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A study of finding alternatives for asbestos in Sri Lanka

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Abstract:
Background: *Worldwide, asbestos is a widely used roofing material in the construction field. In Sri Lanka, 85% of its people use asbestos as a roofing material. According to the World Health Organization, fibers including in asbestos are the most harmful occupational carcinogens. Therefore, the government of Sri Lanka has banned asbestos roofing sheets since 2018 in Sri Lanka.Fibers of coir, bamboo, corn skin, and polythene of rice sacks were considered as alternative materials that can be collected easily. Two samples were taken for each fiber type by changing fiber proportion and testing was carried out to check the breaking load, density, water absorption, and resistance to acidified water of the sheet.Polythene of rice sacks has reached the breaking load up to 7.51 kNm^{-1} while the density of 2946.6 kgm^{-3}. The water absorption percentage was 12.9% and resistance to acidified water was 0.024 kg m^{-2}. According to the Sri Lanka Standards Institute, even asbestos sheets also have a breaking load of 5 kNm^{-1} while the density of the sheet should not less than 1200 kgm^{-3}. Polythene from rice sacks can be utilized as a good substitute for asbestos fibers which meets Sri Lanka Standards Institute standards. Corn husk, coir fibers, and bamboo fibers passed the other three tests except for the breaking load test and can even be used as alternatives by chemically treating to delay the decaying.*

Key Word: *asbestos; alternative; fibers; corn; bamboo.*

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I. Introduction

Asbestos is a naturally occurring and expensive material comprising of extremely durable, thermal, and chemically resistant thin microscopic fibers. Although asbestos has been used for thousands of years, the disease associated with asbestos is not described until recently.

The World Health Organization (WHO) reports that the asbestos fiber deposited in mineral form, extracted by mining operations. This fibrous material is chemically known as hydrated magnesium silicate (WHO, 2017). WHO recognizes that asbestos is one of the most important occupational carcinogens, and the burden of asbestos-related diseases (ARD) is rising. The WHO declared the need to eliminate ARD and cease asbestos use. Recently, the WHO upgraded its global estimate of ARD to 170,000 annual deaths caused by asbestos-related lung cancer, mesothelioma, and asbestosis. A study (2005) of disease burden estimated an incidence of 43000 mesothelioma cases worldwide due to occupational carcinogens, and 27000 were attributed to the Asia Pacific region (Eastwood et al., 2011). At the regional conference of the WHO in 2002, Asian countries were described as the persistent users of asbestos. Of these, Japan was a major consumer in 2005 and later adopted a total ban on asbestos in 2006. Subsequently, in 2009, asbestos was finally banned in Korea due to increasing number of lung cancer cases (Takahashi, 2011).

TheUniversity of Moratuwa, Sri Lanka, attempts to analyses cancer registry in Sri Lanka to evaluate the risk of occupational-related cancer. Around 18,000 people are annually diagnosed with cancer in Sri Lanka. Considering all those problems, in 2018, the government of Sri Lanka decided to ban asbestos roofing sheets (Anon., 2015). Blue asbestos is already prohibited in Sri Lanka since 1997 but white asbestos sheets are still used as a roofing material. National Building Research Organization (NBRO) accepted the responsibility of evaluating and promoting suitable alternatives to asbestos fiber-based materials (Archives, 2015). Currently, there are three main asbestos roofing products are manufactured in Sri Lanka. New technologies have been developed to find the alternatives for asbestos in European countries such as polythene foams, flour fillers, cellulose fibers, thermoset plastic flour, and amorphous silica fabrics (Alternatives, 2010).

Due to its durability, insulating properties as well as its ability to withstand the environmental risks associated with asbestos the above said materials can be used as a roofing material. However, due to inaccessibility of material, absence of testing facilities, and high cost, these materials are not suitable for developing countries such as Sri Lanka. As a substitute, bamboo, coconut fibers, cornhusks, and rice sakes are selected as raw materials. These are cost-effective, common, durable, and simple enough to be used by the rural population.

Our research is based on assessing the use and subtypes of asbestos, harmful health hazards caused by asbestos, and the factors for banning the use of asbestos. The main objective of our research was to find out the suitable alternatives for replacing asbestos fibers. According to the WHO report, in Sri Lanka, about 18,000 people are annually diagnosed with asbestos-related hazards i.e., lung cancer (WHO, 2001).

After careful consideration and extensive studies on asbestos alternatives, many new opportunities were recognized. Safe roofing material advocates the use of corrugated sheets made from coconut fiber, already in use in government-sponsored housing schemes for few years. According to the NBRO records, using coconut fibers as an alternative material is also under the testing stage (Archives, 2015). Therefore, tragedy of asbestos-related diseases and deaths can be ultimately prevented, with reduce use of asbestos and thus, eliminate the asbestos-related products.

II. Material and Methods

All the testing procedures were carried out according to the standards of Sri Lanka Standards Institute (SLSI). Testing was carried out to check the breaking load, density, water absorption, water tightness, and resistance against acidified water. According to the specifications regarding corrugated asbestos sheets; mechanical, physical, and chemical characteristics for straight asbestos-cement corrugated sheets were recorded before use, as mentioned in Table no 1 (SLSI, 2001).

Table no 1: mechanical, physical, and chemical characteristics for straight asbestos-cement corrugated sheets.

Characteristics of roofing sheet	**Quantities**
Breaking load	Not less than 5Kn/m for 1100 mm
Density	Not less than 1200 kg/m3
Water absorption	Shall not exceed be 28% of the dry mass
Resistance to acidified water	Shall not be more than 1.15 kg/m^2

Coir, bamboo, cornhusks, and polythene of rice sakes were used as an alternative material. All fibers excepting polythene of rice sakes were extracted by using a knife. These fibers were then kept for drying under the sunlight before use. 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) (Peiris & Weerasinghe, 2019). Quarry powder (10 kg) and cement (7.5 kg) were selected for the casting purposes with a ratio of 1:3 (Quarry powder: Cement). In total, fibers or strips were taken as two blend combinations (250 g, 500 g) each of the selected alternative material and added to the cement mix. When considering the proportion of powder from the cement quarry, the obtained mixing ratio for an alternative fiber amount of 250 g was 100:130:3 (Quarry powder: Cement: Alternative Fiber) and at the same time, a fiber amount of 500g was 100:130:6 (Quarry powder: Cement: Alternative Fiber). According to the mixing ratios, corresponding water content was selected (Rajkumar et al., 2015). Two asbestos sheets were used as molds to obtain a corrugated shape. Once the sample sheets were prepared, these were kept for 28 stranded curing days. After the curing process, testing was carried out to check the sustainability of the sample sheets. Figure 1 shows the sample sheet before the breaking load test.

Figure 1: Sample of 250g bamboo sheet

A universal load testing machine was used for determining the breaking load. The sample was immersed in water at ambient temperature for 18 hours. The universal testing machine was fixed after testbed preparation and the loading rate was continuously increased by 0.1 kNs^{-1} until the breaking point was reached. The maximum load withstands by the specimens was noted.

A density test was carried out using Archimedes Principles (Loverude et al., 2003). An uncoated specimen, which has been subjected to a breaking load test was taken for the density test. The dimensions of the sample were approximate 40 mm x 60 mm (Length x Width) and it was dried in an oven at a temperature of 100-105 °C until the difference between two consecutive weighing made at an interval of 2 hours not less than 1%. Dry mass was recorded in grams (g). The volume of the specimen was recorded by immersing it in water, volume of water displace was measured and density of the specimen was calculated by using the formula $\rho = 1000\left(\frac{m}{v}\right)$, (1) where m is the mass of the test piece after drying, in gm; v is the volume of the test piece, in a cubic centimeter (cm^3); is the density in kilograms per cubic meters (kgm^{-3}),

Uncoated specimens with dimensions of 175 mm x 75 mm from each of the sheets were selected to determine the water absorption. The specimen was immersed completely in the water at a temperature of 27 °C for 18 hours. The specimen was taken out and surplus moisture was removed with a damp fabric. The weight of the samples was measured and mass was recorded in grams. The specimen was placed in a ventilated oven and the temperature was raised to 150 °C. Specimens were removed and cooled until room temperature is reached. The specimens were kept for 1 hour in a desiccator to dry off the water and weighed at room temperature, as shown in Figure2.

Figure 2: Cooled specimens in a desiccator

Water absorption was calculated by using the equation, Water absorption per unit= $\left[\frac{(m_0 - m_1)}{m_1} \times 100\right]$, (2) where $m_0$is the mass of after water absorption in grams(g) and $m_1$is the mass of specimen after drying in grams (g)

The timber frame was prepared for checking the water tightness of the specimen and bees wax was used as a sealant. Water was filled to a level of 20 mm above the crowns of the corrugations and specimens were kept at room temperature for 5 days. The lower surface of the specimen was examined for water droplets.
Resistance against acidified water test was carried out using 5% acetic acid (CH_3COOH) (w/w) solution. Sodium hydroxide (NaOH) 0.5 M standard volumetric solution and 0.04 gm of thymol-blue solution was used as an indicator. The dimensions of the specimen were 65 mm x 65 mm. Two specimens of each sample were taken for testing.

For determining the concentration of the CH_3COOH solution,10 ml of the solution was taken and 10 drops of the thymol-blue solution were added to it. The solution was diluted by adding distilled water while stirring until the solution volume reaches 100 ml, as shown in Figure 3. It was titrated with the NaOH until the color changes from yellow to blue as shown in Figure 4, corresponding to a modification of the pH value from 8.0 to 9.5. The volume of the 0.5 M NaOH used for the titration was recorded in milliliters (mL).

Figure 3: Adding 10 drops of thymol-blue solution**Figure 4**: Colour change after titration

The test specimen was immersed in 270 ml of CH_3COOH for 24 hours at the temperature, as shown in Figure 5. Thespecimen was removed after 24 hours and CH_3COOH solution was mixed well. 10 ml of solution were taken and 10drops of thymol-blue solution were added. The solution was titrated as described above and the volume of NaOHwas recorded in ml. The mean test results of the two specimens of the same sheet were recorded. The amount ofCH_3COOH used in kilograms per square meters(kg/m2) was calculated using the equation,

$$\text{Amount of Acetic acid used} = \frac{(0.03\times 270)(V_1 - V_2)}{(1000\times A)}, (3).$$

Figure 5: Immersed samples after 24 hours

Where V_1 is the initial volume of 0.5 M NaOH used in mL, V_2 is the final volume of 0.5 M NaOH used in mL and A is the area of the unprotected test specimen in square meters (m^2).

III Results

Summary of results obtained from each sample in breaking load test is shown in Table 2 and plotted graphs of loadvs displacement for each sample are shown in the below figures.

Table no 2: Breaking load test results

Sample Name	**Breaking load (kNm^{-1})**
Cornhusk 250 g	1.39
Cornhusk 500 g	2.72
Bamboo 250 g	3.51
Bamboo 500 g	0.97
Coir 250 g	4.73
Coir 500 g	3.40
Polythene 250 g	7.51

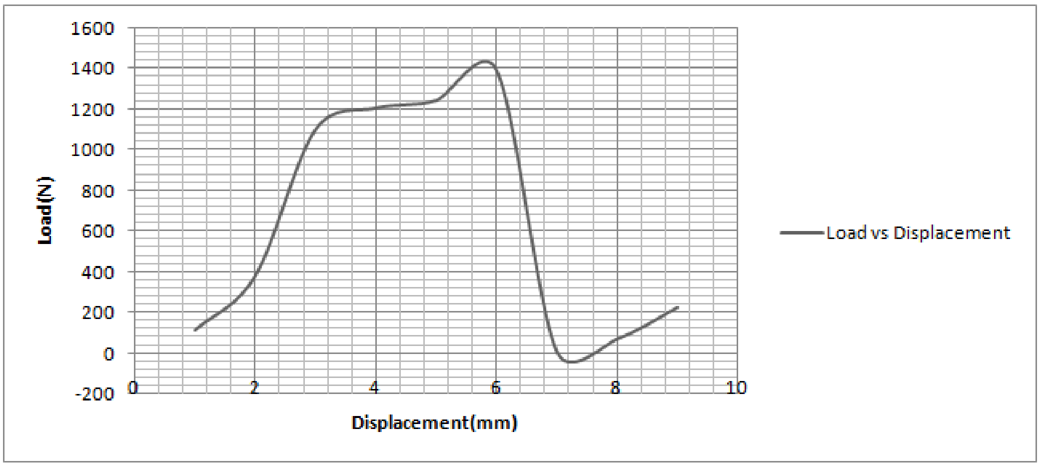

Figure 6: Displacement vs. Breaking load in corn husk 250g sample

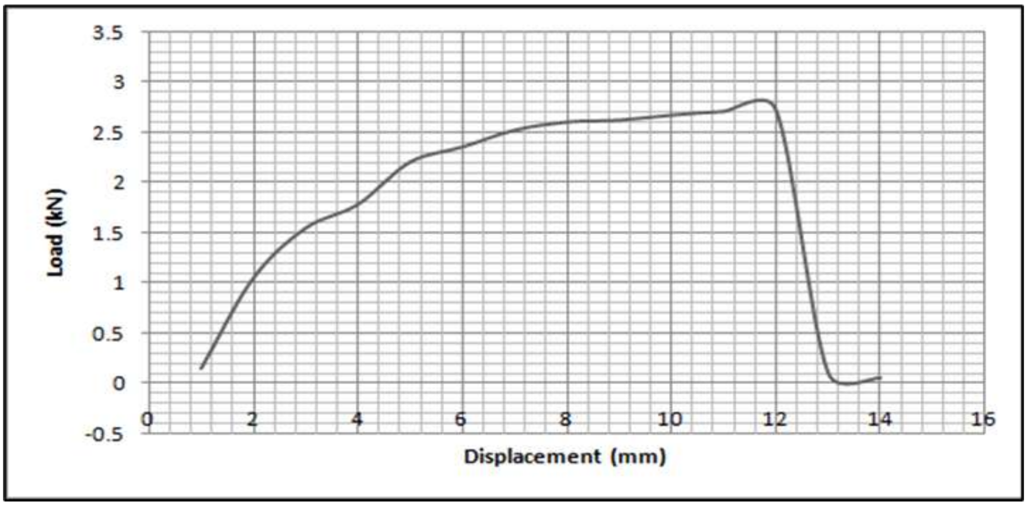

Figure 7: Breaking load result for corn husk 500g sample

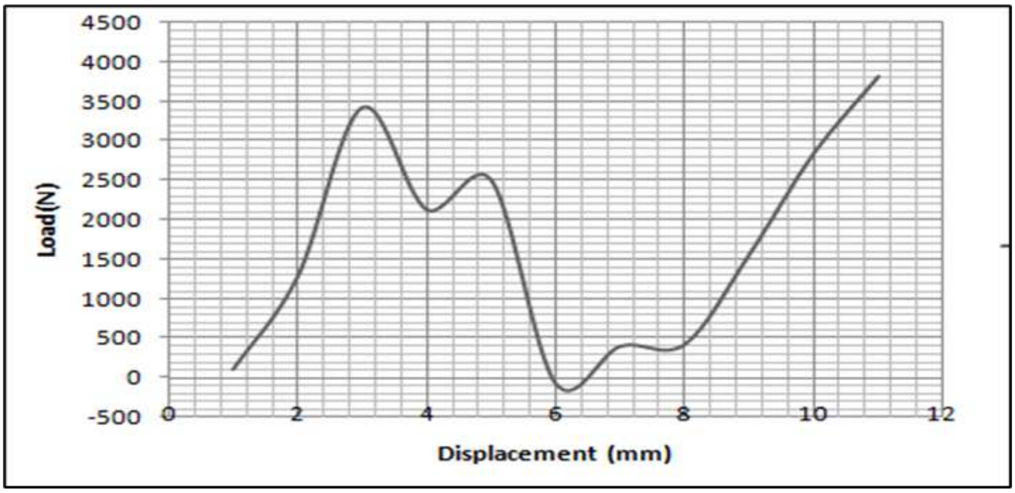

Figure 8: Breaking load test results for bamboo 250g sample

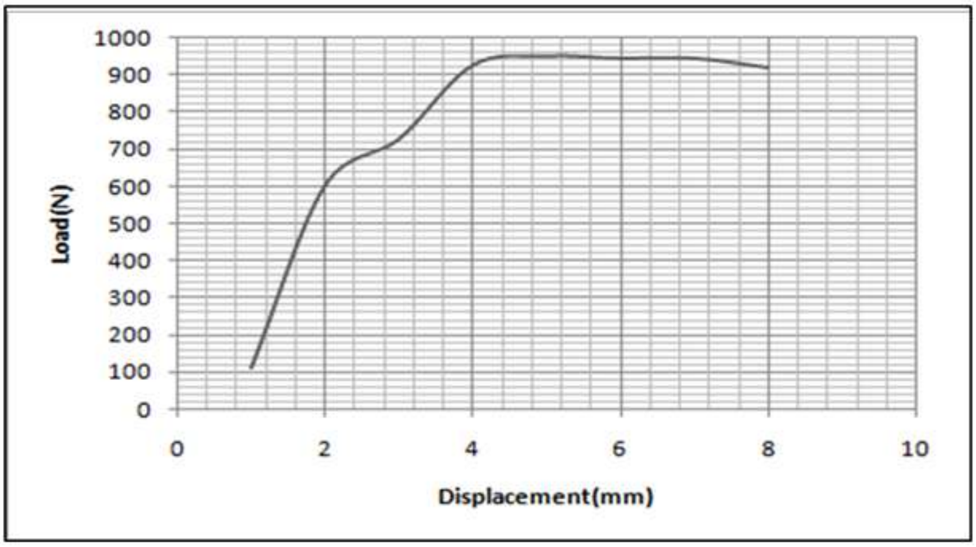

Figure 9: Breaking load test results for bamboo 500 g sample

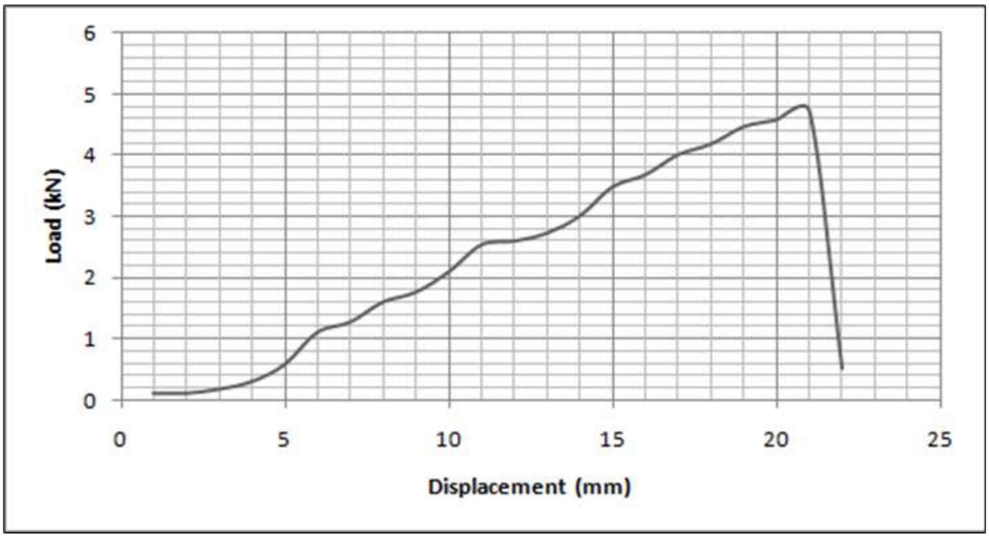

Figure 10: Breaking load test results for coir 250g sample

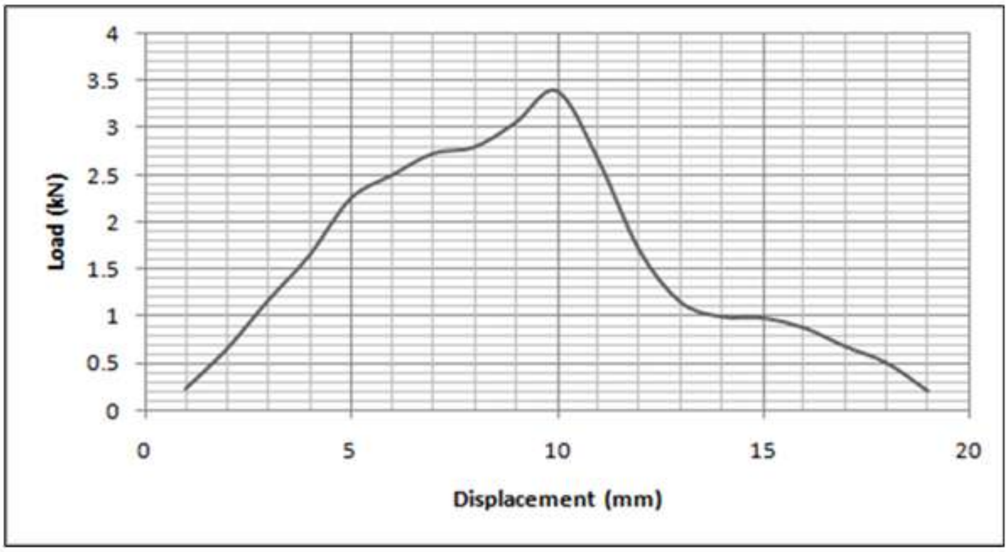

Figure 11: Breaking load test results for coir 500g sample

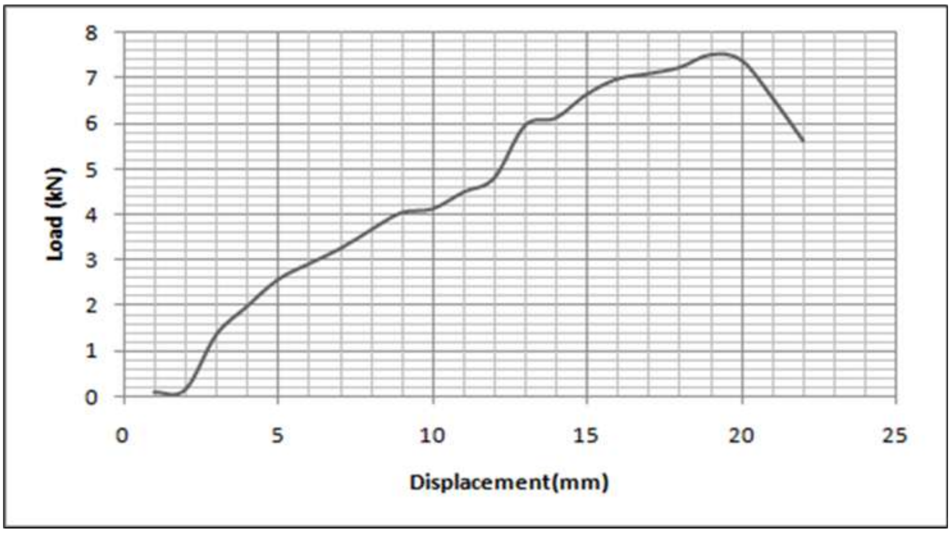

Figure 12: Breaking load test results for polythene 250g sample

Results based on density check are shown in Table 3. All calculations were done using the above-mentioned procedure for density check.

Table no 3: Density check test results

Sample Name	**Density (kgm^{-3})**
Cornhusk 250 g	5948.41
Cornhusk 500 g	2746.90
Bamboo 250 g	3020.16
Bamboo 500 g	2030.24
Coir 250 g	2081.80
Coir 500 g	2350.00
Polythene 250 g	2946.60

Water absorption test results are shown in Table 4,

Table no 4: Water absorption test results

Sample Name	**Water absorption per unit (%)**
Cornhusk 250 g	8.75
Cornhusk 500 g	18.40
Bamboo 250 g	10.35
Bamboo 500 g	44.40
Coir 250 g	12.30
Coir 500 g	13.13
Polythene 250 g	12.90

Results obtained from the resistance against the acidified water test are shown in Table 5,

Table no 5: Resistance to acidified water test

Sample Name	**Resistance against acidified water (kgm^{-2})**
Cornhusk 250 g	0.011
Cornhusk 500 g	0.023
Bamboo 250 g	0.019
Bamboo 500 g	0.022
Coir 250 g	0.023
Coir 500 g	0.016
Polythene 250 g	0.024

IV. Discussion

With the consideration of the harmful effects caused by asbestos and its products, the need for preparing and manufacturing alternatives for asbestos roofing sheets would be an important parameter. Therefore, this project would be a beneficial process indeed.

This research is vastly based on tested parameters with different non-asbestos fiber samples. The findings on the effect of the non-asbestos fibers have shown that the untreated fibers meet the specifications required to produce the properties needed by an asbestos sheet. In regard to the SLSI standards, the breaking load value for asbestos roofing sheets was 5 kNm^{-1}. However, the results obtained were 7.51 kNm^{-1} for the manufactured sample of 250 gm of polythene fibers, and this value is greater than the breaking load value of the asbestos roofing sheet. The breaking load of a manufactured sample of 250 gm of bamboo fibers was recorded as 3.51 kNm-1, indicating the use of micro and lengthy bamboo fibers could increase the breaking load.

According to the SLSI standards, the density value for asbestos is 1200 kgm^{-3} while the highest value for water absorption is 28%. As mentioned above, the density values of selected alternatives were of higher value, and therefore, it shows that the alternatives would be denser compared to asbestos.

The water absorption test showed that all manufactured sheets without 500 g of bamboo sheet absorbed more than 28% water. This test was done without any water-proof chemicals coated with the test specimens.
The effect against acidified water demonstrated that all specimens achieved the requirement mentioned in the SLSI standard. Among all samples tested, 250 g polythene specimen displayed the highest resistance against acidified water. Among all the tests, only the 250 g of polythene sample passed all the tests. Therefore, polythene from rice sacks can be utilized as a good substitute for asbestos fibers with higher strength.

Quarry dust is an ideal alternative material than river sand. It has a higher compression strength than the sand and no voids occurred while using quarry dust due to the fine dust particles. Although quarry dust increases the shrinkage of the mixture, many researchers found that rice husk can control the shrinkage of the mixture when normal quarry dust is used as a mixing material. Therefore, in future, mixtures of rice husk and quarry dust can be utilized instead of only using quarry dust, as it will reduce the shrinkage of the mixture and give a higher strength to the sheets.

V. Conclusion

Throughout this study, all test specimens except polythene fiber failed the breaking load test due to shorter fiberslength. Shorter length fibers reduce the bonding between quarry dust, cement, and fibers. With the use of micro andlengthy fibers, these alternatives can be developed in the future. Based on the results, polythene sacks passed all thetests. The moisture content of polythene sacks was practically nil, and the moisture did not affect it. Many types ofresearch were indicated that polythene sacks needed higher energy to break its fibers because of specific strength.
Resistance to acid at high temperature was high in polythene. But exposure to sunlight will expose the polyethenespecimen to Ultraviolet (UV) degradation, however, this depends on the extent and degree of exposure. If UV treatedpolythene fibers are embedded into the mixture, there will be no issue regarding the degradation of fibers and thedurability of the sheets will be increased.

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