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Temperature and humidity transient simulation and validation in a measured house without a HVAC system

Ana Martínez-Ibernón [a], Carolina Aparicio-Fernández [b], Rafael Royo-Pastor [c], José-Luis Vivancos [b,d,e,*]

[a] Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain
[b] Centro de Reconocimiento Molecular y Desarrollo Tecnológico, Unidad Mixta Universitat Politècnica de València-Universitat de València, Camino de Vera s/n, 46022 Valencia, Spain
[c] Instituto de Ingeniería Energética, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain
[d] CIBER de Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN), Spain
[e] Departamento de Proyectos de Ingeniería, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain

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ABSTRACT

Although old houses are found in the housing stock which are affected by infiltration and condensation, resulting in humid walls, software generally consider properly maintained buildings, assuming dry walls. This study aims to simulate the effect of these pathologies under dwelling indoor conditions. The objective is to assess the reliability and accuracy of different solutions through the mass and heat transfer analogy in air and water vapour mixtures. Two different modelling settings are analysed using TRNSYS thermal simulation software, evaluating the condensation and evaporation effect of temperature and humidity in a house. Simulation results are compared with four months' worth of monitored data, and a validation procedure is presented. The method proved to be a valid assessment tool to test results reliability in aboveground building modelling. The analogy approach accuracy of the mass and heat transfer in mixtures of air and water vapour was also tested. Results can be used to help designers to optimize the humidity transfer simulation in building energy modelling.

1. Introduction

Each indoor climate zone has different temperature and humidity levels [1]. Outdoor characteristics, i.e. thermal and hygrometric conditions, strongly determine the thermal behaviour of buildings [2,3].

The moisture level in a building is a key influencing factor for its durability, indoor environmental quality, user comfort, and energy consumption [4]. This parameter is the result of the transient balance between moisture gain, loss, and storage [5]. The heat and moisture transfer within the building envelope affects its durability, the indoor humidity level and its energy performance [6]. Although approximately one third of the moisture generated inside a room may be absorbed by moisture buffering materials [7,8], most humidity models ignore or lack comprehensive analysis of moisture exchange between the various building envelope components and the indoor air [9].

The usage of transient simulation tools is becoming increasingly common to predict the indoors thermal behaviour. This study uses TRNSYS to predict the thermal behaviour of a case study; the house is unheated and it is greatly affected by moisture in its walls and in its floor. TRNFlow is used to model the airflow through building structure cracks, airflow which varies with weather and indoor house conditions [10].

This study aims to simulate the effect of these pathologies under old dwellings indoor conditions. The objective is to assess the reliability and accuracy of different solutions through the analogy of mass and heat transfer in air and water vapour mixtures [11–13]. The sample house is placed in the countryside (Valencia, Spain), where there is high humidity from ground capillarity on the walls and floor; humidity produces evaporation and condensation effects indoors, which causes temperature and humidity fluctuation usually overlooked in modelling approaches [14].

* Corresponding author at: Centro de Reconocimiento Molecular y Desarrollo Tecnológico, Unidad Mixta Universitat Politècnica de València-Universitat de València, Camino de Vera s/n, 46022 Valencia, Spain.
E-mail address: jvivanco@dpi.upv.es (J.-L. Vivancos).

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Nomenclature

A	Surface air-water, area (m^2)
$\dot{m}$	Mass flow (kg/s)
C_f	Heat change state water-vapour (kJ/kg)
h	Convection heat transfer coefficient ($kW/m^{2\circ}C$)
h_D	Mass transfer coefficient (kg/m^2s)
Q	Heat (sensible heat and latent heat) (kJ/s)
T	Temperature (°C)
W	absolute humidity (kg_{h_2o}/kg_{dryair})

SUBSCRIPTS

air	Air
c	Condensation
e	Evaporation
sat	Water saturation in air conditions
v	Vapour
sv	Saturated vapour
w	Water
wall	Regarding to walls and floors, enclosure of the thermal zone

2. Materials and methods

2.1. Building description

Building characteristics are quite representative of those built in the first third of the 20th century in the Valencian orchard (see Fig. 1). A significant number of houses were built in this countryside area near the sea, but nowadays most of them provide poor indoor living conditions. The house was built with typical brick, wood and mortar materials from the time of construction. The building is placed in a growing area close to irrigation ditches, being affected by high humidity levels on the ground floor and on the inside walls.

The house is a two-storey detached 1930s building situated in the Valencian orchard; the main living spaces are placed in the ground floor (see Fig. 2a); the ground floor area is 60 m^2 and its average height is 2.80m; the first floor is not connected with the ground floor and it was designed to store orchard products; the second floor area is 43 m^2 and its average height is 1.40m. The house orientation was design to take advantage of the gentle wind from the sea. Walls were built as solid masonry walls with no thermal insulation; the wall surface is made of gypsum and mortar (U-value = 2.68 W/m^2K). The roof is covered by ceramic tiles (0.03 m thickness; U-value = 2.68 W/m^2K); the flat roof is covered by lightweight concrete (0.15 m thickness; U-value = 2.68 W/m^2K); and the internal floor is also made of lightweight concrete (0.15 m thickness) and ceramic tiles (U-value = 3.5 W/m^2K). The windows are single glazed (U-vale = 3.4 W/m^2K) and frames are either made of wood or aluminium [15].

2.2. Climate characteristics

The city and the orchard are located on the east coast of Spain, which is the western part of the Mediterranean Sea. The climate in Valencia is Mediterranean, which is characterized by hot summers and moderate winters. During the analysed period (from January to April 2015) the average temperature was 13.3 °C (minimum 1.9 °C and maximum 30.8 °C); it was a dry period without rainfall. Table 1 summarizes relevant weather variables collected during the study.

2.3. Data analysis

Monitoring was carried out during four months (from 4th of January to 30th of April 2015). A weather station (Watchdog 2700) was installed on site to record temperature, relative humidity, solar radiation (horizontal), wind direction and wind speed; a monitoring system was installed to obtain indoor temperatures and humidity. Three sensors, 'RHT10 Extech Instruments', were placed on the ground floor; they sampled data at 0.1 °C resolution with an accuracy performance of ± 1 °C; humidity sensors resolution is 0.1%RH and its accuracy is ±2%RH. Three more sensors were placed in a central location of the house, placed at 1.5 m from the floor (Fig. 2a); data was collected every 10 min. Average data from the ground floor sensors was used in the study.

2.4. Period definitions

The building thermal behaviour was analysed using monitored data from January 4th, 2015 to April 30th, 2015; during this period, the owner frequently opened doors due to the ongoing building work; the effect of the openings can be seen in the dia-

Fig. 1. Site plan of the analysed house. Valencian orchard.
Source: Google maps (Map data ©2016 Google, Inst. Geogr. Nacional).