Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 122 (2017) 3–8
Energy Procedia
www.elsevier.com/locate/procedia

CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale, CISBAT 2017 6-8 September 2017, Lausanne, Switzerland

Sustainable Building Envelopes (Ecobuildings, Retrofit, Performance Gap)

Full scale experimental performance assessment of a prefabricated timber panel for the energy retrofitting of multi-rise buildings

Roberto Garay Martinez [a]*, Josu Benito Ayucar[a], Beñat Arregi Goikolea[a]

[a]*Tecnalia, Sustainable Construction Division*
Parque Tecnológico de Bizkaia, C/Geldo s/n, Edificio 700, E-48160 Derio Bizkaia Spain
+34 667 178 958 roberto.garay@tecnalia.com

Abstract

A prefabricated timber façade system is presented for the energy retrofitting of buildings. Large panel dimensions facilitate the installation of this system, with reduced disturbance to building users and increased overall quality in terms of thermal bridge mitigation and air tightness of architectural junctions. A full scale proof of concept test is performed, where several prefabricated timber panels were installed over a pre-existing brick façade, their junctions tested, and the differential thermal performance of the system is evaluated. It is concluded that the overall thermal performance of the system is satisfactory in terms of overall U-value, thermal bridge coefficient and, temperature factor. Furthermore, and based on experimentally obtained data, a dynamic characterization of the harmonic thermal response of the system is performed.

Peer-review under responsibility of the scientific committee of the CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale

Keywords: Thermal Performance; Timber; Building Envelope; Retrofitting; Experimental Assessment; Prefabrication;

* Corresponding author. Tel.: +34 946 430 069; fax: +34 946 460 900.
E-mail address: roberto.garay@tecnalia.com

1876-6102
Peer-review under responsibility of the scientific committee of the CISBAT 2017 International Conference – Future Buildings & Districts – Energy Efficiency from Nano to Urban Scale
10.1016/j.egypro.2017.07.288

1. Introduction

Building envelopes are the physical interface between indoor and outdoor conditions, and their response to variations on these conditions such as temperature oscillations and incidence of solar radiation, substantially defines the heat dynamics of buildings. Roofs, façades, and glazed areas are responsible for over 60% of heat losses in conventional buildings.

Considering the large building stock and demographic projections in Europe, the quest in energy performance improvement is related to the already existing and ageing building stock. With modern building energy codes in Europe dating back to the 1970s, there has been a steady development and deployment of a variety of thermal insulation systems, such as external thermal insulation systems (ETICs) and ventilated façade systems.

With similar approaches to many other construction processes, building energy retrofits are personnel intensive processes, where raw materials such as insulation, reinforcement meshes, plasters, etc. are delivered on site, and manually installed by crafts. Although increasing care is paid to details in the construction process, large discrepancies are found between design and as-built performance of buildings, and its thermal insulation systems. Many sources are identified for the gap in energy performance, one of the main being poor workmanship.

In this paper an industrialized timber panel is proposed for the energy retrofitting of building envelopes. This panelized system is manufactured in a factory and delivered on-site. Factory production controls minimize performance loss due to poor workmanship. Once delivered on-site, panels are anchored to structural elements in the façade, and junctions are executed in a standardized way.

Within the development of the BERTIM timber façade, a full scale test was constructed comprising a 2-store-high setup, in order to ensure constructability of the system, test the production-transport-installation sequence, and on-site assess the thermal performance of the system. This setup was constructed in the KUBIK by Tecnalia test facility, over a pre-existing brick façade. Brick façades comprise the majority of the building stock in many countries such as Spain, and this particular façade was originally constructed according to thermal performance levels in the 1970s. The building envelope retrofit was sized in order to guarantee a large reduction of the thermal transmittance of the wall, ensuring compatibility of the wall with current energy performance standards.

The presented study shows the thermal performance of this system by means of numerical and experimental thermal assessments, and its differential thermal performance assessment when compared to the existing brick façade.

2. The BERTIM timber panel system and industrialized approach to building energy retrofits

BERTIM [1] proposes a building energy retrofit process focused on the deployment of high performance, minimally intrusive industrialized envelope systems. The Timber-based system is manufactured in large prefabricated envelope sections which are then delivered and installed with minimal on-site works.

In its conception, industrialized Timber-based panels with variable dimensions are allowed. This allows adaptation to variable floor heights, modulation of windows, etc. In some cases, panels spanning over several floor are possible. With this approach specific panel costs per surface are reduced, and on-site installation works facilitated.

The BERTIM system comprises not only envelope insulation elements, but also allows integrating ducts and pipes within the system to allow for the retrofitting of building HVAC systems with minimal intrusion.

In the following figures, the composition of BERTIM panels for insulation and HVAC integration are presented.

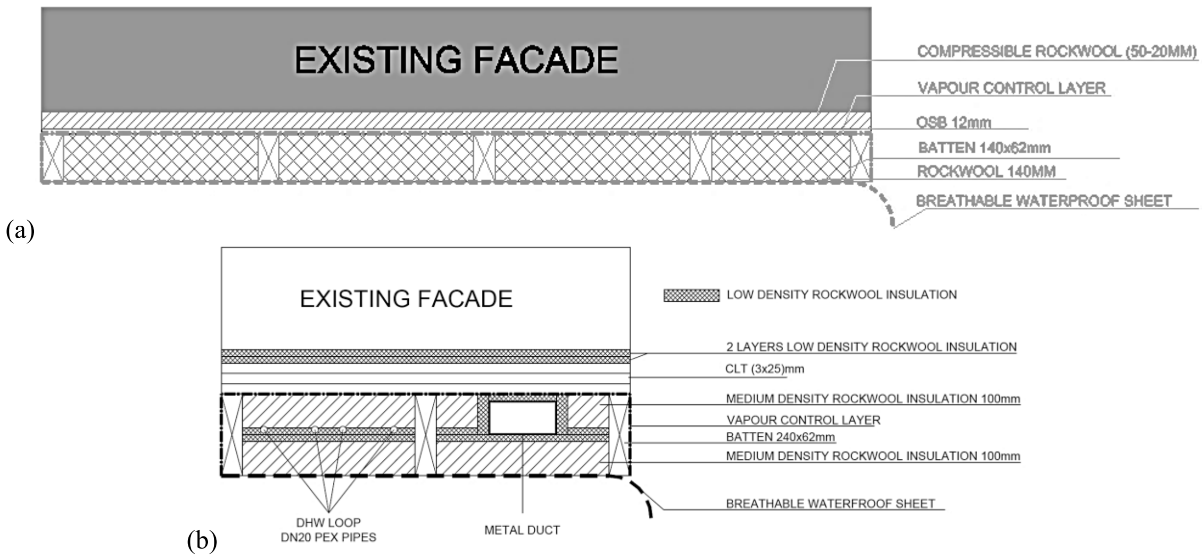

Fig. 1. Composition of the BERTIM timber-based panels. (a) Thermal insulation panels and (b) panels with HVAC systems embedded.

3. Experimental setup

The test was carried out over a portion of the west-facing façade of the KUBIK test facility in Derio, Spain (43° 17′ N 2° 52'W). KUBIK by Tecnalia [2] is a full scale experimental infrastructure focused on research and development of new energy efficient products and systems. It has a total floor area of 500 m² distributed over basement, ground floor and two upper levels. The main distinctive feature of KUBIK is its capacity to create realistic scenarios for the quantitative determination of energy efficiency and energy savings resulting from the interplay of construction solutions, intelligent management of HVAC and lighting systems, and non-renewable and renewable energy sources.

The experimental setup was constructed over a pre-existing brick façade which was thermally characterized within [3]. This façade has already been use in the past to test two thermal insulation systems [3, 4], with various approaches. In [3] stochastic methodologies were used to assess the dynamic thermal performance of the existing wall, and an external thermal insulation system. In [4], steady state methods [5] were used to obtain the differential thermal performance of the wall due to the addition of a prefabricated, lightweight concrete insulation system.

In the particular case of the BERTIM panel system, the setup was designed to cover most of the complexities of a real-case installation of the BERTIM system. Two main areas were differentiated in the test, where different types of panels were installed: (1) Envelope insulation panels and (2) HVAC ducting panels. The architectural definition ensured that all types of junctions (vertical, horizontal, between different panel types…), and panel sizes (one floor or two floor modules) were prescribed, in order to identify any possible failure in the design of the system.

Due to the limited extension of this paper, the thermal performance of HVAC ducting panels is not performed. The assessment is focused in Envelope insulation panels.

Fig. 2. Test area at first floor of west-facing façade in KUBIK facility: (a) original brick wall before installation; (b) BERTIM prototype installed.

4. Pre- and Post-retrofit configuration and thermal performance of the wall

The pre-retrofit configuration of the wall consisted on a cavity wall consisting of two ceramic brick masonry layers, with an internal plaster render. Table 1 defines the characteristics of each of the layers in this wall, along with its total U-value according to numerical assessment methods [6] and experimentation carried out in [3].

Table 1: Characteristics of the pre-retrofit status of the façade

	Thickness [m]	Thermal resistance r [m2K/W]	Internal thermal resistance r_{ss} [m2K/W]	Thermal transmittance U [W/m2K]
Outside		0.04		
Brick wall	0.11	0.21	0.21	
Air gap		0.18	0.18	
Brick wall	0.70	0.16	0.16	
Internal render	0.015	0.019	0.019	
Inside		0.13		
		0.74	0.57	1.35

The dimensions of each of the layers in the timber insulation system were particularized for the test in order to achieve a threshold energy performance. Table 2 presents these characteristics, and its expected thermal performance.

Table 2: Characteristics of the post-retrofit status of the façade

	Thickness [m]	Thermal conductivity [W/mK]	Thermal resistance r [m2K/W]	Thermal transmittance U [W/m2K]
Outside			0.04	
Rockwool	0.14	0.035	4.00	
OSB	0.012	0.20	0.06	
Compressible Rockwool	0.02	0.035	0.57	
Original wall	0.295		0.53	
Inside			0.13	
			5.33	0.19

5. Methodology

The experimental set-up and the data analysis were designed to obtain the thermal resistance of (a) the whole wall integrating the BERTIM solution and (b) the BERTIM component in itself.

5.1. Measurement method and materials

Pt100 temperature sensors by Thermo Sensor GmbH (precision ≤ ± 0.1 °C) and Phymeas heat flux sensors (precision ≤ ± 0.1 % of FSV) were used in the experiment, connected to a Beckhoff Automation PLC system, where data from measurements was recorded at 1 minute intervals. In order to gather the data required for obtaining thermal resistance values for the different layers of the component, the sensors were placed over relevant points of the assembly:

- Layer 1, internal surface of existing brick wall: temperature and heat flux sensors
- Layer 2, external surface of existing brick wall: temperature and heat flux sensors
- Layer 3, external surface of BERTIM panel: temperature sensor only

These sensors give sufficient information for obtaining the following thermal resistance values:

- R_{3-1}, thermal resistance of the retrofitted wall
- R_{3-2}, thermal resistance of BERTIM panel
- R_{2-1}, thermal resistance of the original wall

This arrangement was replicated along 3 measurement axes in different locations over the two-floor-high setup, in order to assess the variability of the thermal resistance due to installation defects and thermal stratification conditions. So as to exclude the effect of thermal bridges, these measurement axes were deliberately placed in an intermediate zone between floors.

5.2. Calculation of thermal resistance

For one-dimensional heat transfer, thermal resistance is defined as the ratio of temperature difference and the heat flux between opposite faces of a material. The input variables (temperature and heat flux) vary over the course of the experiment. Despite a dominant daily cycle, changing weather conditions result in a high variability among different days. Therefore a normalised average method has been used to filter out heat storage effects, where the obtained data is aggregated in order to reduce dynamic oscillations. When carried over a long enough period of time, there is a convergence to an asymptotical value that is close to the steady-state value.

6. Results of the experimental campaign

Minutely recorded data in the period from November 2016 to April 2017 was processed for this assessment. Results were obtained for each of the 3 measurement axes. In order to achieve a robust and stable surface-surface conductance value, the signals were processed by generated cumulated mean values of each of the signals. Quantitative results are portrayed in Table 3.

Table 3. Statistical distribution of experimental readings for temperature and heat flux density.

	Temperature [°C]			Heat flux density [W/m²]
	T_1	T_2	T_3	q
Maximum	28.94	26.1	48.95	7.96
Third quartile	26.09	25.24	16.51	3.42
Average	25.57	24.48	14.42	1.98
First quartile	25.06	23.81	10.54	1.56
Minimum	24.27	21.51	1.746	0.35

7. Conclusions and further work

From the temperature and heat flux density values measured, thermal resistance values have been obtained for both the original wall and the BERTIM panel show an overall thermal resistance of the insulated assembly has been measured at 5.07 m²K/W. This resistance is a significant improvement from the value measured before insulation (0.53 m²K/W). The thermal resistance of the BERTIM panel has been measured at 2.47 - 4.08 m²K/W. Overall; the BRESAER system provides a 7x increase in the thermal resistance of the wall.

The experiment presented in this paper has served as a proof of concept where thermal performance and construction process have been proven satisfactorily. Within the expected development of the BERTIM project, and considering its success in delivering a prefabricated system with thermal insulation properties, BERTIM will be scaled up and a full scale execution over a residential building in Charité-Sur-Loire, in France.

Considering its approach to construction product development through phases (design, full scale proof-of-concept and final deployment in a demonstration building), BERTIM will substantially reduce risks of reduced performance by means of a stepwise mapping of design, with real-life performance. Thus it delivers a guaranteed performance to final users of the system.

Acknowledgements

This paper has been drafted thanks to the funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 636984. The content of this paper does not reflect the opinion of the European Union.

References

[1] BERTIM, Building energy renovation through timber prefabricated modules, EU h2020 GA nº636984, http://www.bertim.eu/ (2017/04/07)
[2] Garay, R et Al, Energy efficiency achievements in 5 years through experimental research in KUBIK, 6th International Building Physics Conference, IBPC 2015, Torino, 2015
[3] Estudio de investigación sobre eficiencia energética y viabilidad de la aplicación de fachadas ventiladas en soluciones de rehabilitación, TECNALIA, ERAIKAL-12.
[4] Garay, R. et Al. Experimental Thermal performance Assessment of a Prefabricated External Insulation System for Buildings Retrofitting, International Conference on Sustainable Synergies from Buildings to the Urban Scale, SBE16, Thessaloniki, 2016
[5] EN ISO 9869-1:2014 thermal insulation –Building elements- In-situ measurements of thermal resistance and thermal transmittance – Part 1: Heat Flow Meter Method
[6] EN ISO 6946: 2007, Building Components And Building Elements - Thermal Resistance And Thermal Transmittance - Calculation Method