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Re-designing a temporary pavilion into a NZEB open lab for a university campus

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Abstract. During the Milan Design Week 2018, a temporary pavilion - “Delight The Light” – has been design and built - as press room for Officina Tamborrino - using their own products as construction technologies. This paper explains the evolution of this project from a temporary architecture into an NZEB open lab for university students. The introduction of innovative multilayer insulator materials characterized by high heat-reflecting properties and the tailored envelope design ensure the satisfaction of comfort both in winter and summer season and reduced drastically the time of constructions. The process, followed to reach the NZEB target, is based on performance-based design analysis. In particular the validation phase has foreseen a very detailed modelling steps on the building model through dynamic thermal simulations with finite element method to validate its thermal and hygrometric performances, coupled with daylighting and fluid dynamics simulations to consider also the users behaviour and well-being during the design stage.

1. Introduction

The increasing awareness on climate changes and the latest EPBD recast 844/2018/UE [1] are stimulating new approaches in buildings design process, renewable energies integration and their upcycle at the end-of-life through the concept of Nearly Zero Energy Buildings (NZEB) [2][3], which are becoming the main stream quality in the AEC industry. Various researches and assessments illustrate worrying environmental trends on the global level that are tightly linked to the process of industrialization which implies a significant increase in the use of energy, materials and related CO₂ emissions, intensifying consequently the competition for raw materials [4]. At the same time, there is a growing demand for ecological and sustainable materials. The demand includes responsibly recycled contents materials and building solutions designed for disassembly.

Attia [5] remarked that we should not only seek to lower the operation energy through better energy insulation and by generation of energy on-site, but also lowering the embodied energy consumed upfront in making NZEB. The environmental impact of the used building materials arises during various stages of building lifespan: construction, operation and demolition; for those reasons we should also consider the overall resource efficiency. In this context, the paper reports an attempt of designing nearly zero energy buildings redesigning a temporary pavilion named “Delight the Light”, initially conceived as press room for the event in-Habits during Milan Design week 2018, into a permanent NZEB open lab for university students at the Lecco Campus of Politecnico di Milano.

Different aspects were analyzed from energy, lighting and environmental point of view to verify the feasibility reconstruction and durability of the new configuration and settings using different software according to the output needed.



2. Method of work

This paper presents part of the results of a wider research project, called "Structura", commissioned by Scaff System s.r.l. to Politecnico di Milano. The company, leader in light weight steel structure production, used mainly for logistic purposes (e.g. industrial free-standing modular storage systems) and industrial buildings, set up a research program to expand the use of its brand products into the architectural building sector. The first step to envisage new market branches was obtained throughout a detailed investigation on the state of the art on the field of cold laminated profiles and a competitor's market analysis in comparison with the whole technical solutions of Scaff System structures. The concept idea for the design of "Delight the Light" comes out by combining the results of the products overview, with the Design week theme focused on the challenge of the future dwellings typologies. A holistic optioneering process has been then followed to take into account NZEB regulations, client requests and event needs to perform and verify the feasibility and construction in Milan of the pavilion. After the event, the pavilion has been disassembled and carried in the campus storage for the preparation of its second life. This final phase foreseen a validations steps trough building model simulation to assess different topic necessary to reach the NZEB target and rearrange the space from temporary pavilion to an open lab for university students. The overall method of the research is shown in the Figure 1.

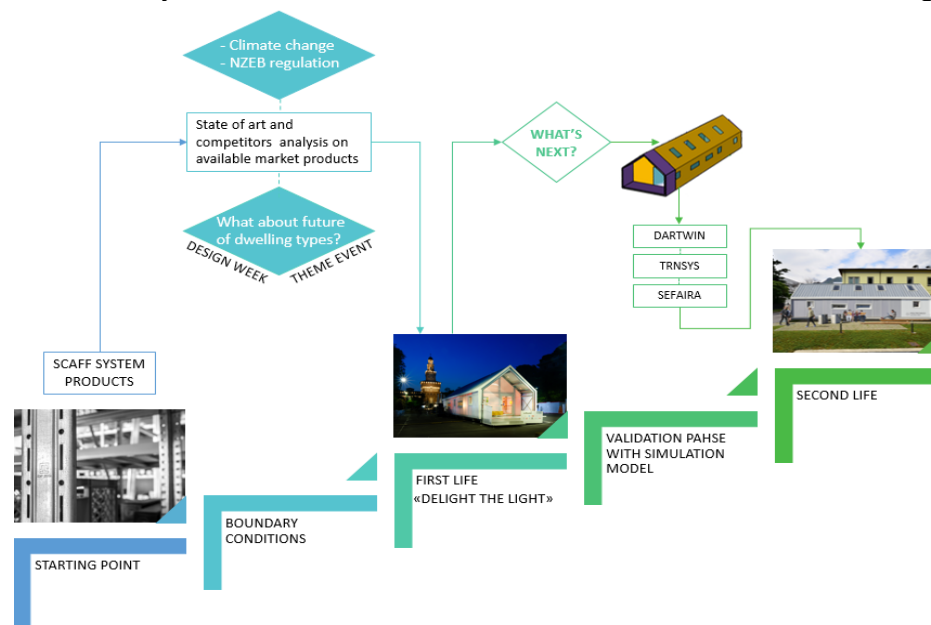


Figure 1. Schematic view of the method

3. Case study

3.1. A temporary pavilion for the 2018 Milan Design Week

The case study presented in this paper is the project results developed for Officina Tamborrino (Scaff System brand) in compliancy to the event theme: "What about the future of the dwelling typologies?" "Delight The Light" has been designed to concretely answer to the need of a dwelling typology for the future: born to be a temporary pavilion, but at the same time to have a new life after the event end.

The polycarbonate cladding pavilion in fact was a beautiful working space with the perfect natural lighting during the day and a light-house during the night, welcoming journalists and technical staff of the Design Diffusion World (DDN) magazine in the prestigious setting of Castello Sforzesco for the entire duration of the Design Week (Figure 2a). The archetype concept of the Home is translated into reality combining the typical hut shape of the shelter with the use of innovative materials and construction system, to bring the structure result forward to modernity looking at the future.

3.2. sNew life: from a temporary pavilion to an NZEB permanent open lab in university campus

As explained in the introduction, since the beginning the desire was to avoid the dismantling of an architectural temporary building after only the event duration, and to give it a second life becoming an

NZEB permanent building (Figure 2b). A well detailed and focused design process has been followed with the aim to re-use the majority of the pre-existing elements, for instance the metal structure, the roof and the deck sandwich panels. Those had been coupled them with thermo-reflective multilayer insulations to enhance the thermal performances maintaining the light weight of the overall structure. Electrical heat pump with 3 kW of photovoltaic panels guarantee low energy consumption with zero local CO₂ emission.

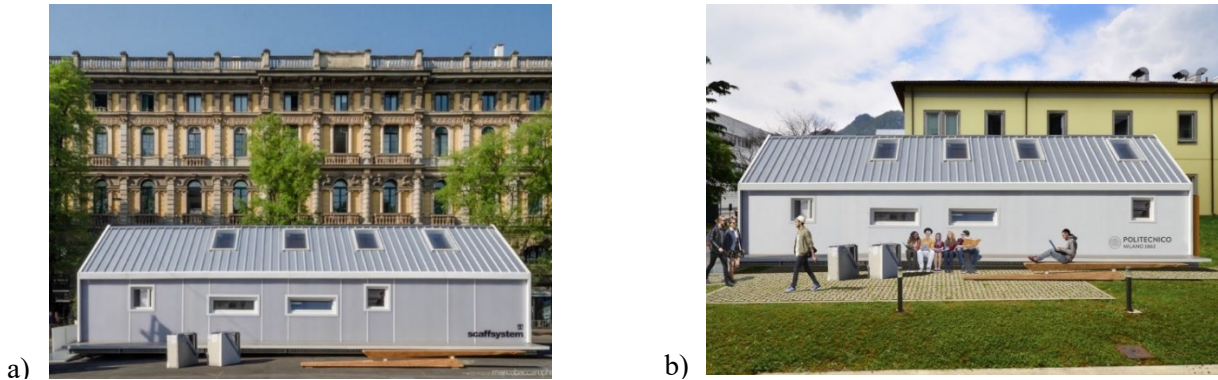


Figure 2. a) “Delight the Light” at Milano Fuori Salone 2018 b) Render of NZEB Open Lab in Lecco

In particular ad hoc dry-layered structure has been investigated for walls, roofing and deck with the addition of high energy efficient thermo-reflective insulation materials derived from aerospace technologies assuring high level of insulation in minimum thicknesses. The building is in fact conceived as an airplane cabin, completely covered with this sort of materials, both from the outside as well as from the inside. Following the design optimization method to reach an NZEB target, different scenarios have been analyzed at finite elements with the software Dartwin Mold Simulator Dynamic, baseline climate conditions set up critical temperature equal to 5° C and critical relative humidity levels equal to 80%, to determine and verify the thermo-hygrometric performances and to choice the more appropriate stratigraphy. The vertical closures are dry mounted wall system composed by several resistive layers contained by simple plaster finishing that hides the lightweight structure. The overall thermal performance is high with U_{value} equal to 0.02 W/m²K. The different insulation layers are chosen taking into account the summer climate conditions. Therefore, high-density materials are alternated inside the layers in order to obtain an optimum value of periodic thermal transmittance (Y_{ie}) equal to 0.02 W/m²K, with high time lag (more than 12 h). In the same way, the roof technology has been designed coupling high resistive layer (polyurethane sandwich panels) with high density insulation (fiber wood) with a total U_{value} equal to 0.08 W/m²K and a periodic thermal transmittance equal to 0.01 W/m²K.

Table 1. Wall’s materials and thermal characteristics

	Material	Th. mm	λ W/mK	Density kg/m ³	U W/m ² K	Y_{ie} W/m ² K
1	Plastering	0.6	0.30	600		
2	Fibrocement	1.25	0.350	1150		
3	Air vent gap	50.0	0.556	1.0		
4	Breathable sheet	0.18	-	-		
5	Wood fiber	16.0	0.090	565.0	0.02	0.02
6	Actis trisolaine	40.0	0.040	1.0		
7	Wood fiber	80.0	0.038	50.0		
8	Actis Hybris	100.0	0.033	10.0		
9	2x plasterboard	2.5	0.200	2500		

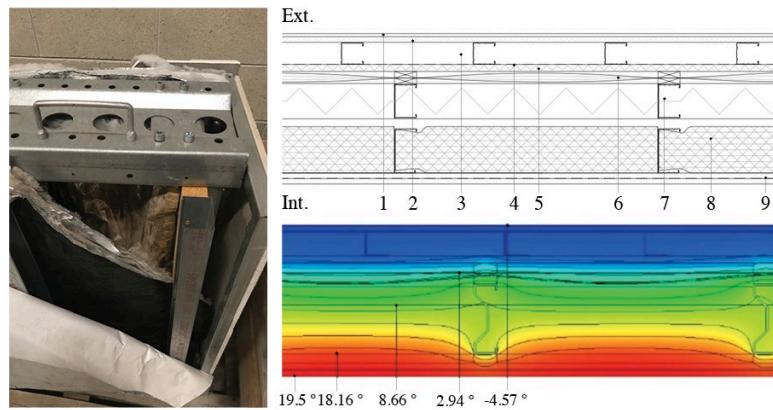


Figure 3. Wall's sample, his graphic draw and FEM thermal analysis

Table 2. Roof's materials and thermal characteristics

	Material	Th. mm	λ W/mK	<i>Density</i> kg/m ³	U W/m ² K	Y_{ie} W/m ² K
1	Sandwich panel	100	0.022	30.0		
2	Wood fiber	100	0.038	50.0		
3	Actis trisolaine	40.0	0.040	1.0		
4	Os b panel	25.0	0.13	550	0.08	0.01
5	Air vent gap	100	0.28	1.0		
6	Actis Hybris	100.0	0.033	10.0		
7	Glasswool	50	0.033	50		
8	Plasterboard	1,25	0.200	1250		

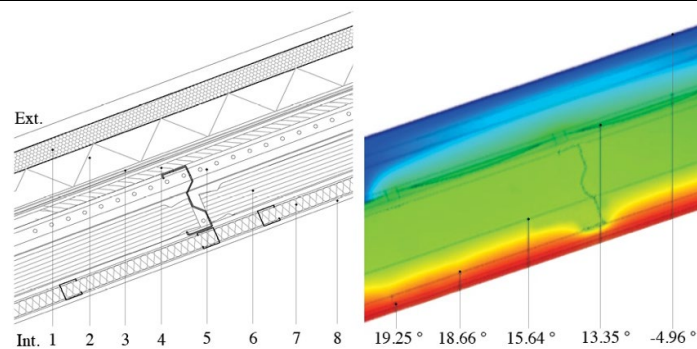


Figure 4. Roof's graphic draw and FEM thermal analysis

4. Building model

The following section presents the building model characteristics considered and analyzed through dynamic simulations for the energy needs estimations. TRNsys v18 [6] simulation environment has been used to enhance the effect of both thermal inertia and resistivity of the developed envelope technology. The simulations have been carried out with 30 minutes time step to show in detail the responds of the building system to internal and external loads. The building model has been considered working in free-floating temperature variation in order to analyses the impact of the technological and architectural design due to the specific climate context and the human-building interaction.

The building geometry has been modeled using Trnsys3d plug-in for SketchUp. The model has been designed considering its geolocalization into the Campus in order to take into consideration, within the simulation assessment, also of the specific climatic context, the surrounding buildings that will impact with massing and shadows on the building thermal and lighting performances. The building has been

modeled as a single thermal zone representing the working open space and assuming a continuous use from 8 am to 8 pm with a mean presence of students equal to 20.

5. Results and discussion

Energy demand was calculated using dynamic simulation approach taking into account the thermal properties of the envelope, the use of the building and the new location. Lighting systems were designed to guarantee adequate indoor illuminance values considering different furniture configurations and the effect of natural and artificial light. The simulation results demonstrate that the new life of the “Delight the Light” solution can be considered as a low energy intensity building. The applied energy efficient design principles encompass all the available techniques of creating a ‘healthy’ interaction between indoor and outdoor climate conditions in buildings using less energy as possible. The Figure 5 shows the response of the building to the climate local condition: the winter months are clearly more energy intensive respect to summer season also due to the shading effect of the surrounding.

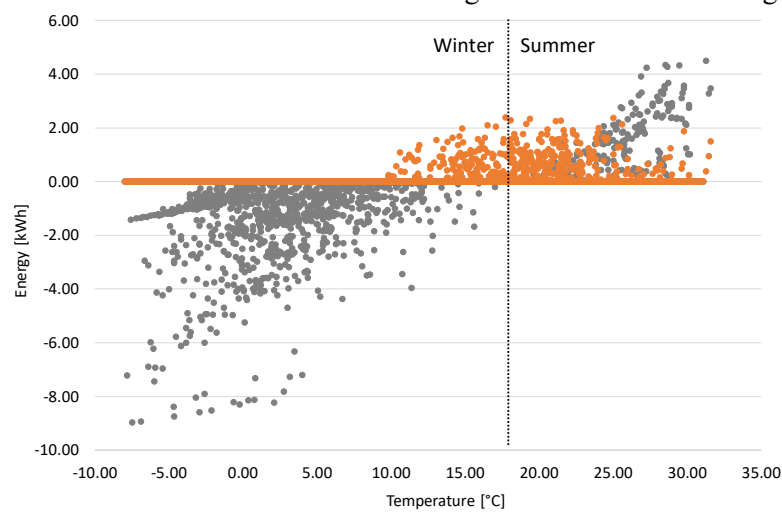


Figure 5. Building energy demand versus outside ambient air temperature. Grey and orange dots represent respectively sensible and latent energy.

The pitched roof has been designed for hosting a PV power plant to guarantee a local renewable energy production. The PV power plant system of 3 KW has been positioned on the east-south oriented pitch due to the shading effect of the building. The analysis shows as expected an overproduction during the summer month and an underproduction during the winter period. The annual energy balance is positive with an energy surplus equal to 865 kWh.

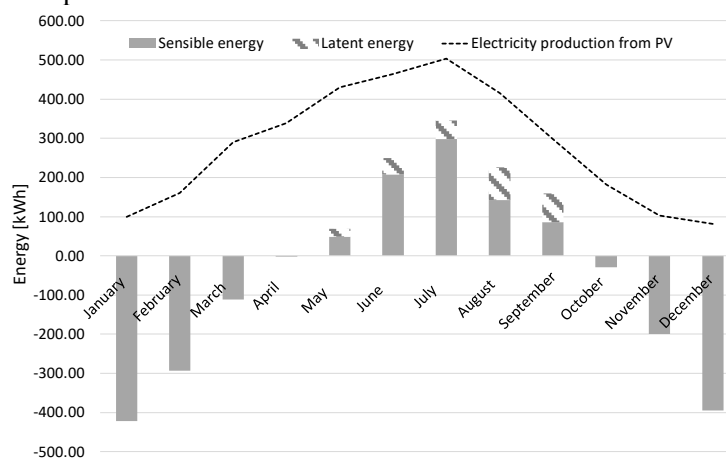


Figure 6. Monthly energy balance: columns represent E absorbed, dashed line the E produce by PV.

The figure 6 shows the monthly energy consumption of the building. The overall energy consumption is equal to 31.9 kWh/m²y (21 for heating, 11 for cooling comprehensive of dehumidification energy). The energy needs show high energy consumption during the winter month due also to the low direct solar gains. Finally, in Figure 7 is presented a daylighting visualization of the respective comfort validation considering the lux levels at a desk high due to the user final goal of the second life of the building, mainly an open lab for students' activities.

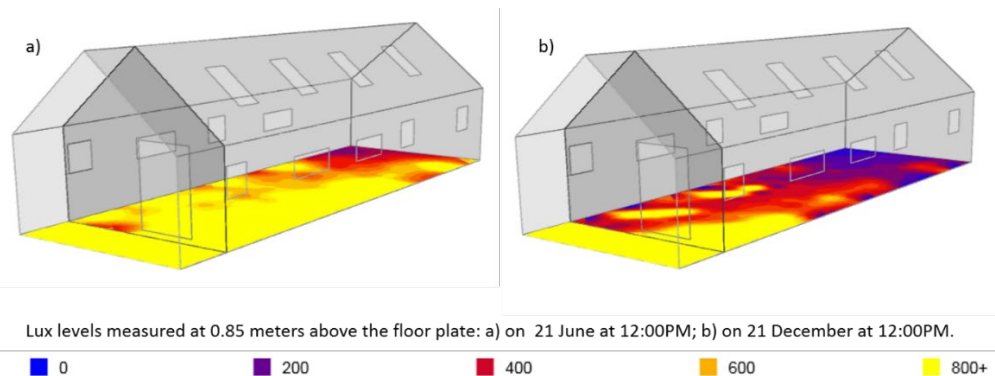


Figure 7. Natural daylight analysis study performed with Sefaira Daylight Visualization.

6. Conclusions

The paper describes as a case study an example of nearly zero energy buildings redesigning a building initially conceived as a temporary exposition pavilion. The upcycled construction is a permanent NZEB open lab for university students at the Lecco Campus of Politecnico di Milano. The high-quality architectural design with high thermal envelope quality allows to reach high standard level with low energy consumption and it demonstrated that energy and thermal simulations are a valuable tool to use since the early design phase for building energy renovation.

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