Experimental facilities for adaptive façades characterization

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Abstract

Adaptive façades, components and systems are very promising technologies to improve energy and environmental performance of building. The characterization and analysis of their thermophysical and optical behaviour is very relevant in order to increase the effectiveness of these systems and to promote both their development and implementation.

Characterization tests for adaptive façade systems and components are usually performed in large scale facilities, such as real-scale buildings, indoor and outdoor test cells. In this paper, five different outdoor test cell facilities developed for testing of adaptive façade solutions are presented. Features, advantages, limitations and possible experimental activities for each typology of test cell are reported.

Keywords: Outdoor test cell; Experimental facilities; Building envelope characterization; Energy performance; Comfort performance; Measurements.

1. Introduction and overview of the experimental facilities

Buildings are crucial for the implementation of EU's energy efficiency policies, as nearly 40% of final energy demand and 36% of greenhouse gas emissions depend on houses, offices, commercial and other buildings. A fundamental way to reduce this environmental load is reducing space heating and cooling energy needs by improving buildings' envelope performance. Material science is continuously providing new solutions that could potentially improve energy performance of the building envelope. Advancement in prefabrication, assembling and manufacturing technologies are providing new envelope systems incorporating several functions. A common characteristic of some emerging solutions is the adaptability to climate and eventually to users, i.e. a dynamic (active or passive) behaviour.

In order to develop further these solutions and to evaluate their performance to address designers and users aims and needs, there is a clear necessity to refine existing characterization/diagnostic tests to make them more useful, usable and consistent, and to develop new experimental methodologies [1]. The experimental assessment procedure may be performed by means of three main facility categories [2], each of these characterized by pros and cons: 1) outdoor real-scale facilities, 2) laboratory indoor facilities, and 3) outdoor test cells.

1) Real-scale facility may give results for whole building performance and the effect of occupant behaviour, but their use to characterize the thermophysical behaviour of envelope components is usually complicated.

2) Steady state tests may instead be performed in indoor laboratories under well controlled boundary conditions. These facilities may also be used to simulated dynamic (usually periodic) boundary conditions, however substantial limitations exist for solar radiation simulation in terms of power, time and consequently costs for the tests.

3) Outdoor test cells fill the gap between the two solutions since they may be used to perform calorimetric tests or comparative tests on building envelope components under real weather condition. Test cells may also provide hygro-thermal characterization of elements; they may test materials weathering, rain tightness and frost damage.

These outdoor facilities may perform both absolute tests, if only one test cell is available, or comparative tests, if two or more are instead installed. The PASSYS/PASLINK projects [3] developed a model for calorimetric tests based on wel-defined envelope and system characteristics, while other research centres develop a guarded zone approach to minimize the error during calorimetric tests [4].

In this paper, five different outdoor test cell systems are presented in order to highlight the available typologies and their distinct characteristics. Possibilities offered by these facilities for the characterization of advanced façade components and systems are described. An overview of the five facilities is given in Table 1, while in Section 2 a detailed description of each system is presented.

Name	Location	Climate	Year	Typology
The Cube	Aalborg, DK 57°02'N; 10°0'E	Dfb	2005	Sigle cell with guarded volume
ESTP outdoor test cell	Cachan, F 48°79′N; 2°33′E	Cfb	Under construction	Single cell with multiple configurations (with and without guarded volume)
TWINS facility	Torino, I 45°06'N; 7°66'E	Cfa	2001	Two identical cells without guarded volumes (fully exposed to outdoor)
ZEB Test Cells Laboratory	Trondheim, N 63°41'N; 10.41'E	Dfc	Under construction	Two identical cells with two independent guarded volumes
Envelope testing facility	La Rochelle, F 46°14'N; 1°16'E	Cfb	Under construction	Five test cells (two couples and one single) with common guarded volume

Table 1: Overview of the five experimental facilities.

2. Outdoor test cells facilities

2.1 The Cube – Aalborg University, Denmark

2.1.1 Aim of the test facility

The Cube (Figure 1) is an outdoor full-scale test facility located near to the main campus of Aalborg University, Denmark. Initially, the test facility was envisioned as a way to study the actual size façade solutions under real weather conditions. Later on it was modified to allow investigation of following systems as a stand-alone solution or in combination with each other:

- a window or a façade system (i.e. double-skin façade) with or without shading solution;
- radiant wall terminals;
- ventilation system combined with or without active chilled beams.

2.1.2 Description of the test facility

The Cube consists of several domains, illustrated in the Figure 1. A test room, with one wall connected to the outdoor environment and remaining walls attached to a guarded zone is constructed within the experiment room. The internal dimensions of the test room are 2.76 m x 3.60 m x 2.75 m (width x length x height), resulting in a floor area of approx. 10 m^2. Façade elements, cooling, heating, lighting and ventilation principle in the test room can be adjusted according to the required boundary conditions.

The west wall of the test room is equipped with six radiant panels, resulting in a total dimension of the activated surface equal to 3.6 m x 1.9 m (length x height). The radiant panels are composed of capillary pipes (3.35 mm diameter and 10 mm spacing) mounted at the back of a plasterboard. The cooling capacity has been measured under experimental conditions and is equal to 21 W/m^2 floor (for $\Delta\theta$ = 8 °C (EN 1264-3 2009)).

The active chilled beam unit is located in the middle of the ceiling and has the dimensions of 0.6 m × 0.6 m. The water flow in the cooling coil varies between 100 and 200 l/h, and the cooling capacity of the active chilled beam is equal to 25 W m^{-2} floor (for $\Delta\theta$ = 8 °C).

The ventilation air is supplied to the room using the same unit as the active chilled beam. If the inlet air temperature is required to be constant, then the ventilation air is supplied from the guarded zone, which is temperature controlled. The infiltration and exfiltration rate between the guarded zone and the test room is minimized by keeping zero pressure difference between the test room and the guarded zone. The infiltration rate is below 0.3 l/(s・m^2 $_{floor}$) at 50 Pa.

2.1.3 Monitoring and control system

Seven energy meters are mounted: one for the active chilled beam and six for the radiant panels (one meter per panel). Each meter has been calibrated and the uncertainty of the measurement has been estimated to ± 0.9 L/h for the flowmeters and ±0.06 K for the Pt-500 sensors. Airflow through the ventilation system is measure using an orifice plate located before the inlet (total uncertainty ± 7.5 %).

The outdoor boundary conditions are measured with equipment placed locally at the test facility. Irradiance is measured on the roof of the building (global, 3% uncertainty and diffuse, uncertainty max 10 %) and on the southern façade (total, 3 % uncertainty). Wind speed and wind direction may be measured at 6 different heights above the ground on a wind mast near the building. A large carpet is placed on the ground in front of the southern façade of the Cube to achieve uniform reflection from the ground (ρ_{carpet} = 0.14).

The test room is equipped with a large range of sensors (over 300), which can be adjusted depending on the purpose of the set-up. Thermocouples and thermopiles have been placed in the construction elements (type K thermocouples, with uncertainty ±0.15 ℃). Air temperature is measured using silver-coated thermocouples, and protected by mechanically ventilated silver shield, in order to avoid influence of solar radiation. Anemometers, lux meters, relative humidity sensors, thermal manikins, power meters can then be added to the set-up. All sensors are individually calibrated and the logging frequency is varying between 0.1 Hz up to 5 Hz depending on the type of measurement. As a result, it is possible to establish a complete heat balance for the test room.

All data are logged using LabVIEW. This interface is also used to control the different equipment of the test-room. The modularity of this software makes the set-up highly flexible.

2.1.4 Examples of research activities

The Cube was built in the fall of 2005 in the frame of IEA ECBCS ANNEX 43/SHC Task 34 for experimental investigation of double-skin façades [5]. Later on, it has been adapted to different purposes i.e. characterisation of intelligent glazed façades [6-7]; performance assessment of radiant walls and chilled beams in dynamic conditions with solar exposure [8]; investigation of thermal and visual comfort for different control strategies of solar shading, performance characterisation of different solar shading devices, etc.

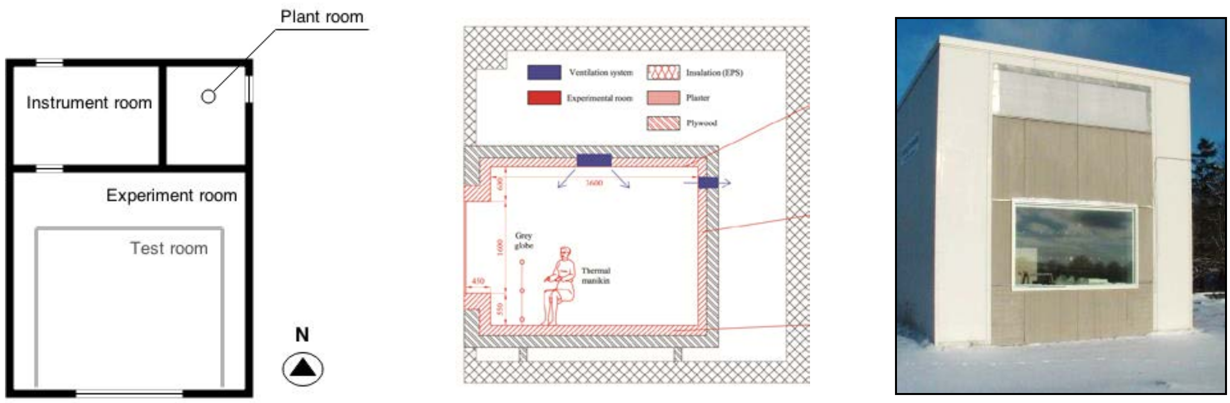

Figure 1. Plan drawing of the Cube (left). Vertical section of the Cube with details on construction elements (center). Southern façade of the Cube (right)

2.2 ESTP outdoor test cell – Ecole Spéciale des Travaux Publics, du Bâtiment et de l'Industrie, France

2.2.1 Aim of the test facility

The outdoor test facility under development in Paris at the Ecole Spéciale des Travaux Publics, du Bâtiment et de l'Industrie (ESTP) in collaboration with the end-use Efficiency Research Group of Politecnico di Milano, will allow to obtain reliable estimates of thermal performance indicators of transparent and opaque building elements. A detailed discussion of design choices and early simulation results can be found in [9]. The major design aim is to build a facility with high accuracy for calorimetric tests but also flexible enough to be used for indoor environmental quality (IEQ) investigations.

2.2.2 Description of the test facility

In order to optimize both calorimetric measurements and IEQ campaigns, the first step is the decoupling of the two test typologies. This has led to a configuration by which the calorimetric tests are carried out in a dedicated metering box, while the IEQ tests are carried out in a larger room. The "room" works as a guard zone during the calorimetric tests. A scheme of both configurations for the operation of the test cell is presented in [9] and can be seen in Figure 2. The internal dimensions of the metering box used for calorimetric measurements are (WxLxH): 3.0m x 1.2m x 3.0 m, while the internal dimensions of the guard zone are (WxLxH): 4.1m x 6.2m x 4.0 m. When the guard zone is used as an office space, it is possible to apply a false ceiling to be used as a technical space for ventilation and lighting systems.

The envelopes of the metering zone and the guard zone are constructed with prefabricated sandwich panels, formed by two 0.6 mm stainless steel sheets and 15 cm thick injected-polyurethane foam. The resulting thermal conductance is equal to 0.153 W m^{-2} K^{-1}. A particular care is taken in order to minimize the thermal bridges around the entrance door and the interface where the test component is installed. The proposed cooling system consists of a high-stability distilled-water storage (keeping water in a range of ±0.1 °C) which feeds both the terminal units of the guard zone and the metering box. In particular, the metering box is equipped with a solar absorber and an auxiliary cooling battery.

The solar absorber, consists of two stainless steel (AISI 304) sheets welded and inflated at high pressure in order to generate internal channels for the passage of distilled water. Distilled water is chosen for the possibility to accurately know its specific heat capacity at constant pressure (cp), needed for the computation of the cooling power. The absorber plate will be coated with a selective TiNOX® coating with solar absorption coefficient α ~ 95 % and thermal emissivity ε ~ 4 %.The solar absorber is also used as baffle in order to help keeping nearly-constant convection conditions on the internal surface of the test element.

The facility will be positioned with its south façade facing an open meadow, thus the hypothesis of unobstructed exposition is well met. A ground reflectance of 0.25, typical of short grass lawns, will be considered. A dedicated structure will protect the guard zone envelope from snow loads and rain and it will shade it from solar irradiance, with the only exception of the south façade where the test sample is installed.

Figure 2. 3D perspective of the new test cell facility under construction at ESTP (Paris)

2.2.3 Monitoring and control system

The monitoring system considers all the most relevant heat flux and environmental quantities contributions:

- heating power and electrical powering of circulation fans and active sensors: measured by means of a high-precision wattmeter (accuracy ±0.02 %);
- cooling power: calculated from the measurement of the water mass flow (Coriolis-based mass-flow meter, accuracy ±0.5 %); and the temperatures at the envelope of the metering box (Pt100 resistance temperature detectors (RTDs), accuracy ±0.07 °C);
- weather conditions: a dedicated weather station is placed on a roof of the ESTP campus, and allows the direct measurement of: global and diffuse solar irradiance, air temperature, relative humidity, wind speed and direction and rainfall water.
- Indoor Environmental Quality main parameters will be monitored during comfort tests. The set of available sensors includes Pt100, T-type thermocouples, omnidirectional anemometers, capacitance relative humidity sensors, globo-thermometers, luxmeters and a gas phase photoacoustic spectroscopy unit. More sensors will be used for dedicated visual and acoustic comfort tests.

The monitoring and control of the facility will be performed by means of an integrated National Instruments system. As concerns the control logics, they are presently being tested by means of a thermal model described with more details in [9].

2.2.4 Examples of potential research activities

The test cell is now under development and will be installed and calibrated at ESTP by autumn 2015. Candidate technologies for the future experimental campaigns include pre-fabricated façade elements for new buildings and retrofits, integrating, for example, active elements (such as photovoltaic and concentration photovoltaics modules or solar thermal collectors) or decentralized mechanical ventilation systems with heat recovery. Other likely candidates are advanced glazing systems presenting thermochromic, thermotropic or electrochromic properties and highly insulating layers such as aerogels. The dynamic behaviour of materials such as air-permeable concrete and organic/inorganic phase change materials, and the cooling properties of highly reflective coatings could also be tested under real solar radiation and wind conditions.

2.3 TWINS facility – Politecnico di Torino, Italy

2.3.1 Aim of the test facility

TWINS (Testing Window Innovative Systems) is a measurement facility built up with the main aim to test the actual performance under real boundary conditions of advanced active transparent/opaque façades and, more in general, responsive building envelope components integrated with HVAC systems. Data are collected mainly in order to assess the energy performance of the façade at the component scale (analysis on the overall energy consumption of the cell cannot be performed); analyses on thermal comfort and of lighting and acoustic related aspects can be also carried out.

2.3.2 Description of the test facility

The experimental test rig consists of two identical outdoor test cells (Figure 3). In the original idea one cell had to be used for reference purposes, adopting a conventional double glazed façade, and the other cell was designed to host different configurations and typologies of responsive façades. The use of a reference test cell allows to make direct comparisons among various configurations and to perform sensitivity analyses even when the boundary conditions were not exactly the same, i.e. assessing the impact on the façade overall energy performance due to different façade features. In the latest years, the high number of components to be tested made it necessary to use the two test cells independently, reserving nonetheless a fraction of the façade to host a reference sample.

The internal sizes of the test cells were chosen accordingly to the IEA-SHC TASK 27 specifications reproducing the typical façade modules dimensions as used in office buildings. The TWINS test cells are thus: 1.6 m wide, 3.6 m long and 2.5 m high. Walls, floor and ceiling are made up of 48 mm thick sandwich panels, in double painted sheet-steel with expanded polyurethane, with a U-value of 0.43 W m^{-2} K^{-1}. The test cells are located on a flat roof, in a position which is not shadowed along the entire year. They are mounted on wheels in order to be rotated to change the façade orientation, but so far most of the experimental activities were done for south-exposed façades. The indoor air temperature of both cells is controlled, with a tolerance of 1 °C, by means of a full air system. Usually the temperature set point is fixed at 20 °C in winter, 23 °C during the mid-seasons and 26 °C in summer. The air from the AHU is distributed through a perforated textile channel as uniformly as possible in order not to negatively influence the response of the sensors located on the internal facing surface of the façade. The ventilation system is completely independent of the air conditioning system (for indoor air temperature control), and the air changes can be adjusted as needed.

2.3.3 Monitoring and control system

The measurement apparatus consists of thermocouples, heat flux meters and pyranometers connected to a data logger. The number and typology of sensors depend on the façades features and they change according to the investigated technology and the purpose of the experimental activity (e.g. a comprehensive investigation of the thermal and fluid dynamics phenomena involved, or the characterization of the performance of the façade, both in terms of energy efficiency and thermal comfort). The measurement chain is preliminary calibrated and/or verified in the laboratory; resulting accuracies are 0.3 °C as far as temperature is concerned, and 5 % for heat flux measurements, 3 % for the solar radiation measurements. During the design and set up of the probes, particular attention is paid to the problem of the measurement of temperatures and heat fluxes in the presence of incident solar radiation and, in order to reduce the errors which can arise under these conditions, particular care must to be taken to properly shield the sensors.

The following sensors are usually adopted: thermocouples (T/J type) to measure the temperature of the indoor air and the surface temperatures; ventilated thermocouples (T/J type) to measure the air temperature in the air gap; a Pt 100 probe to measure the outdoor air temperature; heat flux meters to measure the thermal flux through the façade; pyranometers located vertically on the plane of the façade and behind the façade to measure the solar irradiance. The measurements are typically performed with a scan rate of 15 min and the readings are stored in an internal memory with a capacity of about 1 month of monitoring or directly downloadable through a website.

2.3.4 Examples of potential research activities

In the last 10 years the TWINS facility has been extensively used to carry out monitoring campaigns on advanced adaptive façades. A relevant activity has been devoted to the experimental characterisation of active transparent façades, in particular climate (mechanically ventilated) and hybrid (fan assisted) façades [10-11]. An extensive monitoring was performed on a new multifunctional façade module (MFM), called ACTRESS (ACTive, RESponsive and Solar) [12]. Different dynamic glazing systems have been tested and some are still under investigation: a simple PCM window prototype [13], thermotropic and PCM-filled glazing units (assessed both independently and when coupled together) [14], a polycarbonate panel filled with PCMs used as shading device (now under test). Presently, an opaque modular ventilated façade, made of wood and lightweight components (as cardboard and/or cork), is also monitored.

Figure 3. View of the TWINS test facility at Politecnico di Torino

2.4 ZEB Test Cells Laboratory – Norwegian University of Science and Technology, Norway

2.4.1 Aim of the test facility

The ZEB Test Cells Laboratory is an experimental facility developed within the Research Centre on Zero Emission Buildings at the Norwegian University of Science and Technology. It is a joint-project between NTNU and SINTEF, with the support of several partners of the Research Centre.

Primarily, the Test Cells Laboratory (Figure 4) will allow full scale monitoring of building envelope components (opaque and transparent, adaptive or conventional) to be carried out, under real outdoor and indoor boundary conditions, in a Nordic climate context. Moreover, given the nature of the test facility, interaction between building envelope components and HVAC terminal units will be also tested. Additional analyses with interaction between building envelope, building equipment and building technologies could also be performed (e.g. influence of thermal inertia, finishing of indoor surfaces). Indoor environmental quality analyses, with or without the presence of users in the test cells, will be also possible in this research facility.

2.4.2 Description of the test facility

The test facility architecture is based on two twin test cells with two guarded volumes. The reason to use two guarded volumes instead of a single surrounding volume is to increase flexibility in experimental procedures and experimental activities, enabling for example parallel tests of the same building envelope technology/equipment with different indoor air temperature set-points, occupancy schedules or operations.

Each test cells has the following internal dimensions (WxLxH): 2.4 m x 4.2 m x 3.3 m. The walls, ceiling and floor of each test cell is made of prefabricated panels with 0.6 mm stainless steel sheets and 10 cm thick injected-polyurethane foam. The façade sample area (2.4 m x 3.3 m) is exposed to outdoor conditions and faces south. The two cells are suspended from the floor of the main building (0.5 m). The temperature of the air surrounding the test cells will be kept at the same level of the test cell indoor air temperature so that, if the inertial phenomena are neglected, the test cells envelope should act as an adiabatic surface.

Thermal energy for cooling and heating of the two test cells and two surrounding volumes is managed by four independent Air Handling Units (AHUs). At the time being, no control over the relative humidity is installed, but plans for future configuration of the AHU to control latent load have been developed. It is worth mentioning that, in order to allow experiments with users in the test cells, fresh air is supplied to the two test cells through two of the AHUs, while the other two (controlling the temperature of the guarded volumes) are acting on recirculated air. A smaller, independent AHU provides fresh air intake to the other spaces of the test cell building (a meeting room, a kitchen and a WC) and to the two guarded volumes. Each test cell is also equipped with terminals of one hot-water and one cold-water circuit for installation of different HVAC terminal (with possibility to control the supply temperature and flow rate of the hot/cold water).

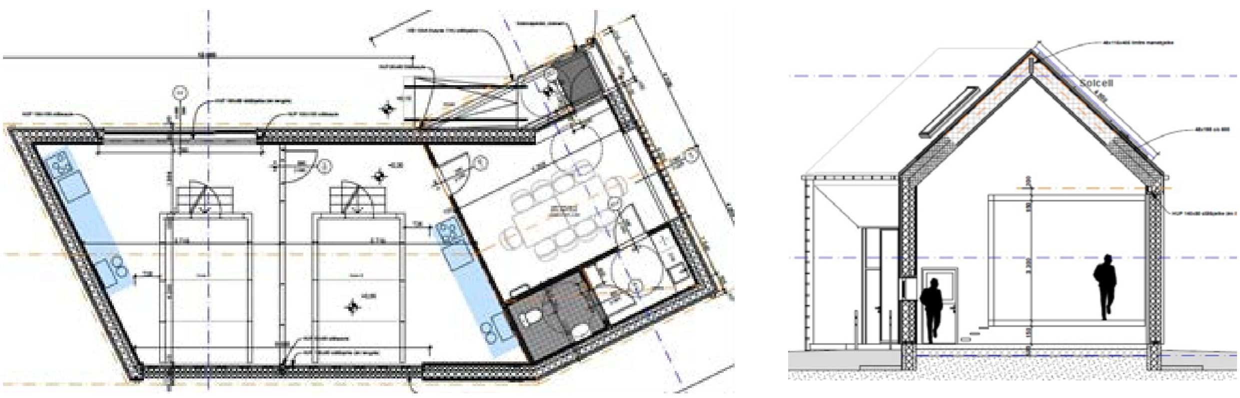

Figure 4. Plan drawing of the ZEB Test Cells Laboratory (left). Vertical section of the ZEB Test Cells Laboratory with one test cell and one guarded volume (right).

2.4.3 Monitoring and control system

The monitoring and control system of the test facility are integrated in just one hardware system, based on the National Instrument CompactRio family. Acquisition of signals for both control and monitoring, as well as control signals are managed centrally by one controller, while a network of distributed chasses for data acquisition systems allow the total length of sensors and control wires to be reduced to a minimum extent, still allowing a very robust management the entire installation – all the sensors and actuators interacts with just one controller. The code for data acquisition and control of the HVAC components is developed in LabVIEW environment and allows a high degree of flexibility to be achieved.

The starting list of sensors installed in the test cells includes: TJ thermocouples (for walls internal/external surface temperature) with accuracy of ±0.5 °C; four-wire PT100 (accuracy of ±0.1 °C in the environmental temperature level range) for indoor air temperature, globe thermometer, and sensors in the HVAC plant for control; hot-wires sensors and differential pressure sensors for monitoring of supply/extract airflow through different procedures (accuracy ±10 %); thermal energy meters (made of PT100 and ultrasonic flow meter) for monitoring of waterborne heating/cooling thermal energy demand (accuracy ±1 %); a weather station for monitoring of boundary conditions, including solar radiation on different planes; several sensors for monitoring of thermophysical and lighting performance of façade components (among which, thermocouples, heat flux meters, pyranometers, luxmeters).

2.4.4 Examples of potential research activities

The research facility is currently in the last stage of the construction. A six-month commissioning and calibration period is planned for autumn 2015 and full operation is therefore foreseen for the first part of 2016. Among the advanced façade solutions that will be tested during the first starting period it is worth mentioning a glazed system integrated PCM. Other technologies that are under consideration so far are different configurations of advanced façades and their interactions with HVAC, among which some double skin windows/façades, innovative dynamic glazing layers and shading systems.

2.5 Envelope testing facility – Université la Rochelle, France

2.5.1 Aim of the test facility

A test-facility for roof and façade components is developed in the Tipee Platform [15] affiliated with La Rochelle University (Figure 5). This real-scale room facility provides in-situ tests (outdoor real conditions) of building envelope components through measuring energy budgets within a controlled cell. The facility is developed in order to evaluate component performances according to measuring in-situ energy budget (ISO 9869 standard) through developed procedures of identification of dynamic thermal properties. PASSLINK testing procedures [3] can be pursued but new identification inverse methods can be tested.

Experimental campaigns will provide data to adjust the numerical models of the studied component, taking into account the dynamic effects that occur within the developed technology. Seasonal thermal behaviour can be studied in different periods and associated cooling and heating demand can be characterized.

2.5.2 Description of the test facility

Five cells are implemented, i.e. five independent tests could be carried out simultaneously. Two pairs of twin cells (for both façade and roof) are required in technical specifications assuming comparison purposes might be needed for scientific evaluation of 2 technologies. The last test bed is built over a double height and will be used to test component requiring an application on large volumes (industrial buildings, ventilated façade…). Façades rigs are oriented south and south-west.

Special attention is given to design ties technology to bond the test component to cells. The concept is such as the technology should allow an evaluation of thermal performances of most of building envelope's technical solutions with or without their original ties. This features means that the studied envelope solutions can be regarded with or without thermal bridges (near 1-D conductive heat transfer).

Cells backsides are included in a controlled thermal guard to impose a control of boundary conditions.

The shell of the test-cells is an assembly of 40 cm thick polyurethane foam panels. The primary framework developed to tie the test-component to the cell is made of reinforced concrete but could be done with metallic profile which could be filled with insulation foam. The thermal guard is made out of walled concrete insulated from inside with 15 cm of rock wool panels.

Heating energy is assured by a moveable fan coil unit which could be positioned on purpose. The cooling system is composed of a fixed fan coil unit with oversized surface of cold battery in order to work with temperatures above the dew-point temperature to avoid condensation.

Ventilation systems are designed in order to meet with the requirements of the monitoring protocol based on thermal comfort or in-situ coupled energy performances. Minimum ventilation rate for hygienic reason will be performed, alternated to mechanical free-cooling/natural ventilation to evaluate the thermal efficiency of different ventilation strategies. A vertical shaft within the thermal guard behind the cells is provided for such purposes. An inlet air duct with supply fan is also positioned on the left side of each cell.

2.5.3 Monitoring and control system

Each cell will be equipped with a switching panel composed of enough measurement channels to receive a set of sensors for a cell and its movable component. Basic set is composed by Pt100 sensors (accuracy: ± 0.1 °C) for different temperatures (surface, air, globe thermometer) measurements, relative humidity probes (±3 %), heat flux meter (with sensitivity up to 500 µV/(W/m²)), and could be completed for special purposes with additional sensors. Heat flux plates shall be used to give qualitative audit of the fluxes heterogeneity.

Systems are equipped in order to accurately measure energy consumptions and injected powers. Pt100 probes measure the inlet and outlet water temperatures of the cooling coil system along with a flowmeter. An accurate voltmeter assures the recording of heater power. The energy brought by air ventilation and infiltration shall also be evaluated.

Data logging has not been studied yet, however the acquisition system is planned to be placed in the thermal guard zone, while measurement to reduce wiring and electric noise will also be taken. HVAC systems are controlled in view of keeping an accurate set-point temperature of the indoor environment and to produce ROBLS sequences of heating power. Set-points values could be manually fixed or they could be set following a control law variable in time.

2.5.4 Examples of potential research activities

The construction of the roof and façade test facility is due for June 2016. It requires also a calibration period to identify the thermal response of test-cells on reference component. This step draws out calibration coefficients in order to correct the model raw thermal responses from particular phenomenon (mainly thermal bridges effects and sensor response).

Potential research activities of such equipment could be focused on studying: 1) the effects of the implementation of envelope systems (mimicking common errors and evaluating their consequences through measurement); 2) the physics phenomena at smaller time scale than current hourly step basis (solar spot) with the aim to use the results to refine numerical codes in dynamic simulation; and 3) roof and façade's performance led on different real-scale within oceanic European climate.

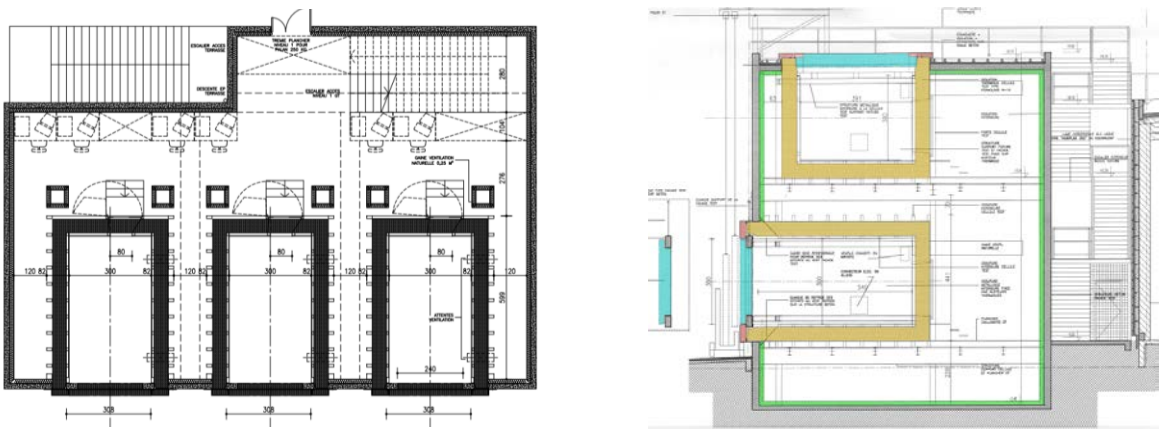

Figure 5: Sectional top-view and sectional front-view of the Test facility (credit: AIA)

3. Conclusion

In this paper, five outdoor test cell facilities are presented. These systems have been developed to suit different types of tests and characterization activities on building envelope components, including adaptive façades. Primarily, two layouts of test rig can be identified (single cell vs. double/twin cell) and combined with two configurations of controls for boundary conditions (guarded volume or no control). The type of test cell depends mainly on the type of tests that are planned, though all these facilities try to be flexible enough to be able to carry out different measurements (e.g. calorimetric tests and indoor environmental quality tests). In the paper, the geometrical and material configuration of each test facility is illustrated, together with the description of the equipment for environmental control, as well as the monitoring and control system. Many of the facilities have very similar HVAC technologies and data acquisition systems, giving space for possible collaboration in development of common test procedures.

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