HIEQLab, a facility to support multi-domain human-centered research on building performance and environmental quality

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HIEQLab, a facility to support multi-domain human-centered research on building performance and environmental quality

A Pellegrino[1,*], V Serra[1], F Favoino[1], A Astolfi[1], L Giovannini[1] and A Clos[1]

[1] Politecnico di Torino, Energy Department, TEBE Research group, corso Duca degli Abruzzi, 24 – 10129 Torino (Italy)

[*] Corresponding author: anna.pellegrino@polito.it

Abstract. Researches on building performances and environmental quality can be performed through different approaches, including dynamic numerical simulations, in-field studies, full scale test facilities and living labs. Researches performed through full scale test facilities allow carrying out studies under controlled realistic conditions, directly involving the final users. Such approach can significantly improve the scientific research on energy efficient and healthy buildings by fostering a synergistic and user-centered innovation process. Within this context, at Politecnico di Torino, the TEBE group (Technology, Energy, Building and Environment) has designed and is realizing a full-scale facility, aimed at implementing researches on building Indoor Environmental Quality (IEQ) and energy performance. The facility will enable multi-domain studies, including thermal, air quality, acoustic and lighting aspects, involving the final user in the research process. The paper describes the features of the facility and the challenges it was conceived to face.

1. Introduction

Buildings are responsible for a significant share of the global energy consumption, but they also affect human health and well-being, due to the amount of time people spend indoor. Therefore, enhancing the building occupants' well-being through high quality indoor environments is becoming a target for most of the construction sector stakeholders. Researches on building environmental quality and/or energy performance can be performed through different approaches: from dynamic numerical simulations, to in-field studies, to full scale test facilities and living labs, which allow carrying out studies under controlled realistic conditions.

Several full scale test facilities are available all over the world, mainly designed to assess the performance of building components and systems, rarely considering occupants, the impact they have on building performance and the impact indoor environmental conditions have on health, well-being and comfort of final users. [1, 2].

Within this frame, at Politecnico di Torino, the TEBE group (Technology, Energy, Building and Environment) has designed and is realizing a full-scale facility (HIEQLab), aimed at implementing researches on Indoor Environmental Quality (IEQ) and energy performance, adopting and testing innovative components for passive and active control of environmental conditions and involving users in the research process, moving from the concept of 'test facility' towards the concept of 'living lab'.

2. Lab design characteristics

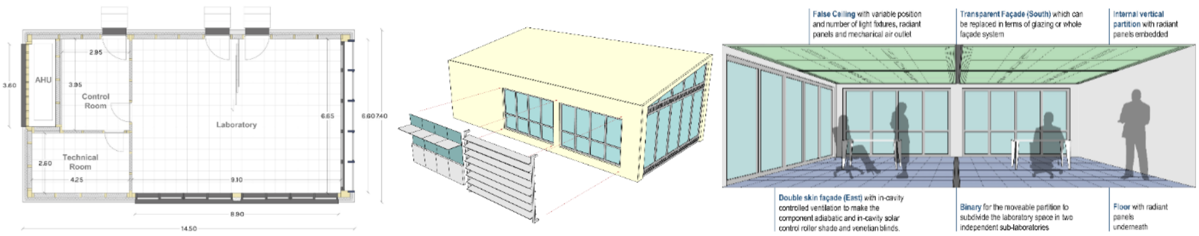

Figure 1. Plan view, external and internal schematic view of the laboratory.

The HIEQ Lab will be realised within the innovation accelerator *Environmental Park*, in the Italian city of Turin (45.22° N, 7.65° E). The site South and East sides are respectively fully free and partially free from obstructions, while high rise-buildings are present on the North and West sides, at a distance of approximatively 100 m. The HIEQ Lab consists of a rectangular structure (14.5 m x 7.5 m) longitudinally oriented on the East-West axis and covered by a flap inclined of 10° towards South. In this space three different rooms are accommodated, whose disposition was designed according to the site obstructions. In fact the main space, i.e. the laboratory, uses both the South and East side of the structure (unobstructed), while the other two spaces, i.e. a control room and a technical room were located on the West side of the facility. The Air Handling Unit (AHU) compartment is located outside the technical room, on the West side of the facility.

The idea underlying the conception of the HIEQ Lab is that of providing a high degree of flexibility to the facility, allowing its adaptation to different types of experiments. Such flexibility can be found in different aspects of the design of the facility, from the definition and control of the technical building systems, to the envelope components and to the geometrical features of the laboratory. In fact, this can be used as a single space, but a moveable partition will allow to transform it in two sub-laboratory spaces with identical features.

The building opaque and transparent envelope were designed to comply with the NZEB (Nearly Zero Energy Building) Italian minimum requirements [3], and to demanding sound insulation requirements. Furthermore, large openings were designed to allow, through their modulation, studies with different daylight supply. The laboratory East façade was designed as a transparent double skin façade with venetian blinds and a solar control roller shade integrated within the cavity. By means of a blackout shade and purposely controlled in-cavity mechanical ventilation, this transparent façade can be transformed into an opaque adiabatic component. The laboratory South façade shows two identical apertures for the transparent envelope, symmetrical in respect to the room middle line. For each of the two apertures a method allowing to replace either the sole glazings, or the whole façade systems, was purposely devised. Both South and East façades can be modified accordingly to the research needs, changing the window to wall ratio (WWR), the type of transparent/opaque materials or adding internal or external shading systems.

Space heating and space cooling are supplied by three independently controllable radiant systems, located respectively on the floor, on the opaque vertical partitions and on the false ceiling. An HVAC system was designed to control and ensure the indoor air quality and to contribute to the space heating and space cooling. The lighting system was designed to be flexible and controllable, in terms of light distribution, light quantity and spectral power distribution. All the technical building systems can be fully controlled and, in the case of two sub-laboratories, their control can be partialized.

The false ceiling hosting the light fixtures, the air outlet and the radiant panels was designed to be flexible and re-configurable according to the experimental needs.

In figure 1 the plan view, with the indication of the internal subdivision of the space, and the external/ internal schematic view of the laboratory are presented.

In the laboratory, all the environmental quantities concurring in the determination of the IEQ (air quality, thermal, lighting and acoustic) could be recorded, inside and outside the facility. Moreover, all the quantities characterising the building envelope and the operation of the building systems will be monitored, as well as the energy consumption of the heating, cooling and lighting systems.

Simultaneously, it will be possible to perform subjective analyses investigating the behaviour and the responses of the occupants. Wired and wireless sensors will be used for data collection.

3. Research objectives and discussion

The HIEQLab is a full scale facility conceived to reproduce a real-life, flexible environment, where envelope technologies, services (HVAC and lighting) and controls are tested and implemented with a user-centered approach. The primary scope is to develop researches on human performance, comfort and well-being and on the energy performance of building environments in a completely controlled space. Users are involved in the research activities, becoming active players in the evaluation process and in the development of building components and design strategies which address health, well-being and IEQ requirements (Figure 2).

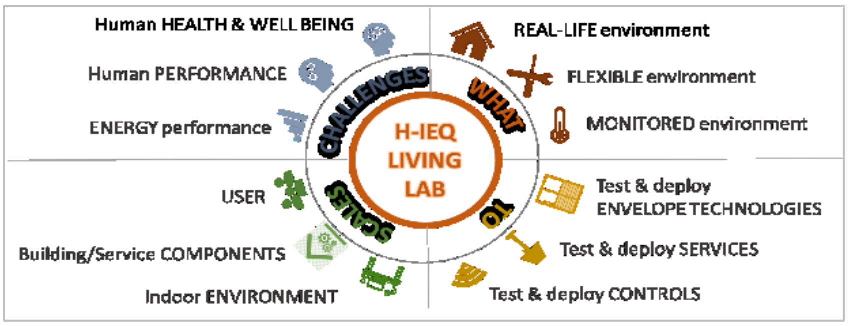

Figure 2. Schematic description of the HIEQLab main features.

The laboratory features and the expertise of the research group will allow to carry out researches and experimental activity with a multi-domain approach. The interactions between thermal, air quality, acoustic and lighting aspects could be studied, allowing to develop new concepts of human-centric IEQ, new metrics for its evaluation, new methods and sensors for monitoring, with the aim of improving the overall comfort and building healthiness in the global framework of Zero Energy Buildings.

Studies on human comfort and well-being are complemented with researches focused on testing and developing building components (e.g advanced transparent facades, shading systems, opaque envelopes) and systems (HVAC and lighting). In this case, users' involvement will allow a deeper understanding of their interactions with building components and systems and will boost the development of a user-centered design approach. The specificity of the laboratory (real-life, fully-controlled environment) will also allow to study the role that operations of both technical building systems and adaptive envelope components play on environmental performance and occupant comfort, and the possibility offered by IoT systems for improving occupant interaction and capturing their preferences. Different control approaches, from rule based to more advanced model-based and model-free, can be tested and implemented taking into account the implications on IEQ, occupant interaction and acceptance and building energy performance. Finally, experimental data collected in the laboratory during dynamic testing could be used to calibrate and validate models to be used in multi-domain simulation workflows, allowing to integrate and exploit the potentials of both research approaches.

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