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The effect of alleviating the sand concrete by wood shavings on wall time lag and decrement factor

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Abstract. In the arid regions, such as the city of Laghouat in the south of Algeria, the major preoccupation is how to build a well insulated building. While taking into account the now days requirements of « sustainable construction ». In this context the sand concrete alleviated by wood shavings, in order to improve its thermo-physicals properties, is an environmental and sustainable approach, which can be a promising alternative in the domain of the building industry. However, the importance of this study is limited to the experimental research of a better thermo-physical performance and to the reduction of the shrinkage while ensuring good mechanical properties.
Finally, and in order to get closer results to the reality, a theoretical study by simulation is conducted in order to appreciate the thermo-physical behavior of the concrete studied for the construction of an exterior wall in a specific region. Two different parameters have been varied in this study: the thickness of the wall (with and without cavity) and the thermo-physical properties of the studied concrete. The results show that the thermo-physical properties of the concrete studied such: the thermal conductivity, the specific heat and the density have a great effect on the time lag ϕ and the decrement factor f. Grater time lag and lower decrement factor minimize the effects of the outside environment on the inside one. The value of time lag and decrement factor for 20cm wall made by sand concrete elevated by wood shavings were 6hours, 0.305, and for the same wall with 5cm cavity were, 8hours, 0.084. The results obtained are useful for designing low energy consumptions buildings.

1 Introduction

The first part of this work is an experimental study to determine the thermo-physical properties of four types of sand concrete elevated by wood shavings, sand concrete without shavings (SC), sand concrete with non treated wood shavings (SCWS), sand concretes with treated wood shavings by cement (SCTWS:C) and sand concretes with treated wood shavings by lime (SCTWS:CH), these treatment was made in order to reduce the wood shavings porosity. The second part is a theoretical study of the thermo-physical properties behavior of exterior walls in arid regions made by these four types of sand concrete in order to reduce the effect of exterior climate on the interior one, to improve the inside thermal comfort. A detailed computational study was made to determined the effect of the thickness and thermo-physical properties of wall on time lag and decrement factor, by using the software heat developed by H. Bencheikh**[1]**..

2 Thermo-Physical Properties Of Studied Concrete

2.1 Thermal conductivity

The useful thermal Conductivity of sand concrete of 28 days age was measured for the four type of sand concrete mentioned above. The weight of 60 (kg/m^3) of wood shavings in the mixture is the optimum value which gives the required material strength used for masonry walls. The chosen values that represent the average of three tests with different samples, are mentioned in table (1).

Table 1. Thermal conductivity

Wood shavings (kg/m^3)	**The useful thermal Conductivity after 28 days (w/m °K)**
SC	2,165 ±0,174
SCWS 60 kg/m^3	0,611 + 0,023
SCTWS:C 60 kg/m^3	1,366 ±0,091
SCTWS:CH 60 kg/m^3	1,490 + 0,069

2 .2 Specific heat

The specific heat was measured for the four type of sand concrete with the characteristics mentioned before, table 2 give the different value of the density and the specific heat of the mixture.

Table 2. Density and specific heat

Wood shavings (kg/m^3)	**Density at 28 days of age (kg/m^3)**	**Specific heat at 28 days of age J/kg °k**
SC	2534,56 ± 78,32	1289.64±30.71
SCWS 60 kg/m^3	1150,60±43.73	808.10±30.71
SCTWS:C 60 kg/m^3	1845.43±58.11	1145.95±36.08
SCTWS:CH 60 kg/m^3	1806.46±97.27	1102.74±59.38

The relation between the thermal conductivity **(λ)** and the specific heat **(ρ_c)** was expressed by the thermal diffusivity **(a)** which is given by the equation;

$$a = \lambda / \rho_c \quad m^2/s$$

Table 3 give the value of the thermal diffusivity for the four types of studied concrete composites, the value in the table shows that the thermal diffusivity can be reduced by 37% for the sand concrete with non treated shavings compared to the sand concrete without shavings.

Table 3. Specific heat and thermal diffusivity

Wood shavings content (kg/m^3)	**Specific heat at 28 days of age J/kg °k**	**Thermal diffusivity m^2/s .10**
SC without wood shavings	1289.64 ±39.85	854 ±57.51
SCWS 60	808.10 ± 30.71	531 ±0.00
SCTWS:C 60	1145.95 ±36.08	740 ±34.41
SCTWS:CH 60	1102.74 ±59.38	824 ±44.31

According to k. AIrim et al. **[2],** the thermal conductivity is a linear equation as function of the density (D), **λ**= f'(D). However, according to A. Benazzouk et al. **[3],** the thermal conductivity decreases with the reduction of density. For our study case and from figure 1, is a polynomial function.

$$Y = -13.44931 + 0.01495x + 3.56228E\text{-}6x^2$$

With a correlation coefficient r = 0.99962. From This relation, the effect of wood shavings on the density and the thermal conductivity was the same

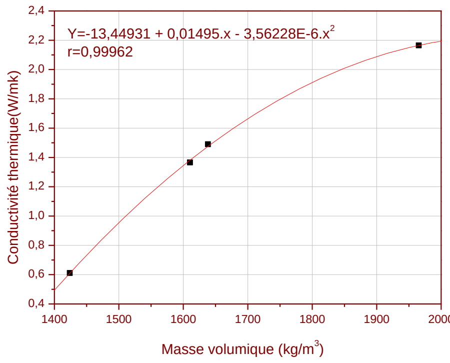

Fig. 1. The thermal conductivity as function of density

According to A. Bouguerra et al. **[4],** the equation λ= f'(P), is a linear equation where (P) is the porosity of the mixture, for our study case and from figure 2, the relationship follows a polynomial law.

$$Y = 324.01298\ x^2 + 8.60504 - 103.11575x.$$

With a correlation coefficient r =0.99907

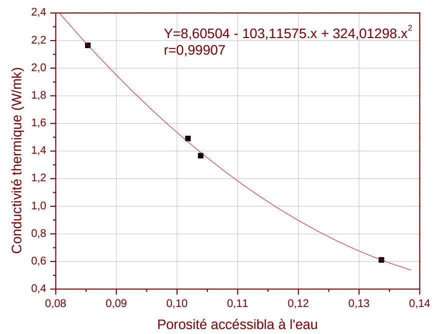

Fig. 2. The thermal conductivity as function of porosity

3 Application In Exterior Walls With Different

Thermal comfort in buildings is directly related to heat transfer through exterior walls from outside environment to the inside, to improve the inside comfort in buildings by using walls made by the studied sand concrete . A theoretical study by simulation is conducted in order to appreciate the thermo-physical behavior of the concrete studied for the construction of an exterior wall in arid regions. Two different parameters have been varied in this study: the thickness of the wall, with and without cavity and the thermo-physical properties of the studied concrete.

C. Time lag ϕ, decrement factor f and sol–air temperature $T_{sa}(t)$

Time lag and decrement factor are very important characteristics to determine the heat storage capabilities of any material. The time it takes for the heat wave to propagate from the outer surface to the inner surface is named as ''time lag'' and the decreasing ratio of its amplitude during this process is named as ''decrement factor''. The schematics of time lag and decrement factor are shown in Figure. 3. In this study, the time lag and decrement factor are computed as follows. The time lag is defined as **[5, 6]**

$$\phi \begin{cases} t_{T_0 max} > t_{T_e max} \rightarrow t_{T_0 max} - t_{T_e max} \\ t_{T_0 max} < t_{T_e max} \rightarrow t_{T_0 max} - t_{T_e max} + P \\ t_{T_0 max} = t_{T_e max} \rightarrow P \end{cases} \qquad (1)$$

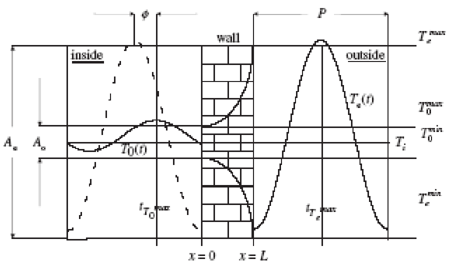

Fig. 3. The schematic representation of time lag **ϕ** and decrement fctor ***f***

where **t** (Tse_{max}), **t** (Tsi_{max}) and (h) represent the time in hours when inside and outside surface temperatures are at their maximums, respectively, and P (24 h) is the period of the wave. The decrement factor is defined as, **[5, 6]**

$$f = \frac{A_o}{A_e} = \frac{T_o^{max} - T_o^{min}}{T_e^{max} - T_e^{min}}, \qquad (2)$$

Where A_o and A_e are the amplitudes of the wave in the inner and outer surfaces of the wall, respectively. The sol–air temperature, Tsa, includes the effects of the solar radiation combined with outside air temperature and changes periodically. This temperature is assumed to show sinusoidal variations during a 24-h period. Since time lag and decrement factor are dependent on only wall material, not the climatological data [12], a very general equation for sol–air temperature is taken as follows **[7, 8]**

$$T_{sa}(t) = \frac{|T_{max} - T_{min}|}{2} \sin\left(\frac{2\pi t}{P} - \frac{\pi}{2}\right) + \frac{|T_{max} - T_{min}|}{2} + T_{min}.$$

In this study, the wall under investigation is assumed to be only in the x direction and time dependent. The problem geometry is shown in Figure. 3. The one-dimensional, transient heat conduction equation for this problem is as follows:

$$k\frac{\partial^2 T}{\partial x^2} = \rho c_P \frac{\partial T}{\partial t},$$

Where k is the thermal conductivity, r is the density and c_p is the specific heat of the wall material. To solve this problem, two boundary conditions and one initial condition are needed. On both sides of wall, convection boundary conditions are present. At the inner surface and the outer surface of the wall, the boundary conditions can be written as follow; **[7, 8, 9]**

$$k\left(\frac{\partial T}{\partial x}\right)_{x=0} = h_i[T_{x=0}(t) - T_i],$$

$$k\left(\frac{\partial T}{\partial x}\right)_{x=L} = h_o[T_{sa}(t) - T_{x=L}(t)].$$

Here, h_i is the wall inner surface heat transfer coefficient, h_o the wall outer surface heat transfer coefficient, $T_{x=0}$ is the wall inner surface temperature, $T_{x=L}$ is the wall outer surface temperature, T_i is the room temperature and $T_{sa}(t)$ is the ''sol–air temperature''.

By using the software heat developed by H. Bencheikh**[1].** A computational study was made to determined the time in hours when inside and outside surface temperatures are at their maximums, the room temperature T_i and the sol–air temperature $T_{sa}(t)$ to calculate the time lag and decrement factor.

4 Results and Discussions

This investigation is carried out for four masonry walls made with, sand concrete without shavings (SC), sand concrete with non treated wood shavings (SCWS), sand concretes with treated wood shavings by cement (SCTWS:C) and sand concretes with treated wood shavings by lime (SCTWS:CH) respectively. The walls thickness were variable; 10, 15, 20 cm thick one layer and 25 cm thick with two layer (10 cm plus 5 cm cavity plus 10 cm). The thermophysical properties **(λ)** and $\boldsymbol{p_c}$ of the materials are given in Table (1, 2). By using the previous mentioned software, the measured solar radiations and outside air temperature around the day hours, we can obtained the wall inside and outside surface temperature, the room inside air temperature and the time in hours when inside and outside surface temperatures are at their maximums. The simulation was done for a summer day on the 4th of July 2006 for a wall assumed situated in Laghouat southern of Algeria. Figures (4, 5, 6, 7) gives the wall inside and outside surface temperature for different walls type and thickness. The time lag ϕ and the decrement factor *f* values can be obtained using equation (1) and (2), tables (4) gives the time lag and decrement factor for different walls type and thickness. As the wall thickness increases, decrement factor decreases and the time lag increases. The effect of wall thickness and the thermophysical properties **(λ)** and $\boldsymbol{p_c}$ of wall's materials on the decrement factor and time lag can be seen from tables (4), for one layer 20 cm wall made with (SCWS) the time lag 6 hours and the decrement factor 0.351, for two layers wall made with (SWTWS) the time lag 8 hours and the decrement factor 0.072, the use of cavity in the wall increases the time lag by 2 hours and reduces the decrement for by around 84%.

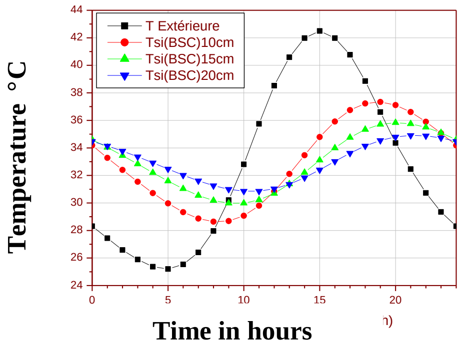

Fig. 4. Outside inside surface temperature for wall made by (SC).

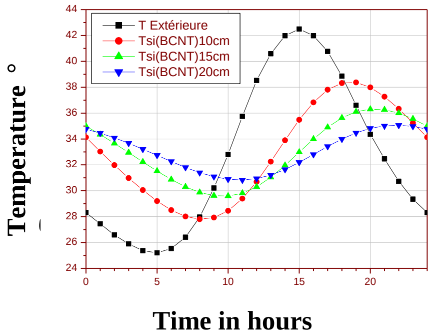

Fig. 5. Outside inside surface temperature for wall made by (SCWS).

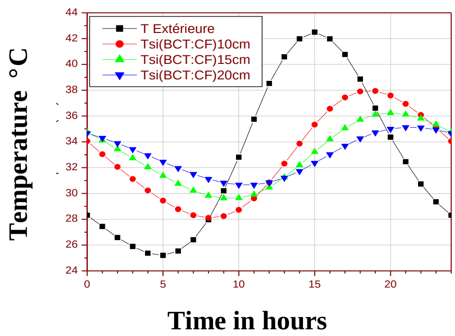

Fig. 6. Outside inside surface temperature for wall made by (SCTWS).

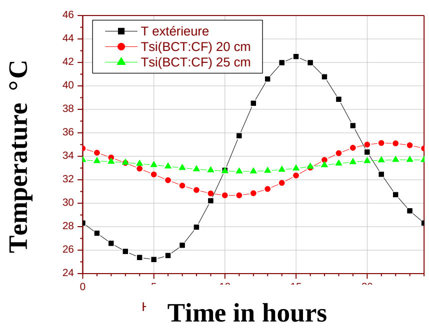

Fig. 7. Outside inside surface temperature for wall 20cm and 25c with cavity made by (SCTWS).

Table 4. Values of time lag for deferent wall thickness and materials

Woods havings content (kg/m^3)	**10 cm one layer**	**15 cm one layer**	**20 cm one layer wall**	**25 cm two layers**
	ϕ hours	**ϕ** hours	**ϕ** hours	**ϕ** hours
SC	2	3	5	7
SCWS	3	4	6	8
SCTWS	2	4	5	8

Table 5. Values of decrement factor for deferent wall thickness and materials

Woods havings content (kg/m^3)	**10 cm one layer**	**15 cm one layer**	**20 cm one layer**	**25 cm two layers**
	f	*f*	*f*	*f*
SC	0.888	0.720	0.530	0.058
SCWS	0.805	0.556	0.351	0.084
SCTWS	0.873	0.679	0.471	0.072

5 Conclusions

In this study, to determine the effect of wall thickness and the thermophysical properties (λ) and p_c of wall's materials on the decrement factor and time lag;

1. An experimental mechanical test on the studied material was made to determine the optimum wood shavings contents which give the required material strength. It was found that the weight of 60 kg/m^3 of wood shavings in the mixture gives strength of materials can be used in masonry wall.

2. An experimental study was made to investigate the effect of wood shaving on the thermophysical properties of the material studied and determine the materials conductivity, density and specific heat. It was found that the wood shavings decreases the thermal conductivity from 2.16 to 0.611 w/mk, the density from 2534 to 1150kg/m3, the specific heat from 1286 to 808 J/kg °k and the thermal diffusivity from 854 to 531 m ²/s.10.

3. A detailed computational study was made by using the previous mentioned software to investigate the effect of the thermophysical properties on the time lag and decrement factor. The reductions in the thermophysical properties had a great effect on the time lag and decrement factors, the time lag increase from 2 hours to 8 hours and the decrement factor decrease from 0.888 to 0.072. The results of this study are useful for designing more effective passive solar building in arid zones such as the south of Algeria which reduce the energy consumption.

As seen in table (4, 5), that 25 cm wall with 5cm cavity made with sand concrete without wood shavings gives the lower value of the decrement factor and that due to , simulation was done for a number of continues days and the space was considered closed and no ventilations was allowed. So the space inside temperature presents a low fluctuation. If the night natural ventilation was associated the inside air temperature can be lower by 3 to 4℃ **[1]** which will give a smaller decrement factor.

References

[1]. H. bencheikh & A Bouchair "passive cooling by evopa-reflective roof for hot dry climate", Renewable Energy 2003, 29, 1877-1886.
[2]. A. Benazzouk, & Al. "Thermal conductivity of composites containing rubber waste: Experimental study and modeling", Constrution and Building Materials 2007, 21, 1803-1808.
[3]. K. Al Rim & Al. "influence of proportion of wood on thermal and mechanical performance of clay cement-wood" Cement & concrete composites. 1999, 21, 269-276.
[4]. A. Bougerra & Al. "Etude de la porosité des bétons de bois à matrice argileuse: relation avec les propriétés mécaniques et thermique " 1996, VC3.DOC, 18-11- 96.
[5]. H. Asan & Y. S. Sancaktar "Effects of wall's thermo-physical properties on time lag and decrement factor" Energy and Buildings 1198, 28, 159-166.
[6]. H. Asan "Investigation of wall's optimum insulation position from maximum time lag and decrement factor" 2000, 32, 197-203.
[7]. H. Asan "Numerical computation of time lag and decrement factors for deferent building materials" Building and Environment 2006, 41, 915-620.
[8]. K. j. Kontoleon & D. K. Bikas "The effect of south wall's outdoor absorption coefficient on time lag, decrement factor rand temperature variations", Energy and Buildings 2007, 39, 111-1018.
[9] K. j. Kontoleon & D. K. Bikas " The influence of wall orientation and exterior surface solar absorbtivity on time lag and decrement factor in Greek region" Renewable Energy 2008, 33, 1652-1664.