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INTESA system: A new high-performance and highly integrated drywall façade

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Abstract

INTESA is an innovative vertical envelope for residential, industrial and service tertiary buildings. It is a drywall façade system with high thermal and acoustic properties, embedding electrical and plumbing systems. The system was developed over two years by a multidisciplinary team, which involved researchers, manufacturers and consultants. An integrated approach has been the key element to design and prototype an innovative double cavity drywall façade, composed by plasterboard layers and blown-in cellulose flakes, with and without a thin layer of Phase Change Material. Thermal and acoustical properties have been optimized through laboratory measurements and simulations and later tested in a prototype building.

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Keywords: Integrated performances; thermo-acoustic properties; high performance façade.

1. Introduction

INTESA (*INTegrazione ed elevata Efficienza con sistemi a Secco per l'Abitare*, Integration and high efficiency with drywall technology for building envelopes), is a research project which involved different expertise in order to determine a synergy among different technological fields. Two façade and an insulation manufacturers, an HVAC consultant, a consultant in the fields of building physics and a team of researchers were involved.

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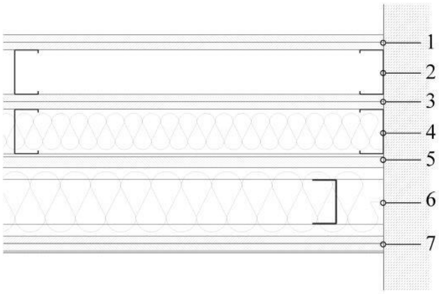
The research project rises to address the gradual but deep change the global construction market is experiencing and to meet the growing demand of high-performance solutions. Dry systems are in continuous evolution and they represent a convenient alternative to traditional products, in terms of costs, weight, velocity of assembly and transportation. Although this general trend, dry technology is almost unused in the Italian residential sector: this is undoubtedly due in part to the present lack of a complete and exhaustive technical knowledge in this field. INTESA objective is to fill this void, tackling the issues less explored until now concerning the light façade technology: connection details and integration with other building components and with plant system. Its aim is an holistic innovation encompassing the fields of product assembly, material and performance. The integrated design is the strategy adopted to achieve a high quality outcome, with a minimization of construction issues causing performance losses and lower material life-cycle. INTESA envisages not just to design and propose a solution, but also to test it and to show benefits quantifying them. Performances are hence verified in laboratory and through a prototype, specifically designed for in-field monitoring.

2. INTESA wall system

INTESA is a lightweight façade composed by two asymmetric cavities. Its cross section, showed in Figure 1, is conceived with the aim of improving the thermal and acoustic performances taking into account the best position of the mass and insulating layers, the cavities dimension and the vibrational and thermal properties of the studs. These parameters have been adjusted until a balance among requirements was found. Plasterboard panels with different thicknesses and with air gaps in between act the mass-spring-mass mechanism, which dissipates acoustic energy. Layers are fixed on innovative transversal hat-profiles, showed in Figure 2.a, conceived to damp vibrations, further increasing sound insulation. High sound insulation was also obtained choosing different densities and thicknesses for the layers and different thicknesses for the air gaps.

High thermal insulation performance has been obtained through thick layers of cellulose flakes, which was blown-in after the wall has been installed. This kind of insulation, usually better suitable in the case of energy retrofit of existing buildings, was here adopted due to its high properties in terms of low embodied energy and low thermal conductivity. Moreover, the cavity filled with flakes was expected to improve the acoustic performance. The presence of two insulated asymmetric cavities was defined in order to slightly increase the thermal inertia of the system. The thermal and acoustical behavior of the light wall was further investigated with and without a thin layer of Phase Change Material (PCM), a 5 mm Energain Dupont panel [1].

INTESA façade is integrated with the plant system through a false wall that can be installed with a variable gap thickness to host cables and pipes. This layout provides significant benefits if compared to the traditional one: maintenance and inspection are easier and the floor thickness is reduced. All the acoustic and thermal bridges are optimized, and connection details specifically solved, as can be shown in the plan of the full-scale prototype in Figure 2.b. In particular, two different types of junction between internal and external walls were designed in order to measure two different values of Vibration Sound Reduction Index, K_{ij}, according to the EN ISO 10848-1.



1. 2x GypsoHd BA 13	12.5 x2 mm
2. C stud	75 mm
3. 2x GypsoHd BA 13	12.5 x2 mm
4. C stud with cellulose flocks	75 mm
5a. Phase change material	5 mm
5b. GypsoHd BA 18	18 mm
6. C stud and hat profile with Cellulose flocks	115 mm
7a. Acquasuper BA 13	12.5 mm
7b. Externawith skim coat AN55	12.5+3 mm

Figure 1. Wall cross section of the INTESA system.

3. Building physics requirements and work methodology for the project of INTESA system

The project phase was structured in three main stages: design proposals, laboratory tests on wall components and simulations. In-field measurements were eventually carried out in a full-scale prototype building. At the design stage the first step was to identify the relevant variables determining the envelope performances and to evaluate their relevance and potential influence. The thermal and acoustical performances of the single components were then verified through laboratory tests in order to have data to perform simulations. The target values to be checked in-field were set out on the basis of national and regional legislation, as listed in Table 1.

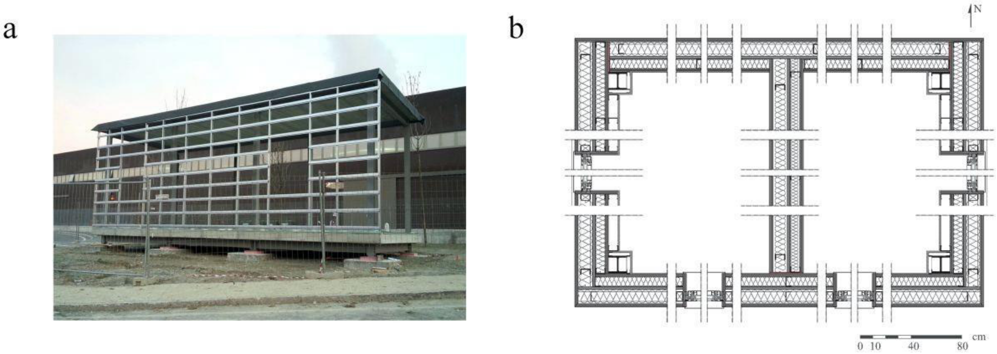


Figure 2.(a) Picture of the full-scale prototype under construction; (b) Plan of the prototype, with INTESA used for external and internal walls.

Table 1. National and regional legislation limit values.

Parameter	Value	Reference legislation
Thermal trasmittance - opaque vertical envelope, limit value (U)	≤ 0.33 W/m²K	D.P.R. 2/04/2009, n. 59
Thermal trasmittance - opaque vertical envelope, incentive value (U)	≤ 0.25 W/m²K	D.G.R. 4/08/2009, n. 46-11968
Periodic thermal transmittance - opaque vertical envelope, limit value (Y_{ie})	≤ 0.12 W/m²K	D.P.R. 2/04/2009, n. 59
Weighted standardized sound level difference of a façade ($D_{2m,nT,w}$)	≥ 40 dB	D.P.C.M. 5/12/1997
Weighted apparent sound reduction index (R'_w)	≥ 50 dB	D.P.C.M. 5/12/1997

3.1. Laboratory measurements

Before the prototype construction, measurements of hygrothermal properties of the wall's layers were performed at the Energy Department of the Politecnico di Torino. Results are shown in Table 2.

INTESA wall was also installed in the laboratory of the National Institute of Metrological Research (INRiM) in Turin, to measure the sound reduction index according to the UNI EN ISO 10140-2 standard. One-third octave band values with and without PCM layer are plotted in Figure 3, leading to a weighted sound reduction index of 68.8 dB and 70.2 dB, respectively, so proving that PCM increased the sound reduction index all throughout the spectrum.

Table 2. Hygrothermal properties of the different layers of INTESA wall.

Layer	Volumetric mass density (kg/m³)	Thermal conductivity, λ (W/mK) UNI EN 12664	Water vapor diffusion coefficient (kg/msPa) EN ISO 12572
AQUASUPER BA 13	817	0.219	1.28E-11
GYPSOHD BA 13	931	0.253	2.18E-11
GYPSOHD BA 18	924	0.253	2.18E-11
EXTERNA	1092	0.215	8.53E-12
NESOCELL	95	0.054	1.61E-10

3.2. Simulations

To make a choice about the wall layers position and thickness, iterative acoustical and thermal simulations were done. Solutions were designed and then assessed with all the partners until a balance between energy and acoustic performances versus construction costs, installation and set-up requirements, was reached. In particular, mass and size of the inner false-wall were debated and adjusted to fulfil all requirements. Acoustic and thermal bridges were optimized, and connection details specifically solved. INSUL v. 7.0.6, BISCO v. 7.0, SONOUS v. 7.00 and an excel spreadsheet based on the national standards EN ISO 13786 and EN ISO 13788, were used for simulations. As example of comparison between measurements in laboratory and simulated values, Figure 3 shows the one-third octave band sound reduction index of INTESA wall, as obtained from measurements at the INRiM and from INSUL v. 7.0.6. A good agreement between the two sets of data is shown, with higher performances at the highest frequencies in the case of measurements.

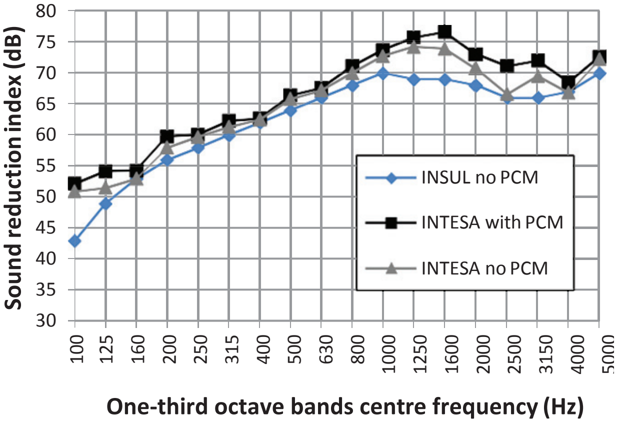


Figure 3. Comparison among one-third octave band sound reduction index of INTESA wall: laboratory measurements with and without PCM and simulation with INSUL v. 7.0.6.

4. In field-measurements

The prototype has been conceived to reproduce all the project details defined at the design stage, as shown in Figures 2. It was built in Calliano d'Asti (AT) far from noisy streets and other noise sources. It is a double-room building made of a light steel structure with concrete slabs. It lays on supports which create a gap between the base and the ground. Each room has a bare façade facing north, to be used as the testing wall for the thermal measurements, avoiding the presence of direct solar radiation on the sensors. The façades facing south have a glazed portion (Figure 4). The prototype is located far from other buildings to avoid that they can cast shadows on it. Two different external envelopes were set, one provided with a PCM layer (room A in Figure 4.a), while the other without (room B in Figure 4.a).

To avoid vibration interferences from the trucks passing nearby, a resilient layer made of elastic polyurethane 50 mm thick was placed at the base of the metal structure. Elastic polyurethane layers, 25 mm thick, were also laid to decouple the junctions between external and internal walls needed for K_{ij} measurements.

To allow an evaluation of PCM effectiveness, room A and room B were monitored for a whole year, to quantify the thermal performance during different seasons and representative weeks were then taken into account. For winter, night data were collected for one week and the wall thermal transmittance (U) obtained. During summer, two different boundary conditions were considered: the first one in a free-running mode, to check how the envelope behaves in terms of indoor overheating; the second, with the cooling system switched on and the temperature set to 25ºC, in order to obtain the phase shift (φ).

Part of the in-field thermal and acoustic measurement results are shown in Table 3. The thermal monitoring has been carried out placing 18 sensors connected to a datataker to continuously collect data [2]. The following sensors were used: heat flow meters, located on the inner side of the wall to measure heat fluxes crossing the envelope; TT thermocouples, located on the inner and outer surfaces in different points and heights to measure surface temperatures; TT thermocouples to measure indoor and outdoor air temperatures and a piranometer to measure the external horizontal solar irradiance.

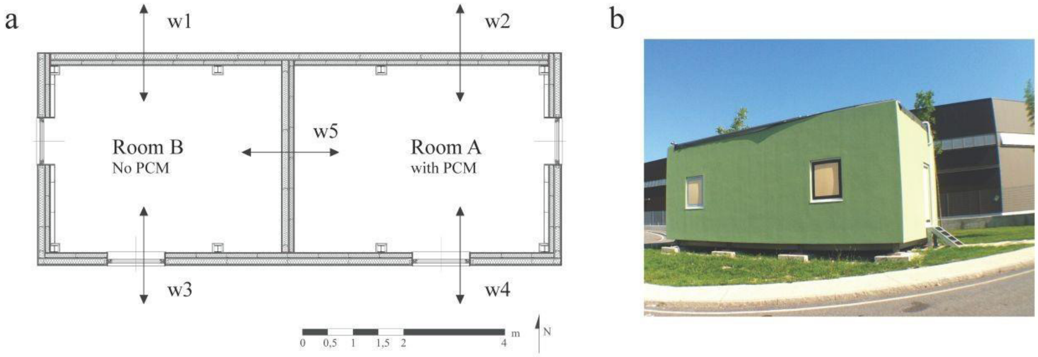


Figure 4. (a) Prototype plan showing reference walls tested for acoustical properties; (b) Picture of the prototype during summer test.

Table 3. In-field measurement results. Values written in bold satisfy the Italian legislation limit requirements.

Measure	Room A (PCM) or B (no PCM)	Figure 4.a reference	Value	Reference standard
Weighted standardized sound level difference of the façade ($D_{2m,nT,w}$)	A	w2	**58** dB (-2;-5)	UNI EN ISO 140-5
Weighted standardized sound level difference of the façade ($D_{2m,nT,w}$)	A	w4	**48** dB (-1;-4)	UNI EN ISO 140-5
Thermal transmittance (U)	A	w2	**0.19** W/m^{2}K	ISO 9869
Phase shift (φ)	A	w2	≈7h	See graphs in Fig. 5.b
Weighted Apparent Sound Reduction Index (R'_w)	A-B	w5	**55** dB (-2;-4)	UNI EN ISO 140-4
Weighted standardized sound level difference of the façade ($D_{2m,nT,w}$)	B	w1	**58** dB (-2;-6)	UNI EN ISO 140-5
Weighted standardized sound level difference of the façade ($D_{2m,nT,w}$)	B	w3	**48** (-1;-4)	UNI EN ISO 140-5
Thermal transmittance (U)	B	w1	**0.21** W/m^{2}K	ISO 9869
Phase shift (φ)	B	w1	≈7h	See graphs in Fig. 5.b

For what concerns the summer behavior, as shown in Figure 5 a and b, the INTESA wall system shows a good performance. In term of indoor overheating risk (Fig. 5a), during the free-running mode the indoor air did not overcome 28°C, registered in the late afternoon, while during the central hours of the day the temperature was about 26-27°C, with an external temperature of 30°C. Moreover, the internal temperature fluctuation is quite reduced. It is nevertheless important to point out that the external conditions during the measurements period were not so stressing. Phase shift was also determined comparing the maximum heat flux measured on the inner side of the wall, with the maximum external surface temperature measured on the surface of the wall facing the outdoor environment; as shown in figure 5b a phase shift of about 7 h was obtained. The presence of the PCM layer does not noticeably affect the system performance, even if a slightly different profile can be noticed for what concerns the heat flux (A and B) during the day characterized by high solar irradiance and high external temperatures.

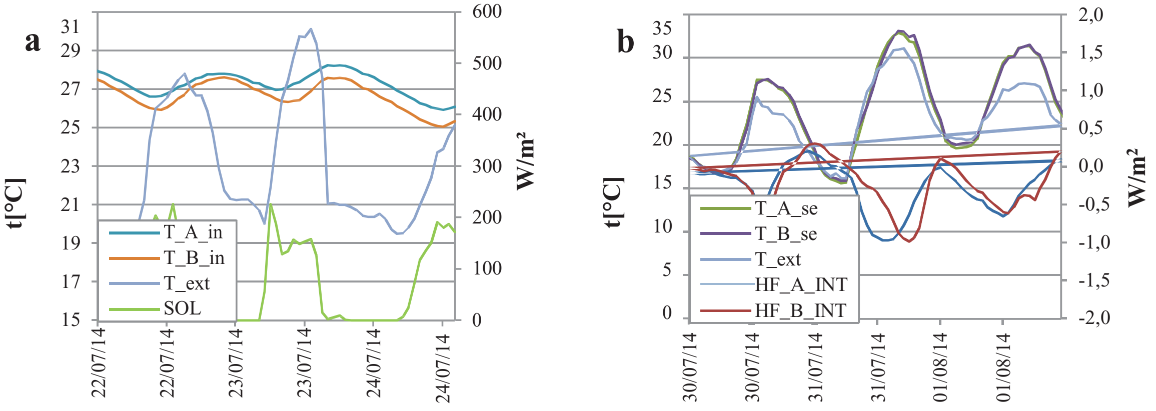


Figure 5. (a), (b) Summer measurement results. T_A_in is the air internal temperature in room A, T_B_in is the air internal temperature in room B, T_ext is the external temperature, SOL is the solar radiation irradiance, HF_A_INT is the heat flux measured on internal side in room A, HF_B_INT is the heat flux measured on internal side in room B, T_A_se is the external surface temperature of the room A, T_B_se is the external surface temperature of the room B.

5. Conclusions

INTESA innovative light façade system owns the characteristics to meet legislation requirements, as can be seen in Table 3, and to face the expansion market demand for high standard housing, which implies high thermal and noise insulation levels. In-field and laboratory measurements showed that light steel framing systems can be conceived to fulfill high functional requirements for residential buildings and that these are well suited for industrial production. Thermal inertia and acoustic performances are comparable with a traditional wall with a mass three times higher. The performances are high, with a lower mass and a thinner section. Costs are reduced, since the system is conceived to be based on units and the construction speed is significantly higher.

Results show that the PCM layer does not give a significant contribution in field, while in laboratory a better performance compared to the case without PCM was obtained in the case of sound reduction index. Generally, simulations give results in agreement with laboratory and in-field measurements.

To sum up, the present work proves that integrated design is a successful strategy to obtain very high performances over all the aspects of the building physics.

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