the selected rice husks sample manually cleaned were put into the water and carry out thoroughly cleaning in order to ensure the raw materials free from mud and other dust particles.

c. Cutting /Chopping to small particles

Rice husks was thoroughly cleaned and chopped into the small particles in order to have more strength whilst mixing with the other particles as well as with the chemical binder,

d. Chemical Cleaning

Then the chopped particles were again washed with the alum, which was the cleaning chemical agent which was used for this process to ensure that the raw material were properly clean.

e. Steaming

One of the sample product was utilizes with the steamed raw material in order to check the particular differences with the strength as compared with non-steamed product sample. During the process the raw materials were steamed with hot water maintain the temperature up to 100^0C

f. Drying

Then it was place to dried

g. Mixing of raw material

Once the pulp of the mixture was prepared as per the above defined ratios to produce sample product A to product E, it was used with 5 types of mixtures separately to produce 5 samples.

Table 4.5: Mixing ratios of sample products

Mixing ratios		**Relative picture**
Material	**Product A**	
Clean dry rice husk	80%	
Wastepaper	20%	
Clean dry rice husk	75%	
Wastepaper	25%	
Clean dry rice husk	70%	
Wastepaper	30%	

Clean dry rice husk	65%	
Wastepaper	35%	
Clean dry rice husk	60%	
Wastepaper	40%	

h. Placing the pulp on mould

The prepared pulp sample was placed on the mould piece and it was tightly tighten the 6 bolts to ensure the height of the sample so as to maintain thickness of 6mm.

j. Fixing the mould

Moreover the aim of the tightening the bolts was to remove the water content in the sample product.

m. Achieving the final product

Then the sample products were placed in the normal environment for a period of 12 hours for drying up the product.

When it was dried up to the required level, it is applied with a polyester resin with the use of paint brush either sides of the roofing sheet. It was also practiced to apply only for required basic quantity to apply on the surface. Then it was placed for drying up under normal environment and considered as final product.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1. Tests Carried Out and Results

The roofing sheets were tested for water permeability, water absorption, density, breaking load, surface defects and for UV resistance aspects. The above mentioned tests was carried out in order to ascertain the effectiveness of the production of rice husk roofing sheets and aiming to the replace asbestos roofing sheets from Sri Lanka to improve the socio economic benefits. The entire tests were carried out within the period of three months.

5.2. Water Permeability Test

Figure 5.1: Manufactured roofing sheet

As shown in the above Figure 5.1 the manufactured roofing sheets product was immersed in the water during the testing period, enabling it to absorb considerable water column on top of the roofing sheet. It measures the water passes through the roofing sheet. After about 24 hours it was observed that no water passed through the sample product.

Result: It is observed that none of the products have been failed during the test. Hence, it is considered that the all samples proved that the test confirming the quality status. Even wetting of the surface was not found to the touch.

5.3. Water Absorption Test

More similar to the above processes the sample products A to E were tested for water absorption test. Here it is recorded the weight of the Sample A to Sample E and. Samples were immersed in a water for a period of 24 hours. Finally, weight was recorded again. The summarized test results are as follows.

Table 5.1: Results of test water absorption

Sample	Mean water absorption percentage	Standard/Recommended limit	Comment on suitability of the product
A	34%	28%	Unsatisfactory
B	15%	28%	Satisfactory
C	8%	28%	Satisfactory
D	1%	28%	Satisfactory
E	28%	28%	Satisfactory

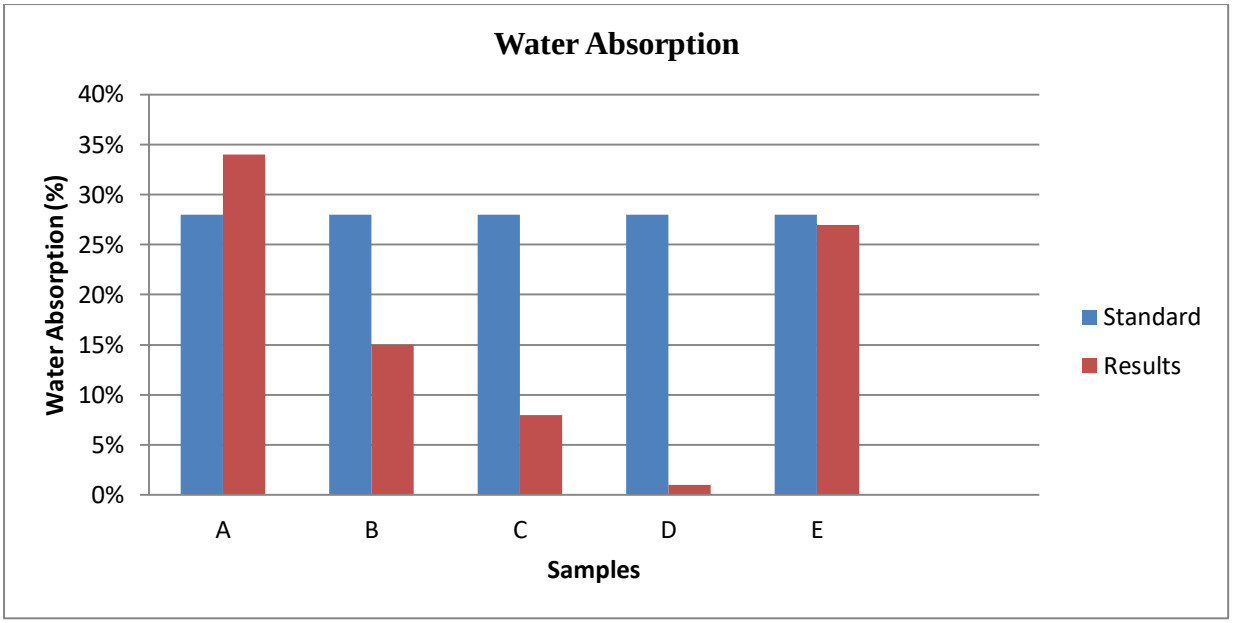

Figure 5.2: Water Absorption

As per the test results in Figure 5.2, Sample A indicated the maximum water absorption property and rest of the samples are within the satisfactory limits. Samples B, C and D are in highly satisfactory limits. Moreover, Product C & D indicated extreme high performance as compared with the standard sample. So it can be confirmed that the protective coating is free of defects. It created water barrier layer.

5.4. Density

Calculated density of the samples are shown in the following table.

Table 5.2: Results of density test

Sample	**A**	**B**	**C**	**D**	**E**
Density kg/m^3	892.00	1062.00	1258.00	1837.00	1100.00

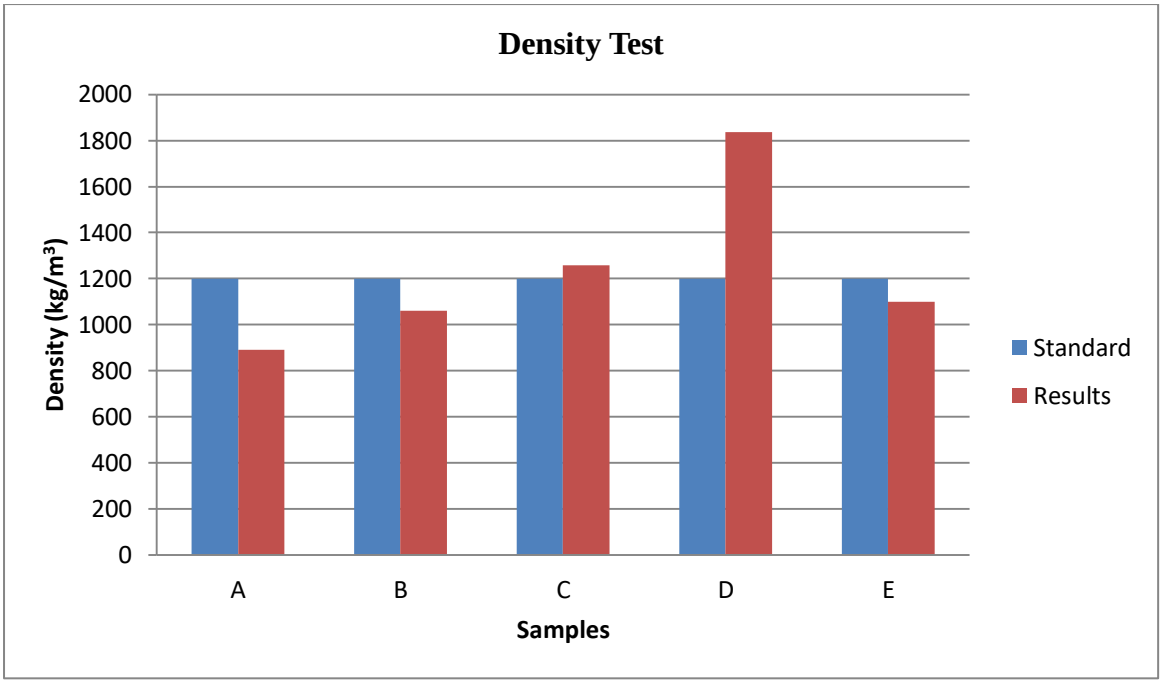

Figure 5.3: Density Test

As per results shown in Figure 5.3, sample A indicated the minimum density and did not satisfy the required condition. A is in substandard condition. Sample C and D were in the acceptable condition.

5.5. Breaking Load Test

As per the Testing procedure mentioned in the methodology the specimen test pieces placed the on the testing fixture with its level surface upward making sure that the supporters are at right angles to the corrugation. Then insert the strips of felts of soft fibre 10 mm thick between the sheet and the loading bar and supporters.

Then it is be applied the load using the loading bar at a rate of about 100 N/s until the breaking the point is reached. Then record the breaking loads in kN and was calculated for unit length as per standard for asbestos sheet should stand without breaking load of over 5kN/m. This way it would be possible to extrapolate the test result for any size of sheet that will be found in commercial applications.

In similar manner it is calculated the breaking load of the each sample products and the summarized results are as follows.

Table 5.3: Results of breaking load test

Product	**A**	**B**	**C**	**D**	**E**
Applied load (50kg)	No deformation or cracks				Failed during the load test

5.6. Ultraviolet Exposure Test

As explained in the methodology section, Sample A, Sample B, Sample C, Sample D and Sample E were exposed to the UV. They were removed from the UV chamber at prescribed time seta of 24, 48, 72, 96, 120, 144 and 168 hours. Visual examination test was performed to evaluate the UV resistance of material.

Results:

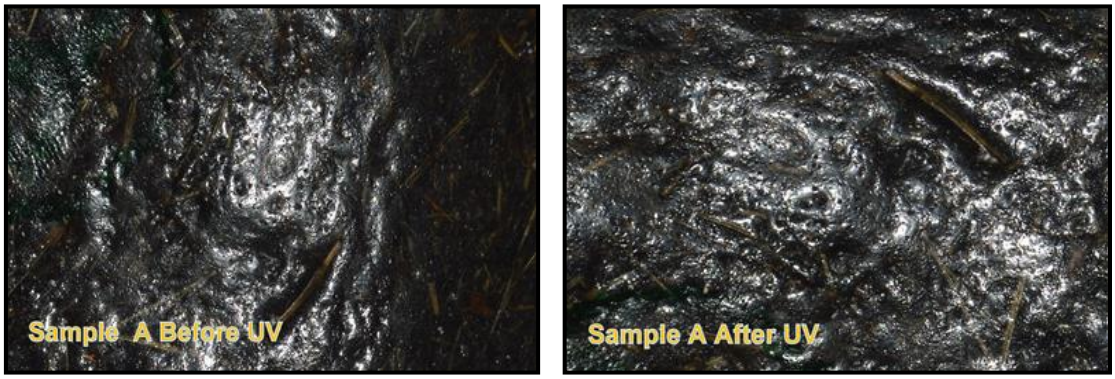

Figure 5.4: UV Test results of Sample A

Table 5.4: Ultraviolet Exposure Test Results of Sample A

EXPOSURE TIME (HOURS)	VISUAL EXAMINATION (Sample A- Side 1)	VISUAL EXAMINATION (Sample A- Side 2)
24	No appearance change	No appearance change
48	No appearance change	No appearance change
72	No appearance change	No appearance change
96	No appearance change	No appearance change
120	No appearance change	No appearance change
144	No appearance change	No appearance change
168	No appearance change	No appearance change

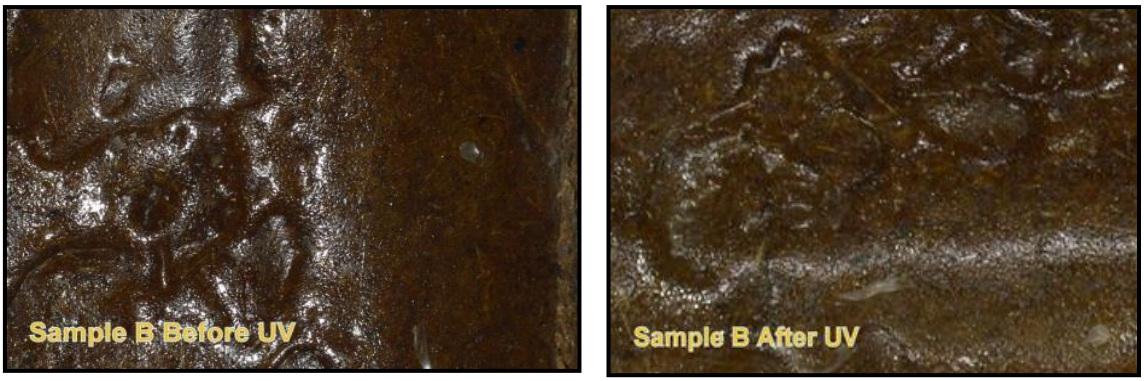

Figure 5.5: UV Test results of Sample B

Table 5.5: Ultraviolet Exposure Test Results of Sample B

EXPOSURE TIME (HOURS)	VISUAL EXAMINATION (Sample B- Side 1)	VISUAL EXAMINATION (Sample B- Side 2)
24	No appearance change	No appearance change
48	No appearance change	No appearance change
72	No appearance change	No appearance change
96	No appearance change	No appearance change
120	No appearance change	No appearance change
144	No appearance change	No appearance change
168	No appearance change	No appearance change

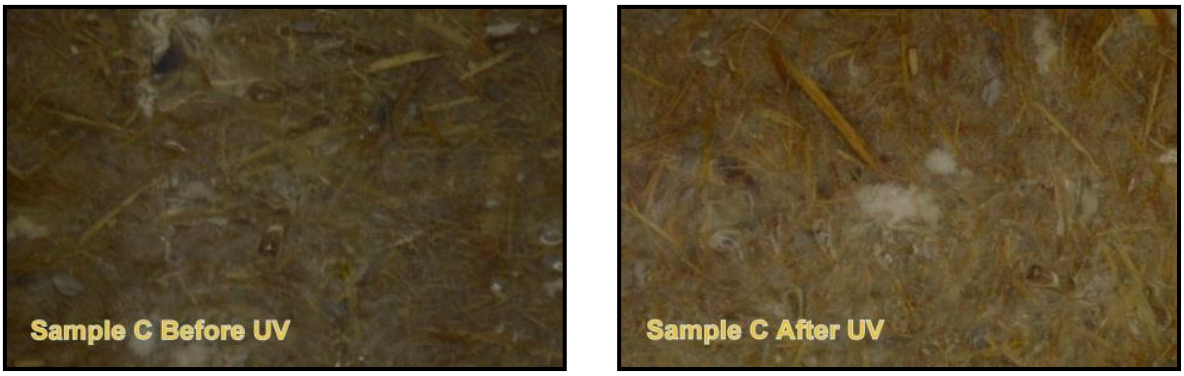

Figure 5.6: UV Test results of Sample C

Table 5.6: Ultraviolet Exposure Test Results of Sample C

EXPOSURE TIME (HOURS)	VISUAL EXAMINATION (Sample C- Side 1)	VISUAL EXAMINATION (Sample C- Side 2)
24	No appearance change	No appearance change
48	No appearance change	No appearance change
72	No appearance change	No appearance change
96	No appearance change	No appearance change
120	No appearance change	No appearance change
144	No appearance change	No appearance change
168	No appearance change	No appearance change

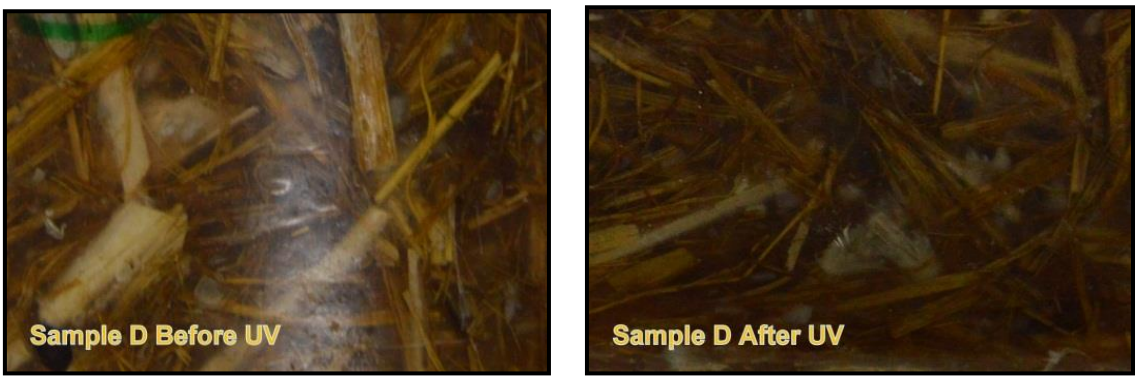

Figure 5.7: UV Test results of Sample D

Table 5.7: Ultraviolet Exposure Test Results of Sample D

EXPOSURE TIME (HOURS)	VISUAL EXAMINATION (Sample D- Side 1)	VISUAL EXAMINATION (Sample D- Side 2)
24	No appearance change	No appearance change
48	No appearance change	No appearance change
72	No appearance change	No appearance change
96	No appearance change	No appearance change
120	No appearance change	No appearance change
144	No appearance change	No appearance change
168	No appearance change	No appearance change

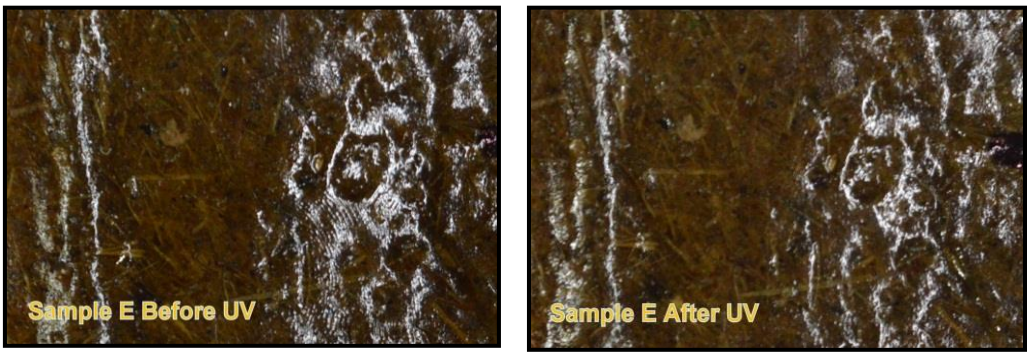

Figure 5.8: UV Test results of Sample E

Table 5.8: Ultraviolet Exposure Test Results of Sample E

EXPOSURE TIME (HOURS)	VISUAL EXAMINATION (Sample E- Side 1)	VISUAL EXAMINATION (Sample E- Side 2)
24	No appearance change	No appearance change
48	No appearance change	No appearance change
72	No appearance change	No appearance change
96	No appearance change	No appearance change
120	No appearance change	No appearance change
144	No appearance change	No appearance change
168	No appearance change	No appearance change

According to the above figures and tables, It showed that the developed product was highly UV resistance. Therefore, these products can be used in outdoor environment.

5.7. Geometrical Characteristics

Table 5.9: Geometrical Characteristics

Test carried out	Asbestos Standard	Sample A	Sample B	Sample C	Sample D	Sample E	Remarks
Test for basic geometrical characteristics	Note Standard 1	Entire samples were produced in par with the standard and based on a mould product. Therefore the basic dimensions were maintained in accordance with the Standard specified.					Acceptable
	Control surface (2 m length)	Sample mould was designed as specified as chapter 4.2 exclusively for sample preparation. Hence the dimensions of the sample are restricted to one meter of length in order to overcome handling difficulties. However the control surface even better with the asbestos standard.					100% Comply
	Thickness Note Standard. 2	It is experienced that difficulty to maintained accuracy to 0.05mm at this juncture due to the experiment highly consider for the quality of the material over the accurate dimensions. However it is measured up to 0.5 mm					Could achieve nearest of 0.5 mm value Acceptable
	Pitch	Comply to the standard to the asbestos roofing sheet					Acceptable
	Corrugation height	Comply to the standard specified to the asbestos roofing sheet					Acceptable
Surface defects	Surface	No visible cracks					Acceptable

Standard 1: For each dimension, record 3 readings to the nearest 0.5mm, one in the middle and each sides leaving 50mm from ends

Standard 2: A micrometer having 10mm long and 4mm wide hemi cylindrical measuring accurate to the 0.05 mm

In overall the develop mould and the procedure adapted in this experiment was found acceptable without significant error.

5.8. SUMMERY OF RESULTS

In order to prove that the attainment of the experiment, it was compared the other mechanical aspects and performances of the product with the characteristics of summarized data tabulated for better understanding the quality of the product.

Table 5.10: Results of Test Summery (mechanical)

Test carried out	Sample A	Sample B	Sample C	Sample D	Sample E	Remarks
Surface defects	No visible cracks	No visible cracks	No visible cracks	No visible cracks	No visible cracks	Acceptable
Density (kg/m^3)	892	1062	1258	1837	1100	Samples C&D Satisfied and other samples Can improve
Water permeability resistance property	Very Good	Very Good	Very Good	Very Good	Very Good	Acceptable
Water absorption	34%	15%	8%	1%	28%	Satisfied except Sample A
Breaking load	Satisfied to the load of 50 kg weight without any deformation or cracks				Failed	Can improve
UV resistance	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied	Satisfied

5.9. Exemption Tests

Due to the time constrains following tests were not carried out during the testing period.

a. Environmental applicability and shelf life of the product.

b. Micro biological aspects and effects on the insecticide.

c. Fire resistance aspects

5.10. Conclusion of the Project

The aim of this research was to develop environmentally friendly roofing sheet with the usage of environmental friendly agricultural wastes based materials to replace asbestos based roofing sheets. The developed product was a rice and paper waste based product and it indicated low cost and potentially degradable properties.

The replica and the mould were fabricated successfully in accordance with the available roofing sheet standard. This developed product showed the minimum water permeability and water absorption properties. That can achieve the required loading capacity. All produced products indicated UV resistivity during the testing period without showing any appearance change in inner surface or outer surface. According to the experimental results, Sample D showed the overall very good performance. It can be concluded that environmentally friendly and low cost, roofing product can easily be manufactured using locally available agricultural waste and available technologies.

5.11. Future Work

It has been proved up to some extend that the possibility of develop roofing sheets using the waste product of Rice straw with available technology in Sri Lanka. Therefore, the future researches should focus to improve the mechanical properties of the product considering the factors of quality and low production cost.

Moreover, to develop standard particularly for agricultural products used raw materials considering the aspect specified in the asbestos production standard SLS 9: part 2: 2001 upon the continuous improvement as well as based on study.

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