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Characterization of Local Insulators: Sawdust and Wool of Kapok

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Abstract: The insulation has an important role in the thermal and acoustic applications in particular in the production of cold. Also within the framework of this study, we studied the sawdust and wool of kapok in order to determine insulator best adapted to the manufacture of the cold rooms or the isothermal vats. The synthetic insulators (polyurethane, polystyrene, glass wool or rock) are very effective, but their use especially burdens the price with the systems carried out until now in the countries of the south. The characterization of local materials, vegetable origin for a possible substitution in the systems and the achievements which call upon the insulation, should make it possible to save energy in the building, heatings water, the cold rooms and to preserve perishable goods (food, drugs, vaccines…). This study enables us to conclude that one can advantageously use wool of kapok or kapok in the place of heat insulators such as the polyurethane, polystyrene, glass wool or cork. However the wool of kapok compared has a better conductivity to the sawdust.

Key words: Conductivity, kapok, sawdust, thermal insulation

INTRODUCTION

Until now, the materials used in the thermo isolation are of origin synthetic. Indeed, one commonly uses glass wool, cork, polystyrene and the polyurethane. The use of these materials makes expensive the isothermal refrigerators, vats and other cold rooms.

Also, the characterization of local materials insulating of vegetable origin will allow a better knowledge of their characteristics, which will have as a consequence:

- The manufacture of refrigerators, isothermal vats, isothermal cold rooms and cans at accessible prices; (Combe *et al.*, 1992; FAO, 1983)
- The reduction of the oil bill of the producer countries (Burkina for example) by energy saving in the tertiary sector;
- Creation of new jobs in the informal sector;
- The respect, so much is little, of the protocol of Montreal.

MATERIALS AND METHODS

This study was carried out at the Department Energy of the Research institute in Sciences Applied and Technologies to Burkina Faso between 2003 and 2007.

For this purpose, the materials hereafter, of vegetable origin, were used:

- sawdust, (Ngohe-Ekam *et al.*, 2006 ; Skogsberg and Lundberg, 2005 ; Demir, 2008).
- Fiber of kapok, (Murdocco, 1999).

Sawdust: Bricks of 200x105x7 mm^3 are carried out by mixture of sawdust with a going binder in the proportions from 20 to 100%.

The study consisted in particular seeking the best binder available on the market, on the one hand, and on the other hand, the proportions of this one.
The binders used are:

- plaster,
- woodworking glue,
- ordinary cement,
- white cement.

The characteristics of the types of bricks are given in Table 1.

Table 1: Characteristics of the types of bricks

Type of binder	Proportioning in %	Weight of briquette in G	Density in Kg/m3
Plaster	25	409.7	278.7
	50	641.2	436.2
Ordinary cement	25	336.7	229
	50	656.7	446.7
Woodworking glue	10	210.1	143
	20	320.8	218
White cement	25	304.8	207
	50	550	374.7

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The material obtained with these proportions is rather light but friable, some is the type of binder used. To avoid this crumbling, proportioning was thorough up to 75%. In this case, the briquette is very heavy, which penalizes its use as insulating on the dynamometers but would be appropriate for the static systems.

To carry out these bricks, a press allowing the manufacture of large-sized bricks was designed.

This system allows the manufacture of bricks various thicknesses according to the compression ratio realized by the operator. It is of an easy use, but the rate/rhythm of exit of bricks is weak, on average every 10 minutes.
The materials obtained have the following characteristics:

- Length: 40 cm
- Width: 20 cm
- Thickness: between 7 and 20 cm
- Ordinary cement proportioning: 20%. The bricks thus obtained were used to isolate a vat from 80 cm black steel edge

Tests on the black steel container: The metal vat actually consists of 2 vats presenting an annular space between them allowing the installation of insulator studied. The interior vat contains the liquid body (warm water) or solid (ice), which we want to note the change of the temperature.

Sensors of temperature are installed in the system in order to note the change of the temperature of the following points:

- Tse: surface external of the vat
- Ts:surface contact isolating - sheet from the external vat
- Ti: surface intern of the interior vat containing water
- Teh: not high of the water vat
- Teb: not low of the water vat

The sensors are connected to a recorder, which ensures of the continuous measurements.

The various surface coefficients of heat exchange h_r and h_c were calculated by using Eq. (1) and (2).

When the air is rigorously calm, the coefficient of surface exchange has as an expression $H = h_c + h_r$, h_c and h_r, respectively translating the influence of the convection and the radiation. (Tye, 1969; Goldstein *et al.*, 2005) These coefficients can be evaluated by the formulas:

$$hc = p\ (Tse - Ta)^{0.25} \quad (1)$$

$$hr = \sigma(Tse^2 + Ta^2)\ (Tse + Ta) \quad (2)$$

With:
p = 2.49 for horizontal surfaces whose flow is directed upwards;
p = 1.31 for horizontal surfaces of which flow St directed downwards;
p = 1.84 for vertical surfaces.

In the case of a movement of air, if V< 5m/s, the convection coefficient is given by the relation:

$$hc = 5.2 + 3.94V \quad (3)$$

The system used shows the following characteristics:

- Volume of the interior vat, V = 73.5 liters
- Starting room temperature (16 h 00) = 33.5ºC
- Initial temperature of water = 72.5ºC
- Room temperature at the end of measurement (7 h 00) =32ºC
- Final temperature of the water of the vat = 61.25ºC

Evaluation of the total coefficient of exchange of the system, K_{moy}: We can write that the heat yielded by the water contained in the vat is equal to the calorific losses through the made up wall ambient water-sheet-air.

$$Q = MC\ (\theta_2 - \theta_1) = K_{moy} S\ (T_{if} - T_{se}) \quad (4)$$

$$K_{moy} = \frac{MC(\theta_2 - \theta_1)}{S(T_{si} - T_{se})} \quad (5)$$

In this case, the coefficient of average total exchange is worth:

$$K_{moy} = \frac{73.5 * 185 * (80 - 65)}{(3.84 * 17 * 3600 * (65 - 32)}$$

$= 0.595\ W/m^2.K$ ou $0.512\ Kcal/h/m^2.K$

4 series of measure made it possible to determine a median value of this coefficient either $0.692\ W/m^2$ or $Kcal/h/m^2.K$.
Calculation of λ_1 means

$$\frac{1}{K_{moy}} = \left(\frac{1}{H_e} + \frac{1}{H_i} + \frac{e_1}{\lambda_1} + \frac{2 * e_2}{\lambda_2} \right) \quad (6)$$

e_1 and l_1: thickness and conductivity of the insulation;
e_2 and l_2: thickness and conductivity of the coast;
H_e and H_i: coefficients of heat exchange of the surrounding air and interior.

Thus,

$$\frac{e_1}{\lambda_1} = \left(\frac{1}{0.692} - \frac{1}{9.56} - \frac{1}{11.72} - \frac{2 * 0.5 * 10^{-3}}{45.5} \right) = 1.255$$

From where characteristics of briquettes:
λ_{means} = 0.08 W/m.°K
σ = 180 kg/m^3
σ being density.

Tease kapok: The wool of kapok is obtained starting from the fruit of a very widespread tree in Africa Sub-saharienne especially in Burkina Faso. This tree is known under the name of cheesemonger or Ceiba Pentandra.
The vat built for the test consists of two vats with an annular space between them allowing the installation of wool of kapok.

Dimensions of these two elements are described in Table 2:

Each wall of vat is made up of outside towards the interior of:

Plywood:

- e_c =0.06 m,
- λ_c = 0.17 W/m°K,

Tease kapok:

- e_l =0.20 m,

Black plate:

- e_t = 1 mm
- λ_t = 52 W/m°K,

Test by interior heating: The interior vat contains 40kg warm water whose change of the temperature will make it possible to characterize insulator. Temperature sensors allowing to measure the following temperatures:

- T_{ex}: Outside temperature
- T_{eau}: Temperature of water
- T_{se}: Temperature of surface external of the vat
- T_{sec}: Temperature of the surface of laminated contact insulating/
- T_{sei}: Temperature of the surface of contact insulating/sheet

A similar assembly is made on a refrigerator whose dimensions are the following ones:

- Heat-transferring surface: 2.24 m^2
- Volume: 170 l
- Insulation: polyurethane 5.5 cm
- Test by interior cooling

The vat isolated with wool from kapok and the hull from the refrigerator isolated with polyurethane contain each one three bars of ice of 20 kg each one. Seconds of temperature make it possible to follow the fusion of the ice in the two enclosures. This test especially makes it possible to compare the time of conservation of the ice of the vat and the hull of the refrigerator (Combe *et al.*, 1992).

Table 2: Dimensions of external and interior vat

Dimensions	External vat	Interior vat
Length	1.33 m	0.91 m
Dispatcher	0.93 m	0.51 m
Height	0.78 m	0.45 m
Volume	0.964 m^3	0.209 m^3 is 209 liters
Material	Plywood of 6 mm	Black plate of 1 mm

Characterization of the isothermal vat and insulator: On the one hand,

$$MCp\,(T_{ie} - T_{fe}) = KS\,(T_{ie}-T_{ex}) \quad (7)$$

$$K = \frac{M.C_p(T_{ie} - T_{fe})}{3600.S.t(T_{pin} - T_{pex})} \quad (8)$$

With,

- M: Mass of water (kg)
- C_P: Specific heat of water (j/kg°C)
- Initial T_{ie}: Temperature of water with T it (°C)
- T_{fe}: Final temperature of water with T (°C)
- T_{pin}: Temperature of contact before the insulation (°C)
- T_{pex}: Temperature of contact after the insulation (°C)
- S: Heat-transferring surface (m^2)
- T: Duration of the test (h)
- K: Total coefficient of heat exchange (W m^2°K)

In addition, we can write that the total coefficient of exchange in terms of the thermal resistances crossed by the heat flow:

$$K = \frac{1}{R_e + R_i + \frac{e_1}{\lambda} + \frac{e_t}{\lambda_t} + \frac{e_c}{\lambda_c}} \quad (9)$$

With

- $R_e = \frac{1}{h_e}$: surface resistance of the external wall in m^2°C/w
- $R_i = \frac{1}{h_i}$: surface resistance of the interior wall in m^2°C/w.

- e_l: Thickness of insulator (m)
- e_c: Thickness of plywood (m)
- e_t: Thickness of sheet (m)
- λ: Thermal conductivity of insulator (W/m°C)
- λ_p: Thermal conductivity of plywood (W/m°C)
- λ_t: Thermal conductivity of sheet (W/m°C)

K and λ are given by using the Eq. (8) and (9) with the following assumptions:

- The phenomena of convection are negligible ($R_e + R_i = 0$)
- Resistances of plywood and sheet are null

Thus, $K = \frac{\lambda}{e_1}$ from where λ = K.e_l with e_l = 0.2 m

The average surface of exchange is given by the relation: S_m = (Si +Se)/2, with Si, the interior surface of the vat and Se external surface.

The characteristics of the types of bricks are shown in Table 3.

This method minimizes the real results of about 12% from where the correction which will be made while multiplying by the factor 1.12, one obtains the results of Table 4.

If one does not take account of the assumptions quoted above, the relation gives conductivity:

$$\lambda = \frac{K.e_1}{1 - K\left(R_i - R_e + \frac{e_c}{\lambda_c} + \frac{e_f}{\lambda_f}\right)} \quad (10)$$

λ = 0.043 W/m.º K is 0.037 kcal/h.mºK

With Ri + Re = 0.17 in accordance with the guide of the AICVF (Combe *et al.*, 1992).

The characteristics of wool of kapok are:

- λ= 0.043 W/m.º K
- Density = 35 kg/m^3

RESULTS AND DISCUSSION

The characteristics of these 2 materials and those of traditional insulators arise as Table 5 shows it:

These results show that the sawdust mixture + cement have a poor coefficient of conductibility. On the other hand the wool of kapok has a rather good thermal resistance and can even compete with certain traditional insulators such as the glass wool, cork and polystyrene.

The Table 6 gives equivalences between these 2 materials and insulators traditional.

Table 3: Average of thermal conductivity and total coefficient of heat exchange

	Vat	Refrigerator
$K_{average}$	0.1934 W/m^2.ºK	0.4546 W/m^2.ºK
$\lambda_{average}$ kapok	0.0387 W/m.ºK	
$\lambda_{average}$ polyurethane		0.0250 W/m.º K

Table 4: Average of thermal conductivity and total coefficient of heat exchange with correction

	Vat	Refrigerator
$K_{average}$	0.217 W/m^2.ºK	0.509 W/m^2.ºK
$\lambda_{average}$ kapok	0.0387 W/m.ºK	
$\lambda_{average}$ polyurethane		0.028 W/ºK

Table 5: characteristics of some materials

Material	W/m.ºK	Density kg/m^3	Source
Mix sawdust cement	0,08	183	Experimentation
Tease kapok	0,043	35	
Glass wool	0,036	100	
Liege in panels	0,048	170	New Pohlman
Polystyrene (foam)	0,031	25	(Verlag, 1983)
Polyurethane	0,028	35	

Table 6: Comparison between the characteristics and other insulators

Designation	Conductivity (W/m.ºK)	Thickness in cm of bricks of sawdust or wool of kapok necessary for 1 cm traditional insulator	
		Sawdust brick (cm)	Tease kapok (cm)
Polyurethane	0.028	2.86	1.54
Polystyrene	0.031	2.58	1.39
Glass wool	0.036	2.22	1.19
Liege	0.048	1.67	0.89

Taking account of its low thermal resistance, the sawdust can be used in the clothes industry of the static isothermal vats.

In addition, one can improve his effectiveness while bringing a fine layer of polystyrene, which would allow its use in the cold rooms.

Being wool of kapok, the Fig. 1 confirms its good behavior like insulator. Indeed, the vat isolated with wool from kapok makes it possible to preserve the ice during 6 days whereas it takes 7 days for the hull of the refrigerator.

However it necessary to improve the other properties of these materials so that they are in conformity with the standard NFX10-020.

The two studied materials have following qualities, as Table 7 shows it, required to an insulator which must be used in the cold rooms and the cold stores.

CONCLUSION

The wool of kapok and the sawdust can advantageously replace synthetic insulators both for their

Table 7: Qualities of studied materials

Quality	Tease kapok	Compressed sawdust sawdust
Low conductivity	Satisfying	Bad but can be improved
Insensitivity to absorption of water and steam	Yes, if it is conditioned under tight plastic	Yes, by using one vapor avoids
Compressive strength	Even behavior that the glass wool	Better behavior than glass wool
Absence of odor	No odor	No odor
Resistance to the moulds and vermin	Yes, if it is removed from its seeds	Yes, if it is mixed with cement in small proportion
Fire protection	Very flammable with the free air (category M5 according to standards P92-501 to 507)	Even behavior that cork (category M2 or M5 according to standards PG2-501 to 507)
Simplicity of implementation	Yes, but can be improved	Yes

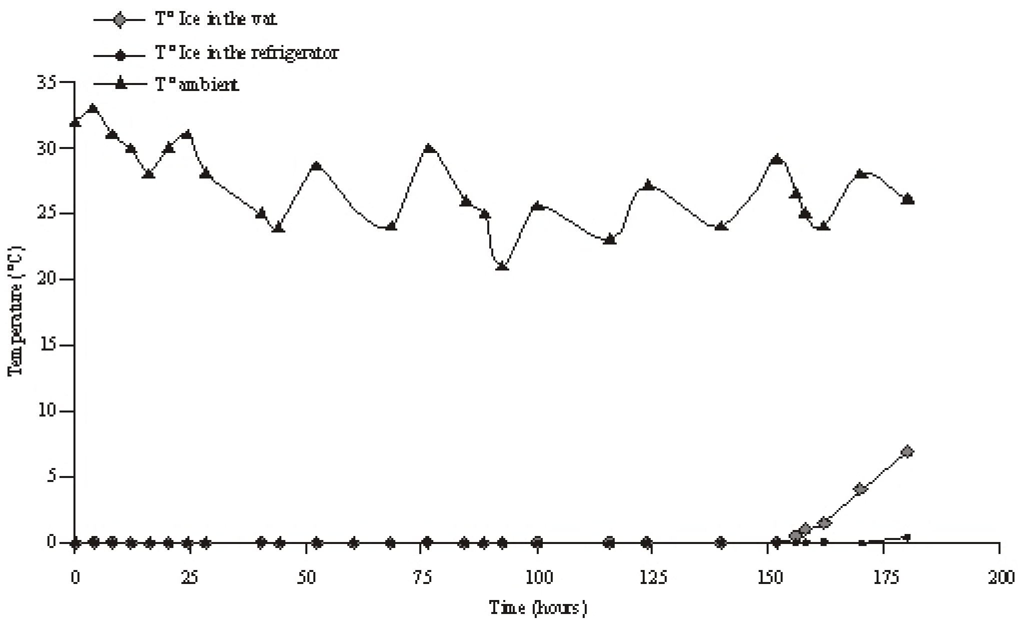

Fig. 1: Conservation of the ice in the vat and the hull of the refrigerator

Table 8: Costs of materials

Nature	Price (fcfa/m^3)	Prix (\$/m^3)
Tease kapok	15,000	30
Sawdust	21,870	43.74
Glass wool	50,000	100
Polystyrene	146,600	293.2

conductivity their cost. Their use will make it possible to develop often forsaken local materials or flaring.

By observing below the costs of two studied materials and traditional insulators, one notices that the price of the insulation occupies a big part in the realization of a cold room that is to say approximately 20% to 30% in the tropical countries.

This cost is worsened especially when one uses polystyrene or the polyurethane as insulator as Table 8 shows it.

REFERENCES

Combe, A.J. and B. Sesolis, 1992. Guide AICVF nº5: Design and calculation of the installations of ventilation and cold. Technical commission Association of the engineers into climatic, Collection des guides de l'AICVF, Pyc Livres.

Demir, I., 2008. Effect of organic residues addition on the technological properties of clay bricks. Waste Manage., 28(3): 622-627.

FAO, 1983. Conception and exploitation des entrepôts frigorifiques Bulletin des services agricoles de la FAO 19/2, Exploitation, Editeur FAO.

Goldstein, R.J., E.R.G. Eckert, W.E. Ibele, S.V. Patankar, T.W. Simon, T.H. Kuehn, P.J. Strykowski and J.V.R. Heberlein, 2005. Heat transfer - a review of 2002 literature, Int. J. Heat Mass Tran., 48(5): 819-927.

Murdocco, S., 1999. Le kapok, de nouvelles applications, l'Industrie Textile nº1312, pp: 23-25.

Ngohe-Ekam, P.S., P. Meukam, G. Menguy and P. Girard, 2006. Thermophysical characterisation of tropical wood used as building materials: With respect to the basal density. Constr. Build. Mater., 20(10): 929-938.

Skogsberg, K. and A. Lundberg, 2005. Wood chips as thermal insulation of snow. Cold Reg. Sci. Technol., 43(3): 207-218

Tye, R.P., 1969. Thermal Conductivity, Academic Press, London and New York, Vol: 1.

Verlag, C.F.M., 1983. New Pohlmann - Technical Handbook of the Cold. Translated by J.L. Cauchepin, pp: 603.