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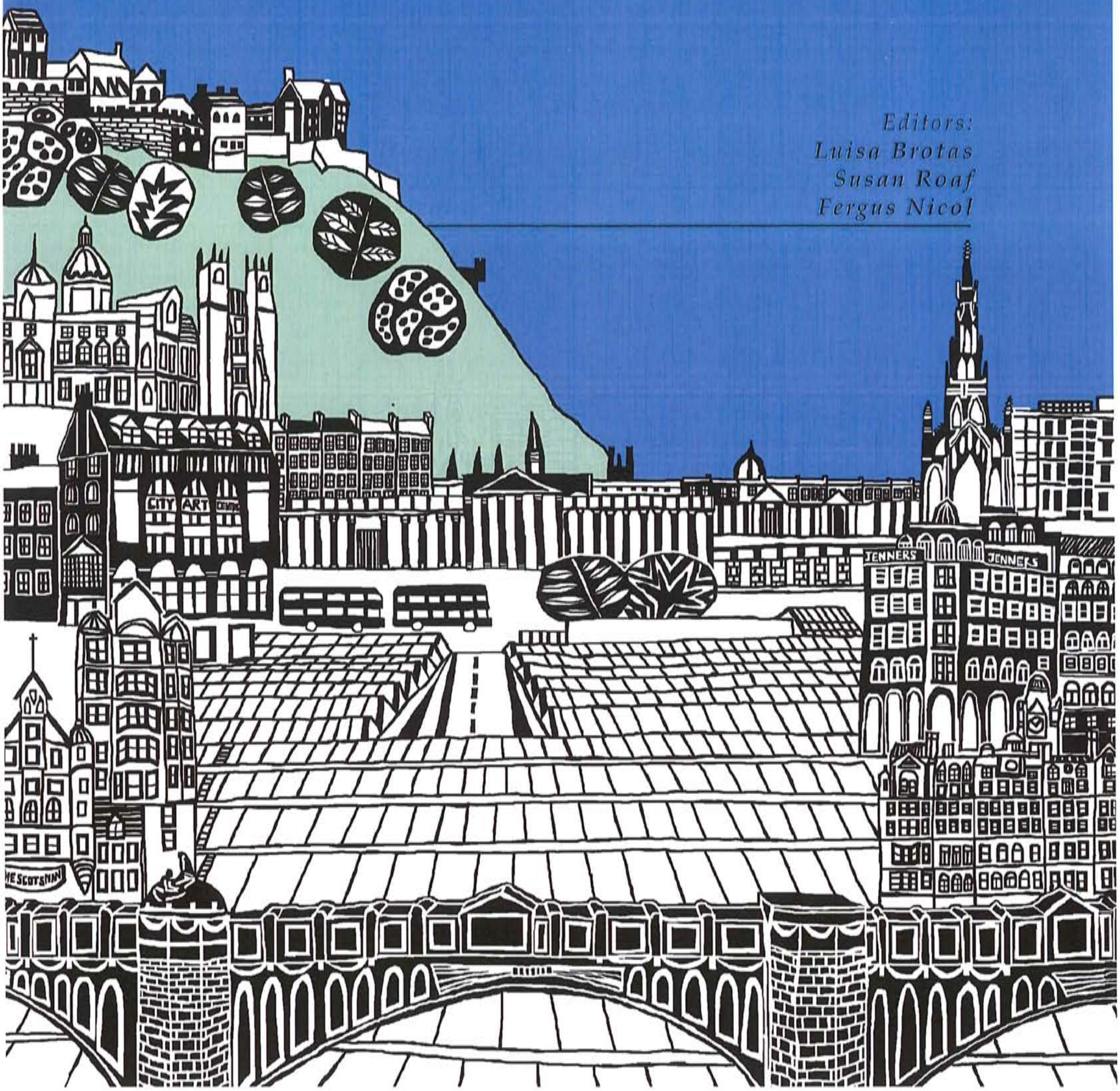

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Introduction to the Proceedings of PLEA 2017

The question we all too often forget to ask is Why? Why, for instance did we in Edinburgh set out on the PLEA 2017 journey to give ourselves all the very hard work of creating a huge conference in which people from all over the world were invited to discuss and develop ideas of Passive and Low Energy Buildings (PLEA)? Well the answer is that we believe the issue of good building design, embraced for thirty five years by the PLEA movement is simply one of the most important there is in the evolution of a safer world in which people will be able to live comfortable and affordable lives in a rapidly changing world.

The PLEA organisation started in 1982 as a small group of international friends dedicated to the ideal of sharing knowledge on how to design and operate minimal and renewable energy buildings. The development of solar buildings lay at the core of its ethos in those early days and still does. PLEA now has a membership of several thousand professionals, academics and students from over forty countries (www.plea-arch.org). Having expected three to five hundred abstracts for the 2017 PLEA conference we were overwhelmed by more than fourteen hundred.

It is obvious that the time for PLEA thinking has come.

Where better to share these important ideas than in Edinburgh, the 18th Century capital of the European 'Age of Enlightenment'? It is here we set about creating our Team Scotland to organise the conference, held on the 2nd – 5th July 2017 and including 665 papers published in these Proceedings. The impressive list of people who helped us included: the Scottish schools of architecture and engineering, the City of Edinburgh, the Scottish Government, Historic Environment Scotland, the Royal Incorporation of Architects in Scotland, the Chartered Institution of Building Services Engineers and a host of related professional companies and organisations.

Reflecting the diverse interests of the team involved, the subject matter of the conference is separated in the following proceedings into papers sorted according to the thirty-one Forums in which they were presented at the conference. Readers should first review the contents lists to see which subject areas are of particular interest to them and then browse through the varied papers by selected Forums. Separation of the papers into these various fields enabled authors to present their ideas at the conference to smaller groups with whom they could expertly explore and discuss their own results while learning from other related studies that might lend light to their own thinking.

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Design to Thrive

From lightweight pioneering steel houses to zero energy buildings

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Abstract: In XX Century California, three generations of architects pushed the boundaries of language, experimenting the use of then uncommon materials to build lightweight, modern houses. It all began with Neutra in the 30's, who achieved the ideal of the house made like a car, building his Lovell house out of steel framing and sprayed concrete at a time when his European counterparts applied machine aesthetic to houses who still were brick and mortar below the clean coat of white plaster. Architects such as Ellwood, Eames, Soriano and Koenig produced a fascinating skin and bone aesthetic, making no nonsense use of commercial steel sections in order to produce economical yet refined buildings. However, it was not just their fascinating aspect, but the logical, almost scientific, approach that makes those buildings so appealing. Today's knowledge of materials, energy conservations and building dynamics can produce high performance buildings that greatly improve on yesterday's standard. A case study shows how sites and building technologies work together. Sites was studied to minimize excavations and exploit prevailing breezes in order to minimize use of HVAC. A dynamic analysis of the building was run to determine the composition of walls and roof and glazed surfaces.

Keywords: residential architecture, bioclimatic design, dry-assemble technology, nZEB, Californian architecture

Lightweight Californian steel houses

Innovation in the twenties

In his History of Architecture of 1899, Auguste Choisy wrote that "styles do not change following the whimsies of fashion, variations are the results of changes in the construction process". In the early twentieth century, the industrialization of processes in most spheres of man made products, led progressive architects to promote a new wave of industrialized buildings. "If houses were built industrially –wrote Le Corbusier in 1920- in line, as automobile frames, we would quickly see the rise of unexpected, yet healthy, forms, and the aesthetic would be formulated with surprising precision". On the same page we find Richard Neutra, who preached that "the house of the future will be built out of standard steel components, assembled like a car, and it will take on a beauty which will not be based on the old decorative forms, but on a new beauty of rhythm and order" (Neutra, 1931).

However, if Europe was the one pushing the ideal of the "house built like a car", it was America who made this dream possible. Between 1927 and 1929, at a time when his collegues back home were applying machine aesthetic to houses which were still brick and mortar below the clean coat of white plaster, Neutra was building the Lovell House out of steel and sprayed concrete (fig. 1).

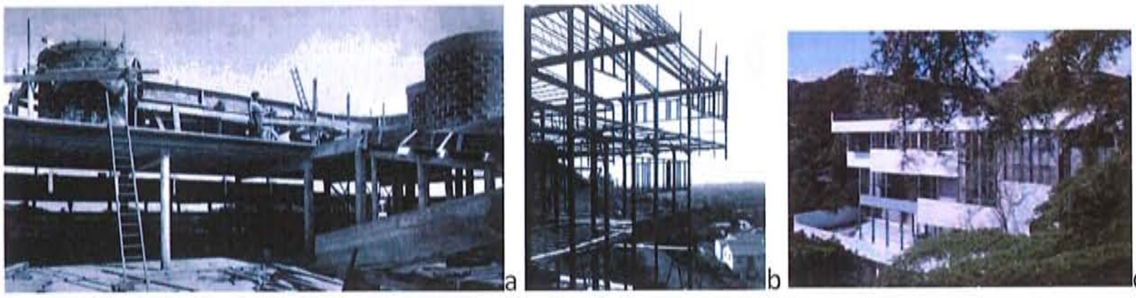

Figure 1 a/b/c. (a) Le Corbusier-Jeanneret, Ville Savoye, 1928-31. (b) (c) Neutra, Lovell House, 1927-29

Neutra's biographer Thomas Hines claims it to be "the first steel framed residence in America". This is a well-established notion, but it is not true. In fact, a research published in 1930 by the America Institute of Steel Construction[1], records six steel framed homes in 1927, 42 in 1928 and 65 in 1929. In fact, although the first steel framed residence in America was built near New York almost thirty years earlier, what makes the Lovell House stand out and steal the limelight is well summarized by Kenneth Frampton, who defines it the apotheosis of International Style, thanks to an architectural expression directly derived from a steel frame, clad by a light synthetic skin (Frampton, 1980). Design of Steel Buildings by Harold D. Hauf, first published in 1932 and probably the first manual on steel construction in the US, is a good meter of the Lovell House achievement. In fact, studying this manual, it becomes clear that technological and aesthetical innovation did not go hand in hand: besides the framing, the steel buildings were not different from most current production.

Developing a language

To develop a language that fully exploits the potential of new materials and technologies takes time. If the Lovell House, with its steep site, free flowing plan and big glazed surfaces was making full advantage of steel, it was not yet the epitome of the light steel and glass pavilions associated with California lifestyle. This is mostly due to one reason: steel profiles were not visible in the finished building if not as window mullions (fig. 1b and 1c).

The minimal skin and bone aesthetic, defined by Reyner Banham "The Style that Nearly...", was to appear another thirty years later, at the peak of Arts and Architecture Magazine Case Study Houses program (Banham, 1971). It was the development of a process of expression of the steel frame which allowed Raphael Soriano to show most of it in the forties, and Pierre Koenig to show it all in the fifties. In between these experiences are those of Charles Eames and Craig Ellwood. Eames built for himself a house which was of great consequence, especially in Europe, where it came to epitomize the potential of a residential architecture made out of off-the-shelf components, dry assembled (fig. 2b). Ellwood built some significant specimens which helped define the new architecture vocabulary, before shifting towards Miesian mannerism.

[1] Facts and Figures about Steel Construction

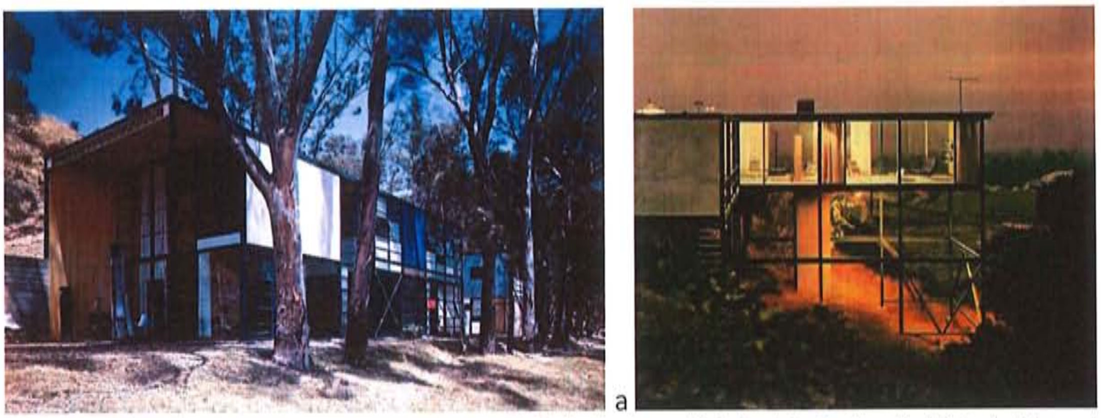

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Figure 2 a/b. (a) Charles Eames, Eames House, 1949 (J. Shulman/© J. Paul Getty Trust). (b) Craig Ellwood, Smith House, 1958 (© Marvin Rand)

Whilst Soriano tested the use of steel in houses more than anyone else before him, proving it was possible to use the material within ordinary budgets, it was Koenig who delivered the most memorable shot in the CSH #22, hovering above West Hollywood and incarnating modern lifestyle in countless movies and commercials (fig. 3a and 3b).

a b c

Figure 3 a/b/c. (a) Raphael Soriano, CSH #1950 (J. Shulman/© J. Paul Getty Trust). (b) Pierre Koenig, Case Study House #22, 1959-60 (J. Shulman/© J. Paul Getty Trust). (c) P. Koenig, Case Study House #21, 1958 (©author).

Still, Koenig did not limit himself to fully developing a convincing aesthetic for steel in residential buildings, but moved one step further in pioneering the use of passive means to cool his houses at a time when steel and glass buildings were made possible not only by the materials themselves, but by the massive use of HVAC systems. The fact that these passive means became so inextricably tied to what makes the best Koenig's buildings iconic is proof of how the conscious use of energy and available resources can the final look of a building in a successful way. In CSH #21, his most successful demonstration of a repeatable building for mass production, he relied on the orientation of the building to block the sun, completely blinding facades on the East and West, where solar radiation is more difficult to control, and using a vertical external sunscreen on the South and North facades (fig. 3c). He adopted wide overhangs in CSH#22, which worked especially well in giving the house a "floating" quality over the dramatic hillside site.

Moving forward

Although fascinating on their own, buildings by Soriano and Koenig share a logical, almost scientific, approach that makes them especially appealing. Each is a step forward in pushing the progress of a specific building type. Whilst Soriano devoted over 20 years of his professional life to releasing the potential of steel, in his later years he applied himself to exploring the application of the even lighter aluminum, while Koenig moved forward on the path of exploiting passive means of getting rid of HVAC, establishing the Natural Forces Laboratory at USC. The interest in bioclimatic design already present in his work of the fifties was further developed in projects such as the house he built for himself in the mid-eighties, were free cooling techniques are tested.

The first Californian experiences of bioclimatic and low-energy houses of the 60s and 70s were joined by the "intelligent building" concept of the 80s, when several buildings gradually included the control of various equipment and systems. From these experiences, the US Department of Energy (DOE) launched the Zero Energy Home Initiative (ZEHI) in 2003 and the Building Technologies Program (BTP) in 2008 (Panagiotidou and Fuller, 2013). For the ZEHI, five demonstration projects have been developed, most located in California. For the BTP, the aim is to introduce a common national Zero Energy Building definition with supporting nomenclature and guidelines to facilitate its use. Crawley et al. (2009) has provided the first definition of ZEB as "a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies". A broadly accepted definition of ZEB metrics and boundaries is foundational to efforts by governments, utilities, or private entities to recognize or incentivize zero energy buildings, and would have a significant impact on the development of design strategies for buildings[2]. Then, the net Zero Energy Building is not a building where the energy demand is zero, but a building for whom the energy delivered is equal to the exported energy for 1 year of operating.

The Case Study: the Grand View drive House GVH

Lessons from the former generations along with new building design technology aids were applied to the design of a new single family residence in the Laurel Canyon area of Los Angeles in 2013[3]. Here, the constraints posed by site, accessibility and building codes made for a small project of amazing complexity, located in a high fire hazard severity zone in a region whose seismic risk ranks among the highest in the world. The lot is steep and narrow, sloping South to North on top of the ridge of the hill above West Hollywood. It is an interesting coincidence that the site at 8413 Grand View Drive sits on an ideal line joining Case Study House #21 and #22 by Pierre Koenig.

The themes developed in those seminal houses overlap in Grand View: the site shape calls for a building orientated on the North/South axis as in CSH#21, and the challenge of building on a slope, dramatized in CSH#22, is even more demanding here. Yet, the steep slope and the height limit regulation implies that a single story pavilion as the CSHs is out of question, thus linking Gran View House GVH to other precedents in the off the shelf prefabricated steel framed houses lineage: Helmut Schulitz's own house in nearby Beverly Hills and Koenig's Gantert House in the Hollywood Hills (fig. 4). Dimitry Vergun, structural engineer for the latter and Grand View House, is an even more direct connection ring.

[2] https://energy.gov/eere/buildings/zero-energy-buildings

[3] Gran View House, Los Angeles (USA). (PAT. architects, 2013)

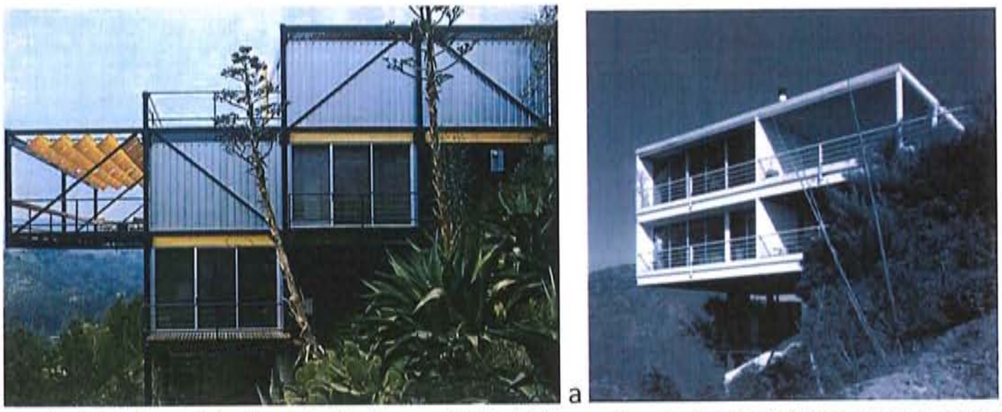

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Figure 4 a/b. (a) Helmut Schulitz, Schulitz House, 1976. (b) Pierre Koenig, Gantert House, 1981 (J. Shulman/© J. Paul Getty Trust).

From the road the lot slopes downhill facing the Canyon. Early studies explored the potential of the building to grow in height trying to reach city views versus the temptation to cantilever a simple box on the size of the hill, minimizing excavations. The final massing is composed by a three storey "tower" and a two storey "box" separated by a pool. The garage at street level is on top of the tower, a studio/recreation room is at level -1, a storage at -2, which is the level the "box", partially cantilevered, is accessed. Served and servant spaces are separated and clearly articulated. Not only service spaces such as storage and garage are separated by the living quarters, but also vertical circulation and toilets are moved to the periphery of the building and become both a mean for architectural expression and a way to fit the trapezoidal contour of the lot.

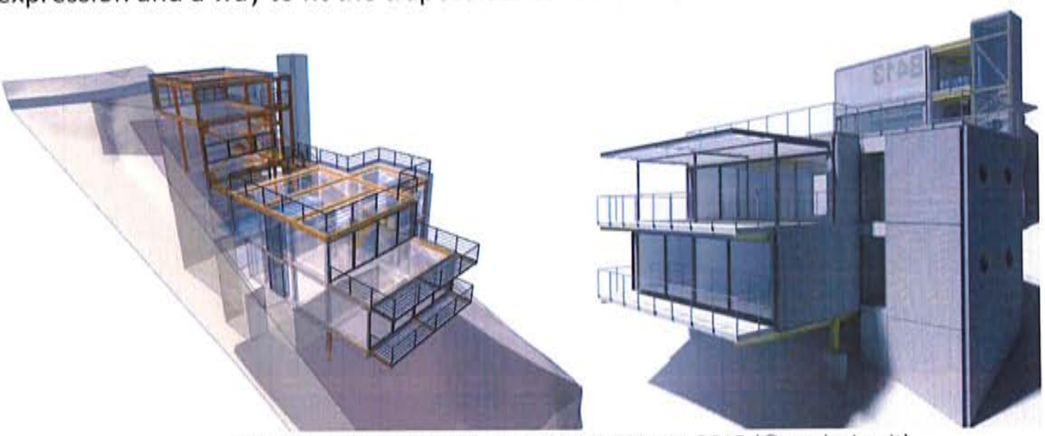

Figure 5. PAT. architects, Grand View House, 2013 (©patdesign.it).

Integrated design: architecture, technology, structure and systems

An integrated design team was assembled for the task and worked with an holistic approach to nurture synergies and interactions. The case study shows how site and building technologies worked together to improve building efficiency. The Site was studied to minimize excavations and exploit prevailing breezes in order to minimize use of HVAC. The building was oriented on the North-South axis, with sides facing East and West almost completely blinded in order to control solar radiation, while North and South facades, easier to shade, are glazed and open to cooling breezes. Lightweight, dry assembled techniques, typical of the Region and appropriate for the task of building on a hillside, were preferred. Nevertheless, it was deemed appropriate to have some mass for thermal comfort. The use of PCMs, summing up lightness and passive cooling properties, was explored and eventually discarded. Steel bays spanning 26 feet support composite metal floors, whose screed is polished and exposed in order to avoid further finishing and exploit the thermal mass. A dynamic analysis of the building provided the basis for determining the composition of walls and the roof and the specs for glazed surfaces. The analysis led to discard the use of SIPS panels, originally envisioned for their ease of construction, LEED credential and high R value, and opt instead for a multi layered ventilated facade clad in galvalume sheets.

All the design strategies contribute both to reduce the energy needs enhancing energy efficiency with passive and active technologies, and to generate on-site energy balancing cost and benefit. In term of ZEB strategy, table 1 summarized the measures applied in the case study presented.

Table 2 – net Zero Energy Building strategies of the Grand View drive house

ENERGY EFFICIENCY	DESIGN STRATEGIES
site and orientation	Orientation on the North-South axis, with sides facing East and West almost completely blind in order to control solar radiation.
advanced thermal insulation	Dry assembled envelope highly insulated and without thermal bridges.
high thermal mass	Dry assembled envelope with high density insulations and exposed screed to exploit the thermal mass.
sun-shading and ventilation	Glazed North and South facades, shaded by the balconies and overhangs, opened to cooling breezes and natural light.
mechanical ventilation	Efficient HVAC system embedded in ceilings and walls and integrated with passive night cooling. It takes benefit from the building thermal mass.
comfort outdoor	The presence of the pool cools the air on the outdoor spaces
water demand	System for collecting and reusing grey and rain water
ON-SITE ENERGY PRODUCTION	
solar thermal collectors	Domestic hot water production
photovoltaic panels	Electricity for systems, lighting and home's appliances

Dynamic analysis

A dynamic analysis of the building under study has been carried out in order to determine both the composition of its walls and roof and the thermal specs of its glazed surfaces. A dynamic analysis requires little extra effort at the design stage and bring advantages such as: the optimization of the envelope system and its relationship with the mechanical systems, reducing operational energy loads; it allows to earn extra points in voluntary environmental assessment tools and the related economic benefits.

From its early stages the design of a nZEB building requires an integrated approach involving different professionals and a careful evaluation of the thermal flows needed to determine the overall building energy balance. The design is aimed at assessing and controlling the future winter and summer thermal performances reducing the load on air-conditioning plant systems and ensuring high hygrothermal comfort.

The design choices of Grand View Residence were all supported by thermal analysis derived from simulation models and characterized by different detail levels on the basis of the specific project needs and phases. For each component of the building envelope, both winter and summer thermal behaviour parameters were compared with the project targets so as to validate or reject the choice made for stratigraphies and constructive nodes. Table 2 allows us to compare the values of thermal transmittance (U), periodic thermal transmittance (Y), phase shift (φ) and attenuation (a) of specified building roofs (R) and walls (W) with the target values assumed by the designers. The building components adjoining the external environment and exposed to sunlight, are characterized by high thermal lag values: more than 7 hours for walls and more than 12 hours for horizontal roofs being particularly affected by solar radiation in the summer and therefore potentially responsible for the interior overheating. The choice of using insulating materials characterized by a low value of thermal conductivity, high values of mass density and specific heat, enables a lightweight dry assembled structure to get high summer thermal performances.

Table 2 - Performance characteristics of the individual components.

	U [W/(m²K)]	U target [W/(m²K)]	Y [W/(m²K)]	□ [h]	□ target [h]	a [-]	ENVIRONMENT
W01	0,225	< 0,4	0,082	7h 01'	> 7 h	0,3637	SUN
W02	0,223		0,062	7h 54'	> 7 h	0,2808	SUN
W03	0,388		-	-	-	-	GROUND
R01	0,386		0,235	5h 01'	-	0,6098	SHADE
R02	0,365		-	-	-	-	GROUND
R03	0,182		0,046	12h 19'	> 12 h	0,2539	SUN
R04	0,190		0,047	12h 58'	> 12 h	0,2482	SUN
R06	0,183		0,023	7h 59'	-	0,1233	SHADE

The design choices with regards to the shape, orientation, and the exposure of the building, as well as the envelope technologies and facilities, were supported by an hourly thermal evaluation (dynamic analysis), through the use of TRNSYS software - Transient System Simulation Tool. The calculation has been carried out for a full calendar year in order to quantify both winter and summer thermal loads, temperature profiles in the absence of air conditioning and air conditioning operating hours to maintain comfort levels. Table 3 shows the boundary conditions used for the TRNSYS computation.

Table 3 - Boundary conditions used for the computation

Parameter	*Values*
Temperature	20°C heating 26°C cooling
Local employment / operating systems	24/24h, 365 days
Internal thermal contribution	5 W/m² (50% convective, 50% radiative);
Ventilation	0,5 vol/h

Figure 5 illustrates the results of the simulation analysis of two types of insulated and low-emissivity glass: A) Ug= 1,4 W/(m²K) and g= 0,59; B) Ug= 1,26 W/(m²K) e g= 0,4. The choice of glass B) allows to reduce solar radiant contribution: as a consequence air conditioning load is reduced by 33% in the summer, thermal requirement is reduced by 36% in the summer even though, in the meantime, it is increased by 16% in the winter.

The building as a whole, has a thermal requirement of:

- Summer: 20,98 kWh/(m²year)
- Winter: 18,33 kWh/(m²year)

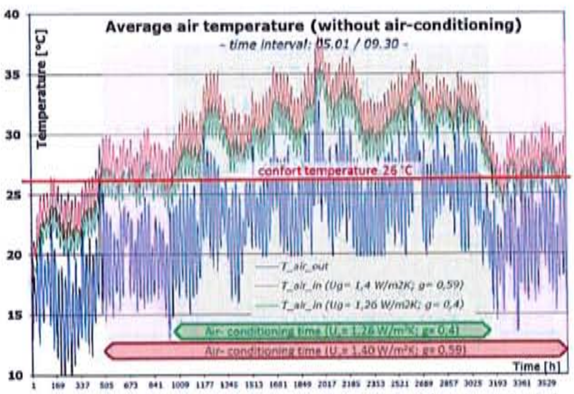

Figure 5. Dynamic simulation analysis of two types of insulated and low-emissivity glass: A) Ug= 1,4 W/(m2K) and g= 0,59; B) Ug= 1,26 W/(m2K) e g= 0,4

Conclusion

Following in the footsteps of Auguste Choisy, Raphael Soriano said that "the process of questioning, validating, and designing for performance is what bring progress in architecture" (Laskey, 1988). New aesthetics can arise as a result. Advances in construction techniques and computer aided design, along with a rising conscience of the centrality of an integrated design approach can foster both efficiency and the development of an architectural language. But aesthetics by itself does not tell the whole story.

Looking at picture 6, a comparison between the stratigraphy of CSH#21 and GVH highlights how the complexity has increased below the skin of buildings.

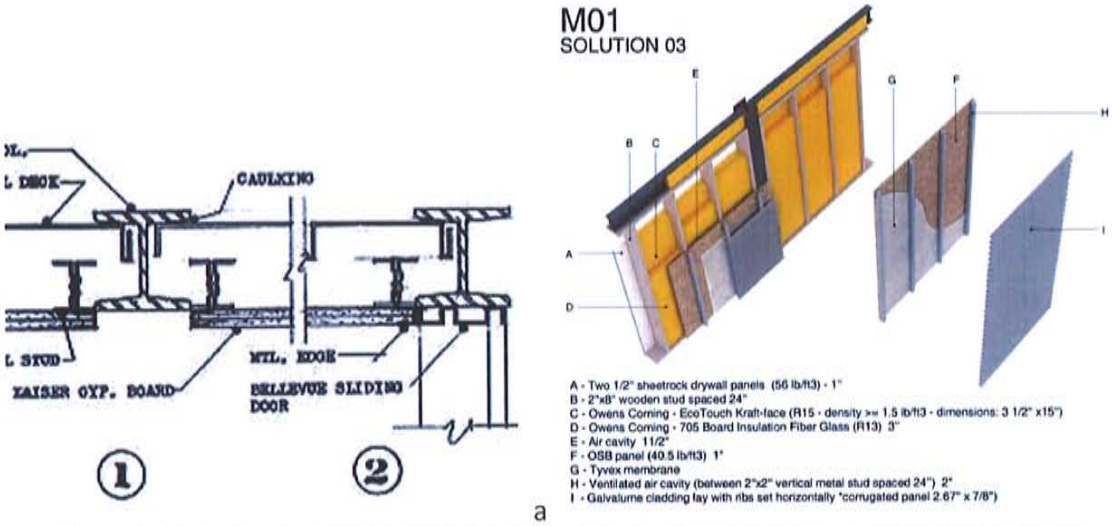

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Figure 6 a/b. (a) Koenig, CSH#21, 1958 (b) PAT. architects, Grand View House, 2013 (©patdesign.it).

New software allow to verify design hypothesis, guiding choices toward maximum performance and improving the understanding of the building over its entire life cycle. An interesting outlook of the research could be the comparison of several recent buildings of the same typology in order to recognize benchmarks and improve the state of the art.

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