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Data Article

Dataset on the hygrothermal performance of a date palm concrete wall



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ABSTRACT

The present data article is concerned with the hygrothermal performance at the wall scale of a new bio-based building material including date palm fibres. A specific test setup allowed to measure temperature and relative humidity (RH) profiles at three different depths of the bio-based wall subjected to outdoor boundary conditions. Besides, a partial differential equations resolution software was then used to solve two mathematical models (*i.e.*, Kunzel and Mendes models) describing heat and moisture transfer in porous building materials. Both experimental/simulated temperature and RH profiles are provided with this dataset article. The proposed experimental setup can be used for studying the hygrothermal performance of different kinds of bio-based building materials at wall scale, while experimental/numerical data can serve as reference values for the validation of mathematical models intended to describe heat and mass transfer.

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Specifications Table

| | |
|--------------------------------|---|
| Subject | Renewable Energy, Sustainability and the Environment |
| Specific subject area | Bio-based building materials |
| Type of data | Figures, graphs and tables |
| How data were acquired | Temperature and relative humidity measurements were performed using hygrothermal sensors located at different depths of the wall, while this latter was subjected to dynamic outdoor conditions in a climatic chamber. Numerical data were obtained using COMSOL Multiphysics PDE modes, where the mathematical models were implemented and solved over the wall thickness. |
| Data format | Schemes Raw and processed data Csv files |
| Parameters for data collection | Several scenarios (dynamic boundary conditions) were applied to the outdoor side of the wall using a climatic chamber. Outdoor temperature was varied between 18°C and 40°C and relative humidity between 50 % and 75 %. The measured data were implemented as outdoor boundary conditions in COMSOL Multiphysics. |
| Description of data collection | Hygrothermal sensors were inserted inside the wall at three different depths (3 cm, 7.5 cm and 12.5 from the left side). These sensors were connected to computer with the help of an acquisition chain. Numerical temperature and relative humidity profiles at the same depths were exported from COMSOL Multiphysics in text files after resolution. |
| Data source location | Institution: Paris-Est Créteil University City/Town/Region: Créteil Country: France |
| Data accessibility | Data are presented in this article |
| Related research article | Alioua, T., Agoudjil, B., Chennouf, N., Boudenne, A., & Benzarti, K., Investigation on heat and moisture transfer in bio-based building wall with consideration of the hysteresis effect, Building and Environment 163 (2019) 10633. DOI: https://doi.org/10.1016/j.buildenv.2019.106333 |

Value of the Data

- These data are useful because of the wide use of bio-based building materials related to their interesting thermal and hydric properties.
- This dataset consists of an experimental data and numerical simulations that can be very useful to study the hygrothermal performance of bio-based building materials at wall scale
- Up to now, there is no specific standard method dedicated to the evaluation of hygrothermal performance of bio-based building materials at the wall scale. The experimental setup presented in this data article could be adopted for this purpose, or serve as basis for further development. In addition, experimental data and numerical results provided with this article can be used to validate mathematical models and simulation tools intended to predict the hygrothermal behaviour of buildings materials.

1. Data

This data article represents the experimental setup used to study heat and moisture transfer in date palm fibres concrete wall. Date Palm Concrete (DPC) is a new bio-based building material consisting of sand, cement, water and date palm fibres. The constructed wall was insulated from lateral surfaces and instrumented with hygrothermal sensors that are connected to computer for data acquisition. The wall was then placed in a climatic chamber and subjected to dynamic conditions of temperature and relative humidity.

Experimental data collected during the tests at different depths of the wall (3, 7.5 and 12.5 cm from the outer side), as well as boundary conditions (both in the outdoor and indoor environments), are presented in four graphs and four excel files as follows:

- Fig. 1a represents temperature profiles versus time after applying scenario 1 conditions. [Multimedia component 1 \(xls file\)](#) represents dataset corresponding to temperature profiles presented on Fig. 1a.

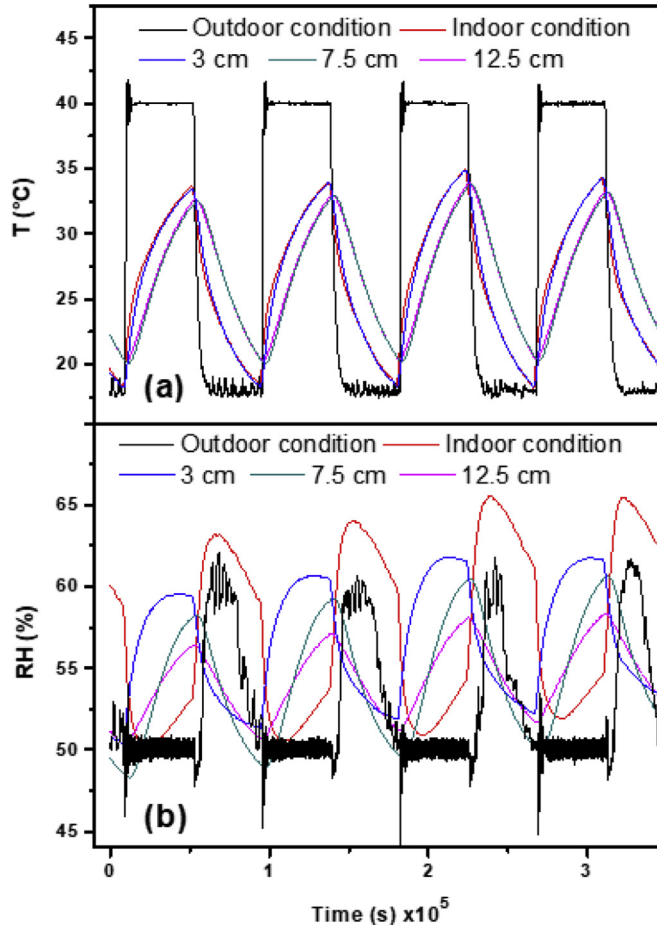


Fig. 1. Temperature (a) and relative humidity (b) profiles versus time inside the DPC wall, together with outdoor/indoor boundary conditions in the case of scenario 1.

- [Fig. 1b](#) represents relative humidity profiles versus obtained after applying scenario 1 conditions. [Multimedia component 2 \(xls file\)](#) represents dataset corresponding to relative humidity profiles presented on [Fig. 1b](#).
- [Fig. 2a](#) represents temperature profiles versus time obtained after applying scenario 2 conditions. [Multimedia component 3 \(xls file\)](#) represents dataset corresponding to temperature profiles presented on [Fig. 2a](#).
- [Fig. 2b](#) represents relative humidity versus time profiles obtained after applying scenario 2 conditions. [Multimedia component 4 \(xls file\)](#) represents dataset corresponding to relative humidity profiles presented on [Fig. 2b](#).
- [Table 1](#) represents the simulated variations of temperature over time at a depth of 3 cm inside the wall, in the case of scenario 1. [Multimedia component 5 \(xls file\)](#) represents dataset corresponding to simulated temperature profiles at depths of 3, 7.5 and 12 cm inside the wall in the case of scenario 1.

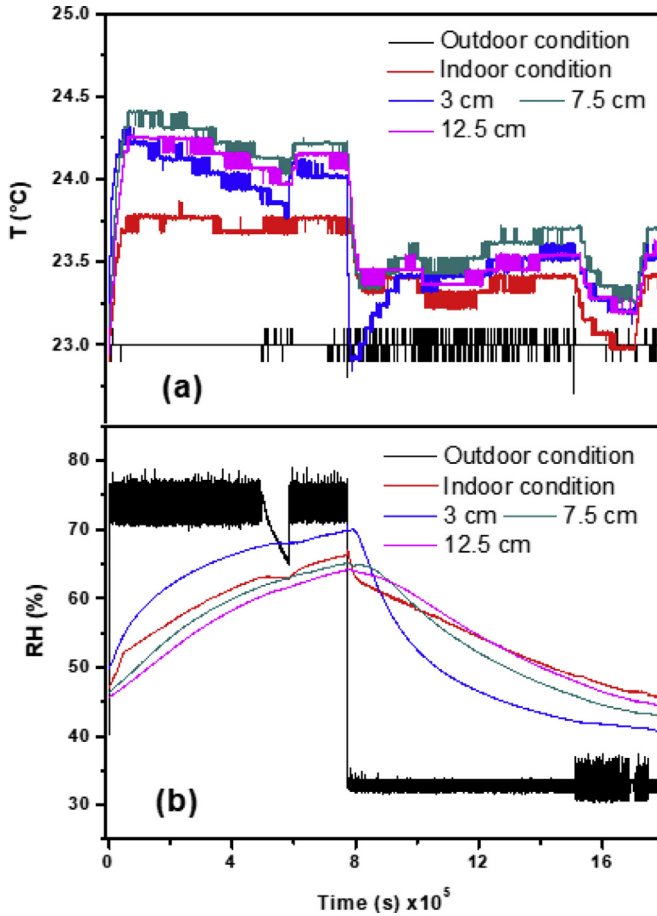


Fig. 2. Temperature (a) and relative humidity (b) profiles versus time inside the DPC wall, together with outdoor/indoor boundary conditions in the case of scenario 2.

- [Table 2](#) represents the simulated variations of relative humidity over time at the depth of 3 cm inside the wall, in the case of scenario 2. [Multimedia component 6 \(xls file\)](#) represents dataset corresponding to simulated humidity profiles at depths of 3, 7.5 and 12 cm inside the wall in the case of scenario 2.

In addition to this experimental data collection, two mathematical models (namely Kunzel and Mendes models) were implemented in COMSOL Multiphysics and resolved, in order to provide theoretical profiles of temperature and relative humidity inside the bio-based wall, while this latter is subjected to boundary conditions of scenarios 1 and 2. More details are given in section 2.

Numerical data provided by the two models at a depth of 3 cm inside the wall are reported in [Tables 1 and 2](#), for boundary conditions of scenario 1 and scenario 2 respectively.

Table 1

Simulated variations of temperature over time at a depth of 3 cm inside the wall, in the case of scenario 1.

| Time (s) | Temperature (°C) | |
|----------|------------------|--------------|
| | Kunzel model | Mendes model |
| 0 | 49.64 | 49.70 |
| 57600 | 52.99 | 51.45 |
| 115200 | 56.69 | 54.09 |
| 172800 | 59.05 | 56.03 |
| 230400 | 60.68 | 57.49 |
| 288000 | 61.91 | 58.63 |
| 345600 | 62.91 | 59.57 |
| 403200 | 63.77 | 60.36 |
| 460800 | 64.51 | 61.05 |
| 518400 | 65.13 | 61.64 |
| 576000 | 65.28 | 62.12 |
| 633600 | 65.05 | 62.26 |
| 691200 | 65.61 | 62.61 |
| 748800 | 66.19 | 63.09 |
| 806400 | 66.30 | 63.43 |
| 864000 | 61.50 | 60.40 |
| 921600 | 56.59 | 55.99 |
| 979200 | 53.05 | 52.38 |
| 1036800 | 50.54 | 49.93 |
| 1094400 | 48.71 | 48.16 |
| 1152000 | 47.33 | 46.70 |
| 1209600 | 46.23 | 45.55 |
| 1267200 | 45.33 | 44.74 |
| 1324800 | 44.56 | 44.09 |
| 1382400 | 43.87 | 43.53 |
| 1440000 | 43.26 | 42.97 |
| 1497600 | 42.71 | 42.39 |
| 1555200 | 42.25 | 41.79 |
| 1612800 | 41.84 | 41.16 |
| 1670400 | 41.41 | 40.81 |
| 1728000 | 41.02 | 40.48 |
| 1785600 | 40.48 | 40.12 |
| 1803600 | 40.31 | 40.00 |

2. Experimental design, materials, and methods

2.1. Experimental setup

Methods for evaluating the hygrothermal properties of building materials; defined in existing standards, provide information on their behaviour and performance under equilibrium conditions. However, in reality the hygrothermal boundary conditions are dynamic. For this reason, it is necessary to investigate the hygrothermal behaviour of DPC at the wall scale.

A DPC wall of dimension $0.5 \text{ m} \times 0.4 \text{ m} \times 0.15 \text{ m}$ (length \times height \times thickness) was fabricated, as shown in Fig. 3. This bio-concrete formulation consisted of 62 wt% cement (CEM II/B-LL32.5R CE NF), 23 wt% sand (particle size 0–4 mm) and 15 wt % date palm fibres (mean diameter = 3 mm). A water to cement ratio W/C of 0.68 was chosen in accordance with previous works [1–4].

The potential of the DPC wall for the mitigation of humidity and temperature variations is evaluated according to works of Chennouf et al., Latif et al., Rahim et al. and Ferroukhi et al. [5–8]. The experimental device consists of a climatic chamber in order to simulate the outdoor climate conditions and another cell to simulate the indoor conditions, as shown in Fig. 4.

The cell simulating the indoor climate allows to evaluate the performance of DPC wall through the response of this wall to cyclic and static variations of temperature and relative humidity generated by the climatic chamber “Mettmert HPP 750”. This latter can operate in a temperature range from 0°C to

Table 2
Simulated variations of relative humidity at a depth of 3 cm inside the wall, in the case of scenario 2.

| Time (s) | Relative humidity (%) | |
|----------|-----------------------|--------------|
| | Kunzel model | Mendes model |
| 0 | 19.36 | 19.89 |
| 11820 | 20.89 | 21.90 |
| 23640 | 29.97 | 30.33 |
| 35460 | 32.94 | 33.11 |
| 47280 | 34.82 | 34.86 |
| 59100 | 30.59 | 30.61 |
| 70920 | 24.91 | 24.87 |
| 82740 | 22.50 | 22.60 |
| 94560 | 21.07 | 21.15 |
| 106380 | 29.98 | 29.82 |
| 118200 | 33.08 | 32.99 |
| 130020 | 34.88 | 34.73 |
| 141840 | 34.49 | 34.24 |
| 153660 | 26.26 | 26.03 |
| 165480 | 23.32 | 23.32 |
| 177300 | 21.55 | 21.60 |
| 189120 | 28.02 | 27.83 |
| 200940 | 32.39 | 32.43 |
| 212760 | 34.49 | 34.50 |
| 224580 | 35.95 | 35.88 |
| 236400 | 28.02 | 28.05 |
| 248220 | 24.22 | 24.15 |
| 260040 | 22.20 | 22.26 |
| 271860 | 24.38 | 24.52 |
| 283680 | 31.53 | 31.40 |
| 295500 | 33.92 | 33.78 |
| 307320 | 35.46 | 35.34 |
| 319140 | 30.33 | 30.36 |
| 330960 | 24.95 | 24.79 |
| 342780 | 22.64 | 22.59 |
| 354600 | 21.18 | 21.20 |
| 354960 | 21.14 | 21.16 |

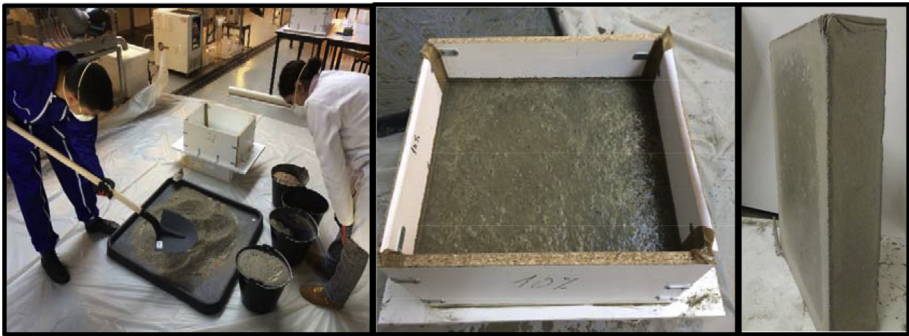


Fig. 3. Preparation of the DPC wall.

+70°C and humidity range from 10% to 90 %RH. The second cell (mini chamber) was highly hygro-thermally insulated on the 5 sides of the wall, and only one side is in contact with the climatic chamber conditions, as shown in Fig. 4. Extruded polystyrene panels wrapped with glass wool were used for ensuring thermal insulation.

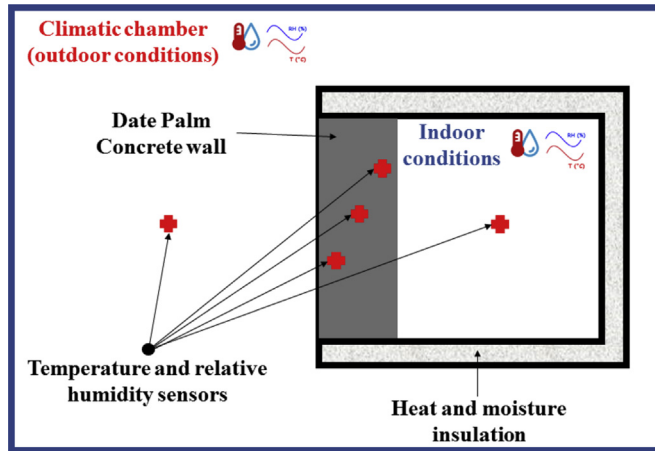


Fig. 4. Overall experimental setup.

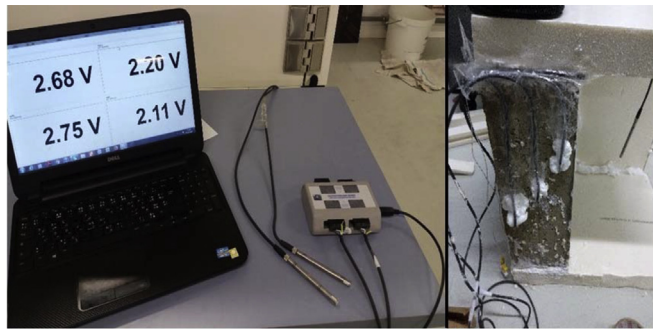


Fig. 5. Humidity/temperature sensors after installation in the wall.

Monitoring of temperature and relative humidity was performed in each room (climatic room and the mini chamber) and at different depths of the wall (3 cm, 7.5 cm and 12.5 cm) with DKRF400 humidity/temperature sensors from Driesen + Kern, Germany (measurement range of RH: 0–100% with an accuracy of $\pm 1.8\%$, and measurement range of T: -40°C to $+45^{\circ}\text{C}$ with an accuracy of $\pm 0.5^{\circ}\text{C}$). Sensors have a diameter of 8 mm and a length of 100 mm and can be easily inserted into the wall at different depth levels (see Fig. 5).

Fig. 6 summarizes the two scenarios that were programmed to apply dynamic boundary conditions to the outer side of the wall, based on previous works [6,9–11]. Temperature and RH data collected at the different depths of the wall, as well as indoor and outdoor conditions are presented in Figs. 1 and 2, respectively for scenarios 1 and 2.

2.2. Numerical simulations

In order to simulate heat and moisture transfer in the studied building wall, Mendes and Kunzel mathematical models [8] have been implemented in COMSOL Multiphysics and resolved to obtain temperature and relative humidity profiles at different depths of the bio-based wall. The implementation was done under the PDE Modes (Partial Differential Equations), coefficient form, where the

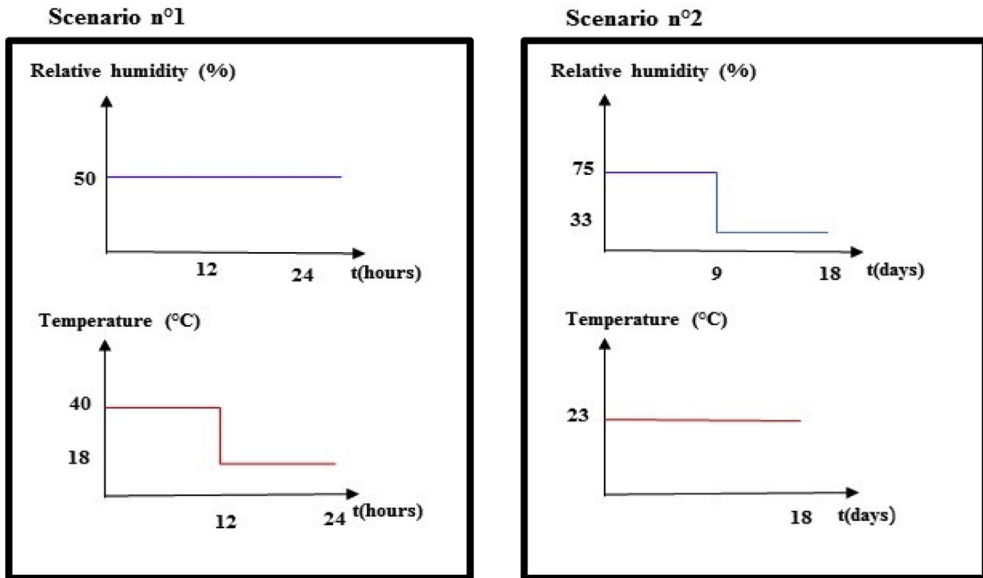


Fig. 6. Boundary conditions applied to the outer side of the DPC wall.

heat and mass transfer equations coefficients were introduced in the PDE coefficients defined in COMSOL. Afterwards, the date palm concrete wall configuration studied in the lab was simulated in COMSOL using the same dimensions and boundary conditions (Fig. 6). Since the transfer is considered one dimensional through the thickness of the wall, mesh was generated following transfer direction where the wall was discretised into 100 layers [12]. Numerical results at 3 cm depth corresponding to scenarios 1 and 2 are presented respectively in Tables 1 and 2.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.dib.2019.104590>.

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