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Simplified method for yearlong thermal analysis of building prototypes

E.L. Krüger [a,*], B. Givoni [b,c], C. Laroca [a]

[a] Departamento de Construção Civil, Universidade Tecnológica Federal do Paraná, Av. Sete de Setembro, 3165, CEP, 80230-901 Curitiba, PR, Brazil
[b] Department of Architecture, School of Arts and Architecture, UCLA, Los Angeles, CA, USA
[c] Ben Gurion University, Israel

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ABSTRACT

The paper presents the thermal analysis of a low-cost prototype consisting of plywood panels, which was designed and built by one of the authors within the scope of a program for subsidized low-cost housing. The object of analysis is a building prototype located in Canoinhas, in the South of Brazil (26°10′38″S, altitude 765 m above sea level). The present paper is concerned with evaluating the thermal performance of the prototype over given periods of the year by means of onsite measurements and indoor temperature predictions for the various rooms of the building prototype. From obtained results, the overall performance of the building as well as the individual performance of each room was evaluated.
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1. Introduction

There are a number of studies on the use of wood-based building systems for the Brazilian low-income population. Publications on the subject refer to general construction requirements, in some cases through housing cooperatives; supply chain analysis in wood production; life-cycle-assessment of wood constructions; energy consumption for the fabrication of wood panels in social housing; design and construction of wood houses for the low-income population, and, more specifically, to the wood-frame building system [1–3].

Traditionally, however, one verifies that most of the Brazilian wood constructions are built informally. Contemporary architects avoid building with wood and work rather with conventional masonry (ceramic bricks) in low-cost housing projects. This factor is related, among others, to the lack of skilled labor in building with wood.

One of the first contributions in Brazil with regard to thermal performance evaluations of wood-based building systems consisted of thermal simulations with the NBSLD program of wood shelters in Antarctica [4]. The authors pointed out the difficulties arising from the use of a building material with a good thermal resistance, but which presents a low heat capacity. Giglio [5] simulated wood panels used in wood-frame constructions with the French design tool COMFIE [6], compared results to the recommendations of the Brazilian Thermal Performance Norm [7] and concluded that wood-based building systems may not attend the recommendations of the Brazilian Norm in the Southern region of Brazil, although with improvements those systems may show a good thermal performance. In a comparison between different wood-based building systems in Santa Catarina State, in southern Brazil, Bogo [8], also taking into consideration the recommendations of the Brazilian Thermal Performance Norm, showed that only 13 out of 24 building systems and partly other two would attend the proposed standards.

This brief literature review on thermal performance evaluations in wood-based building systems in Brazil suggests the need of developing more adequate wood dwellings for the low-income population, which could guarantee comfortable levels. Wood constructions are still regarded as having low quality and as provisory dwellings. In many cases, the lack of interest with regard to wood houses is mostly related: to the unskilled construction of such dwellings; to a common prejudice of clients and civil engineers and architects, who are usually not familiar with wood constructions, in favor of conventional masonry buildings; and to legal restrictions (building codes and fire safety standards impose strict constraints with regard to wood houses). From this historical trend, although examples of industrialized wood construction are still an exception in Brazil, informal wood constructions are more common.

The purpose of this paper is to present a simplified method for extended, yearlong evaluations of housing prototypes, focusing on a wood-based housing prototype (presented in the next section), which was built and monitored in the summer period of 2006–2007 in Canoinhas, Santa Catarina, Southern Brazil. As a means of expanding the database of measured indoor air

* Corresponding author. Tel.: +55 41 33104725; fax: +55 41 33104712.
E-mail addresses: ekruger@utfpr.edu.br (E.L. Krüger), bgivoni@ucla.edu (B. Givoni), wood_arquitetura@yahoo.com.br (C. Laroca).

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temperatures, distributed over four rooms of the prototype, predictive formulas for minimum, average and maximum temperatures were developed, taking into account outdoor temperatures and fluctuations and daily solar radiation totals (received on a horizontal plane and on each façade) and applied to other periods of the year.

2. Description of the evaluated housing prototype

In 2006, the southern Brazilian state of Santa Catarina received US$ 23 millions within the low-cost housing program PSH (*Programa de Subsídio à Habitação de Interesse Social)* for subsidizing low-cost dwellings for families with a monthly income up to US$ 420. The state of Santa Catarina then decided to subsidize do-it-yourself housing units. Municipalities would be in charge of providing the residential lots, supervising and assuming technical responsibilities for the construction of the housing units. The state has a long tradition in wood construction and is the second greatest Brazilian producer of pine forests. In association with the local housing cooperative (*Companhia Habitacional – COHAB*), the state determined the choice of pre-fabricated wood housing units for meeting the demand for low-cost dwellings. In this sense, the staff of the Brazilian Association of Mechanically Processed Wood Industry (*Associação Brasileira da Indústria de Madeira Processada Mecanicamente – ABIMCI*) sponsored the construction of two housing prototypes, one built with massive wood boards, located in Lajes, Santa Catarina, and a second one built in Canoinhas, Santa Catarina, which resulted from the present research. The construction of such prototypes usually has commercial objectives (show house). In the case of the prototype which was built in Canoinhas (26°10'38″;S, altitude 839 m above sea level), one of the goals was

Fig. 1. The evaluated prototype (show house in Canoinhas).

to present a low-cost housing type of easy assembly for the low-income population, which could be built with unskilled labor within a self-help process.

The prototype consists of small sized reforestation wood elements and double wall panels composed of plywood (Fig. 1). A floor plan, commonly adopted in ceramic masonry units was used in the wood prototype. The basic plan was adapted to modules of 122 cm × 244 cm. Built area corresponds to 48.93 m^2. The roofing system consists of a pinewood structure covered by fiber cement tiles and a pinewood ceiling. The double walls also have a pinewood structure. Internal plywood panels have a wall thickness of 9 mm and external (façade) panels of 12 mm, which yields a wall thermal transmittance (*U*-value) of 2.17 $W\,m^{-2}\,K^{-1}$. Fig. 2 shows the prototype's floor plan.

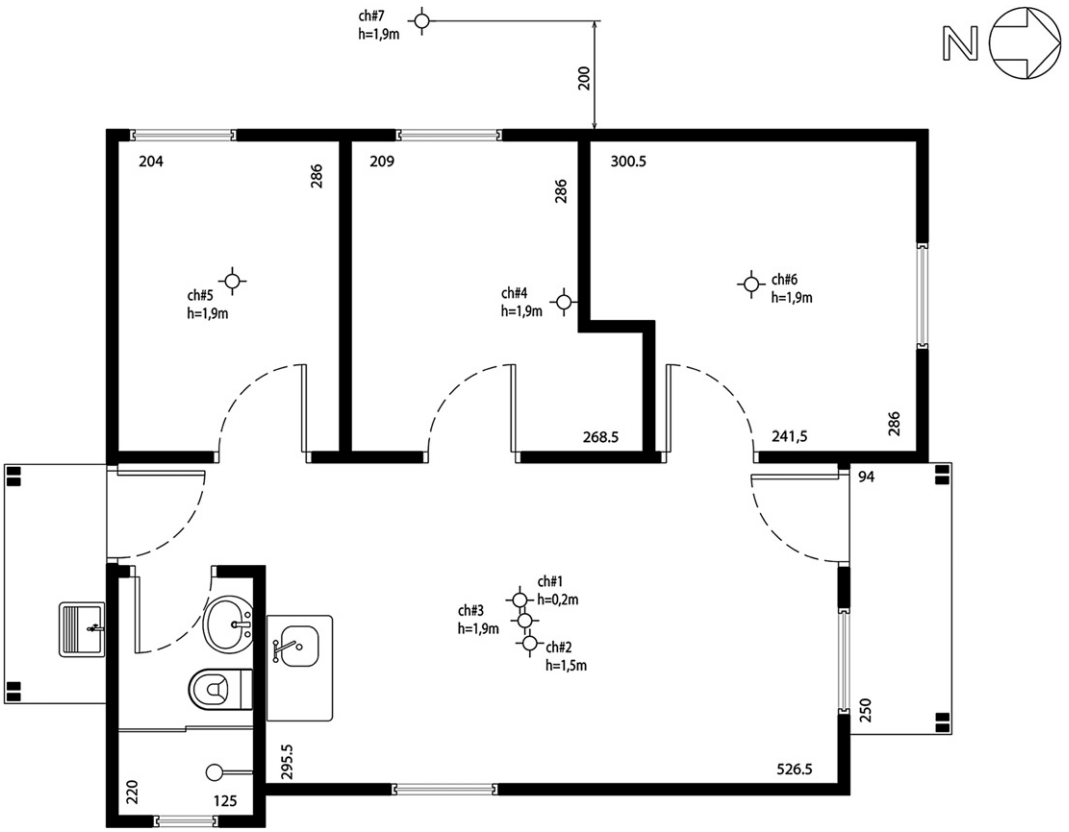

Fig. 2. Lay-out and monitoring points.

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