Innovative Use of Textile Cotton Micro Dust Waste as Thermal Insulation Board

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Executive Summary

Cotton yarn is one of the major products from textile industries which produces around 100 billion kilograms every year globally. During the manufacture of cotton yarn, around 3% of waste are micro dust that cannot be processed further for textile application dumped as a landfill. Based on the global production, nearly 3 billion kilograms of micro dust ends up in landfill causing environmental problem. India alone account 20% of the global cotton yarn production and 90 million kilograms of waste generated annually. Hence, reusing of these industrial wastes (micro dust) by blending with other materials will be a proficient solution for the pollution problem. Considering the potential of natural waste materials with low thermal conductivity, energy efficient solutions can be made.

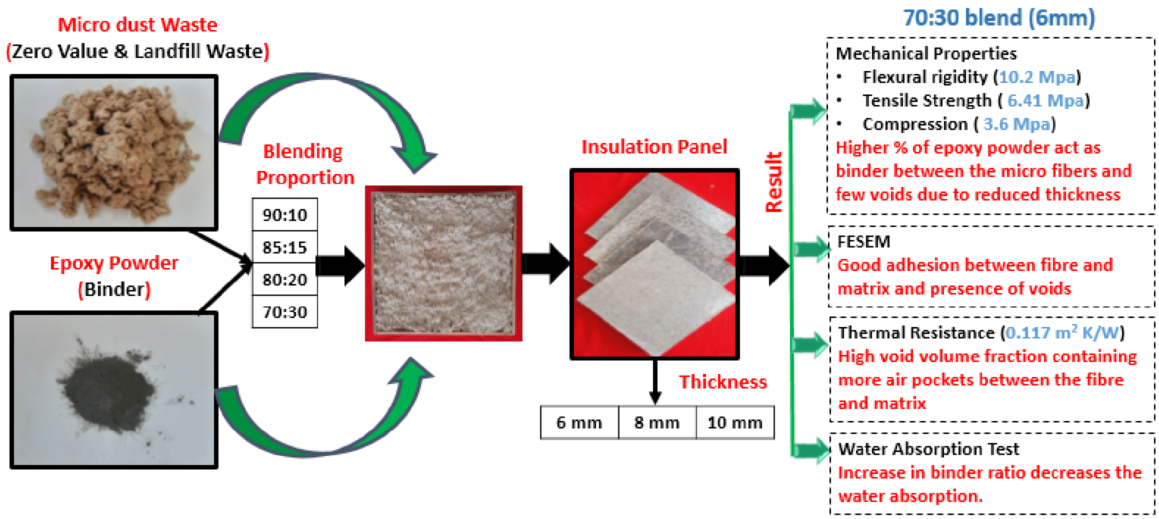
The objective of this research work was to develop a thermal insulation composite panel using micro-dust with epoxy polyester powders with respect to temperature, time and blend ratio. The characterization of the developed insulation panel for thermal resistance, tensile, flexural and compression properties as well as water absorption were investigated and compared with commercial product.

The cotton micro dust fibres were blended with epoxy polyester powder at different proportions such as 90:10, 85:15, 80:20, and 70:30. The composite boards were developed using a compression molding under a constant weight by varying the thicknesses. The developed panels were cut into required size for characterization such as thermal and mechanical properties (Tensile, Flexural, and Compression). Also, water absorption characteristics were investigated.

70/30 blend ratio showed better bonding between all fibers confirming good adhesion between fiber/matrix leading to increased mechanical properties. At 6 mm thickness, the panel showed higher mechanical properties due to higher proportion of epoxy adhesive which act as a binder between micro-fiber and matrix. But, the thermal resistance values were found to be highest for thicker (10mm) panels than 6 mm due to high void volume fraction containing more air pockets. Also, it was clear that the water absorption rate decreases with increase in epoxy powder blend from 188% (90/10) to 67% (70/30) during 24 hours of water immersion

From overall analysis and comparison, the composite board developed from 70/30 blend ratio with 6 mm thickness showed better result among other proportions. The thermal insulation value was found to be 0.117 m2 K/W which is equivalent to commercial sample having a value of 0.120 m2 K/W and the density being 795 kg/m3, tensile 6.41 MPa, compressive 3.6 Mpa, flexural 10.2 Mpa and water absorption rate of 67%. The thermal characteristics satisfy the relevant required standards for a thermal insulation panel and show that the cotton micro dust composite panel is comparable to the commercially available panel. Hence it could be an economical alternative for thermal barrier panels.

Graphical Abstract



Participants Biography

A short biography of the participants including, i.e., the applicant's contact data, career achievements and history, education, list of publications, etc.

Attached separately as PDF files

Exceptional Achievements

Research Focus

The project is **focused** on developing an ecofriendly thermal insulation panels from spinning industry is unusable final waste of micro dust (landfill waste) for the technical textiles applications. The **challenge** taken in this project is to utilize the micro dust waste into a value added products with techno commercial value. The micro length fibres in the dust provide high surface area to volume ratio and dust particles that provide the required strength when formed as a composite structure. In addition, these micro fibres provide good thermal insulation characteristics and the product developed would be biodegradable and sustainable in line with SDG-goals. The developed product would reduce the landfill and opens the new market for the spinning industries.

Perused aim

The **novelty** of this work is, reusing the micro dust waste into a useful product as thermal insulation panels. Micro dust waste from spinning mill is unusable and further process in textile machineries is not possible due to its inherent disadvantage properties such as micro length, uneven length, sand particles and chaff particles present in the waste. On the other hand, we have been working for a long period in the area of sound and thermal insulation panel and we found that the disadvantage characteristic features quoted by the spinning industries are the unique features required for making thermal insulation panels. The micro length fiber, uneven length will create micro air pocket and soil, chaff particles act as additional low thermal conductor. Based on this science background, we have prepared the thermal insulation panels.

Methodical approach and results:

The cotton micro dust fibres were blended with epoxy polyester powder in the proportions of 90:10, 85:15, 80:20, and 70:30. The uniform mixing was achieved by homogenizer machine and the blended micro dust/epoxy powder was laid in the mold with the required spacer plates to adjust the final outcome thickness. The 2 x2 composite boards were developed with a constant weight of about 2kgs by varying the thicknesses as 6 mm, 8mm, and 10mm. The developed panels were characterized for thermal properties (ASTM D518) and mechanical properties such as tensile (ASTM D 3039), Flexural strength (ASTM 790), Compression (ASTM D 695). Also, water absorption characteristics were investigated.

The thermal resistive properties of the developed panels depend on the thickness and quantity of the epoxy binder. From figure 1 (a), it was found that 10mm thickness composite panels have higher thermal resistance (R) value than 6mm due to high void volume fraction containing more air pockets. The 10mm thick composite board with 85/15 blend ratio showed highest thermal resistance (R) value of 0.1879 m^2K/W when comparing with other boards. This is due to high void volume fraction present in the thicker sample (10mm) than the 6mm sample. The density of composite panel is reduced due to reduced voids present in between the reinforcement fiber and matrix. Maximum level of voids found at 70/30 blend ratio (10mm thickness) and other parameters such as micro fiber length, chaff percentage, sand particles percentage and homogeneous nature of the micro duct cannot be controlled (Binici et al (2013)). However, all the developed composite panels showed higher thermal resistance value than the market available commercial sample. The presence of high void volume fraction act as a weak place during the mechanical properties.

Amongst all composites shown in figure 1(b), 70/30 blend ratio with 6 mm thickness showed higher mechanical properties due to higher proportion of epoxy adhesive which act as a binder between micro-fiber and matrix. And while comparing the test results with respect to the thickness of the board, the mechanical strength was found to be higher for 6 mm than 10 mm thickness due to presence of few voids and more binding points in 6mm thickness board. At 70/30 blend ratio of 6mm thickness panel, showed highest tensile, flexural, and compression strength (6.41 MPa, 10.2 MPa, and 3.6 MPa respectively) than other blends including commercial sample. On comparing the FESEM Images of all developed panels, 70/30 blend ratio showed better bonding between all fibers confirming good adhesion between fiber/matrix leading to increased mechanical properties.

The water absorption test was carried out for one month to understand the swelling and disintegration behavior of the developed composite panel. There are three mechanisms reported by Bodur et al (2017) that occurs during water diffusion into the polymer composites. First, diffusion of water molecules happens by the micro gaps between the adjacent polymer chains, second by the capillary action where the voids presence in the fibre matrix interface, and the third by transport of water molecules through micro cracks/voids in the fiber matrix structure. From the Figure 1(c), it was clear that the water absorption rate decreases with increase in epoxy powder blend from 188% (90/10) to 67% during 24 hours of water immersion (Claudia A. Echeverria et al (2019)). The commercial sample has 115% of water absorption which is higher than the 70/30 ratio of the composite panel. The blend ratio of 80/20 and 70/30 panels almost reached its saturation level after 14 days but the other samples like 90/10 ratio panel and commercial sample gradually absorb the water.

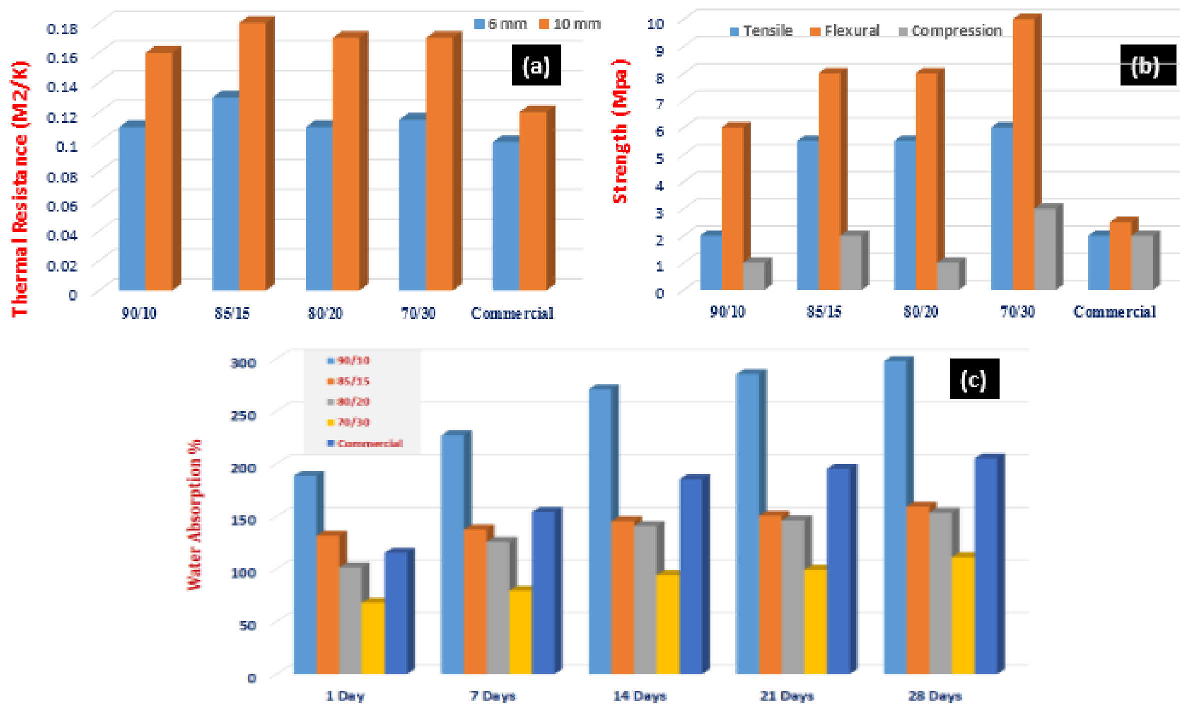


Figure1 Characterization of developed thermal insulation board (a) Thermal Properties (b) Mechanical properties at 6mm thickness and (c) Water absorption %

<u>Overarching Goal:</u>

The **value** of this project is

(1) The product would be 100% techno commercial

(2) Reduce the carbon foot print

(3) Value addition for the waste,

(4) A new / sustainable product for spinning mills

(5) Recyclable

(6) Biodegradable

(7) Reduce the landfill.

<u>Future Advances</u>

The **environment impact** of this project is that it would reduce 100% landfill of micro dust waste as the waste is converted into a value added product. The developed product would be an **economically viable** one, as the conversion cost is low -- Rs 41 [raw material - Rs.26/- and processing cost - Rs. 15 per square feet], with scope for further reduction if processed in bulk. Hence this project has 100% techno commercial viability, will reduce the environment load, and presents a potential source of additional revenue for spinning mills.