DEVELOPMENT OF A LOW-COST CEILING BOARD PRODUCED FROM A COMPOSITE OF CEMENT, SAWDUST, RICE- HUSK ASH, AND WASTE POLYESTER YARN

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INTRODUCTION

In the modern construction industry, several types of modern construction materials are available that enhance human comfort and aesthetics. Ceiling boards provide thermal comfort while reducing noise. However, due to the presence of hazardous materials, they pose a threat to the health of dwellers. Asbestos present in the most popular types of ceiling boards used in Sri Lanka is known to cause cancer.

Using alternative materials instead of asbestos, especially the problematic waste materials which cause environmental pollution due to uncontrolled dumping, solves this problem while reducing the amount of waste. Three such problematic waste materials - rice husk, sawdust and polyester yarn, together with Ordinary Portland Cement (OPC) as the binder - were used to make an asbestos-free composite ceiling board (CCB) in this research study. Trial mix proportions were selected based on the previous research conducted on the selected materials to produce similar products.

METHODOLOGY

Albert Abraham and Ponmalar (2014) conducted studies on the effect of substituting natural and ground rice husk ash instead of cement in concrete. They concluded that 10% replacement of natural rice husk ash and 15% replacement of ground rice husk ash improves the strength by 4.3% and 11.4%, respectively, compared to control concrete.

Ikubanni et al. (2018) concluded that sawdust and rice husk together with the binder is suitable for producing particleboard and recommended that interfacial bonding strength be increased by reducing the particle size of rice husk and sawdust.

Sarkar et. al. (2012) studied the mechanical properties and dimensional stability of cement-bonded particleboard from rice husk and sawdust and concluded that water absorption values could be significantly reduced with increasing board density by increasing the cement-particle ratio.

Nathani and Nakrani (2016) conducted studies on textile-reinforced Concrete by using an M20 concrete mix by adding 0, 0.25, 0.5, 0.75 and 1% of waste polyester yarn. They concluded that the compressive strength, flexural strength and tensile strength increase proportionally with the increase in the volume of the ratio of polyester fibres with reference to the controlled mix without fibers, and 0.75% gives the optimum value.

Kumar and Rohal (2016) concluded that concrete containing 0.6% – 0.9% of waste polyester fiber significantly improves the strength parameters of concrete compared to conventional concrete.

Hence, it was decided to produce ceiling boards from sawdust, ground rice husk ash and waste polyester yarn with cement as the binding agent with varying percentages. Ground rice husk ash was selected due to its well-known cementitious properties to reduce the amount of cement which is the only costly material of the constituents. A total of five different mix

proportions, M1 to M5, with composition as shown in Figure 1 were tested in the study. The Polyester yarn percentage was kept constant at 0.8% in all five mixes to increase the flexural strength. Equal percentages of ground rice husk ash and sawdust were used as the balance material. Samples were tested to determine the density, water absorption, flexural strength, compressive strength, and split tensile strengths.

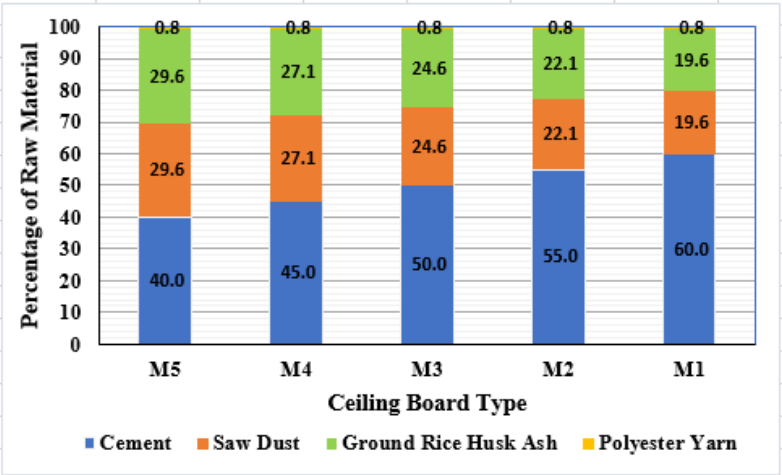

Figure 1- Mix Proportions of Composite Ceiling Board (CCB)

RESULTS AND DISCUSSION

Compressive Strength

The tested compressive strength value varies between 539.4 and 4,673.3 kPa as shown in Figure 2 and increases with increasing cement content. According to the ASTM standards, the compression strength requirement for ceiling boards is 448 - 868 kPa as shown in Table 1. Hence all the tested ceiling board types satisfy the compressive strength requirement of ASTM standard. These favorable results are due to adequate compaction and finer properties of sawdust, ground rice husk ash and cement.

Modulus of Rupture

The variation of the flexural strength of tested samples is shown in Figure 3. The Modulus of rupture (MOR) varies between 1.72 - 2.87 MPa as shown. Sample M1 has the highest MOR value, while sample M5 has the least. According to the ASTM standards, the MOR requirement for ceiling boards is 0.03 - 0.07 MPa. Hence, it can be concluded that all the samples have good resistance to flexural failure.

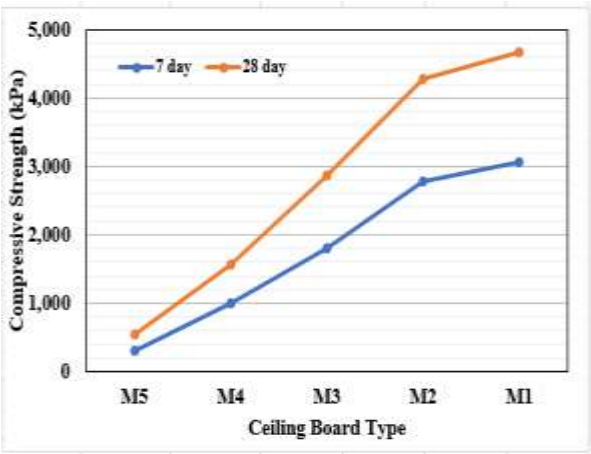

Figure 2: Compressive strength of CCB

Figure 3: Flexural Strength of CCB

Density

The density of the composite board varies from 1077.8 to 1332.4 kg/m^3 as shown in Figure 4. The density range specified in the ASTM standard for ceiling boards is between 350-400 kg/m^3 (Table 1). Hence, all the tested samples have densities much higher than the standard. Further, the range is equal to the density range of Fiber cement flat sheets, Trilite board and Masconite AC flat sheets which are widely used for the same purpose.

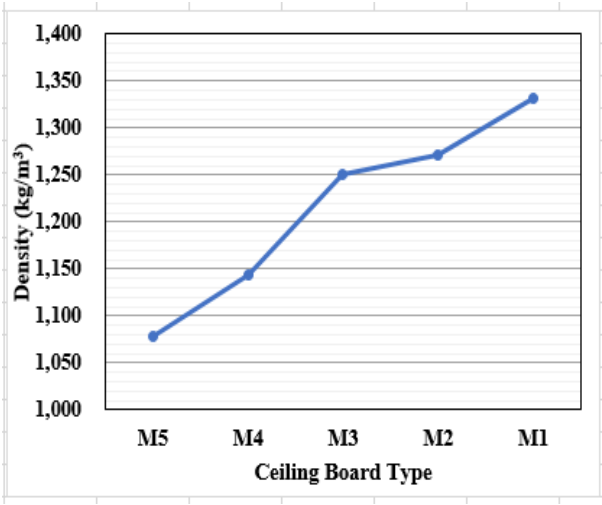

Figure 4: Density of CCB

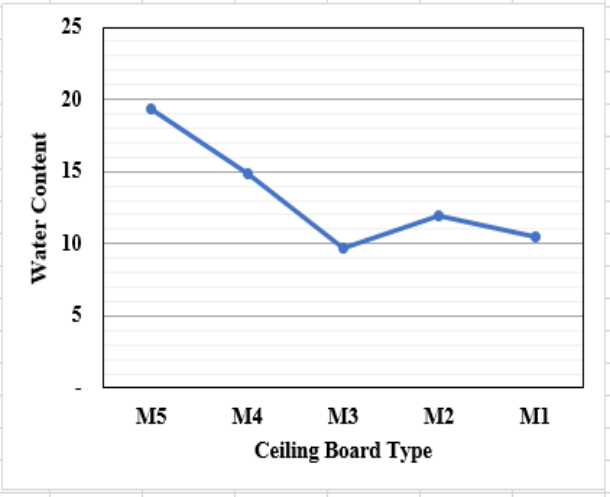

Figure 5: Water absorption of CCB

Water Absorption

The water absorption values vary from 9.7% to 19.39% as shown in Figure 5. Water absorption values of Fiber cement flat sheets, Trilite boards, and Masconite AC flat sheets lie within the same range, but outside the range specified in the ASTM standard.

Cost analysis

Figure 6 shows how the cost of the production of CCB compares with the standard types of ceiling boards, 1200 x 1200mm in size, that are currently available in the market.

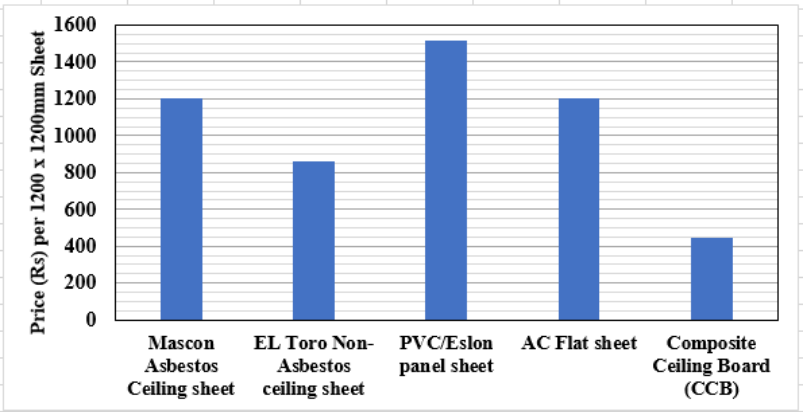

Figure 6: Comparison of CCB cost with price of conventional ceiling boards

It can be seen that CCB is the cheapest with a wide margin when compared with other widely used ceiling board types. Mascon Asbestos ceiling sheet, EL Toro non-Asbestos ceiling sheet, and PVC/Eslon panel sheet are, respectively 269%, 193% and 341% more expensive when compared to the cost of CCB. The main reason for this is that other than cement (OPC) all the other constituent materials used in the making of CCB, rice husk ash, sawdust and polyester yarn are waste materials.

CONCLUSIONS/RECOMMENDATIONS

The ceiling is an essential component in a standard dwelling unit, which accounts for a substantial portion of total construction cost. Hence, it is essential to maintain this fraction of cost to reduce the overall construction cost. This research study proposes a solution to this problem by utilizing otherwise problematic waste materials to produce a low-cost composite ceiling board. Moreover, CCB is free of hazardous asbestos which is known to cause cancer.

Table 1 - Comparison of physical and mechanical properties of CCB with other types of ceiling boards and the ASTM standard

Properties	Asbestos ceiling board	Fiber cement flat sheet	Trilite board	Masconite AC flat sheet	ASTM standard	Composite ceiling board (CCB)
Density (kg/m^3)	1500-1950	1250 - 1350	1000 - 1050	1200	350 - 400	1078 - 1332
Water Absorption (%)	0.5 – 3.0	< 35	< 35	<28	0.32 - 0.64	9.7 -19.39
Flexural strength (N/mm^2)	1.0 – 3.0	3.0 – 7.0	12.1 – 17.1	13.0-16.0	0.03 – 0.07	1.72-2.87
Compression strength (kPa)	Not available	Not available	Not available	Not available	448 - 868	539.45-4676.3
Split tensile strength(kPa)	Not available	Not available	Not available	Not available	Not available	468 - 1150

Engineering properties of tested CCB, namely compressive strength, flexural strength and density satisfy the requirements specified in ASTM standard for ceiling boards. Only the observed water absorption values lie outside the range specified in the ASTM standard. However, water absorption values given in the published data sheets of fiber cement flat sheet, Trilite board and Masconite AC flat sheets also lie in the range observed for CCB. Further, it is customary to apply some types of paints on ceiling boards which help to reduce water absorption. All the five mixes, M1 to M5, showed similar behavior and hence the most economical mix is M5, having the least cement content. Further research needs to be conducted to fine-tune the proportions of constituent materials.

Hence, it is highly recommended that the composite of rice husk, saw-dust and polyester yarn with cement as the binder is suitable for producing ceiling boards that could be useful for indoor purposes. Further study is necessary to tackle the water absorption properties by reducing the polyester yarn content while continuing with fire resistance, durability, thermal conductivity and modulus of elasticity tests.

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