Study on use of Environmentally Friendly Alternative Fiber materials for Asbestos Roofing sheets in Sri Lanka

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Abstract: International Programme on Chemical Safety (IPCS), 2011, reveals that all forms of asbestos pose a health hazard. According to WHO, 107,000 people die each year from asbestos related lung cancer, mesothelioma and asbestosis mainly due to occupational exposure. As such more than 50 countries have banned the use of asbestos fiber. Therefore, it is highly justifiable that Sri Lanka should ban the use of this product and should go for an alternative product to safeguard the future of the country.

While keeping with the policy of IPCS, Sri Lanka banned blue asbestos in 1997 and allowed white asbestos to be used mainly for the production of roofing sheets. Recently, the Sri Lankan government had taken a decision to gradually reduce the import of asbestos fiber from year 2018 and to totally ban the use of asbestos in 2020. Many products that once contained asbestos are now being manufactured with natural and synthetic fibers.
The objective of this study is to find out an environmentally friendly alternative fiber material available in Sri Lanka for manufacturing of non-asbestos roofing sheets. During the study, asbestos fiber was replaced by alternative cellulose fiber materials found in Sri Lanka such as rice husk, paper pulp, coir fiber and coconut charcoal.

Breaking load, apparent density, water absorption, water permeability, visual inspection & weights of the sheets were tested for all fiber types & compared with both asbestos fiber and non –asbestos fiber standards to check the feasibility of the use of alternative asbestos fiber.

Both parameters of water permeability and visual inspection were complied with International Organization for Standardization, ISO 10904: 2011 as well as Bureau of Indian Standards, IS 14871: 2000 for all fiber types. The results of water absorption of all fiber types showed less than 25% of the dry mass and complied with Sri Lanka Standard Institution, SLS 9-2: 2001 for asbestos corrugated sheet. The weight of non-asbestos sheets was within the limit between 14 kg to 18 kg for the sheet size (1.0×0.9) m × 8.5 mm which is reasonably an acceptable weight for a roofing sheet. Test results of density of all fiber types are well within the limit of Sri Lanka Standard Institution, SLS 9-2: 2001.The breaking load of rice husk sample was 694 N/m which is compatible with International Organization for Standardization, ISO 10904: 2011 standard. The breaking load of four samples out of five samples also complied with both ISO 10904: 2011 & IS 14871: 2000.

Based on the results obtained and comparing with standards, rice husk could be considered as the best alternative fiber material in the production of roofing sheets. Paper pulp sample also marginally complied with both ISO 10904: 2011 & IS 14871: 2000.

Keywords: Asbestos fiber, breaking load, Rice husk, Coconut charcoal, Coir fiber and Paper pulp

Introduction

Asbestos is a natural fiber that was used for decades in insulation, siding, asbestos floor tile, joint compound, asbestos ceiling tile, asbestos roofing, and brake pads. Asbestos was commonly used in these products due to its heat resistant characteristics and durability. Asbestos containing insulation, gaskets, and packing has been used in conjunction with high temperature equipment such as boilers, turbines, steam pipes, pumps, valves, and furnaces. Asbestos containing materials were also commonly used during the construction of homes and offices, as well as on ships and in industrial settings.

Asbestos became increasingly popular among manufacturers & builders due to its sound absorption, tensile strength, resistance to fire, heat, electrical & chemically damage & affordability. Older generation in Sri Lanka were exposed to woven Asbestos in their homes as wicks of lamps & mantles in Patrolmax lamps during kerosene days. Also, Asbestos products became very popular in Sri Lanka as substitute building material because of scarcity of other building materials such as timber, clay tiles. According to the statistics, for more than 60 years Sri Lanka has been importing white Asbestos mainly from various countries. Though there are many forms of Asbestos, Sri Lanka imports only the white variety of Asbestos (Chrysotile) for production of roofing and ceiling sheets, where Asbestos is mixed with cement acting as a binding agent reducing fiber escape. It has already been scientifically proven that blue and brown asbestos fiber can cause cancer, and hence it needs to explore the impact of white asbestos fiber on human health.

Asbestos is not a mineral itself. It is a collective term given to a group of minerals whose crystals occur in fibrous forms. The term Asbestos was adopted for commercial identification. Asbestos fibers are naturally occurring minerals found in underground rock formations. It is a set of six naturally occurring silicate minerals which has long thin fibrous crystals. These fibrous materials can be released by abrasion and other processes (King, 2007).
The six minerals commonly referred to as Asbestos come from two distinct groups of minerals such as Serpentines & Amphiboles. Amphiboles group is sub divided in to 5 groups such as Amosite (Brown Asbestos), Crocidolite (Blue Asbestos), Anthophyllite and Termollite & Actinolite (King, 2007).
Asbestos has got many unique properties, which has led to its application in more than 3000 products. The main properties are high tensile strength, high resistance to abrasion, resistance to corrosion, resistance to heat, non-combustibility, resistance to alkali attack, durability & toughness, good electrical insulation properties & chemical inertness.

International Programme on Chemical Safety(IPCS) with World health Organization(WHO), 2011, reveals that all forms of Asbestos pose a health hazard. According to WHO, 107,000 people die each year from Asbestos related Lung Cancer, Mesothelioma & Asbestosis due to mainly from occupational exposures. Asbestos factory workers, carpenters who work on roofing projects, labourers of Asbestos stores facilities & workers at building demolishing sites are in high risk categories. IPCS 2011, worked with members to strengthen the capacities of the Ministries of Health to provide leadership for activities to improve workers' health, to formulate and implement policies, action plans and stimulate intercessional collaborations etc. More than 50 countries have banned the use of asbestos fiber.
According to Basel convention on trans-boundary movement of hazardous wastes & their disposal, 1992, Asbestos has been listed in the category of controlled waste. Although International Labour Organization convention on safety in the use of Asbestos, 1986, was introduced and signed by 162 countries in the world, it has been ratified by 36 countries only.

The International Agency for Research on Cancer (IARC), 2006, identified the classification of hazard substances. According to the classification, there are five groups of human carcinogens such as, Group 1 –Cacogenics to humans – 108 agents, Group 2A – Probably Carcinogenic – 63 agents, Group 2B– Possibly Carcinogenic – 271 agents, Group 3 – Not classifiable – 509 agents & Group 4 – Probably not Carcinogenic -1 agent. Presently, IRAC has classified Asbestos in group one.
Concentration of Asbestos fibers in the air, duration of the exposure, frequency of exposure & size of the Asbestos fibers inhaled are some of the factors that contribute to the seriousness of Asbestos related health hazards (Ministry of Health, New Zealand, 2014).

The persons who are prone to risk of asbestos related diseases in Sri Lanka are the:

1) Workers in Asbestos manufacturing industries
2) Carpenters working on installation of asbestos roofs and ceilings
3) Policemen on traffic duties exposed to asbestos emanating from vehicle brake pads
4) Carpenters/ masons working on demolishing of asbestos roofs and ceilings
5) Persons who lives under asbestos roof

In Sri Lanka, blue asbestos was banned in 1997 but white asbestos has been used mainly for the production of roofing sheets. Sri Lanka ratified the Rotterdam convention in 2006 and the Sri Lankan government officially announced that the import of asbestos fiber would be reduced by year 2018 and totally banned in 2020 due to health and environmental risks.

Since the use of Asbestos roofing and its production process shows many health impacts on the people who involve in the production of asbestos and also on the users, it is highly justifiable that Sri Lanka should ban the use of this product and should go for an alternative product to safeguard the future of the country. As the use of asbestos is already banned by the Government of Sri Lanka with effect from 2020, it is high time to find out an alternative and environmentally friendly product which could be a solution for non-asbestos roofing in Sri Lanka.

Objectives

Main objectives of the present study are to:

- find out an environmentally friendly alternative fiber material instead of asbestos fibers
- Check the feasibility of selected alternative fiber materials for non-asbestos roofing solution in Sri Lanka.

Methodology

Method of research used in this study is an action research. During the study, Asbestos fiber was replaced by alternative cellulose fiber materials found in Sri Lanka. Selected alternative cellulose fiber materials are Rice husk, Burnt Rice husk, Paper pulp, Coir fiber & Coconut Charcoal. These materials are found in abundance in Sri Lanka and are thrown to the environment as waste materials. Fly ash was also selected to the study in order to improve the strength while sand was used as a filler material.

This study selected the following ratio (Ordinary Portland Cement: Sand: Fly Ash: Non-Asbestos fiber materials 12: 2: 1: 5) of raw material to produce non-asbestos sheets.

Thirty non-asbestos sheets were made from six (6) different formulas which changed only the fiber materials such as Rice husk, Burnt Rice husk, Paper pulp, Coir fiber & Coconut Charcoal & Mixture of all fiber materials). Five (5) samples made from each formula, were tested for feasibility of using as alternative fiber materials for asbestos. The dimensions of the corrugated sheet were selected as 1.0 m x 1.0 m x 8.5 mm (Length x Width x Thickness).
The non-asbestos sheet was made through conversion of flat sheet to corrugated sheet by hand making process as follows. The formula was weighed and mixed well by using trowel. Then clean water was added to the mixture and mixed well until a paste was formed.

Then cement paste was filled on to the flat mould and flattened the surface by using trowels and leveler. After that flat sheet was pulled out with the help of Polythene and kept on the Asbestos corrugated sheet to create the shape of a corrugated sheet.

Figure 3.1: Keeping the Polythene layer

Fig.3.2: Leveling the Cement paste on the flat mold

Figure 3.3: Transferring on to the sheet

After one hour, period edges were cut/stringed by using a knife. Then all samples were kept for 24 hours for normal air curing and then allowed for water curing. Water curing was done for 7 days and de-molded it after 21 days. After that all samples were tested for the parameters of appearance & finish, dimensions and physical parameters as per International Organization for Standardization, ISO 10904: 2011.

Results & Discussion

This research is vastly based on tested parameters with different fiber samples. Types of common defects such as hair lines, spots and cracks, edge cracking and smooth surface have been visually monitored on each and every samples and test results were complied with both ISO 10904: 2011 & IS 14871: 2000 standards. This process is very important because hair lines or cracks could be increased when sheets are exposed to different climate conditions as hot and cool weather normally in Sri Lanka as well as when transporting and handling etc. Opera (2006) recorded that there were no cracks formed on sheet samples casted from both treated and untreated burnt rice husk but some light cracks were found in sheets casted from boiled rice husk. Further, samples of untreated rice husk were very brittle.

Thicknesses of the samples were prepared as 8.5 mm during the research project. As per ISO 10904: 2011 standard, the average thickness of the asbestos cement corrugated sheets should be within the range of (8.5 mm ± 10%) 7.65 mm to 9.35 mm. This research maintained a constant thickness of non-asbestos sheets and thickness of the sheets were complied with both ISO 10904: 2011 and IS 14871: 2000. The thickness of the sheet is a design parameter of the product. It shall be complied with the requirements of the relevant standard and depended on the production process of the sheet and mould dimensions.Test results of the average thicknes vs fiber types are shown in Figure 4.1.

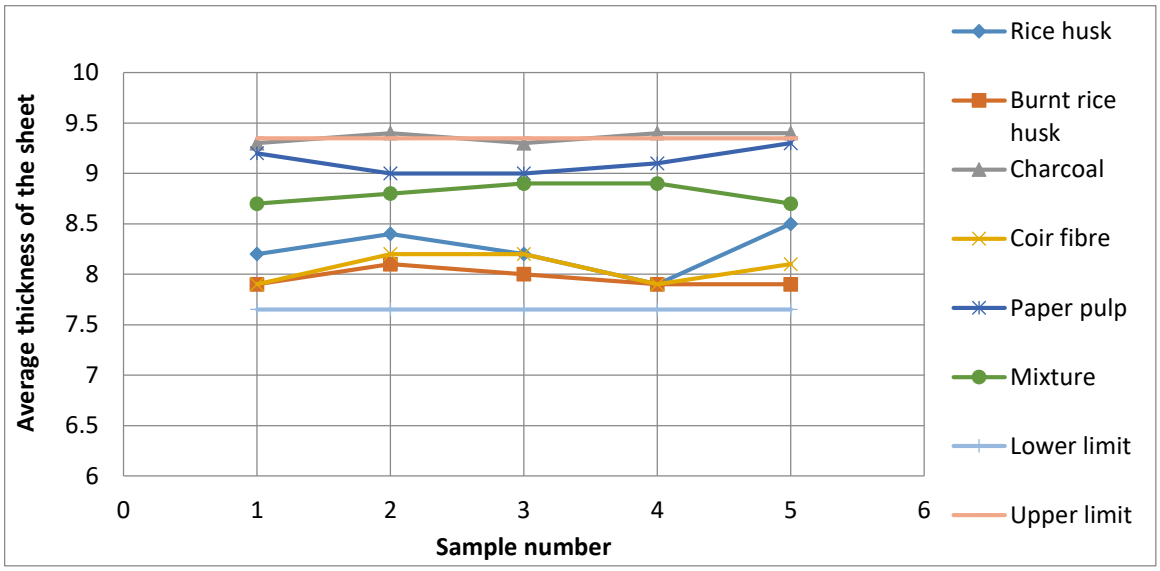

Figure 4.1: Thickness vs. fiber type

As per International Organization for Standardization, ISO 10904: 2011, the height of corrugation of non-asbestos sheet should be within the tolerance limit of ± 3 mm from specified height of corrugation. Accordingly, specified limit value is 46 mm and deviation should be between (43 - 49) mm. The results of the present study are well within the limits and hence prepared specimens are acceptable in respect of height of corrugation value as follows (Fig. 4.2).

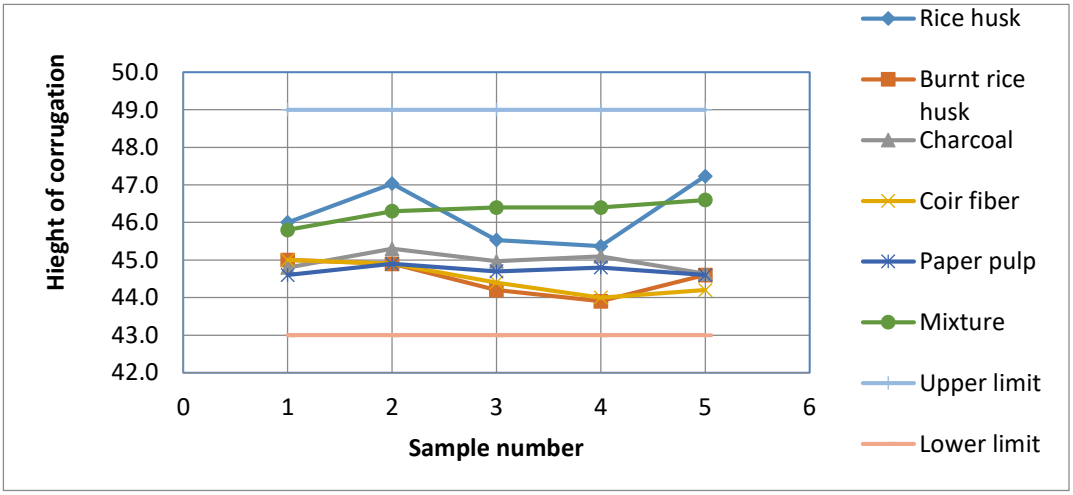

Figure 4.2: Height of Corrugation vs. fiber type

Ramakrshna *et al.*, (2011) explained the height of corrugation was compatible with galvanized corrugated sheets but test results were not given. All researchers used the same profile which is available to them in their country when preparing the non-asbestos sheets. Hence the heights of corrugation values are different from country to country.
Breaking load of each and every fiber type of reinforced corrugated sheet had been tested and are given in the Figure 4.3 below**.**

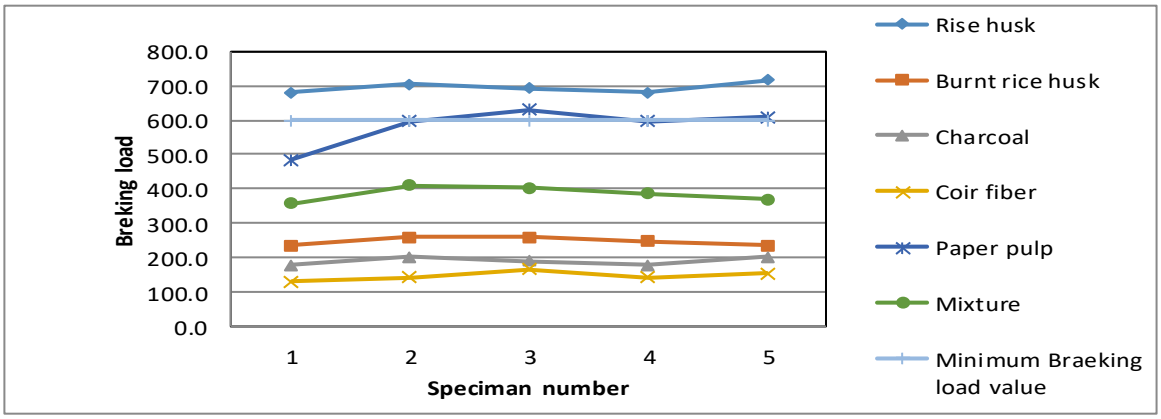

Figure 4.3: Breaking load vs. fiber type

Specified minimum breaking load value is 600 N/m as per both standards. The breaking load of rice husk sample complied with ISO 10904: 2011 as well as IS 14871: 2000 by obtaining an average value of 694 N/m. It was also observed that the value of paper pulp also marginally complied with both standards. All other samples did not comply with the breaking load test as per International Organization for Standardization, ISO 10904: 2011 standard. It was noted that the maximum breaking load of treated burning rice husk sample is 152 kg/mm (Opara, 2006).
According to the Patel & Arunkumar (2014), 3.678 N/mm^2 of maximum flexural strength at 50% of Ground Granulated Blasted Slug (GGBS) mixed with 0.75% polyester fiber was reported. As per Rajakumar *et al.*, (2015), flexural strength values of coconut shell fiber sheets were observed as 1.48 N/mm, 1.52 N/mm, 1.99 N/mm and 2.32 N/mm. Further, Central Building Research Institute in India, 1991, reported a value of 5.0 kg/cm of breaking load in corrugated roofing sheet made from coir waste or wood wool and Portland cement. Beijing Horcreboad Building Materials Co. Ltd, China supplied composite fiber roofing sheet and showed a minimum value of 800 N/m, Breaking load.

According to ISO 10904: 2011, the manufacturer's literature shall specify the minimum Apparent Density of the profiled sheets. Test results of apparent density as well as proposed apparent density of each fiber types are shown in Table 4.1.

Table 4.1: Proposed Apparent density values for each formula

Fiber type /Sample Identification	Test results of Apparent density as a range (Minimum – Maximum)in kg/m^3	Proposed Apparent density (Specified) value, in kg/m^3
Rice husk	1713-1758	1700 – 1800
Burnt Rice husk	1660-1695	1600 – 1700
Coconut Charcoal	1758-1788	1750 – 1800
Coir fiber	1692-1784	1650 – 1800
Paper Pulp	1700-1822	1650 – 1850
Mixture	1862-1946	1800 – 1950

Ramakrishna *et al.,* (2011) revealed that minimum density values of 1170 kg/m^3, 1171 kg/m^3, 1173kg/m^3 were recorded at 35% maximum amount of coconut shell fiber used and all other density values were recorded more than 1200 kg/m^3 at 25% and 20% of coconut shell fiber used. According his report, minimum 1200 kg/m^3 of density value below 35% of coconut charcoal fiber used which is equivalent to the value specified by SLS 9–2: 2001 standard (asbestos corrugated sheet has minimum 1200 kg/m3 density). The density values obtained for the present study (1660 – 1946 kg/m^3) are similar to the results of Opara, 2006 (1456.16 kg/m3, 1832.41 kg/m3 & 1832.41kg/m) and were also compatible with Sri Lanka Standard Institution, SLS 9–2: 2001.

The results of water permeability test were well complied with both SLS 9–2: 2001 and IS 14871: 2000 standards for all fiber types. Test results are tabulated as follows (Table 4.2).

Table 4.2: Test results of water permeability

Sample identification	Presence or absence of water drops under the sheets
Rice husk	No any formation of water drops (impervious)
Burnt Rice husk	No any formation of water drops (impervious)
Coconut Charcoal	No any formation of water drops (impervious)
Coir fiber	No any formation of water drops (impervious)
Paper Pulp	No any formation of water drops (impervious)
Mixture	No any formation of water drops (impervious)

There was no any formation of water drops obtained for test results of water permeability by both Opera (2006) and Ramakrishna et al., (2011) which are similar to the results of the current study.

Since Sri Lanka is a country with a heavy rainfall during the Yala and Maha seasons, it is very important to test water absorption. Therefore, all non- asbestos fiber sheets were tested to see whether they comply with SLS 9–2: 2001 standard. The results of water absorption values of this study are graphically shown in Figure 4.4.

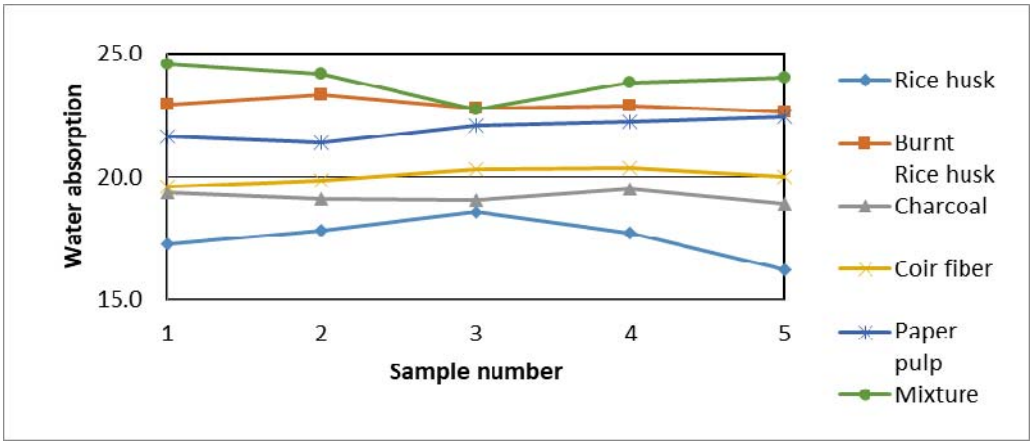

Figure 4.4: Water absorption vs. fiber type

Although water absorption is not mentioned in the International Organization for Standardization, ISO 10904: 2011 standard, it was declared in the Sri Lanka Standards Institution, SLS 9–2: 2001 standard as maximum being 28% of the dry mass. However, the results of this study suggest to fix the standard value of water absorption to a maximum of 25% in non-asbestos corrugated sheets. The suggested values based on the above test results are compatible with Patil & Arunkumar, (2014), Rajakumar *et al.*, (2015) and Opera (2006).

The weight of non-asbestos samples was compared with asbestos samples. As per Figure 4.5, the weight of non-asbestos sheets was in the limit between 14 kg to 18 kg for the sheet size (1.0 *0.9) m*8.5 mm.
Asbestos cement corrugated sheets made by Sigiri Roofing Lanka (Pvt) Ltd in Sri Lanka has a weight of 25.5 kg for the size (1.75×1.09) m×6 mm sheet which is higher than this study's weight and hence the sample is easier to handle than the other sheet. Other sizes are greater than this study sample and therefore cannot be used for the conclusion.

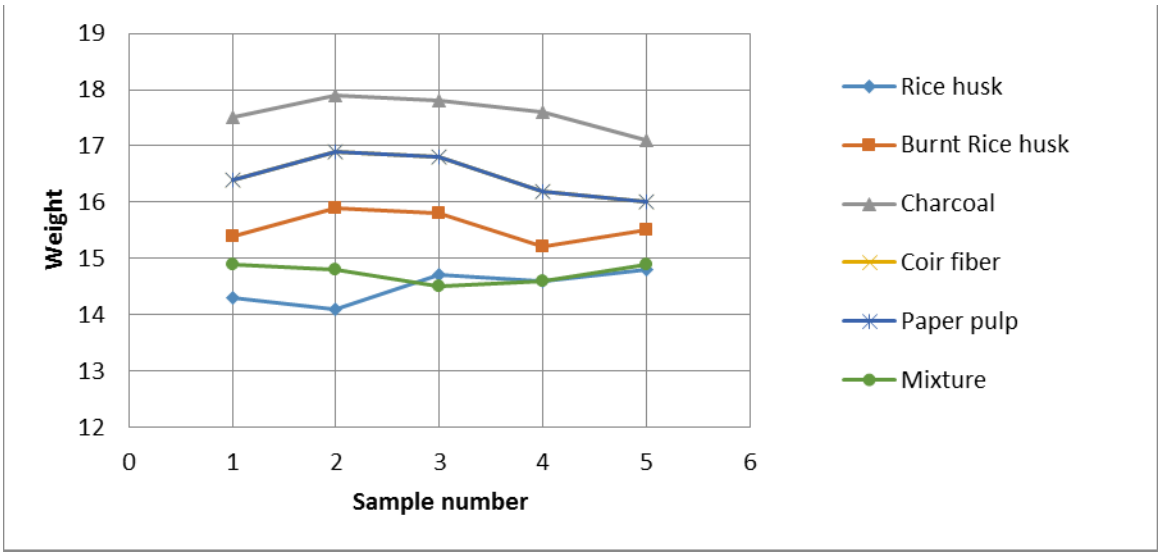

Figure 4.5: Weight vs. fiber type

Table 4.3: Summary of the test results for non-asbestos corrugated sheet made with different fiber types

Parameter	Rice husk	Burnt rice husk	Coconut charcoal	Coir fiber	Paper pulp	Mixture
Visual inspection	S	S	S	S	S	S
Length	S	S	S	S	S	S
Width	S	S	S	S	S	S
Average thickness	S	S	S	S	S	S
Height of corrugation	S	S	S	S	S	S
Breaking load	S	NS	NS	NS	Marginally pass	NS
Water permeability	S	S	S	S	S	S
Pass/fail as per ISO 10904:2011	**pass**	Fail	fail	fail	**Marginally pass**	Fail

Where, S : Satisfactory , NS : Not Satisfactory

As per the results obtained, rice husk can be used as an alternative fiber material for Asbestos fiber followed by paper pulp fiber as per both International Organization for Standardization, ISO 10904: 2011 & Bureau of Indian Standards, IS 14871: 2000 standards except for the marginal failure in breaking load. All other tested fiber sample parameters complied with both ISO 10904: 2011 & IS 14871: 2000 standards except for the breaking load test. However, it would be prudent to continue the same study by changing the formula (mix proportions) for successful results.

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