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Antonio Passaro (edited by)

Sustainable Mediterranean Construction

Sustainable environment in the Mediterranean region: from housing to urban and land scale construction

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Sustainable **M**editerranean **C**onstruction

Sustainable environment in the **M**editerranean region: from housing to city and land scale **C**onstruction

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NEW DYNAMIC BUILDING ENVELOPE SYSTEMS FOR MEDITERRANEAN AREA

keywords

Building envelope, dynamic facade, energy saving, renewable energy

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Abstract

The new Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, the rising cost of fossil fuels in recent years, the high emission and tiny air pollution particles, let us to development new systems facades into current project research ABITARE MEDITERRANEO[1]. The system facades should guarantee a considerable energy saving in office building. The research is characterized by the development of new building envelope components which can ensure the reduction of heat loss, which is caused to insufficient building insulation, including glass facades with reduced heat transfer and the use of renewable energy technologies.

In this particular case, the collaboration with local companies has been possible the development of building envelope prototypes, which can control the performance of it during the year through the integration of shielding, heat exchangers, and phase change, ensuring the reduction of energy consumption.

In the following, we introduce two systems: a ventilated facade systems and double skin facade. In both case the study focused on dynamic envelopes for office building with high-energy performances and formed by the dry assembly of advanced facade components, which analyzing the evolution of façades system in terms of: building construction, innovative systems, smart materials, dynamic system. Aiming to improve building energy performances.

Keywords: Energy Saving, Dynamic Skin, Smart Envelopes, Renewable Energy

1. Introduction

The two facade systems have been developed with the aim of spreading sustainable building technologies in The Mediterranean Area and in Italy. The aim is to develop new facade systems to reach the goals of 20/20/20 and to diffuse regulations that govern energy efficiency in buildings. The European Union established these regulation through the Energy Performance Building 2002/91/CE and EU Directive 2010/31. These aim to diffuse local and national regulations to guarantee high the efficient buildings, using appropriate policies which consider local climate conditions. From 31st December 2018, we must start building zero energy public buildings.

In Southern Europe, we must think about on winter and summer conditions and avoid copy in Northern Europe energy efficiency architectural solutions, to create appropriate solutions in energy efficient buildings. Southern Europe has specific climatic conditions, with the problems of indoor summer comfort, and the consumption of water resources and natural resources. Therefore it is necessary to improve research into new technologies for envelope solutions with regard to the energy consumption.

In Italy, the constant dependency on fossil fuels, oil and methane gas is still high in housing and office buildings sector. At a national level, Italy has adopted the European Directive 2002/91 with the Dlgs. 192/2005, that has been integrated and modified over the years. The new regulation introduce new parameters of evaluation, like the periodic thermal transmittance or the indices of summer energy consumption.

In this paper we describe the two smart facade that we have developed to improve the energy performance of the new office buildings in the South Europe and to reduce the costs of heating, cooling and lighting, responding to national and international energy laws.

[1] http://www.abitaremediterraneo.eu/

2. Advanced shading envelope element and a terracotta slab: "shading screen"

2.1 Technological features

The proposed multilayer ventilated envelope element is composed of two sub-systems: the first, the inner layer, is formed by a dry-mounted system, while the second, the external closing system, consists of a "ventilated wall package". Each of the two sub-systems is in turn divided into several functional layers.
The external closing advanced screen system is composed of extruded brick slabs mounted - through mechanical anchor pins – on metal structure uprights (with a "groove" profile of 300 x 200 x 2 mm) anchored in turn, to the main structure of the building by "L" shaped brackets (around 500 x 500 x 5 mm).
The stratigraphy of the screen is formed by:

- bearing facade substructure (columns, brackets, anchor elements);
- accessory elements and joints (PVC spacer pads with circular section and rectangular shading rods);
- insulating rock wool layer (50 mv);
- control layer;
- ventilation layer;
- brick slabs
  - Shading screen TR1 slab (tile used in two directions)
  - Shading screen TR2 slab (angular horizontal and/or vertical)
  - Shading screen TR3 slab (sill)
  - Shading screen TR4 slab (string course)
  - Shading screen TR5 slab (shading rods).

SHADING SCREEN SLAB

The "shading screen" slab was designed to create a self-shading ventilated facade cladding. The slab is obtained by optimizing the geometry of the outer surface, so that in itself it helps to reduce heat absorption through the creation of the largest possible dispersion area. The "shading screen" slab, indeed, has an outer surface which is 2,8 times the size of a normal dry curtain wall slab.
The slab also features a design of the external surface which can be applied in two different directions (horizontal and vertical), both to suit aesthetic requirements and to ensure protection from the solar radiation under different orientation conditions. The choice of colour also contributes to the thermal improvement of the slab. Light colours are more reflective and less absorbent towards solar radiation, allowing the slab to cool down more easily; on the other hand, in the case of dark colours, the absorption of solar radiation is significantly higher.

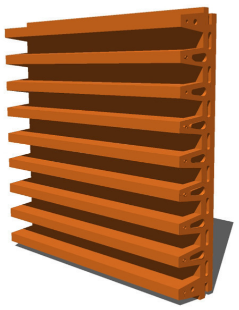

Figure 1. "Shading Screen" slab

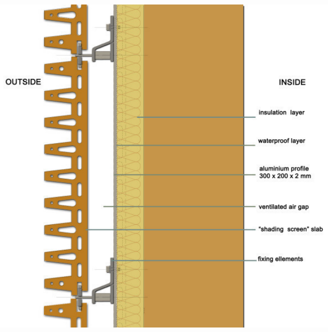

Figure 2. Stratification layer

2.2 Verification of the energy performances of the dry envelope element

The audit was performed[2] through the simulation carried out for a building located in Abu Dhabi (latitude 24.6°N); the choice of location was made to evaluate the system's behaviour under extreme conditions. The audits of the energy performance of the dry multilayer casing element were conducted in three phases:

- hygrothermal tests;
- physical and thermal tests;
- energy consumption on a Test-Room with the application of the facade component.

The simulation was carried out using the energy simulation "TRNSYS" and calculating "ECS" programs. The initial conditions are:

- assessment of an area of 100 sm (10x10 m);
- slab colours: red and sand;

[2] The energy performance of building envelope was developed in collaboration with the Department of Energy "S. Stecco" to University of Florence – prof. M. de Lucia and Ing. D. Fissi.

- size of air gap: 2.5 cm, 5 cm and 10 cm;
- horizontal arrangement of the corrugated outer surface of the slab;
- comparison was made with a terracotta slab with a constant section of 7 cm. This allows to evaluate the performance of the "shading screen" slab in relation to another component that has the best features of the considered range, and therefore the survey is carried out under the most disadvantageous conditions for the proposed slab.

In addition, the survey was developed with a progressive induction methodology of data values from a sequence of calculation steps on various parameters, such as:

- percentage of shaded area of the slab;
- average temperature of the outer surface of the slab;
- heat flow from the outer surface of the slab to the inner surface of the wall.

For the slab of red colour the diagrams reveal, however, an efficacious reduction of surface area exposed to radiation, showing that:

- in the case of eastern orientation[3], the shading of the surface of the slab reaches a maximum of 68.81%;
- in the case of western orientation, shading of the surface of the slab reaches a maximum of 71.51%;
- in the case of the southern orientation, the shading of the surface of the slab reaches a maximum value of 60.09%.

During the calculation phase of the average temperature of the outer surface of the red slab, as in the following stages, comparison is made between the effects of radiation on the "red shading screen" slab and those on the flat slab.
The results show that even if on one hand the temperatures reached by the external surface of the slabs under consideration are very similar, despite the morphological diversity, on the other (as the next stage of calculation will show), the loss of heat by the "red shading screen" is greater than that of the flat slab, demonstrating not only the efficacy of the corrugated surface as a system of heat dissipation, but also that the performance of the corrugated sheet improves even more in the more extreme geographical contexts.

2.3 Case Study Results

The data which can express the amount of energy consumption for heating or cooling indoor air depending on the temperature difference between outdoor and indoor air set operating at 20 ° C, are expressed in Wh, and refer to a volume called "test room" of 10 m per side, allowing for a kind of spatial-energy unit represented by the perimeter of the 10x10x10 unit volume, comparable to the design of a building structure.
The calculation procedure allows detection of:

- average annual consumption of each of the sides of the test room, depending on their orientation;
- average annual consumption of the test room as a whole.

Consumption is obtained as a direct function of the factors considered in the previous stages and includes, as in these stages, the comparison between walls with shading screen slabs, divided into red and sand colour walls, and walls equipped with the reference flat slab.
As shown by the Tab.1 in the case of Abu Dhabi, total energy consumption of the test room by applying the "sand shading screen" slab is higher (+8%) than with the flat slab. This allows us to understand that a light coloured shading screen is inefficient in the analysed context (considering however, as already mentioned, that the simulation is limited to the analysis of the passing heat flow and does not include fluid dynamics evaluations).
Applying instead the "red shading screen" slab the situation is reversed and the same consumption is significantly reduced (-16.1%) in comparison to that with the application of a flat slab, as there is a greater absorption and dispersion of heat. The best results (higher savings) occur on the eastern and western faces, while on the north and south sides, as can be imagined, benefits could be obtained by orienting the slab with vertical corrugations. These excellent results are even more encouraging, as:

- the simulation does not consider the needs of smaller indoor humidity control due to a lower inflow;
- the simulation provides the less advantageous "conditions" for the application of the shading screen, since the flat slab has a greater width (7 cm) compared to the thickness of the common wall slabs (3 cm).

Table 1. Total energy consumption analysis by applying the sand shading screen and the flat slab in Abu Dhabi

ABU DHABI						
	SHADING SCREEN SLAB		**FLAT SLAB**		**DIFFERENCE**	
EAST	144352	Wh	132319	Wh	12033,36	Wh
NORTH / SOUTH	280910	Wh	268438	Wh	12471,49	Wh
WEST	174691	Wh	153250	Wh	21440,58	Wh
TOTAL	599953	Wh	554007	Wh	45945,42	Wh
					8,3%	

[3] In locations close to equator, the east and west surfaces are subject to higher irradiation

	SHADING SCREEN SLAB		FLAT SLAB		DIFFERENCE	
EAST	388603	Wh	491765	Wh	-103162	Wh
NORTH / SOUTH	637477	Wh	729577	Wh	-92099,2	Wh
WEST	466158	Wh	558244	Wh	-92085,4	Wh
TOTAL	1492238	Wh	1779585	Wh	-287346	Wh
					-16,1%	

3. SMART FACADE

3.1 Technological features

The smat envelope is a unitised system modules, "dry" assembled and allows an easy installation on building site. This façade system has a simple geometric design made with two modules: transparent and opaque. The modules can be installed with different geometries and in their frames different types of materials with different colors can be placed

The modules consist of fixed and mobile parts, that can be operated trough automatic or manual controls. The mobile parts, placed in the aluminum frames, are:

- an aluminum shading device
- a transparent panel with stratified glass 4 + 4

A vertical mosquito net made with a metallic grid is placed in front of the indoor transparent module and prevents the entering of animals and insects in the office, and ensuring the night cooling.

The façade system is designed as a double skin façade system, where is possible to customize the indoor skin, the air gap and the outdoor panel.

The dynamic facade achieves good performance in the terms of:

- Thermal transmittance: the transparent indoor wall has a U value of 1,2 W/m2K and the opaque indoor wall has a U value of 0,3 W/m2K
- Acoustic insulation: 50dB
- Mechanical Resistance: the façade has a good fire resistance and mechanical properties and can be tested with accidental and dynamic loads
- Air and water permeability: the weather strip used in the frame avoids the formation of condensation and guaranteed a good air proof
- Maintainability: the modular elements enable to repair, with isolated action of maintainability, the facade system without changing the global performance of the façade

The facade system uses a technological solution with the recessed panels. This mechanism allowed to hide in the aluminum box the mobile elements: the glass panel and the shading device. The recessed panel can bear a weight of 180 Kg.

In the opaque outdoor module can be installed three PV panels that have a electrical energy production between 0,50 and 0,30 kWP. The energy production depends on orientation and localization of the façade system.

In winter the mobile glass panel is placed in front of the transparent module. So the smart facade will have the shape of a double skin facade with a buffer zone that increase its U value to 0.6 W/m2K. In this configuration the façade guarantees a good thermal insulation and doesn't decrease the natural lighting into the work spaces.

In summer the panel with the shading device is placed in front of the transparent module, regulating direct solar radiation and decreasing heat load in the office. The mosquito net is down so is possible to obtain a natural ventilation in the indoor spaces all day long.

The san screen, made with mobile and metallic lamellae, allows to regulate the light and minimize the glare phenomena.

3.2 Energy Simulations

We have simulated the energy performance of the facade system using thermodynamic and lighting software. The dynamic energy simulations have been made in three different climatic zones in Italy:

- Milan
- Florence
- Palermo

And compared to four cardinal directions:
- East
- South
- West
- North

We have built a virtual test room (3) that has a size of 5,00 x 5,00 x 3,00 m and has a wall where is possible to put the following façade systems (opaque and transparent):

1. Window with double glass and thermal break frame. Size: 3,00 x 1,35 (4) m.;
2. Window with double glass and thermal break frame. Size: 3,00 x 2,50 m.;
3. Glass curtain wall with double glass and thermal break frame. Size: 5,00 x 3,00 m.;
4. Glass curtain wall with double glass, thermal break frame and external fixed shading device system with aluminum venetians . Size: 5,00 x 3,00 m.;
5. Glass curtain wall with double glass, thermal break frame and external mobile shading device system with aluminum venetians . Size: 5,00 x 3,00 m.;
6. Double skin façade (unitized system typology) with natural ventilation of the buffer zone. Internal and external layers have size: 5,00 x 3,00 m.;
7. Double skin façade (unitized system typology) with natural ventilation of the buffer zone and fixed shading device system located inside the buffer zone. Internal and external layers have size: 5,00 x 3,00 m.;
8. Double skin façade (unitized system typology) with natural ventilation of the buffer zone and mobile shading device system located inside the buffer zone. Internal and external layers have size: 5,00 x 3,00 m.;
9. Opaque curtain wall made with a insulated panel with rock wool (thickness 8,00 cm) and a window with double glass and thermal break frame. Window size: 3,00 x 1,35 m. (5);
10. Smart façade. Winter configuration
11. Smart façade. Summer configuration without shading device
12. Smart façade. Summer configuration with shading device

The thermal simulations have been done with TRNSYS (TRaNsient System Simulation Program) (6), analyzing for each situations the following parameters:
- Primary energy for heating (Q_{heat}, kWh)
- Primary energy for cooling (Q_{heat}, kWh)

Then we have calculated:
- The total primary energy supply (kWh)
- Heating and cooling consumptions (€)
- Heating and cooling CO_2 emissions (kg)

The simulations show that:
- **In winter months** for the smart facade, the primary energy supply for heating is lower than that required by a brick wall (Case 2, 50% of transparent module and 50 % of brick wall: 4500 kWh). The primary energy supply for the three cities chosen and the four cardinal direction is, in fact, of 4380 kWh.
  But for the smart facade the energy primary need is bigger than that required by a glassed curtain wall and transparent double skin (Case 3: 3450 kWh and Case 6: 3750 kWh) because the solar heat gain decreases with decrease of transparent surface.
  When the mobile glass panel is placed in front of the transparent module the heating needs decreases by the 5%.
  In the future, aiming improve the summer energy performances, could be interesting to evaluat the input given by the use, in the mobile panel, of TIM or other change phases materials.
  The smart facade should be oriented toward south in the purpose to improve the solar heat gains and decrease the energy consumption for heating .
- **In summer months** the smart facade guarantees good energy performance and in the configuration with the shading device placed in front of the transparent module the primary energy need is of 770,00 kWh (reduction by the 70% for the cooling), lower than that performed by a brick wall with central window (Case 1: 1100,00 kWh) and also lower than that of a glass curtain wall or of a double skin with fixed or mobile shading device (Case 4: 1500 kWh, Case 7: 895 kWh, Case 5: 1527 kWh and Case 8: 899,00 kWh).
  The smart facade should be oriented toward south or north so to reduce the thermal loads and the solar heat gains and decrease the energy consumption for cooling.
- **The best orientation** during all year, in Florence and Palermo, is south, with a reduction of primary energy for heating and cooling by the 40%

The lighting simulations have been made with the software Relux, with wich has been possible to evaluate the average of natural lighting in the test room. The simulations have show that the smart façade, that has a transparent module of size 1,50 for 3,00, allows to achieve the following results:

- Good performances in summer months, with a illumination of 592 lux;
- Inadequate performances in winter months, when the glass panel is placed in front of the transparent module, with a illumination of 300 lux.

In order to reduce the energy consumptions for the lighting, the smart façade should be located in the spaces where is possible to have two window located in opposing wall. It's also necessary to install a electronic light system that controls the artificial light and allows to switching on only the lights in areas that aren't reached from the solar radiation.

Figure 3. Smart Facade. Prototype

Figure 4. The dynamic envelope in east facade of the New Centre in virtual environments and ICT of Lucca Chamber of Commerce

4. CONCLUSIONS

The research has involved companies, leaders in the engineering and production of facades: Schueco, Metra, Permasteelisa, Focchi, Cotto Imprunetta, Palagio Engineering. In both cases, the advice of the industrial companies has improved the technological solutions of the production process and of the construction phase.
In the first case, the advanced shading envelope, in particular the "shading screen" slab prototype is being processed. Final results of simulation envisage that the efficiency demonstrated by the proposed slab may help even in temperate climates, especially with regards to hot seasons.
In the second case the smart façade prototype was developed and realized by DAVINI, a Tuscan company, and was used in the construction of the south and east facades of the New Centre in virtual environments and ICT of Lucca Chamber of Commerce . In the next months, finally, we will analyze the real performances of the smart façade applied to the construction of the building in Lucca and in the test cell in Florence, evaluating its energy behavior in Mediterranean clime.

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The Cittam (Centro Interdipartimentale di ricerca per lo studio delle Tecniche Tradizionali dell'Area Mediterranea) has always been dealing with the great subjects of the architecture, landscape and urban design within the Mediterranean region, through a number of different studies about the traditional technologies and strategies employed by the populations inhabiting this so rich cultural basin.

This international conference has the aim of investigating about the reflection – over the sustainable development strategies and the ecological approach – of a number of principles, already present and rooted in the Mediterranean traditional culture, such as the bioclimatic response of buildings, the local resource employment and the social and cultural factors involved in the human activities. In fact, following the Meridian Thought, the dialogue, the communication, the fertility and the nomadism of ideas and people, and last but not least the slowness set against the frantic life, can be taken as re-founded values for the Mediterranean common culture. As far as contemporary architecture is concerned, and thus new application of city and land configuration, the teaching lectures learnt from the aforesaid principles, included in the Mediterranean tradition, will provide a large and deep aid to the actions and design items aimed at reducing the ecological footprint and at respecting the existing landscape.

The challenge of this Cittam conference is the enhancement of the cultural connection between the architecture, the infrastructures and the XXI century city configuration, all of which had contributed to the whole process – from the big works of the 19th century, till the nowadays innovation in material and product employment; by means of comparison and discussion about examples, theories, ideas and studies, the relationship between the various scale design and the sustainable development approach within the Mediterranean region will be faced.

FrancoAngeli
La passione per le conoscenze

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