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ROLE OF AGRICULTURAL WASTE- CORN COB IN ENHANCING INDOOR THERMAL EFFICIENCY OF A BUILDING

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Abstract

The present work investigates the role of agricultural waste in enhancing the indoor thermal Efficiency of a Building by using agricultural waste as cladding material. Agricultural waste being a porous material when used as cladding to walls reduces the indoor temperature. The heat loads are reduced and this in turn reduces the load on air conditioning. An enormous amount of energy is required to maintain the thermal comfort in infrastructure like industries, complex, metro transit stations etc. A sustainable building allows natural lighting as well as reduces the indoor temperature. This can further be made sustainable by using flora which absorbs toxic gases nullifying the VOC (volatile organic compounds) materials. Passive techniques like vegetative waste fill /cladding or Corn cob waste may be used for the preparation of building materials. The present study reviews the works carried out by various researchers in adopting agricultural waste corn cob in building materials.

Keywords:

Sustainability, Thermal Efficiency, Passive Techniques, Agricultural waste, Indoor Environment, thermal Comfort.

1 Introduction

"Sustainable concept of designing the building, architectural planning, macro and micro level building analysis to achieve sustainability of the building, efficient natural resource utilization in an economic integrated approach" are some of the approaches for sustainable designs. The sustainable building emphasizes more on natural lighting, temperature control, as well as reduces the cost of operation. India is composed of 6 climatic regions/zones, "Hot and dry", "Warm and humid", "Moderate", "Cold and cloudy", "Cold and sunny", "composite". Excessive daytime temperatures, with very less precipitation and a short and mild winter season describe Hot and Dry climate, the main feature being very hot during the day and cold at night. This is due to the swift radiation heat loss from the ground or the building to the clear night sky. As humidity is low, cooling by evaporation of water would be an easy and effective way of gaining thermal comfort. The regions are subjected to sandstorms, dust storms. Small openings are provided, and ventilators are a must feature in these buildings to remove hot air. Warm and humid climate is predominantly in coastal regions of India, where the humidity is very high, at times reaching 100%. The temperatures are in the range of 32 to 38o C. Providing large eaves over open verandahs and also providing large openings to allow air circulation are some of the features adopted in this zone.

Cold and cloudy and cold and sunny climates are predominant in Northeast, Jammu and Kashmir. Solariums are a common feature to allow sunlight inside the building. Thick walls are also provided to allow thermal storage so that heat is released inside the building during cold nights. Cities like Bangalore and Pune in India have Moderate climates, where the temperature and humidity are well within thermal comfort. In Bangalore, there is no specific design adopted which is vernacular to that zone. In the last decade the temperatures have soared in even modern climatic zones and hence the need for using insulating materials.

2 Literature Review:

Wood fiber, cellulose, wool, hemp, hemp Crete, cellular glass, straw bales, glass mineral wool, rock mineral wool, aerogel and some agriculture waste like corn stalk, coconut husk, rice husk, bagasse, durian peel, corn cob etc. are used for insulation of walls, floors and roofs [1].

Corn cob is chosen since the properties and characteristics of it are helpful in regulating thermal efficiency. Corn cobs are the long-rounded parts of the maize or corn plant on which small yellow seeds grow.[2].

Corn cobs has three different layers, layer 1 is macro structure, layer 2 is same as compacted soft wood and 3rd layer is an irregular layer, all these helps in Thermal separation [3].

It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 % (782 m t) in the global grain production. Major maize producing stated of India are tabulated in table 1:

Table 1: Major maize producing states of India are

Sl. No.	**States**	**Production (%)**
1	Andhra Pradesh	20.9 %
2	Uttar Pradesh	6.1 %
3	Karnataka	16.5 %
4	Madhya Pradesh	5.7 %
5	Rajasthan	9.9 %
6	Himachal Pradesh	4.4 %
7	Maharashtra	9.1 %
8	Bihar	8.9 %

Andhra Pradesh which ranks 5th in area (0.79 m ha) has the highest production (4.14 m t) and overall yield (5.26 t ha) in India. The selected waste material is mixed with the different binding materials and is casted in a mold of definite size. Passive cooling systems are less expensive means of cooling building which in turn increases the efficiency of the building without any hazardous effect both to environment and living beings.

3 Methodology

The heat loads can be reduced by using suitable materials depending upon location of the site. The best orientation depends on the location of the site. It is also recommended to use flora which absorbs toxic gases and gases emitted by the VOC (volatile organic compounds) materials. By adopting passive techniques like vegetative roof/cladding, (also some of the examples which can be adopted are earth air tunneling, passive downdraft evaporative cooling and roof pond which are environmentally friendly. The present study investigates the feasibility of using corn cob as an insulating material.

3.1 Corn cob

A corncob is the central core of an ear of corn. Corn cob may be used as a raw material to manufacture thermal insulating products, light partition walls, ceiling coating, indoor doors and furniture. Figure 1and figure 2 shows the different layers in the sandwiched material as well as its microscopic details.

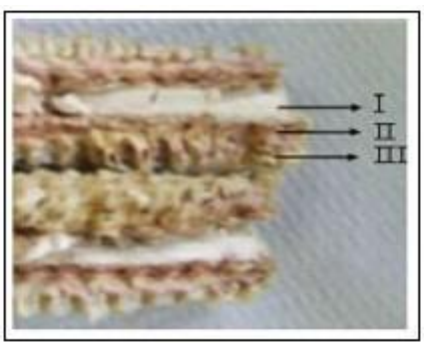

Figure 1: Layers of cob

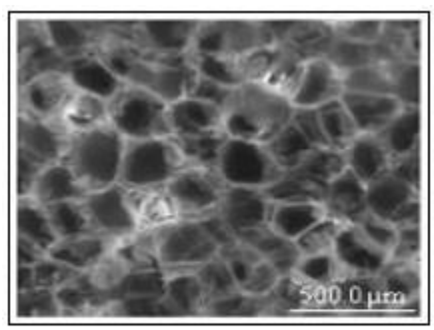

Figure 2: Microscopic view of corn cob

The corn cob is considered as agriculture waste. This natural and organic waste is used as building material in the construction industry. Research data is available to assess its macrostructure and microstructure, elementary chemical composition, density, water absorption, fire resistance and thermal insulation capacity. These properties of the corn cob were compared with the corresponding ones of the most common thermal insulation products applied in the Portuguese building industry, which are extruded polystyrene (XPS), expanded polystyrene (EPS), cork and expanded clay. Several similarities were found when comparing the properties of these materials, between the corn cob and the cork, which suggests that the corn cob may be used as a raw material to process thermal insulating products, light partition walls, ceiling coating, indoor doors and furniture, among other possible applications.

3.2 Preparation of Composite Corn Cob

Corn cob powder is mixed with different kinds of binding materials to improve the efficiency and durability of corn cob powder as shown in figure 3, figure 4,figure 5 .The composite materials prepared out of corn cob powder were left undisturbed for drying. The prepared materials were tested for thermal transmittance in a controlled environment.

Figure 3: Preparation of corn cob composite

Figure 4: Different proportion of cob

Figure 5: Thermocouple setup

The source of heat for external temperature (T1) was given by hot air gun. Thermally stable and insulating sealant and pipe of diameter 8cm were used to create a controlled environment. Thermo couple apparatus were used for the measurement of the heat supplied and heat transmitted. The thermo couple sensors used were of range -2000C to 13700C and 328 0 F to 24980 F. Every sample material prepared was tested for thermal transmittance till it attains the temperature of 1000C. The supplied temperature (T1) and transmitted (indoor) temperature were measured using thermo couple apparatus with respect to time. The difference in the temperature is calculated (T1-T2), thereby heat transmission capacity of the material is known. Fig 4 shows the experiment setup.

Figure 6: Thermocouple setup - 1

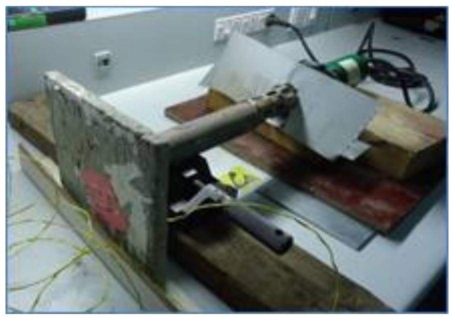

Figure 7: Thermocouple setup 2

3.2.1 Sample-1:

One proportion corn cob powder +2 cup jaggery +20ml water

In this sample, one proportion of corn cob powder was taken a bowl. Two proportion of jaggery was heated along with the addition of 20ml of water till a viscous jaggery liquid was obtained. Before the viscous jaggery liquid dries it was mixed thoroughly with the corn cob powder and the mixture was casted in the mould. This proportions are casted in the mould of 20cm*20cm*10mm as shown in fig5

Figure 8: Corn cob waste

Figure 9: Corn cob sample

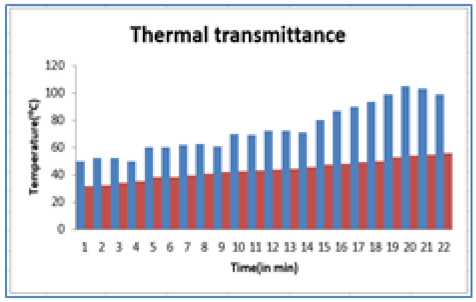

Figure 10: Thermal transmittance of sample 1

3.2.2 Sample 2:

Three proportion corn cob powder + nine proportion cement + 500ml water

In this sample, volumetrically 3 proportion of corn cob powder was taken in a bowl, and then 9 proportion of cement was added and mixed till the color is uniform as shown in fig 6. 500ml of water was added, mixed and casted within the setting time of the cement. This proportions are casted in the mould of 20cm*20cm*10mm.

Figure 11: Dry corn cob

Figure 12: Corn cob sample 2

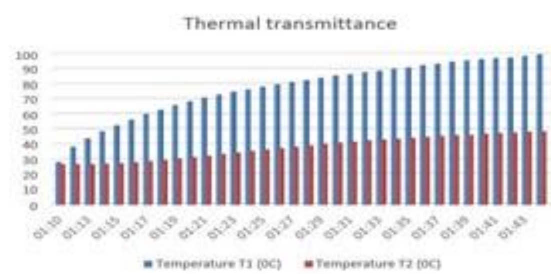

Figure 13: Thermal transmittance-sample 2

3.2.3 Sample-3:

Three proportion corn cob powder + 6lime + 9 cement + 3 M-sand + 800ml water.

In this sample, volumetrically 3 proportion of corn cob powder was mixed with 6 proportion of lime, 9 proportion of cement and 3 proportion of M-sand thoroughly till a uniform color is obtained as shown in fig 7. Then 800ml of water was added, mixed and casted within the initial setting time of cement. This proportions are casted in the mould of 20cm*20cm*10mm.

Figure 14: Corn cob sample 3

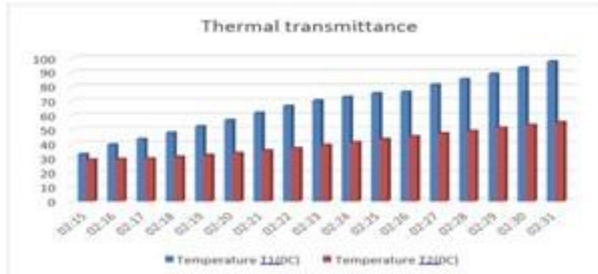

Figure 15: Thermal transmittance of Sample 3

3.2.4 Sample 4:

4 cement + 8 lime + 600ml water + 2 m-sand + 4 proportion corn cob powder. In this sample, volumetrically 4 proportion of corn cob powder was mixed with 8 proportion of lime powder, 2 proportion of M-sand, 4 proportion of cement was mixed uniformly as shown in fig 8. Then 600ml of water was added, mixed and casted before cement sets. This proportions are casted in the mold of 20cm*20cm*10mm.

Figure 16: Corn cob sample 4

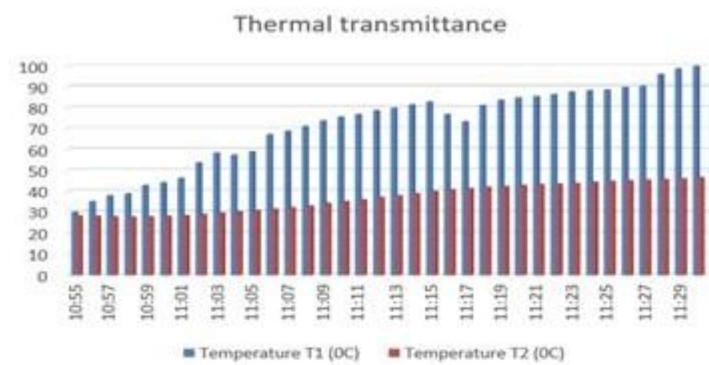

Figure 17: Thermal transmittance of Sample 4

3.2.5 Sample 5:

Seven proportion corn cob + 4 cement + 8 lime + 800ml water + 2 M-sand.

In this sample, volumetrically 7 proportion of corn cob powder was mixed with 8 proportion of lime powder, 2 proportion of M-sand and 4 proportion of cement was thoroughly mixed till a uniform colour is obtained as shown in fig 9. Then 800ml of water was added, mixed and casted. This proportions are casted in the mold of 20cm*20cm*10mm.

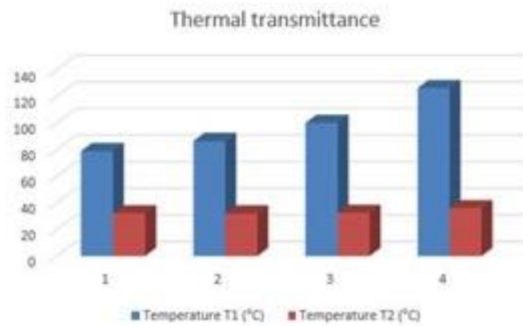

Figure 18: Corn cob sample 5

Figure 19: Thermal transmittance ofsample 5

3.3 Comparison of the different samples

Comparison of the different samples of materials based on its thermal transmittance as shown in Table 2

Table 2: Comparison of different samples

Sl.No	Material	Heat transmitted across the material	Thermal Transmittance
1	1 Proportion corn cob powder + 2 cup jaggery +20ml water	20˚C	0.328
2	3 Proportion corn cob powder + 9 proportion cement + 500ml water	49.1˚C	0.805
3	3 Proportion corn cob powder + 6lime + 9 cement + 3 M-sand + 800ml water	34.7˚C	0.56
4	4 Proportion corn cob powder + 4 cement + 8 lime + 600ml water + 2 m-sand.	51.2˚C	0.83
5	7 Proportion corn cob powder + 4 cement + 8 lime + 800ml water + 2 M-sand	57.6˚C	0.94

The comparison shows that, the 5th sample (i.e., 7 proportion of corn cob +4 proportion of cement + 8 proportion of lime + 2 proportion of M-sand + 800ml of water) has very minimum heat transmittance across the material. It was observed that the surface of the material is absorbing the heat. Energy is rapidly dissipating in shorter duration, also the material has minimum strength hence this material is not preferred for the field applications. All the other samples performed better with respect to heat transmittance.

Selection of the right sample can be based on the climatic zone. Hot and humid zone requires very less thermal resistance hence the sample 1 and sample2 are best in hot and humid zone. Windy regions require high degree of thermal resistance hence sample3 and sample4 are suitable.

4 Applications:

Corn cob can be used in various components in a structure. It can be used as false Ceiling, wall cladding material, cavity walls as well as a filler material in coffered slabs.

1. False ceiling: Corn cob composite material can be used as the material for false ceiling since this material requires least maintenance, less self-weight and mainly it is having very minimum thermal transmittance [4].

2. Wall cladding: The corn cob mixed material is best suited for wall cladding. The material is best suited as it has high thermal resistivity, high thermal stability, and less thickness hence space is also saved.

3. Puffed wall: The material can be used in the puffed wall since it resists heat more than that of the PVC coated puffed wall.

4. Cavity fill: This material can be used in masonry structures (Rat trap wall) and also in partition walls.

5 Results & Discussion:

Research on the Feasibility studies of corn cob as a sandwiched material to improve thermal insulation is still in nascent stage. However, the results are encouraging. Samples 1,2,3,4 are giving promising results and further work should be carried out with these samples. The sample 5 which is exhibiting unique characteristics (the surface of the material absorbs heat rapidly to maximum extent but transmission of heat across the material is very much minimum) could be further studied to further improve its performance.

Table 3: Transmittance of different materials

Sl. No.	Material	Thermal Transmittance ($W/m^2{-}K$)
1	1 Proportion corn cob powder + 2 cup jaggery +20ml water	0.328
2	3 Proportion corn cob powder + 9 proportion cement + 500ml water	0.805

3	3 Proportion corn cob powder + 6lime + 9 cement + 3 M-sand + 800ml water	0.56
4	4 Proportion corn cob powder + 4 cement + 8 lime + 600ml water + 2 m-sand.	0.83
5	7 Proportion corn cob powder + 4 cement + 8 lime + 800ml water + 2 M-sand	0.94
6	Plain glass sheet 3mm thickness	5.23
7	White Painted glass	5.22
8	Yellow painted glass	5.22
9	Green painted glass	5.22
10	Heat absorbing glass	4.65
11	100 % shaded glass sheet	5.23
12	75% shaded glass sheet	5.23

Further work needs to be carried out to implement this material in the construction industry.

- The corn cob composite material prepared can be further studied and its thickness could be minimized without any impact on its performance.
- The corn cob composite material should be enhanced by its strength and durability with further research on the materials.

6 Conclusions:

The preliminary study on different samples of the corn cob composite materials shows that based on the zone one can select the sample. Enormous amount of energy is utilized for thermal comfort in infrastructure like industries, complex, metro transit stations and residency. Hence in order to avoid such impact on environment the best way is adopting passive method of thermal comfort.

7 References

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