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Abstract. In low and medium-rise buildings, flat and pitched roofs might represent the largest exposed area to the outdoor environment and to the solar radiation. To reduce the heating and cooling demand it is important to provide very high insulation level together with good thermal inertia. For this reason, in the last few years the interest on advanced materials and technologies dedicated for the roof application and the prevention of winter heat loss and summer overheating of attic spaces have grown significantly. As a consequence, the request of testing procedures for assessing the performance of these systems under actual operating conditions is increased.
In this short paper the new experimental facility TRIS (Testing Roofing Innovative Systems) for the thermal testing and the comparative analysis of innovative roof systems, in real conditions, is described.

Keywords: Roof, Test-room, Attic space, Advanced insulation, Vacuum Insulation Panels, Phase Change Materials

1 System description

The TRIS system (acronym of Testing Roofing Innovative Systems) consists of three identical small test-rooms with a south exposed pitched roof located in the Turin metropolitan area (Italy). In table 1 the relevant information about dimensions and orientation are summarised.
All the partitions (walls and floors) are designed to face an internal control volume (temperature-controlled environment) while the roof elements (replaceable part for testing the specimens) are facing the outdoor environment. The TRIS are well insulated thanks to the stratigraphy of the envelope. In particular, the walls (Fig.1.C) consist of two faces of gypsum boards and an insulation core of mineral wool (5 cm) and the floors (Fig.1.D) consist of two faces of OSB (Oriented Strand Board) and an insulation core of XPS (extruded polystyrene) with a thickness of 3 cm.

Table 1. Information about the Test-rooms

Information	Value
Floor internal size [m]	0.78 X 1.64
Minimum internal height [m]	1.45
Maximum internal height [m]	2.20
Internal volume [m^3]	~ 2.3
Azimuth	193° (South-Southwest)
Roof slope angle	28°

Fig. 1 a) The three test rooms; b) Internal view and sensors position; c) Construction of walls d) Construction of floors

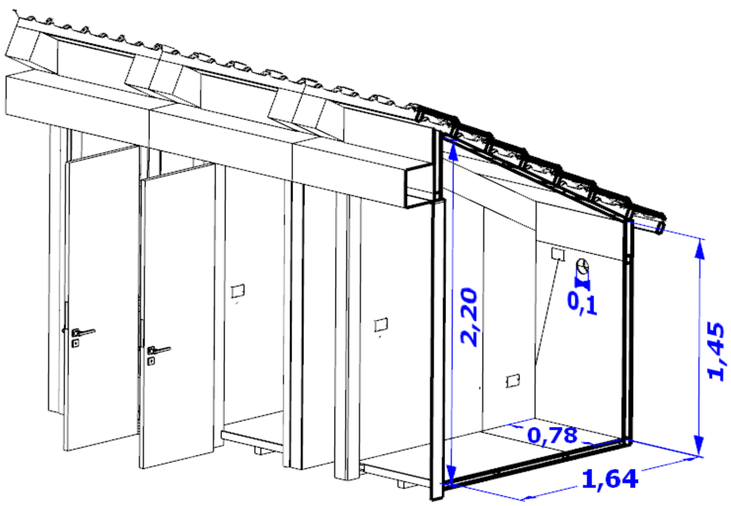

Fig. 2 Internal dimensions of TRIS

The system allows the development of several testing procedures that can be used for different purposes:

- In-situ U-value measurement according with EN ISO 9869 [1];
- Indoor free-running temperature monitoring (surface, mean radiative, and air temperature) for model validation;
- Comparative analysis for in-situ performance demonstration;
- Heating and ventilation cycle test;
- Ageing tests.

Each TRIS test room is equipped with 2 HFP01 (Heat Flux Meter sensor) for heat flux measurement on the indoor surface, and 14 Type-T Thermocouples (6 for the internal surface temperature, 6 for the roof layers temperatures, 1 for the outdoor air temperature and 1 for the internal air temperature) and a black globe temperature sensor (50 mm diameter). Moreover, the outdoor conditions (air temperature, relative humidity, wind speed/direction, and precipitation) are measured with a weather station installed on the top of the roof. The horizontal and incident global solar irradiance are measured with n.2

LP02 (Pyranometer sensors). Monitored data are acquired by a DT85 Datalogging system equipped with a channel expansion module (CEM20). The real-time data are displayed by means of a LCD 24' screen.

1.1 Heating and ventilation system

Two alternative heating devices can be used as heating system: a) an electric oil radiator (max power 1000 W) and b) an electric heating foil (nominal power 55 W). Both systems are controlled by a temperature thermostat with sensitivity of (± 0.3°C). Moreover, system can be scheduled by a plug timer.
The ventilation system consists of a 100 mm insulated circular channel with length of ~270 cm. The external air can be supplied to the indoor test-room with a 100 mm helicoidal fan (power 15W). The ON/OFF switching of the ventilation system can be programmed by a plug timer and with an additional thermostat for rule-based supply air temperature control.

2 System requirement and commissioning

To assure an accurate comparative testing, the three test rooms were designed and built identically. Moreover, to verify that heat and air exchange of the rooms are comparable, a series of simultaneous heating and ventilation tests were performed.
This check was made by heating up simultaneously the test-rooms with an identical roof insulation (50 mm of extruded polystyrene XPS) generating an internal heat source of 1000W (electric oil radiator). The test parameter "*C*" is represented by a percentage value, determined as the ratio between the maximum difference of the monitored indoor temperatures of the three rooms and the difference between the average indoor temperature and the weighted average of the boundary temperatures (outdoor and control volume). It has been assumed that the three rooms behave analogously if $C_{MAX} < 5\%$. In table 2 the results of the thermal commissioning test are presented.
The air infiltration was tested by means of the tracer-gas decay technique [2], using Sulfur hexafluoride (SF6). Two different configurations were tested: Config. a) Only natural infiltration; and Config. b) a fan-assisted mechanical ventilation. The results of the Air Change per Hour (ACH) in the two different testing configurations are summarized in Table 2. The parameter adopted to judge the similarity of the three test rooms is the standard deviation of the measured ACH. For the ventilation/infiltration commissioning phase a value lower than 5% of standard deviation was assumed as a threshold verification criterion.

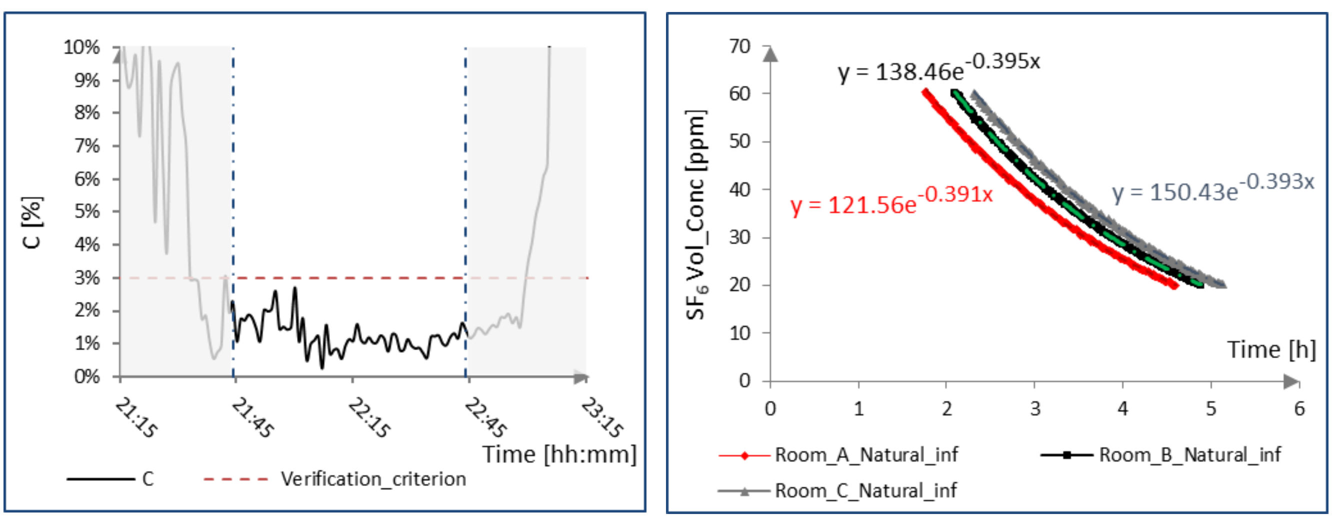

Fig. 3. Left) Thermal commissioning (natural infiltration); Right) Tracer gas technique (natural infiltration).

Table 2. Results of commissioning

Commissioning	Type	Value	Measured parameter	Threshold value	Passed
Thermal commissioning	Test 1 (Natural infiltration)	-	1.3%	5.0%	Yes
	Test 2 (Mechanical ventilation system)	-	4.0%	5.0%	Yes
Ventilation/infiltration commissioning	Test 1 (Natural infiltration)	ACH = 0.39 ± 0.01	0.5%	5.0%	Yes
	Test 2 (Mechanical ventilation system)	ACH = 4.50 ± 0.21	4.3%	5.0%	Yes

3 Conclusions and research perspectives

The lack of testing procedures suitable for advanced envelope materials/components (Phase Change Materials, super insulating materials, ventilated air layers, and reflective insulation), under actual operating conditions, and their rapid diffusion in the building sector, have highlighted the need of developing testing facilities suitable for the performance demonstration and the long-term performance monitoring of innovative roof components (some example of roof performance monitoring were recently reported in [3] and [4]).
The design and construction of TRIS create an experimental test-rig aimed at filling this gap. In this paper, the main features and the experimental capabilities of the system is presented. Moreover, the results of the commissioning tests showed the reliability and the accuracy of the system in performing comparative parallel analyses on different roof insulation technologies (standard VS advanced).
First preliminary tests on roof components making use of Phase Change Materials and Vacuum Insulation Panels are still ongoing and are providing promising results. Moreover, to support and implement the future research activities, a calibrated "Digital Twin" (Digital Model of TRIS) is under development by using different dynamic Building Energy Simulation software (BES).

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