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SBE21 Sustainable Built Heritage: renovating historic buildings towards a low-carbon built heritage

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SBE21 Sustainable Built Heritage: renovating historic buildings towards a low-carbon built heritage

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Foreword

From small medieval towns to nineteenth-century boulevards or post-modern concrete structures, buildings reflect our culture and should be preserved for our future generations. In Europe, historic buildings account for a quarter of the existing building stock. Renovating these constructions presents many opportunities for reducing carbon emissions and for improving the comfort of the people living and working inside. However, this can be particularly challenging. Each building is unique and needs specific measures to enhance energy efficiency while preserving historic and aesthetic traits. In this sector, the "one-fits-all" approach hardly applies.

From the 14th to the 16th April 2021, the SBE21 Heritage Conference brought together experts working in the fields of energy efficiency and historic building conservation. The conference aimed at fostering multidisciplinary dialogues and finding new affordable and efficient retrofit approaches to save our common heritage and guarantee a sustainable future. Scholars and practitioners worldwide were invited to send their contributions and participate in the debate.

Being the event also the final conference for three research projects at Eurac Research – IEA-SHC Task 59, Interreg Alpine Space ATLAS and HyLAB –, the conference was a great opportunity for these projects to present their findings and achievements, in 34 scientific papers and oral presentations, two workshops on *Balancing heritage preservation, local RES potential and BIPV technology exploitation* (IEA-SHC Task59 and BiPV meets History) and *Historic Buildings Retrofitting 4.0: The Potentials of Simplified Digital Twins in Low Carbon Retrofitting of Historic Buildings* (ATLAS) and organizing the "Research meets Practice day" with seven best practice presentation and a round table discussion. These best practices, along with other examples of energy retrofits of historic buildings, have been thoroughly documented for the www.hiberatlas.com database and can be accessed online. The main outputs of the roundtable were summarised by Franziska Haas, moderator of the discussion and president of the ICOMOS Scientific Committee on Energy and Sustainability, and included in these proceedings.

The conference had to be organised as a virtual event due to the constraints of the global pandemic. However the decision to organize it as "like presence" virtual conference – without recording and the risk to dilute the presence – with as many direct interactions as possible (ranging from limiting parallel sessions to two, having moderated question and answer sections, providing the pre-print of papers to the audience and offering the possibility of virtual coffee breaks to catch up with colleagues and ask directly to speakers), proved to be the right one. We had around 140 registrations, and on average two thirds actively participating in the parallel sessions. More than 30 scientific papers came from complementary projects and research groups, showed that the event was able to attract the research community working on the topic and to give a comprehensive picture of the state of the art of the research on retrofit for historic buildings.

The Sustainable Development Goals, as proposed by the UN, stood at the centre of conference topics. Actually, papers related to two to three SDGs on average: SDG 11 "Sustainable cities and communities" with 33 being the most tagged one, but also SDG 13 "Climate action" with 22 tags and SDG 7 "Affordable and Clean Energy" with 24 tags not being left behind. Furthermore, SDG 3 "Good health & well-being" (15), SDG 9 "Industry, innovation and infrastructure (10), SDG 4 "Quality education" (9) and SDG 12 "Responsible consumption and production" (8) were also mentioned often highlighting the importance of historic building renovations in social implications, the

economic dimension, the need for involving the future generations, or the common responsibility of society.

Themes of the research projects mentioned above led to the three conference's thematic tracks. Firstly, "*Conservation of heritage and resources in the built environment"* collected contributions ranging from climate resilient design solutions to integration of renewables solutions underpinning the hypotheses that conservation of our built heritage and natural resources will go hand in hand in the near future. Secondly, "*Creating favourable framework conditions"* studied the question what is needed to foster renovations of historic buildings, looking at policies and programmes, as well as education experiences and examples of best practice, that can enable a faster implementation towards a low carbon built heritage. And finally, the third track "*Development, analysis, and implementation of technical solutions"* showed that innovation in materials, products and systems will be key in achieving a low carbon built heritage.

After three days full of interesting presentations, motivational keynote lectures, informative workshops and a roundtable that included some of the key actors in the field of energy renovation of historic buildings, it is important to summarise some of the key messages that emerged from the conference.

The importance of dialogue and exchange was a recurring topic across all sessions, starting with the role of *Heritage* in achieving a sustainable built environment. As Dr Ege Yildirim pointed out during her opening keynote lecture, Heritage has been identified as a cross sectional issue in most of the Sustainable Development Goals. However, these references to heritage can only be found implicitly in the text and for those not working in the field it can be easily overlooked. This poses some interesting questions regarding the role of heritage, and more specifically the built heritage, in the European agenda. Why is it only implicitly recognised? How can it be made more explicit? The same way that the heritage significance of a post-war building might not be immediately evident, and the guidance of an expert is sometimes needed, the value and potential of heritage in achieving a better and more sustainable future for all must be highlighted. Now, we, as scholars working in the field, have the opportunity to use the results of our research to shed light on the importance of heritage in our changing climate and society so that new policies can be brought forward.

Reflecting on the significance of heritage is not only important in defining its role in the future agenda, but also in achieving a deeper understanding of what a building might represent and reasons to protect it for the future, and thus informing the adoption of the suitable interventions. Focusing only on an adaptive reuse that is strictly compatible with the elements worth of preservation might hinder potential ideas. If heritage is not seen just as a label but rather as a process, a new possibility to present heritage as a negotiated and re-negotiated cultural asset arises, as the work of Stijn Cools has shown.

The idea of a "negotiation space" has been present in several presentations, especially when it came to unveiling the narratives behind some of the best practice examples of energy renovations presented during the conference. The experiences that Prof. Harald Garrecht shared during his keynote lecture showed that establishing a dialogue around a working table that includes heritage and industry views makes possible what in the beginning of a project might look impossible. Sometimes the development of new prototypes is needed (and possible), but sometimes just giving access to a broader range of solutions might be enough to overcome a barrier that otherwise felt decisive.

The SBE21 Heritage conference brought together a community of researchers, policy makers and practitioners with different backgrounds but working towards a common goal. That is without a doubt a strength in the message we are bound to bring forward.

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The organising committee of the SBE21 Heritage conference, and we as chairs, would like to thank all participants for their involvement and especially of the keynote and roundtable speakers for their valuable contributions.

In Bolzano April 2021

Alexandra Troi
Daniel Herrera

Conference chairs

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The SBE21 Heritage Round Table: a discussion about the role of historic buildings in new European policies

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The SBE21 Heritage Round Table: a discussion about the role of historic buildings in new European policies

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In the framework of the international conference SBE21 Sustainable Built Heritage, a round table was organised to discuss the role of historic buildings in the light of the new European policies recently launched. The European Commission highlighted in a communication related to the European Green Deal that the current renovation rate will need to at least double in order to achieve the EU's energy efficiency and climate objectives. In order to address the enormous energy and resource consumption in the building sector, the Renovation Wave was also launched. When Ursula van der Leyen explained the idea of a New European Bauhaus (NEB), she clearly pointed out the need for a climate-neutral building sector not only as an environmental or economic project, but as a new cultural project for Europe. It is therefore all the more surprising that in all these initiatives the built cultural heritage has not been given any special attention. Reason enough to discuss possible strategies for anchoring the architectural heritage in the EU climate initiatives with the invited panellists of the SBE21 Heritage Round Table. All of them know the current policy making in the framework of the Green Deal from a different perspective – from EU-Level to the local implementation, from research to practice. The invitation to the round table was accepted by:

- Erminia Sciacchitano, Officer in the Minister's Cabinet of the Italian Minister of Cultural Heritage, Activities and Tourism and Chief Scientific Advisor for the European Year of Cultural Heritage 2018
- Roswitha Kaiser, head of the Directorate General for Cultural Heritage in Rheinland-Pfalz Germany
- Johanna Leissner, scientific representative of Fraunhofer-Gesellschaft at the European Union in Brussels and currently chairing the EU OMC Group Strengthening Cultural Heritage Resilience for Climate Change
- Jacqui Donnelly, senior Architect in the Built Heritage Policy section of Ireland's Department of Housing, Local Government and Heritage.
- Lisanne Havinga, Assistant Professor at the Building Performance group at Eindhoven University of Technology in the Netherlands

1. Decarbonisation of the building stock

The first question addressed to the panellists was intended to show the different perspectives on what decarbonisation of the building stock means. The European policy within the Green Deal gives priority to the energy efficiency of buildings. While the reduction of buildings´ energy demand is supported by all participants, the priority should, however, be the carbon neutrality of the building stock. Especially in the heritage community, the issue of environmental impact is thoroughly discussed, as the preservation and refurbishment of historic buildings is seen as being of great benefit compared to demolition and new construction. A holistic approach is needed to take into account not only the operational phase of the buildings, although the parameters for such considerations have not been precisely defined yet. In this respect, Sciacchitano, Leissner and Donelly pointed out the lack of research. More evidence-based data is urgently needed to better assess the climate neutrality of renovations.

Havinga briefly reported on a Dutch research project that deals with the climate neutrality of renovations. The example of a photovoltaic (PV) installation for single buildings was used to demonstrate the difference between carbon neutrality and zero energy in building operation. While PV produces more electricity in summer, the energy demand for the heating system is increased in winter, what would result over a whole year in zero energy. Furthermore, using the post-war district in the study, Havinga explained that according to her calculations new constructions would only be more sustainable than the renovation in approximately 60 years and only if taking into account today's energy use. Considering that the energy production and distribution is becoming more carbon friendly, new constructions will not pay off in terms of carbon neutrality in the near future. Here she even goes one step further in stating, that also a less invasive renovation can win out in comparison to deep renovation packages in terms of the carbon optimal solution. And by talking about the enormous fine dust pollution during demolition work and the impact on the air quality in urban environment, Leissner brought up another argument in favour of refurbishment of existing buildings, which has not been discussed sufficiently before.

2. From building to urban level

The general consensus among the panellists was that the problem of a climate-neutral building stock can only be solved if broadening the view from the individual building to the urban level. This is all the more relevant if at the same time the historical values of the built environment are also to be preserved. It will not be possible to renovate every building to a zero-energy standard. Kaiser gave the example of the Town Hall in Mainz, a listed building from the 1970s by the architects Arne Jacobsen and Otto Weitling. For this significant building there are no technical solutions available to renovate it towards zero energy. In order not to subject the heritage values to inappropriate renovations, she sees potential in compensating the higher energy demand of single buildings and to obtain a carbon neutrality on a district level. To be able to assess the complex situation, she highlighted the existence of energy consultants in Germany specially trained with a reference to the issue.

However, the first step should always be to optimise the building side, as Donelly emphasised. She observes that a lot of potential remains unused and many retrofit measures that would be possible even while preserving the sensitive historic structures are not undertaken. Niels Larson, one of the Organisers of the SBE Conference Series, also pointed out during his closing speech that these adaptation of existing buildings as a "heritage idea" is very much supported from the more general sustainable built environment movement.

Havinga also sees the municipalities in particular as having a responsibility here in terms of raising awareness of how renovation can have a negative impact on the characteristics of the building. Two points were important for her to be emphasised. Renovation strategies should not have the focus purely on reducing the energy demand of the building but also on other environmental impacts such as materials. Likewise, projects should not only be tackled for individual buildings, but also at the district level. After all, the aim is to replace fossil energies. If this is done by means of a local network, it entails different requirements for the renovation measures to result in a zero-energy building stock. The complex issues must also be made accessible to the building owners connected with specific retrofit advice but also making them aware of the building value.

From Leissner's point of view, this is precisely the task since people living in the pre- and post-war environments often don´t consider their houses worth of preserving. The trend, especially in rural areas, is still towards newly built homes while buildings built between 1900 and 1940 are being abandoned. Thus, Leissner sees the municipalities as having a duty, to encourage owners to renovate the buildings and with that keep the character of the village, district and city.

3. Target of Investments

Targeted investments are necessary to steer the renovation of the building stock in the right direction. Everyone agreed that the reduction of CO_2 for the use phase of the building must not be the sole criterion for the support of renovation measures. Sciacchitano explained that in recent years there have been large investments made in cultural heritage, for example through the ERDF fund. However, the panellists demanded better quality management for the funding programs. In future, aspects such as maintenance management or risk assessment should be given more recognition. In connection with public funding for the renovation of historic buildings, also Kaiser believes that the incentives are not yet properly in place. For example, individual manufacturing on site, which is more resource- and energy-efficient than the use of standardised imported products, is not promoted accordingly.

In the Netherlands, the corresponding funds are not linked to the persons/owner, but to the building. Havinga explained, that many private owners are hesitating to implement energy-saving measures due to the long payback periods, even with the state programmes. With the Dutch system the credits remain with the subsidisers/banks, meanwhile the tenants continue to pay their normal electricity bills.

Here, also the question was discussed how to prevent people from doing the wrong things by targeted funding. Leisner sees the absolute necessity of informing building owners early on about the possibilities of renovation, even before they make the first plans. The main part of the historic building stock is in private hands. If the building is not legally protected, there is no regulation that prevent the private owners for examples from exchanging old windows instead of repairing or to implement external insulation without thinking about alternatives. For Leisner the question is how we can ensure that these building owners get the right advise to ensure that the renovation wave will really be beneficial in preserving the characteristic villages and cities.

In this context, attention was given not only to the protected buildings, but to the entire historic building stock. The participants agreed that the protection of younger heritage, which is particularly difficult to deal with, must be a priority. Kaiser drew attention to the lack of technical solutions for this group of buildings in particular. Both funding programmes and advisory services must be more effective for these buildings that are often not listed. Best practice examples are therefore welcome for mediation.

When Donelly demands that the historic buildings need to be mainstreamed in the Green Deal and in the Renovation Wave, she also has the owners and the occupants in mind, as they should not be denied access to appropriate funding. All building owners should be given the opportunity to make energy improvements, whether their building is protected or unprotected. A good tool to support in this direction should be the guidelines that are currently being developed in Ireland. Donelly expressed once more her concerns about the preservation of cultural significance when adapting historic buildings to the requirements of Energy Performance of Buildings Directive, especially in the case of not listed buildings that are not protected by legislation but shape our cities and villages.

4. Need for further research

Sciacchitano underlined the need for heritage specific research because decision-makers in Green Deal initiatives need well-prepared information for shaping not only the funding strategies but all the related policies also in terms of cultural heritage. There is an urgent need for more data to convince the policy makers. Even in Italy, with this large historic building stock, there are no figures and thus no reliable information available. Her claim was supported from Leisner, who underlines also the challenge to define these key figures out of research. These data, says Leissner, are necessary for bringing the historic building issue in the recovery and resilience plans on a member states level. Finally, Sciacchitano invited all the audience to share available data on European level, to know e.g. the share of historic buildings compared to the whole building stock and to have better information about building typologies and their specifications. Donelly also agrees from an Irish perspective. A quantitative assessment of the existing building stock and a possible contribution to CO_2 mitigation is required and will be a much stronger argument for bringing the issue of historic buildings into the national policies. In Ireland, this research has already been initiated.

However, the need for research is not limited to quantitative analyses. As Leissner points out, in Germany there is practically no research looking at how to adapt our cultural heritage to climate change and become carbon neutral. Therefore another field of research is the development of technical solutions and planning tools. According to Leissner, a number of research projects were already performed in this direction on European level, but she sees still deficits in the dissemination of this knowledge. In this context, also Sciacchitano highlights the lack of research results transfer to practice so that new developed solutions are available on the market. Often, a decision is made for a certain solution because of availability and economic reasons. Again, she calls for more Best Practices examples which can help in the dissemination.

5. New European Bauhaus: Chance or risk for cultural heritage?

At the end of the lively exchange of ideas, the question was raised whether the New European Bauhaus, and with it the proclaimed Renovation Wave, is also seen as an opportunity or as a threat for a sustainable and respectful treatment of architectural heritage.

Sciacchitano makes a strong case for mainstreaming interventions on cultural heritage in the Green Chapter of the Recovery and Resilience Facility Plan for Italy and urges this for other countries as well. This will only be possible with continuous awareness raising and providing key information to decision makers. She stresses the importance of adopting a holistic approach and thinking of sustainable development in all its dimensions. Cultural heritage interventions should be not the exception, but an enabling factor for sustainable development.

Also, Donnelly sees the need to place cultural heritage at the heart of all the programs like the New European Bauhaus and the Sustainable Development Goals. Historic buildings are preserved for their cultural heritage values but also as a source of material and their embodied carbon. Therefore it is important that historic buildings are given special consideration by the European Council when setting up the strategies for a Renovation Wave and all other policies.

Leissner referred here to experiences from the EU OMC expert group when reporting that only few countries have mentioned specifically Cultural Heritage in their National Sustainability Strategies. Looking to the upcoming research programs within the framework of the Green Deal or New European Bauhaus, it is still possible to submit project applications with this specific focus on cultural heritage even if it is not always explicitly mentioned in the calls. Leissner's attention is not only focused on the large monuments, but also on the broad range of anonymous historic architecture. Here, it is urgent to find ways of preservation that also guarantee a decarbonisation of the building stock.

For Kaiser, too, the funding options associated with the initiatives of the Green Deal must be made available for the cultural heritage sector. There is an urgent need for best practice case studies but also for programs to train professionals. The preservation of the cultural heritage and all buildings worth preserving provides the framework for our historical identification potential and also means the conservation of important resources, both cultural and material.

Havinga supports this broader scope of cultural heritage that does not only refer to protected monuments. She sees the whole building stock as a built heritage that needs to be considerate of. At the same time, Havinga reminds that about half of all buildings are built before 1970 - with high potential for energy saving. For Havinga, packages of measures should therefore be addressed in all programmes.

In concluding remarks, Alexandra Troi, one of the conference chairs, emphasised that the ambitious goals of preservation of cultural heritage as well as the decarbonisation of our historic building stock can only be achieved through an interdisciplinary dialogue. In doing so, she drew a connection to Ege Yildrim's keynote on the first day of the conference, which highlighted the proactive role of the heritage community.

The organisers of the SBE21 Heritage conference were happy that the panellists emphasised the value of the event towards promoting such discussions. The large presence of young scientists in particular shows the interest of this generation in the topic of sustainability and the willingness to contribute to the research in the field.

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Plaster ventilated façade system for renovating modern and ancient buildings. A CFD analysis

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Plaster ventilated façade system for renovating modern and ancient buildings. A CFD analysis

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Abstract. In the past decades several researches have been related to energy saving and emissions reduction. The technologies that exploit passive natural ventilation, like ventilated roofs and façades, have been recognized as the effective methods to provide energy saving and comfort. Ventilated façades represent dry assembled coating systems for buildings, traditionally made of panels in different materials. Very few ventilated façade systems with plaster finishes are already present on the building market. The potentiality of their design solution can be considered, e.g., when an historic building has to be recovered, since they can enhance the energy efficiency of building without changing its appearance. CFD simulations have been carried out by the authors in order to analyze the thermal energy behavior of a ventilated façade system with a plaster finishing and for comparing the benefits derived from its use to the corresponding unvented insulated façade. The ventilated façade shows a relevant energy saving thanks to the effect of ventilation: a reduction of 70% of heat flux was achieved, furthermore, a reverse conductance calculation showed relevant differences with the same calculated by thermo-physical material properties, since in this last calculation the heat and mass transport effect are not considered.

Keywords – ventilated façade; plaster; CFD; refurbishment; energy saving;

1. Introduction

In the last decades CO2 emission reduction, renewable technology penetration and energy efficiency increase have been the main aims of different nation policies worldwide.

An analysis of present building stock led to an imperative necessity: the implementation of both passive and active systems, thus achieving an increase of energy efficiency and greenhouse gas (GHG) emissions reduction, as demanded by the United Nations Framework Convention on Climate Change (UNFCCC) [1]. In particular, most of the researches carried out by scientists specialized in different disciplines -with the aim to quantify the benefits derived from the use of different strategies/products for retrofitting the building heritage of the Mediterranean Basin and to reduce its energy consumption-are focused on passive systems. Among these, the technologies that exploits natural ventilation, like ventilated roofs and façades, have been recognized as effectively able to enhance the building performances with low installation costs [2, 3]. The application of a ventilated facade let to reduce the effects of direct solar radiation by 27.5 %[4] and the ventilation of roofs can reduce significantly the heat fluxes (up to 50%) during summer season [5]. Several efforts are aimed to enhance the ventilation in the ventilated structures also by developing innovative building components. In [6] the experimental results show that the introduction of a novel roof tile shape in ventilated roofs let to increase the ventilation in the "above sheet ventilation" layer, and, consequently, to achieve better results in terms of energy savings than ventilated roofs equipped with standard tiles.

The building envelope provides the primary conditioning factor to heating and cooling loads and the inevitable ensuing energy cost for users [7]. A refurbishment must ensure balanced efficiency by overseeing "comfort per cost," and maximum benefits from investments, while also safeguarding economic returns within the solutions lifespan: all of this combined factors must set the strategy [8].

Ventilated façade contribute to the thermal insulation of existing buildings, lowering energy needs, and GHG emissions [9]. These solution should differ by country and region conditions, explicitly considering the available energy sources and climate features [10]. It is composed by the following elements: an opaque vertical wall with an external coating constituted by finishing elements such as slabs, panels and others, separated from the opaque wall by a ventilated cavity. Actually, the ventilated cavity acts as a passive cooling element and, therefore, let to avoid thermal bridges and condensation problems.

Nowadays, on the building market it is possible to find ventilated façade systems that adopt different materials as finishing layer. They usually use panels made of ceramic, metal, plastic and so on as cladding solution that allow to reduce time and costs of installations. Very few ventilated façade systems already present on the building market use plaster finishing. The potentiality of this solution can be considered when, e. g., an historic building has to be recovered, as it can enhance the energy efficiency of building without changing its appearance testified by its original plastered façades.

CFD simulations have been carried out by authors in order to analyze the thermal energy behavior of a ventilated façade system with a plaster finishing and compare the benefits derived from its use to the corresponding unvented insulated façade.

2. Design and analysis of the case study

The building chosen as case study is part of the Cappuccinelli Social Housing district in Trapani. The project of this particular neighbourhood, designed by Michele Valori [11], dating back to 1956. The design is based on an ante litteram holistic approach aimed at ecology, sustainability and energy retrofit.

Actually, the original project derived from the idea of courtyards similar to those of the agricultural communities in Trapani surroundings. Inside the large courtyards there was an extensive vegetated space, with some tall trees and vegetable gardens. Courtyard buildings are made of duplex apartments symmetrically coupled. Inside the apartments the space is distributed as following: on the ground floor, a hall where is located the staircase, a kitchen and a dining room; on the first floor, three bedrooms and a toilet. The apartments have a private garden located on the back.

Figure 1. A courtyard during its construction.

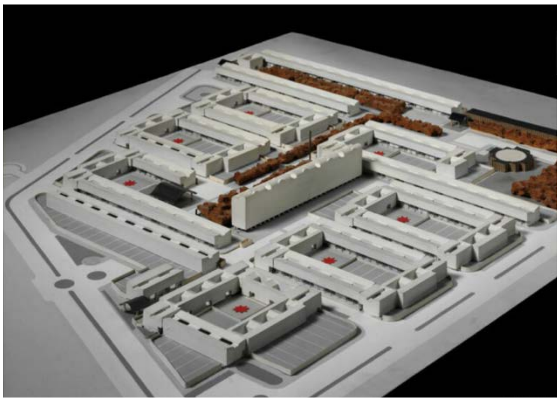

Figure 2. The original model of Cappuccinelli.

Today all Cappuccinelli's buildings are particularly degraded: starting from the reinforced concrete structures up to the external finishing plasters which show serious flaking due, also, to the proximity to the see. Actually, the SH district is 150 m far from the waterfront and it is located near the cultural heritage site named "Tonnara Tipa" located just along the coast. Most of the buildings have been changed by tenants during the last years and by Autonomous Social Housing Institute (IACP); actually, the firsts have changed the original design of buildings by adding new volumes without licenses; the second changed building details, through (e.g.) the modifications due to the consolidations of pillars.

A recovery project is going to be designed by authors in the field of their research activity. It foresees to recover these buildings by retrofitting them through the use -among other systems and strategies- of a ventilated façade system with plaster finishing. This will let to improve the energy performance of buildings without changing their original appearance, as well as designed by Valori.

3. Metodology

CFD simulations for comparing the energy behavior of ventilated façade with an unvented insulated have been carried out by authors.

3.1. Domain description

A model of the described ventilated façade system has been implemented in the finite-elements software Comsol Multiphysics V 5.4 [www.comsol.com]. The effect of the ventilation channel, at the expense of a simplification to the external fluid flow problem has been investigated in detail. Hence, a 2D domain was modelled as a section of the case study building, thus neglecting the 3D heat and mass transport effects due to the interaction between building and wind. This method, adopted by several authors, let to focus the analysis on a significative section whose behaviour is analogous to the other ones [12, 13, 14]. The thermo-fluid steady state problem was solved by coupling three physics: heat transfer in solids and liquids, turbulent flow, radiation surface to surface. For the turbulent flow the k-ε model under the Boussinesq approximation [15] was implemented, the effects of the buoyancy forces were considered.

For the environmental conditions, a data set based on historical measured data was used for wind, air temperature and solar radiation.

Cappuccinelli's case study building is 7.2 m height and 12.6 m large; it is covered by a flat roof and it is surrounded -in the scheme used for the simulations- by an air domain composed as follows: 2 m large in front of the ventilated façade, 10 m high above the roof and 10 m large in the back side (figure 3).

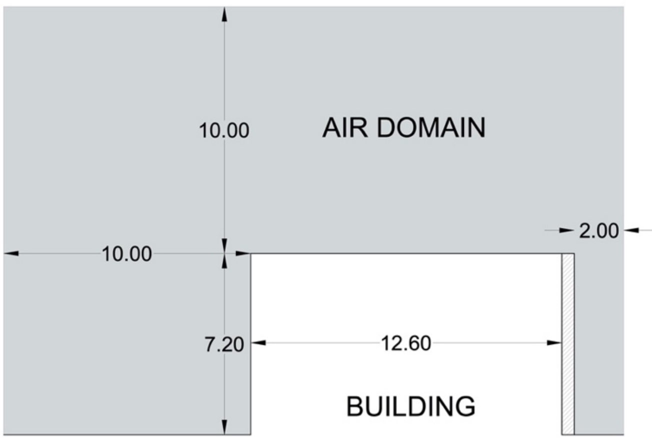

Figure 3. Building section scheme with geometrical domain set in Comsol Multiphysics.

The ventilated façade has an upwind exposition, the chosen size of the upwind domain (on the right side of the building, figure 3) is sufficiently large to consider the fully developed wind fluid flow. The downwind and upper domains (on the left and upside of building) were sized by considering the turbulent effects induced by the building shape.

The unvented insulated façade is composed by calcarenite blocks with an air cavity interposed between the two ashlars; a plaster layer; a rockwool layer and a final external plaster layer (figure 4).

In the ventilated façade system, a ventilated air cavity and a finishing plaster layer were added on the external side (figure 5).

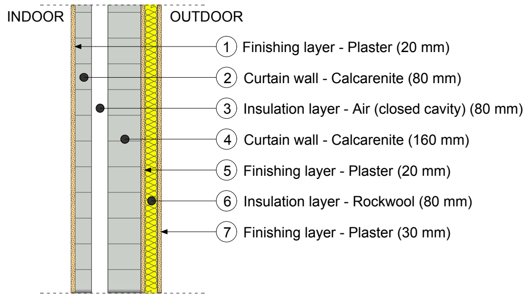

Figure 4. Unvented insulated façade section.

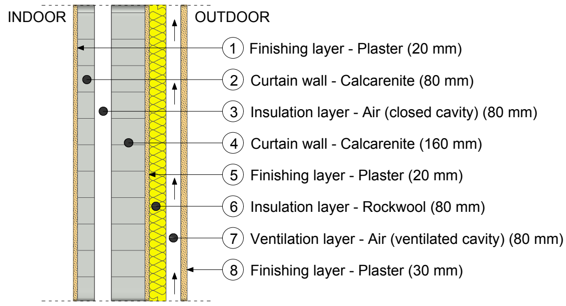

Figure 5. Ventilated façade section.

The thermo-physical properties of materials are indicated in table 1; the calculated thermal conductance for unventilated wall is 0.32 W/m^{2}K, for ventilated one is 0.28 W/m^{2}K

Table 1. Thermo-physical properties of materials.

Materials	Dimensions [cm]	λ [W/mK]	$\boldsymbol{\rho}$ [kg/m^3]	c_p [J/kgK]
Plaster	2	0.7	1400	840
Calcarenite	8	0.63	1500	840
Air	8	0.19	1.2	1005
Calcarenite	16	0.63	1500	840
Plaster	2	0.9	1800	840
Rock woll	8	0.035	70	1030
Finishing plaster	3	0.9	1800	840

Size and layout of ventilation inlet and outlet sections were set according to technical products widely used by manufacturer (figure 6).

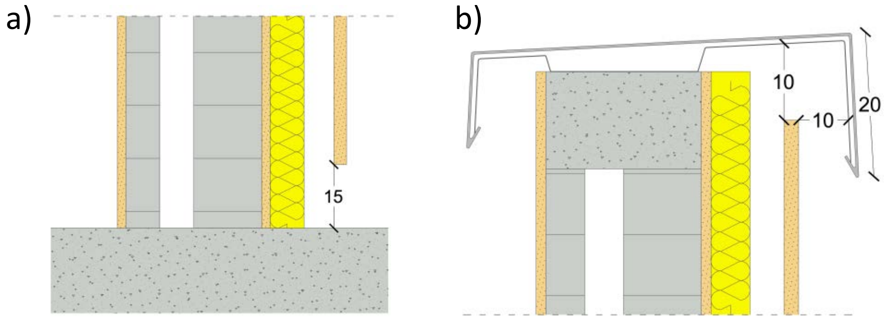

Figure 6. Inlet (a) and outlet (b) sections of ventilated facade. All measures are expressed in cm

3.2. Case study

The present study is focused on the effects of the wind speed, air temperature and solar radiation on the thermal behaviour of the facade, in terms of ventilation, heat flux and temperature. The simulations were carried out in steady-state for summer environmental conditions. A solar radiation flux of 500 W/m^2 is applied on the vertical external layer through the software interface "Surface to surface radiation" directly exposed to the sun, the external air temperature was set to 30°C. A uniform wind speed profile defines the inlet boundary condition in the domain, applied to the external boundary layer of the upwind air domain. Wind is supposed entering from the right side of the domain with horizontal direction, perpendicularly to the facade. The wind speed profile is variable with the altitude, according to the following power law

$$v = v_0 \left(\frac{z}{z_0}\right)^{\alpha} \quad (1)$$

where:

- v_0 is the wind speed (v_0=5 m/s) at the reference height z_0 (z_0=10 m);
- α is an empirical factor depending on the surface roughness, for a urban area like Trapani was considered $\alpha = 0.3$ [16].

An equivalent convective heat transfer coefficient equal to 4 W/(m²K) is applied on the internal wall surface; it considers the heat transfer from the wall surface to the room (indoor air at 24 °C).

The chosen environmental parameters are representative of the typical summer project conditions for the indicated location. All the boundaries of air domains were considered as open boundaries to let the air free outflow. It's important to underline that the buoyancy effects were considered also in the closed air cavity (layer n. 3 in figure 4 and figure 5), the heat transfer is affected since in this layer both heat and mass transport occur. The whole mesh is composed of triangular linear elements with 42525 degrees of freedom for the insulated unvented façade model and 53338 in the ventilated one. To improve the solution, the elements are more concentrated within the ventilation channel and in the near areas (figure 7).

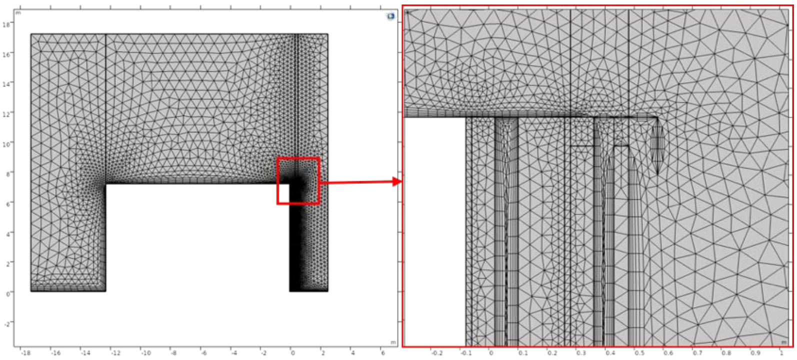

Figure 7. Physics-controlled mesh with free triangular geometry.

4. Results and discussion

The multiphysics approach let to evaluate the global energy performance of the analysed ventilated façade. The main aim of the simulations is to underline the effect of the ventilation on the thermal insulation in hot climate conditions. The most representative parameter is the net heat flux inward into the conditioned room. In figure 8 the inward heat flux variation on the building height is reported; a comparation between ventilated and unvented simulation case is showed.

The ventilation cavity shows an evident heat flux decrease thus enhancing the passive energy saving. The peak showed from the unventilated heat flux curve is due to the air velocity gradient; the heat transport due to wind is lower at low height.

Ventilated façade shows an average heat flux reduction of 70% if compared to the unvented one. The mitigation effect of ventilation cavity is well visible also in terms of surface temperature (figure 9): the external façade of ventilated case is always cooler than the unventilated one; the average difference between 1.5 m and 6 m height is 4°C. This difference is evident on the internal wall surface and positively affects the indoor comfort due to mean radiant temperature in the ventilated case.

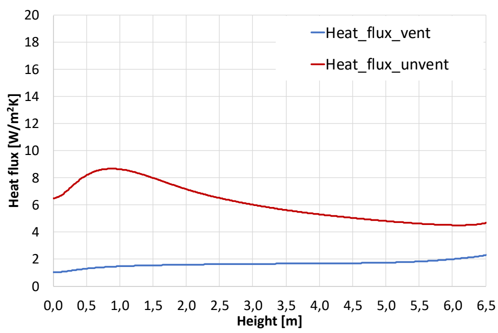

Figure 8. Heat flux trend.

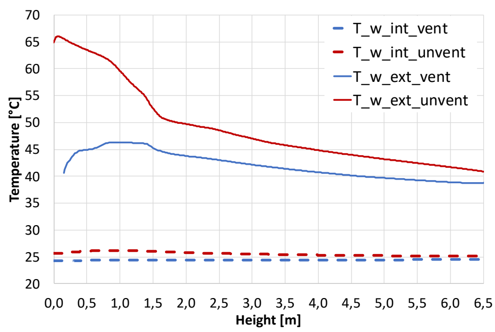

Figure 9. Surface temperature of wall.

In figure 10 a 2D plot of temperature distribution on different section sketches is showed.

On the base sections the overheating, due to radiation effect, is more marked in unvented façade: a temperature difference of more than 15°C are reported on the external layers. Significant differences on temperature distribution are evident also on the average height section far from boarder heat transfer effects: the ventilation channel removes heat from the external plaster layer; moreover, the radiation heat transfer between the plaster layer and the rockwool one is clearly showed. Finally, on the top of the façade, the temperature distribution in the air flow outlet from ventilation channel is evident.

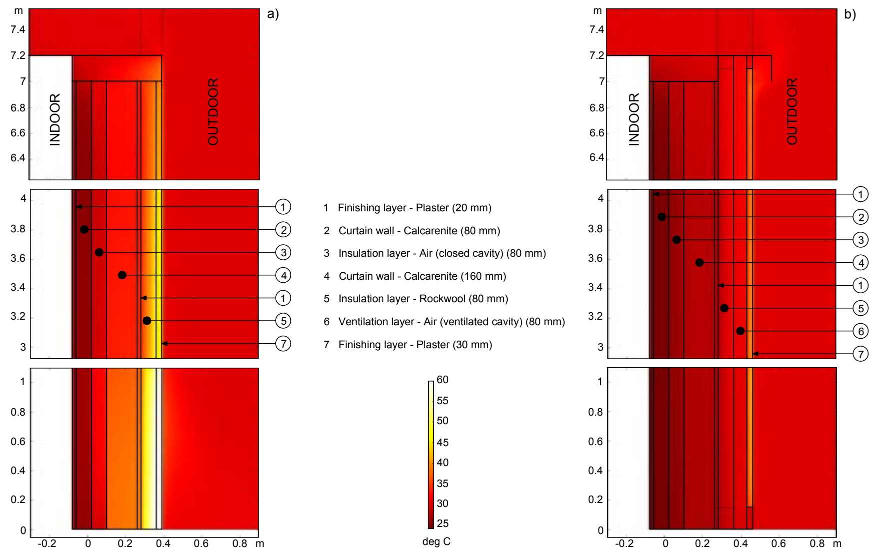

Figure 10. 2D temperature distribution of unvented (a) and ventilated (b) façades.

In figure 11 the distribution of air velocity is showed. Forced convection is predominant on buoyancy effects in presence of external wind: the effect of the outlet section geometry is evident. With the described environmental boundary conditions, a flow rate of 0.33 m^3/s and mass flow rate of 0.39 kg/s for 1m of cavity section depth have been calculated.

Finally, a reverse calculation of thermal conductance was performed as in equation (2)

$$C = \frac{\dot{Q}}{T_{w,ext} - T_{w,int}} \qquad (2)$$

An average value of 0.1 W/m^2K was obtained for the entire ventilated façade system (layers from 1 to 7), this value is 65% lower than the thermal conductance calculated from thermophysical properties, this because in the calculation carried out by material properties the effect of heat and mass transport is not considered and the ventilated air cavity is considered as a pure conductive element.

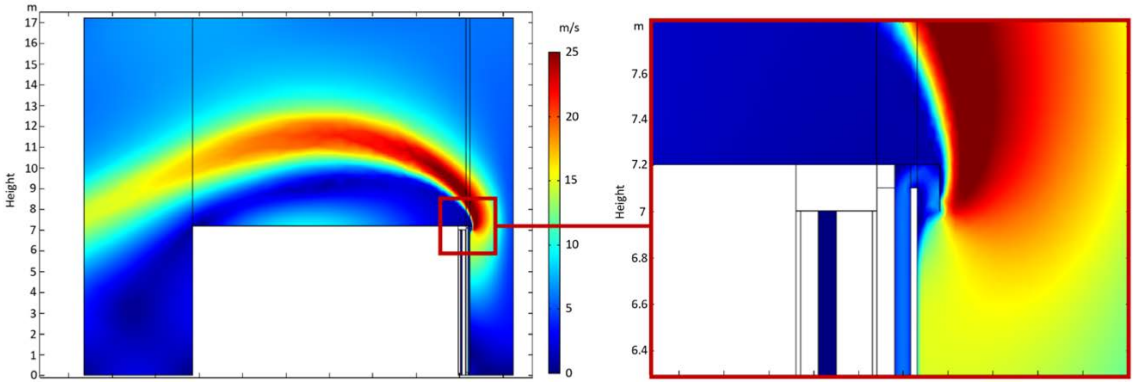

Figure 11. 2D air velocity distribution, a focus of ventilated facade outlet section is showed.

Analogously, the behaviour of the closed air cavity affects the thermal conductance if the convective phenomena are not neglected: for the unvented wall a conductance of 0.28 W/m^{2}K was obtained through the previous expression (reduction of 12% with respect to the thermal conductance calculated from thermophysical properties). In order to better evaluate the benefits of the ventilated wall, a further comparison was made. It was assumed to replace the ventilation chamber with an additional layer of thermal insulation, maintaining the same total thickness of the wall. So, the stratigraphy of the new external wall was defined as follow: 30 mm plaster, 80 mm calcarenite, 80 mm air cavity, 160 mm calcarenite, 30 mm plaster, 160 mm rockwool and finally 30 mm plaster. The resulting thermal conductance is 0.18 W/m^{2}K if the closed air cavity is considered as a pure conductive element, conversely, the value 0.17 W/m^{2}K is obtained by considering the buoyancy effects in the same layer. The heat flow trend of the new configuration shows lower values if compared with the unvented case and higher ones than in the ventilated case, although the thermophysical thermal conductance is lower for the last one. This shows that the thermal conductance calculated by the thermophysical properties cannot be considered as the only significant parameter to evaluate the performances of the ventilated facades. Figure 12 and figure 13 shows the trend of the heat flow and wall temperatures simulated in the new wall configuration with double layer of thermal insulation.

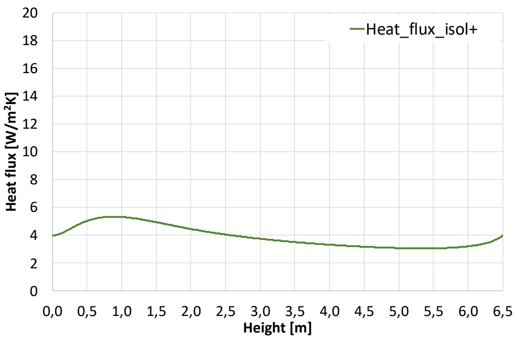

Figure 12. Heat flux trend.

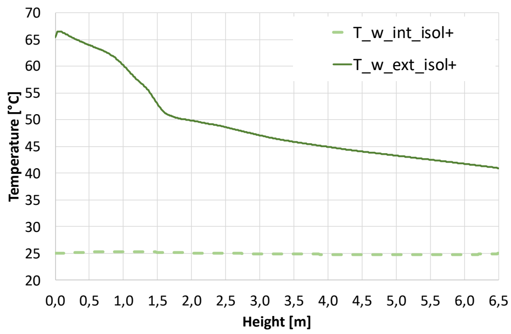

Figure 13. Surface temperature of wall.

5. Conclusions

The ventilated façades were widely studied in literature and are commonly used in design and building technologies; the ventilated cavity mitigates the effect of solar irradiation, especially in Mediterranean climates. An unusual type of ventilated façade system has been analysed in this paper. It is made of a plaster finishing that allow to consider this technological system useful also for retrofitting the historical buildings. This new type of ventilated façade has been considered for the refurbishment of Cappuccinelli SH district in Trapani (Sicily, Italy). A CFD model was implemented in order to compare the energy performance of the new ventilated façade with an insulated and unvented one; the commercial software Comsol Multiphysics was used. A steady state calculation was performed by assuming typical environmental and boundary conditions of the geographical area related to the case study. The ventilated façade shows a strong heat gain reduction thanks to the effect of ventilation: a reduction of 70% of heat flux was achieved. Moreover, the ventilated solution showed lower internal and external surface temperatures, thus enhancing the internal comfort conditions. A mass flow rate of 0.39 kg/s for 1m of cavity depth has been calculated; the fluid dynamic performances of the ventilated cavity could be improved through planning a new design of inlet and outlet sections. A reverse calculation of thermal conductance was performed, the obtained values were compared with the same ones calculated from thermophysical properties. For ventilated façade system a value of 0.1 W/m^{2}K was obtained, 0.28 W/m^{2}K for the unvented one; the respective values calculated from material properties were 0.28 W/m^{2}K and 0.32 W/m^{2}K. This difference was achieved since the effect of heat and mass transport is not considered and the ventilated air cavity is considered as a pure conductive element when the thermal conductance is calculated only by considering the material properties. A last case was considered by replacing the ventilated cavity with an insulating layer. The results show that there are no significative improvements in terms of heat flux reduction in comparison with the ventilated case, figure 14 - figure 15. The results of this study offer promising perspective since the plaster finishing will be widely used in plastered ventilated façade through an experimental campaign in order to better understand its operating and dynamic behaviour in hot climate conditions.

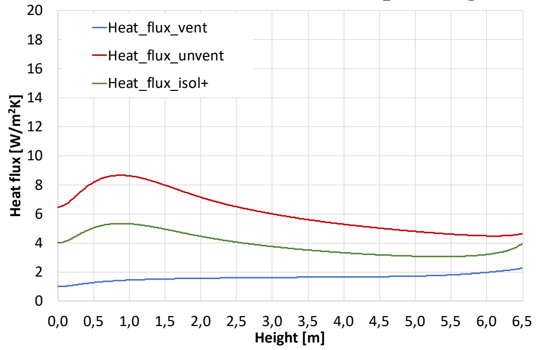

Figure 14. Heat flux trend.

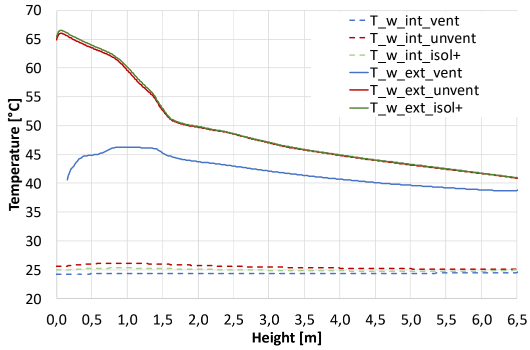

Figure 15. Temperatures of wall.

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