A PICTURE ON BIO-BASED BUILDING MATERIALS AS THERMAL INSULATION FOR SUSTAINABLE BUILDINGS

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Abstract

The movement of heat, air, and moisture through the buildings are related to the energy consumption for heating and cooling in order to achieve the satisfaction of the building occupants. The differences in temperature and relative humidity between the inside and the outside of a building induce transfers of heat and moisture through the envelope which exhibit different behaviors according to materials composing it. A wise choice of wall component allows a better energy and environmental performances limiting condensation and mold development. The Bio-based hygroscopic materials have been developed for a wide range of applications, and it is a good solution to enhance building performances. They have a low environmental impact, and are used for different purposes. They can be selected as structural components, thermal insulations or finishing materials with their good moisture buffering properties. The objective of this paper is to present a review of bio-based building materials focusing on their hygrothermal properties, and specific experimental methods for their characterization, use in building and finally, their life cycle analysis. A comparative study was also achieved based on several considerations; Thermal conductivity, Buffering capacity, Heat storage, Condensation and Mold growth risk. Explored methods use both experiments and computational models for simulation.

Keywords:

Bio-based materials; moisture adsorption; thermal Insulation; condensation risk

1 INTRODUCTION

The building sector is the most consumed energy in France, it represents 43% of the whole energy consumed in 2014. By enhancing thermal insulation properties and its characterization of building envelopes, it could help to reduce the energy consumption of the building. The movement of Heat, Air, and Moisture through the buildings are related to the energy consumption for heating and cooling in order to achieve the satisfaction of the building occupants. The influences the comforts of occupants called Relative Humidity (RH) will affect the condensation and respiration of the building. The differences in temperature and relative humidity between the inside and the outside of a building induce transfers of temperature and moisture through its walls. In the pores of walls, the moisture can be existed in two phases: liquid and vapour. The main mechanisms of moisture transport in building materials are the diffusion of water vapour and liquid transport under the action of capillary forces. The factors that influence the hygrothermal flows passing through the wall depending on the moisture level, a variety of fungi, bacteria, and insects. Therefore thermal Insulation Systems aims to reduce the transmission of heat flow through the building, the performances are measured by thermal conductivity and thermal transmitted. Hygroscopic materials can improve the energy performances of the building by reduces heating and cooling 5% until 30% [Osanyintola 2006]

The thermal conductivity of the air is about 0.026 W/(m.K), and 0.6 W/(m.K) for water, the problem are occurring when a part of the air in the thermal insulation material porous was replaced by water, the presence of water will increase the thermal conductivity of the insulation material. Therefore, the highest moisture means the highest thermal conductivity of the materials.

Bio-based materials came from animal or plants, it has been developed as the insulation materials and this is a sustainable way to be developed in the future because it has a small impact for the environment and it could be as a renewable source. Mnasri et al. found that bio-based building materials had a better hygrothermal behaviour compared to a concrete material [Mnasri 2016]. The objectives of this paper are to present the information around bio-based materials.

The review will present the comparative study around the variety of bio-materials in terms of characterization and hygroscopic behaviours, it will bring the information based on several considerations; The thermal conductivity; Moisture management & Buffer capacity; Heat storage & Transport; Condensation & Mold growth risk of the materials.

Bio-based materials divided into several kinds:

1. Bio-Mass materials are the materials that came from the biological process, exceptional for fossil fuels.

2. Bio-Source materials is a material derived from plant or animal that can be used as raw material in the building, furniture, or the decoration.

3. Bio-based construction products is a construction material or building materials.

2 OBJECTIVES

The objective of this paper is to report a state of the art of bio-based thermal insulation material that had abundant quantities so it has the potential to be used in large of a number for the future. A comparative analysis of each material was achieved based on several considerations i.e; thermal conductivity (λ), moisture management & buffering capacity, heat storage (PCM) & transport, condensation & mould growth risk. A brief description is also provided which region that available to use this kind of materials.

Thermal conductivity is used to evaluate thermal insulation performance in the steady state, normally could be measured using guarded hot plate methods. It defines the steady state heat flow passing through a unit area of homogenous material, 1 m thick, induced by a 1 K difference of temperature on its faces, it expressed with W/(m.K). A material as thermal insulator characterized by thermal conductivity under 0.05 W/(m.K) and specific heat over 1.4 kJ/(kg.K) can be considered as a very performing thermal insulation material even in unsteady state conditions [Asdrubali 2015].

The moisture buffering capacity of hygroscopic materials may also be regarded as the ability to dampen the cyclic indoor moisture variations. Condensation and mould growth are caused by airtightness performances in the interior of buildings [Lee 2016] and the respective air leakage on the insulation materials, a different air leakage path would result in different locations within the material assemblies at risk of condensation and mold growth. Hot and humid weather in Summer making the large amount of moisture caused by indoor activity, but the condensation risk is high during winter season as the surface temperature is relatively low [Chang 2015].

Condensation of humidity can lead to sufficient humidity to support mould growth. Especially in highly insulated airtight buildings, the risk of high humidity and liquid water inside structural elements is potentially increased. In addition, exposure to organic dust, spores, pollen, and other contaminants may cause mould growth inside the structural elements [Fedorik 2017]. The most effective ways to control the internal condensation are by design external insulation system in order to increase the internal temperature above the dew point temperature. Therefore, this reviews aiming to bring the information about bio-based materials that have a good hygrothermal properties to make a good external insulation system.

Another possibility of mould growth in the interior is the natural ventilation or condensation on weakly insulated envelopes of the buildings. The following moisture production and transport sources are considered: air exchange between indoor and outdoor air [Haldi 2015]. This case was commonly found on ancient buildings in European country. It is different compare with the tropical regions which allowing natural ventilation and large open area to reduce the humidity in the buildings. Therefore, the thermal insulation materials that been discussed in this reviews was for sub-tropical regions.

3 REVIEW OF THERMAL ABILITY OF BIO-BASED MATERIALS

The thermal insulation properties of some bio-based materials were studied by several authors in order to assess the characterization of hygroscopic. This material available in large of a number in some regions, some of this material already exists in the market and they should be used preferably where they are harvested and produced. This paper is mainly focused on thermal insulation performances.

3.1 Bamboo

Bamboo is a renewable material and rapidly growing compares to the woods materials. Traditionally, Large diameter of Bamboos is broadly applied in the construction of buildings in tropical regions, especially in Asia-Pacific (67%), Americas (30%), and Africa (3%), as they are easy to obtain, cheap, and earthquake-resistant. bamboo is stronger in axial tension and axial compression than timber [Shah 2015]. Since the 1970s, Bamboo based Panels (BBP) have been regarded as an ideal alternative to construction timber, these products have been applied in concrete formworks, load-bearing structures, carriage floors, furniture, and finishing works.

From the research of Huang Z. et al, they involved the comparison between Raw Bamboo panels and Bamboo-based Panel (BBPs), both have different Hygric properties. For analyzing the storage and transport of heat, moisture, and air in building envelopes they used coupled heat and moisture transfer models (HAM models). The Hygrothermal properties of bamboo panel show a stronger correlation with open porosity than bulk density. Oscar Hidalgo Study the microscopic drying characteristic of bamboo, they conclude that bamboo is easily splinters and cracks owing to its drying characteristics compares with wood. Huang et al. Also measured the liquid water properties and find that the water absorption coefficients are 0.014, 0.008, and 0.0019 kg/m^{2}s for the exterior, middle, and interior parts of bamboo culm wall, and the capillary saturation moisture contents are respectively 572, 479, and 385 kg/m^3 [Huang 2017].

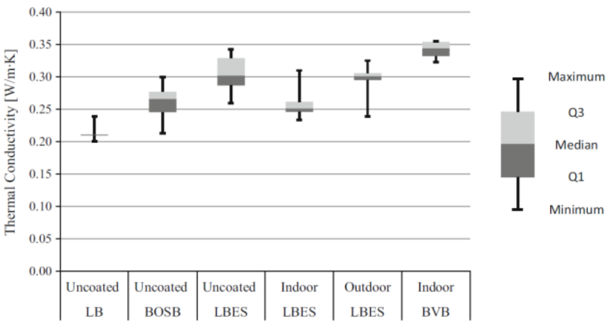

Fig. 1: Thermal conductivity measurements for uncoated laminated bamboo, uncoated Bamboo-oriented strand board, uncoated Laminated bamboo esterilla sheet, and coated Bamboo veneer board [Shah 2015]

Shah et al. study for the density of 1500 kg/m^3 of bamboo they measured that the longitudinal conductivity of the bamboo cell wall is 0.55-0.59 (W/m.K) and the transverse thermal conductivity of the bamboo cell wall 0.39-0.43 W(/m.K). They make a comparative study between bamboo based-materials and wood-based materials and conclude that bamboo-based materials have lower conductivities at high density than wood-based materials. The measurements of thermal conductivity are also carried out towards some of the bamboo-based products using hot disk thermal constant analyser; the range is between 0.20 W/(m.K) until 0.35 W/(m.K) as shown in figure 1.[Shah 2015].

3.2 Wood-Fiber Insulation Panels and wood-based materials

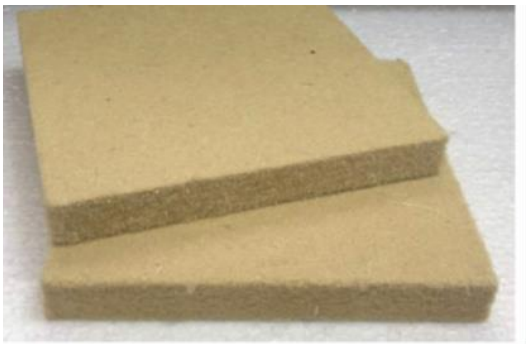

Fig. 2: Wood-fiber insulation panels [Vololorina 2014]

Raw-wood materials have a thermal conductivity around 0.12 W/(m.K), which the thermal conduction is really high for thermal insulation materials. Wood-fibre insulation materials are obtained by the defibration of softwood falls. Vololonirina et al. Studied for the density of 150 Kg/m3 wood-fibre panels, distinguished between 2 cm thickness and 8 cm thickness thermal conductivity is 0.045 W/(m.K) during dry State. The thermal conductivity of wood-fibre insulation was measured in the steady state by the guarded hot plate method, the measurement was made at different temperatures (10 oC, 25 oC, and 40 oC). Thermal conduction is increased as the thickness of the materials are decreased. The dry bulk density is one of the main parameters influencing the hygrothermal properties of wood-based materials because thermal conductivity will increase with the dry bulk density of the various materials [Vololorina 2014].

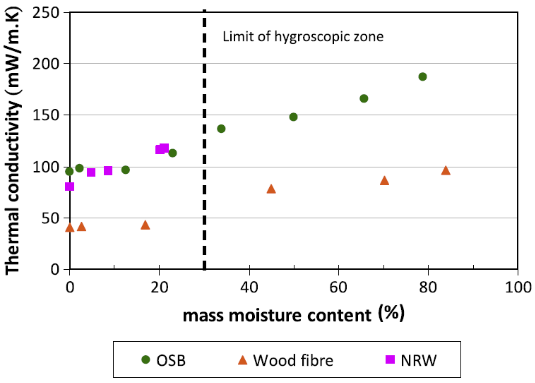

Fig. 3: Thermal conductivity of wood-fiber insulation affected by moisture content [Vololorina 2014]

Xiaobo, Z. Studied that a Wood fibre board had a thermal conductivity around 0.0320 W/(m.K) for the density of 180 kg/m3, the conductivity of wood fibre board are increasing proportionately with the increases of temperature about 0.04% per degree [Xiaobo 2016]. Dry wood fibre insulation panels are generally more resistant to moisture than initially wet ones and have more capability to store water vapour. But they have a difficulty of studying heterogeneous, hygroscopic wood-based materials. Water vapour diffusion was measured with the cup method. Test with dry cup and wet cup corresponded to relative humidity ranges of 9-50% RH and 50-97% RH respectively and good-fibre insulation performed permeability to water vapour. A study of the isotherms confirmed the hygroscopic nature of wood-based materials through the high value of water content reached high relative humidity. The dry wood-fibre materials are more resistant to the moisture than initially wet ones. There is no clear information about mould growth risk was stated in this study.

An experimental and numerical analysis of a wood fibre panel insulation by Slimani, Z. Et al. Using Numerical Modelling of HAM (Heat, Air, Moisture) and a new experimental device that shows in figure 4., they found an 8 cm thickness wood fibre insulation has a high vapour diffusion coefficient indicate that water vapour passes through this material insulation almost as easily as in air [Slimani 2016]. Buffering capacity of massive wood walls was increased in effectiveness as the rate of moisture released is doubled, it present in the study carried out by Hameuri, S. [Hameuri 2005]

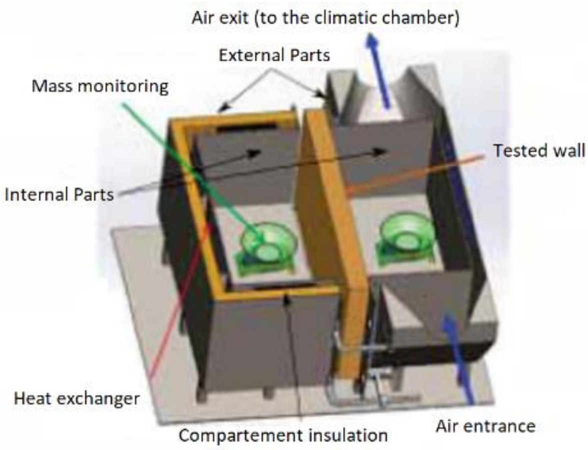

*Fig. 4: Scheme of the experimental de*vice [Slimani 2016]

Mould growth risk of wood materials has been studied by Fedorik, F. et al., this study conducts a combination between several materials; wood, weather barrier, water-proof membrane, mineral foam, EPS, mineral wool, gypsum board, masonry, and cellular glass. Then it is forming some cavity wall as building envelopes, the results of mould growth index measurements as shown in figure 5, that the combination between wood materials and Mansory brick walls is the best combination to reduce the risk of mould growth. Mould growth Index (M index) is a methodology that used for describing the potential of mould growth in building material surface, the higher score of the M index means higher risk for mould to grow in the materials. The study also gives the information that the exterior side of the buildings more easily to have a mould growth than the interiors [Fedorik 2017].

The study conduct by Chang, S.J et al. for a Plywood board that have a thermal conductivity around 0.100 W/(m.K) for 16.0 mm of thickness and the thermal capacity around 1500 J/(kg.K). Using The Lowest Isopleth for Mold growth (LIM) system for evaluation of the mold growth risk, they found that a mold growth risk of wood structures when the relatives humidity is around 78% or more, and mould growth risk on concrete wall structures is appeared when the relatives humidity is around 89% or more. It concludes that the wood frame structures and a plywood boards have a bigger fluctuation and higher condensation risk compare to the concrete structures [Chang 2015].

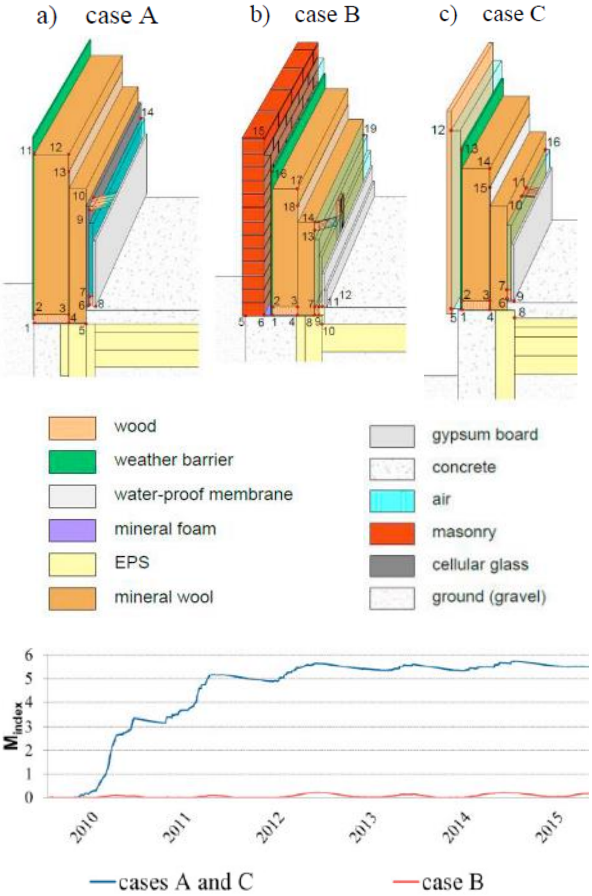

Fig. 5: Geometry of three types combinations forms building envelopes (Up) Growth risk Index between three types combinatios (bottom) [Fedorik 2017]

3.3 Cotton Stalks

The materials come from a residue of cotton and could be used as thermal insulation particleboards for wall elements. Available in large of a number in Asia and America as industrial purposes. Thermal characterization of the material was performed by X, Zhou. et al using the particleboard of cotton stalks a residue of cotton production, the thermal conductivity measured between 0.0585 and 0.0815 W/(m.K), Less dense particleboards has better performances.

Fig. 6: Cotton Stalks (left) and panels (right)

3.4 Straws

Straws is kind of materials are available in large quantities in many countries, straws materials derived from wheat cultivation have been considering as a low-cost building materials: A thermal characterization of the material was performed by Goodhew et al: for a 60 Kg/m^3 dense sample of straws panels supplied by a local farmers in United Kingdom, has dimension about 360 mm by 615 mm, the thermal conductivity is measured around 0.067 W/(m.K) with a specific heat capacity of 600 J/(kg.K) [Dimen 2016].

As thermal coupling of the fibres via gaseous conduction is already well developed at atmospheric pressures, an additional application of binders might not increase the total thermal conductivity significantly. The latter study reported that samples made with the stalks or straw perpendicular to the heat flow have better thermal insulation properties [Asdrubali 2015].

Fig. 7: Straws materials (left) [Dimen 2016] and the application in building as insulation materials (right)

3.5 Paddy Straws

This material is the residue of Paddy corps, One of the most produced commodity in the world. The residues available in large of number especially in Asian countries but still rarely being developed as a building material. The residues of paddy straws could proceed as the component of construction for wall or ceiling insulation.

Fig. 8: Paddy Straws (left) and Rice husk panels (right) [Dimen 2016]

Yardbrough et al, evaluated thermal conductivity at 24 degrees Celcius were between 0.0464 W/(m.K) and 0.0566 W/(m.K), 0.0464 W/(m.K) value was measured for 154 Kg/m^3 dense specimen of particleboards made of rice hulls/straws [Asdrubali 2015]. The study using high-frequency hot-pressing methods conduct in thermal insulation made from rice straws with 200-350 kg/m^3 of density has a thermal conductivity around 0.051 W/(m.K) until 0.053 W/(m.K). The thermal conductivity of particle boards is increased as the particle size decreases, but the particle moisture content did not significantly affect the thermal conductivity.

3.6 Reeds

Known as *Phragmites Australis*, this plant material harvested during the winter season. Reeds materials could be put together with iron or nylon wires in the panel and normally it could be used as roof or wall covered with plaster. This materials is commonly being found and used in eastern Europe and considered as a low-cost material. Reeds straws form some space inside of the stems allowing air to stay in, it increases the ability of reeds as thermal insulation. The thermal conductivity of reed panel are measured between 0.045 – 0.056 W/(m.K) for the density from 130 – 190 Kg/m3

[Asdrubali 2015]. The thermal conductivity by 150 x 150 x 50 mm dimension of reeds panels is also being studied. The best result is 0.070 W/(m.K), made with the combinations of reeds strips, ground straw, and polyvinyl alcohol [Miron 2017].

Fig. 9: Reeds (Phragmites Australis) materials and panels [Asdrubali 2015]

3.7 Bagasse

This material was a residue from sugarcane after the juice had been extracted, the bagasse particleboards could be used as laminated floors and available in tropical countries such as Brazil, Cuba, and Asian countries. Normally bagasse particleboards do not have enough strength and water resistance to used on its own. For the density of 100 Kg/m^3 of panels, the thermal conductivity is 0.046 W/(m.K), and 0.049 W/(m.K) for the 250 Kg/m^3 dense particleboard. Another tested adding bagasse fibres to a cement composite; the measured thermal conductivity decreased from 0.62 to 0.46 W/(m.K) adding only 3% of fibres [Asdrubali 2015]. Another study stated that high-density boards can be formed from bagasse without using any chemical binders [Dimen 2016].

Fig. 10: Sugarcane, sugarcane bagasse [Asdrubali 2015], sugarcane particleboards

3.8 Cattail

Cattail plants or Typha genus commonly grow in wetland areas such as South-east Asia, Australia, and Pacific Nord America.

Fig. 11: Cattail plant and cattail fiber panels [Asdrubali 2015]

For cattail thermal insulation particleboards were studied by Luamkanchanaphan et al, the fibres were brought together by a Methylene Diphenyl Diisocyanate binder, for the cattail fibre that has a density between 200 and 400 kg/m^3 the thermal conductivity was between 0.0438 and 0.0606 W/(m.K). Another research performed by Fraunhofer Institute allowed designing a thermal insulation panel made of cattail fibre characterized by a thermal conductivity of 0.052 W/(m.K) [Asdrubali 2015].

3.9 Corn Cobs

Corn cobs considered as the residual of corn plants after processing of food industry. In terms of shape, texture, density, and colour, corn cob presents three layers different makes corn cob as heterogenous materials. The thermal conductivity of particleboards made of ground corn cobs and wood glue was estimated around 0.101 W/(m.K) [Asdrubali 2015], which is too high for the proper insulation material.

Fig. 12: Corn cob. Raw (Left), ground (middle), and panel (right) [Asdrubali 2015]

Another study of corn cobs particle boards using wood glue as a binder with the density around 212.11 kg/m^3 and the dimension of 250 x 250 x 50 mm in 27 degree celsius of constant temperatures, the measurement was done continously (10 min timing interval) for 7 days, and show the thermal conductivity around 0.139 W/(m.K) [Dimen 2016].

3.10 Oil Palm Fiber

Oil Palm mainly found in Southeast Asia, Africa, and South America Regions. Oil Palm fibre is a residue of the oil palm (Elaeis guineensis).

Fig. 13: Oil Palm Residue (Left), Oil Palm fiber (right) [Asdrubali 2015]

Recent years this materials has developed in Southeast Asia as the alternative building materials. The thermal conductivity of oil palm fibre sample was investigated in 2012 by Manohar, with 100 Kg/m3 density will get 0.055 W/(m.K). The thermal and physical properties of a structural material made of 40% of oil palm bunch fibre and phenol-formaldehyde were studied by Singh et al. The sample developed within the research activity was characterized by a thermal conductivity of 0.293 W/(m.K) and thermal diffusivity of 0.158 mm^2/s [Asdrubali 2015].

3.11 Durian Peel

Durian is a kind of fruit in South East Asia, durian peel could proceed as thermal insulation particleboards. Khedari et al. Evaluated the thermal insulation properties made of durian peel, the thermal conductivity is measured 0.064 W/(m.K) for the density of 428 Kg/m^3. And the thermal conductivity of particleboards made of a mixture of durian (50% of content) and coir fibre was measured 0.0728 W/(m.K) by a density of 330 Kg/m^3.

Fig. 14: Durian peel Raw (Left), ground (middle), and panel (right)

3.12 Vegetable fat and Vegetable fibers

The vegetable fats such as soybean oils, coconut oils, palm oils, and palm kernel oils. This study conducted Palm kernel vegetable fat composed of fatty acids experimented as a bio-based PCM for an application of LHTES (Latent Heat Thermal Energy Storage) in buildings. Palm kernel oil can be found in Southeast Asia. The hot disk was used to measure the thermal conductivity of the bio-based PCM. This bio-based composite-PCM was made by the combination of kernel vegetable fat, Natural Clay, cellulose fibres, and graphite. The palm kernel vegetable fat itself has a very low of thermal conductivity, it is measured around 0.2 W/(m.K). Graphite was added in the composite-CPM to improve the thermal conductivity, then the thermal conductivity of the composite-CPM is 0.5 W/(m.K), 0.63 W/(m.K), 0.68 W/(m.K), and 0.86 W/(m.K) [Boussaba 2019].

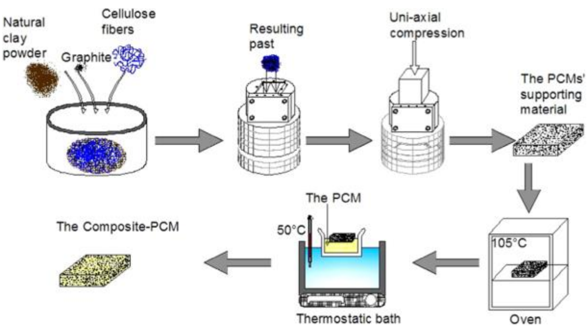

Fig. 15: Procedure of preparation of the composite-PCM [Boussaba 2019]

A hygrothermal study of vegetable fibres materials using experiment and simulations. The panels are the combination between leaves and branches of olive trees with clay, sand, and gravel is conduct by Liuzzi, S. Et al. for the density of 1409 kg/m^3, it has the thermal conductivity around 0.428 W/(m.K) which is very high as proper insulation materials, the specimen with higher fibres content have a lower thermal conductivity. But the comparison of hygrothermal performances between Gypsum Plaster and clay-olive plaster shows that the clay-olive plaster have better performances in terms of a reduction of energy demand in summer [Liuzzi 2017].

3.13 Pineapple Leaves

Pineapple is a kind of tropical fruit, could be found in Asian and America. Industrial processing of pineapple fruits to become a food product leaving abundant residues such as leaves and peels. This residue later proceed as particle boards for insulation materials binder with natural rubber latex. With the dimension of 200 x 200 mm and 15 mm thickness, the particle boards densities from 178-232 kg/m^3 had the thermal conductivity around 0.043 W/(m.K) and 0.035 W/(m.K)

Fig. 16: Pineapple fruit (left) Pineapple leaf fibres (right) [Dimen 2016]

Particle:Binder	Moisture contents (%)	Density (kg/m^3)	Water absorption (%)	
			2 h	24 h
1:2	4.99	178	376	413
1:3	4.52	210	272	310
1:4	3.77	232	190	250

Fig. 17: The physical properties of Pineapple leaves fiber particle boards [Dimen 2016]

3.14 Sheep Wool

The sheep wool could be sustainable bio-based materials as they could growth of a lifetime of sheep, this materials has been used for producing textiles products in a long time. The study of sheep wool materials was conducted in the USA, using the plated methods at steady state for 300 mm x 300 mm samples with varying thickness around 80, 70, 60, 50, and 40 mm. The result shows the thermal conductivity of sheep wool materials are around 0.034 W/(m.K) until 0.050 W/(m.K), this is indicated that sheep wool materials are proper material for thermal insulations [Dimen 2016].

Fig. 18: Sheep wool and its application in building constructioin [Dimen 2016]

3.15 Cellulose-graphene-based

This material is called thermal interface material paper, based on a composite of cellulose and graphene. The thermal conductivity of thermal interface material papers itself had been measured using a laser-flash-methods (LFM) around 5 W/(M.k), therefore the addition of graphene was conduct to make this material suitable for insulation materials. They found that the thermal conductivity of Graphene paper is significantly affected by the paper type due to the difference of porosity. The bare paper it self measured around 0.05 W/(m.K) [Jeon 2018]. From these reviews, it brings the information that the using of paper-based materials as insulation in building construction especially a waste of the paper materials were possible in the future.

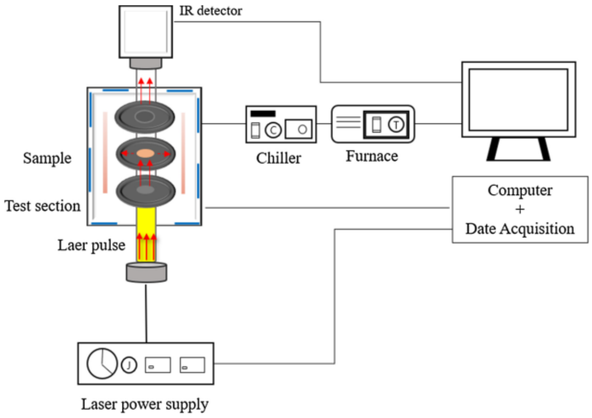

Fig. 19: The schematic diagram of Laser Flash Method [Jeon 2018]

3.16 IBS-IZOLOX Bio-Based Panels

This bio-based material panels is a multi-layer structure wall which is composed of two different layers. The first layers composed from wood chips (89%), cement, and water glass, it has 26 cm of thickness with the thermal conductivity around 0.38 W/(m.K). The second layer is an insulation layer (grey wall), it has 42 cm of thickness with the thermal conductivity around 0.14 W/(m.K). This bio-based materials was developed by ISOLHABITAT company in Belgium.

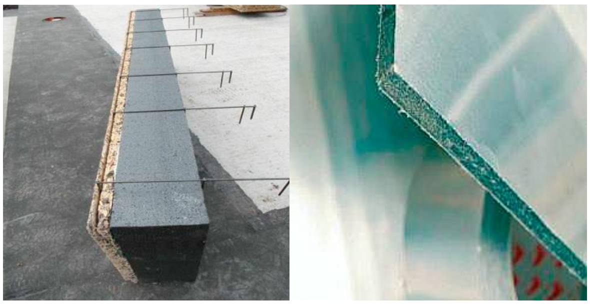

Fig. 20: IBS-IZOLOX Panels (left) PCM *Energain* Panel (right) *[Kharbouch 2017]*

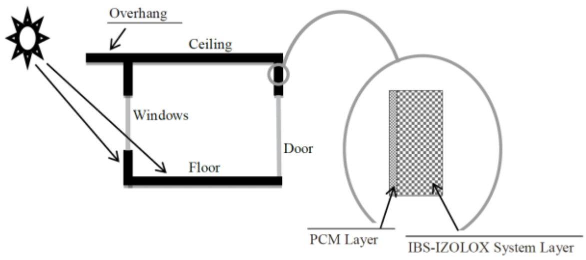

Fig. 21: The scheme of comparative study betwen bio-based panels combine with PCM panels *[Kharbouch 2017]*

The simulation of thermal performance was carried out in France using thermal dynamic simulation and building energy analysis tool, ENERGYPLUS software. The study is using the combination of IBS-IZOLOX Panels with PCM Panel, the PCM Layer thickness is 1 cm, the latent heat is about 70 kJ/kg and the density about 855 kg/m3. The result prove that thermal inertia is importance to reducing overheating, the combination between 42 cm grey wall with PCM panels gives the best performance to improve the thermal comfort of the room during summer period because its reduce the overheating level [Kharbouch 2017].

4 CONCLUSIONS

There are many bio-based materials that could be used as insulation materials, recent studies show that bio-based insulation materials have proper hygrothermal properties and low value of thermal conductivity that comparable to the conventional insulation materials being used by the construction industry worldwide. There are some advantages of using bio-based materials than conventional insulation materials because these materials are not harmful to the environment and human health, each of these bio-based materials has the potential to be developed in every region according to where these materials are mostly produced. Several researchers determined the hygrothermal properties of bio-based materials demonstrating the dependence to the fibre contents. The problem of bio-based materials as thermal insulation is some of the bio-based materials have to combine or mixing with other material to improves its durability and thermal performances.

Beside of wood materials in [Fedorik 2017] and [Parekh 2016], there is still a lack of information about mould growth risk on bio-based insulation materials. Mould growth risk and moisture transport on the bio-materials are essential to study because it was one of the criteria to assess the hygrothermal performance and it affected the building structural lifecycles. Mould has the ability to degrade the properties of the materials of the building, accelerate ageing, and reduce the performance of building structures. The appearance of blackish such microorganisms or bacteria because of high moisture levels exposes occupants to allergies, asthma, infections, toxicoses, etc. Mould could easily appear if the materials are containing high water content, organic particles, especially in humid conditions.

Therefore for the future study, further research must be carried out on the mould growth risk especially for a sensitives organic particles of thermal insulation bio-based materials, in order to make bio-based materials more suitable as an innovative low-cost material to be applying building constructions.

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