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# Energy efficiency and thermal properties of the composite material clay-straw

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# Objectives

## The Objectives

► To improve the energy efficiency of unfired clay.

► To develop the thermal properties of unfired clay as an insulation material by mixing it with straw.

► An experimental measurement of thermal properties of unfired clay mixed with straw was done.

► A building was simulated using the unfired clay–straw envelope with the climate data of south Morocco region,

## Samples preparation

- The used unfired clay was extracted from Ouarzazate region located in the south of Morocco.
- The fibers were taken from wheat straw.

The chemical characteristics and composition are presented in table .

**chemical composition of straw fibers**

| Cellulose | Hemicellulose | Lignine | proteine | Cinder |
|---|---|---|---|---|
| 40,8 % | 31,7 % | 10 % | 2,4 % | 5,9 % |

- The samples were prepared by mixing clay with straw using an aggregate water ratio (W/g) of 0.23. The mass fractions $\phi_m$ of 2%, 3%, 4% and 5% relative to the initial mass of unfired clay are used


View of composite samples with different percentages of straw

**Density of different samples composites used**

| Samples | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| Density (kg/m³) | 1985,18 | 1827,58 | 1760,85 | 1619,55 | 1544,98 |
| $\phi_m$ (%) | 0 | 2 | 3 | 4 | 5 |

## Experimental methods

- *Thermal conductivity (λ):* The measurement of thermal conductivity was based on the use of the hot plate method in the steady state regime

- *Thermal diffusivity (a):* The thermal diffusivity of the studied samples was determined by the flash method.

- Knowing of the thermal diffusivity, the thermal conductivity and the density of each sample, we can easily deduce the specific heat of the sample according to the following formula: **$Cp=\lambda/(\rho \times a)$**

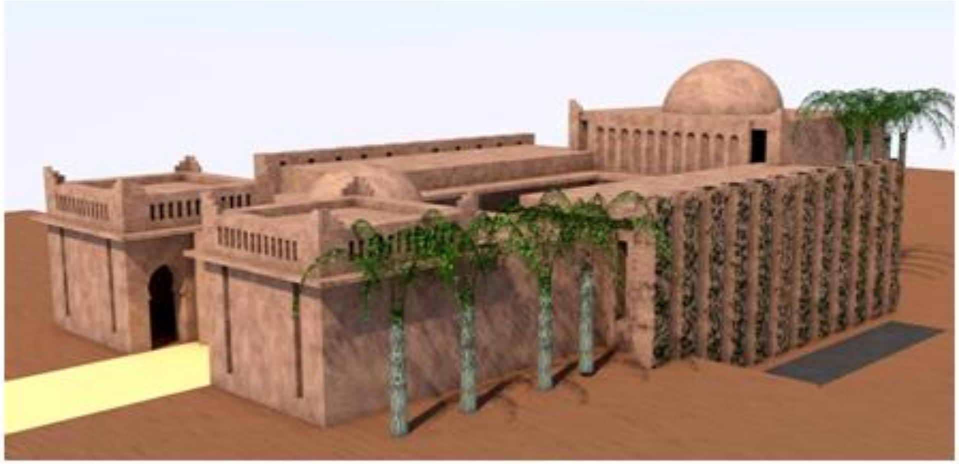
## Results of experimental methods

| Sample | $\phi_m$(%) | λ (W/m.k) | a ×10 $^{-7}$(m²/s) | Cp (J/kg.K) |
|---|---|---|---|---|
| E1 | 0 | 0.504 | 3.728 | 678.41 |
| E2 | 2 | 0.405 | 3.508 | 631.11 |
| E3 | 3 | 0.358 | 3.306 | 614.97 |
| E4 | 4 | 0.306 | 3.112 | 607.13 |
| E5 | 5 | 0.263 | 2.858 | 595.62 |

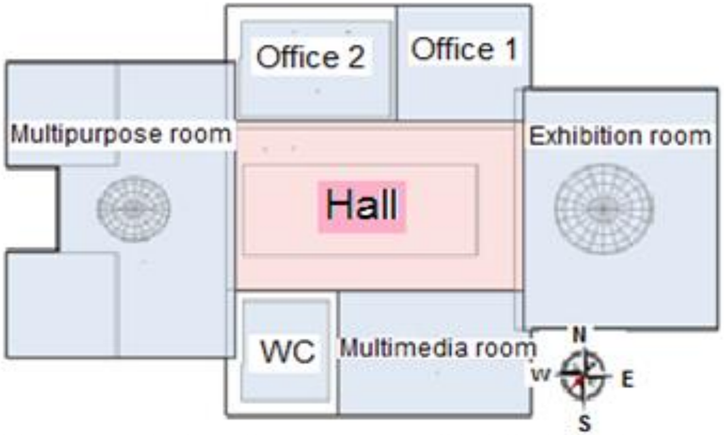
- The thermal properties results reported in Table present the calculated average value of the three experimental tests.
- The maximum measurement error didn't exceed 1.5%. .
- The addition of straw fibers has an important effect on the reduction of thermal diffusivity.
- The result demonstrated the use of fibres to minimize thermal losses during the seasons due to its low conductivity, which is necessary in thermal insulation in building construction.

# The studied building

- In order to improve the energy efficiency of the used composite material, a pedagogic traditional building is simulated using Design builder software.
- The building is situated in Ouarzazate city in the south of Morocco, oriented to south-west and divided into 7 thermal zones as is shown in figure.
- The ventilation rate including infiltration is about 36 $m^3$/h/pers with density occupancy of 0.14 pers/$m^3$.

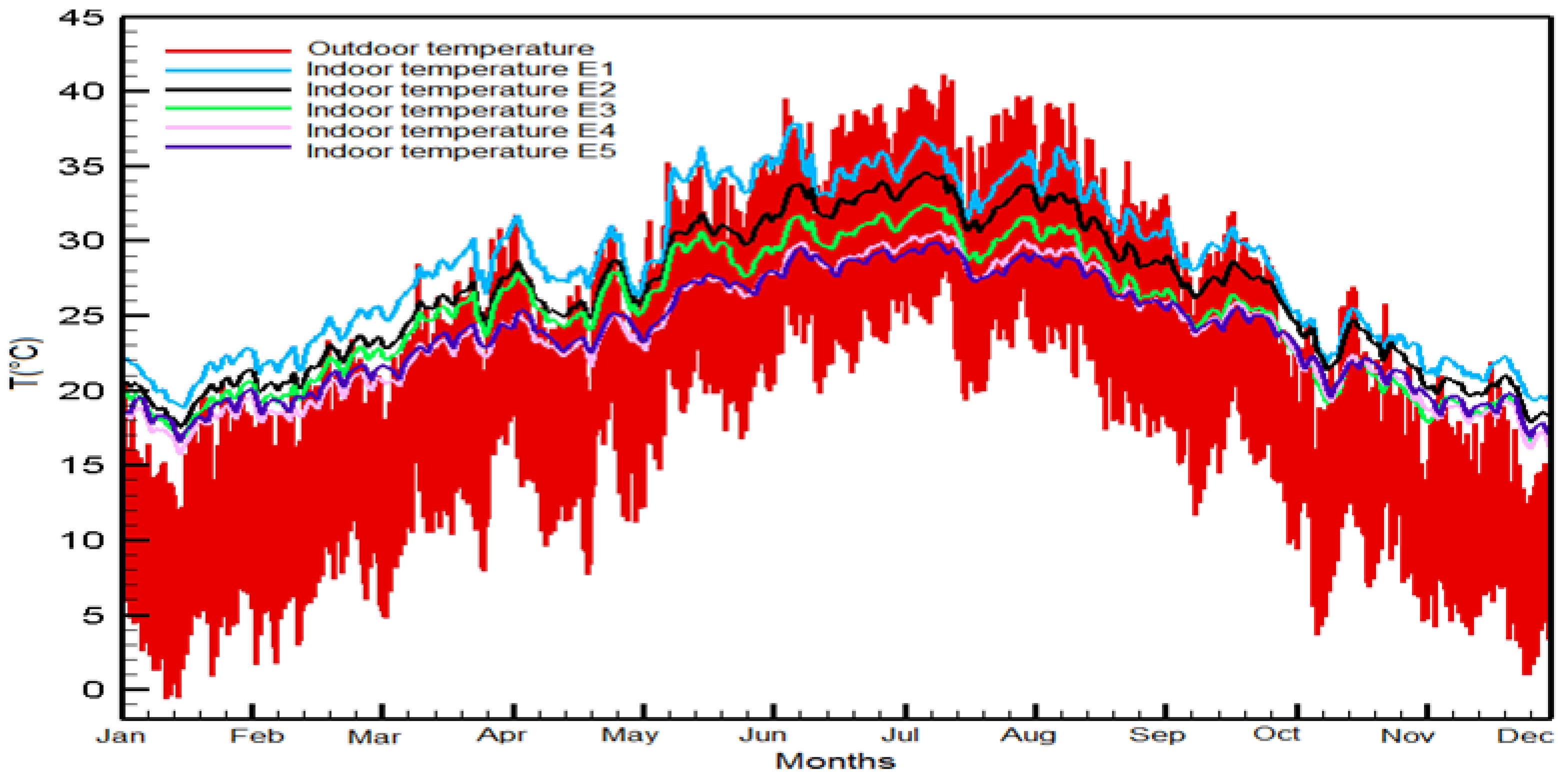


The simulated building model




The typical plan of the pedagogic building S=383.4m²

# Results of simulation




The hourly variation of the temperature inside and outside the building during the year

► The Figure presents the hourly variation of the temperature inside the building according to exterior environment during the year.

► $R_{E1}$= 1.15 m²K/W, $R_{E2}$= 1.39 m²K/W, $R_{E3}$= 1.56 m²K/W, $R_{E4}$= 1.78 m²K/W $R_{E5}$= 2.093m²K/W for the same wall thickness (e=50cm),

# Results of simulation

▶ By comparing the five types of the studied building envelopes with the R-values varied from $R_{E1}$ to $R_{E5}$. The addition of different percentages of straw induces:

- The decreasing of the thermal transfers through building walls.
- The reduction of indoor temperature fluctuations.
- The analysis of temperature variations improve the thermal performance and comfort conditions,
- The clay walls E1 (pure clay) can better ensure a satisfactory comfort during winter due to the capacity of the clay walls to store solar energy.
- During the hottest period, the maximum of outdoor temperature exceeds 42°C, although the maximum indoor temperatures achieved 35°C for the wall envelope E1 and reduced to 28°C for the wall E5.
- The clay-straw composite exhibits good thermal resistance in summer and allows for optimum comfort for the inhabitants.

# Conclusion

- The present study was devoted to obtain the thermal comfort in the habitat through the judicious use of clay-based building materials resisting to the hard climatic conditions.

- The composite material of clay-straw has valuable thermal properties for the storage of heat and the regulation of temperature changes between day and night during the winter period and prove its ability of resisting to the Warm and dry climate without any use of cooling or heating system.

# Thank you

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