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Prof. Dr J.-L. Scartezzini

Chairman of CISBAT 2013

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INNOVATIVE DYNAMIC BUILDING COMPONENT FOR THE MEDITERRANEAN AREA

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ABSTRACT

An appropriate envelope is the main element in sustainable building design, but in mild temperate/mesothermal climates, the rapid changing of outdoor conditions additionally requires a dynamic response of envelope parameters to allow the maintenance of good adaptive interior comfort.

The traditional response of the window components that characterizes the Mediterranean architecture has recently developed by the ABITA Centre into a new range of innovative facade modules and new materials able to play different roles and ensure a dynamic response to climate.

The ABITA Research Centre of University of Florence has a long experience in the field and presents here two prototypes able to modify their performances according to occupants' needs and outdoor conditions, but trying to integrate them into the contemporary architecture.

The design approach focuses on:

- Control of solar radiation (redirect, diffuse or reflect direct radiation)
- Control of air changes (natural and forced ventilation)
- Reduction of energy losses and recover the heat in ventilation
- Increase in security and control in windows frame
- Integration of Renewable Energy in facade components
- Increase of the thermal mass of industrialized building envelopes
- Increase of the overall prefabrication in buildings

The new Directive 2011/27/EC of the European Parliament on the energy performance of buildings, the rising cost of fossil fuels in recent years, high emissions and tiny air pollution particles, led us to the development of new façade systems in the framework of the current project research ABITARE MEDITERRANEO[1]. The façade systems should guarantee considerable energy savings in office buildings. The research is characterized by the development of new building envelope components which can ensure the reduction of heat loss, caused by insufficient building insulation, including glass facades with reduced heat transfer and renewable energy technologies.

In this particular case, the collaboration with a local company has enabled the development of building envelope prototypes, in which the performance is controlled during the year through the integration of shielding, heat exchangers, and phase change materials, ensuring the reduction of energy consumption.

In the following, we introduce the double skin façade DOMINO; an innovative facade system.

The study focused on dynamic envelopes for office buildings with high-energy performances, formed by the dry assembly of advanced facade components; aiming to improve building energy performances.

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

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

1. INTRODUCTION

The DOMINO facade system described in this paper has been developed with the aim of spreading sustainable building technologies in The Mediterranean Area. The aim is to develop new facade systems to reach the goals of 20/20/20 and to promote regulations that govern energy efficiency in buildings. The European Union established these regulations through the European Directives: 91/2002, 31/2010 and 27/2012. These aim to release local and national regulations to build sustainable buildings, using appropriate policies that consider local climate conditions. In Southern Europe, we must think about winter and summer conditions and avoid copying Northern European energy efficiency architectural solutions, to create appropriate solutions for 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 energy consumption in these regions.

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

In this paper we describe the a smart facade that we have developed to improve the energy performance of new office buildings in Southern Europe and to reduce the costs of heating, cooling and lighting, responding to national and international energy laws. In particular we show the thermal results that we have analysed for the Domino façade, an innovative dynamic façade system developed for the ICT Centre in Lucca.

2. SMART FAÇADE DOMINO

2.1 Technological features

DOMINO facade is a unitised modular "dry assembled" system that 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 different types of materials with different colors can be placed in their frames.

The modules consist of fixed and mobile parts, that can be operated trough automatic or manual controls. The mobile parts, placed in the aluminum frame, 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 offices, ensuring night cooling.

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

The dynamic facade achieves a good performance in the terms of:

- Thermal transmittance: the transparent indoor wall has a U value of 1,2 W/m^2K and the opaque indoor wall has a U value of 0,3 W/m^2K;
- 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 recessed panels. This mechanism allowed hiding 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 an electrical energy production between 0,50 and 0,30 kWP. The energy production depends on orientation and localization of the façade system.
- Other types of panels done of: metal or glass or terracotta tiles; so to guarantee the application of this type of façade also in the retrofit of the existent buildings.

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 increases its U value to 0.6 W/m^{2}K. In this configuration the façade guarantees a good thermal insulation and doesn't decrease the natural lighting into the workspaces.

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 it is possible to obtain natural ventilation in the indoor spaces all day long.
The shading device made with mobile and metallic lamellae or with terracotta tiles, allows regulating the light and minimizing the glare phenomena.

Figure 1: Smart Facade. Prototype with PV panel

Fig. 2. Smart Facade. Prototype with Brick panel

We have realized two prototypes of this type of dynamic facade:
- A prototype with a PV panel in the opaque module and a shading device made of aluminum thin sheets;
- A prototype with terracotta tiles in the opaque module and in the shading device.

2.2 Energy Simulations

We have simulated the energy performance of the facade system using thermodynamic software. The dynamic energy simulations have been made in three different climatic zones in Italy: Milan, Florence and Palermo, and compared for the cardinal directions East, South, West, North. We have built a virtual test room that has a size of 5,00 x 5,00 x 3,00 m and has a wall where it 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 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 an 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;
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), analyzing for each situation the following parameters:

- Primary energy for heating (H_{eat}, kWh)
- Primary energy for cooling (C_{ool}, kWh)

Then we have calculated:

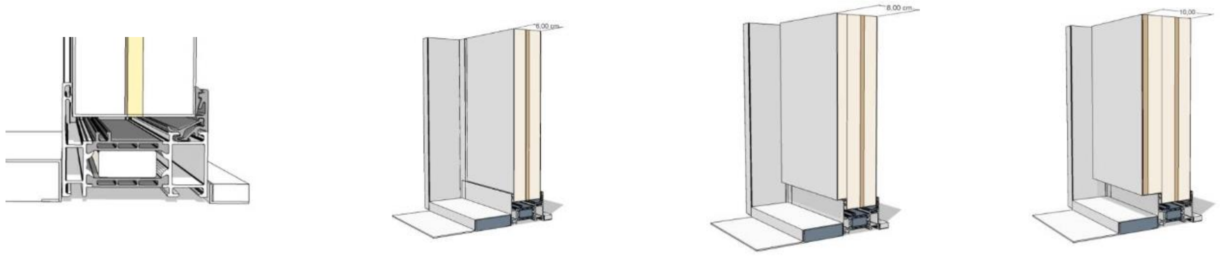
- The total primary energy supply (kWh)
- Heating and cooling consumptions (€)
- Heating and cooling CO_2 emissions (kg)

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: 4422 kWh). The primary energy for heating supplies for the three cities chosen and the four cardinal directions is, in fact, of 4187,69 kWh. However in the smart facade the primary energy need is bigger than that required by a glassed curtain wall and transparent double skin (Case 3: 3447 kWh and Case 6: 3759 kWh) because the solar heat gain decreases with the 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 evaluate the input given by the use, in the mobile panel, of TIM or other phase change materials. The smart facade should be oriented toward south 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 770,16 kWh (reduction by the 70% for the cooling), lower than that performed by a brick wall with a central window (Case 1: 1049,00 kWh) and also lower than that of a glass curtain wall or of a double skin with fixed or mobile shading device (Case 4: 1509,21 kWh, Case 5: 1527,41 kWh, Case 7: 895,01 kWh and Case 8: 899,87 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 40% reduction of primary energy for heating and cooling.



Thickness insulation panel (mm)	60	80	100
Thickness Aluminium panel (mm)	4	4- 5	5
Peso (Kg/m^2)	9,2	10,6	12,1
K (W/m^{2}K)	0,38	0,24	0,21
kcal/m^{2}h°C	0,28	0,21	0,18

Tab.1: Opaque component: analysis of energy performance increasing the insulation

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

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

In order to reduce the energy consumptions for lighting, the smart façade should be located in spaces where it is possible to have two windows located in opposing walls. It is also necessary to install an electronic light system that controls the artificial light and allows switching on only the lights in areas that are not reached by solar radiation.

Heating [kWh]

	South			West			East			North		
	Milan	**Florence**	**Palermo**	**Milan**	**Florence**	**Palermo**	**Milan**	**Florence**	**Palermo**	**Milan**	**Florence**	**Palermo**
Case 1°	5623.49	3717.68	220.95	6920.75	5179.38	1291.08	6842.05	4829.31	1295.46	7677.02	5795.49	2058.26
Case 2°	5699.82	3801.07	1196.59	6989.62	5228.12	1424.44	6886.81	4793.86	1394.48	7860.29	5995.17	2000.78
Case 3°	4236.16	2010.35	0.00	5969.93	4239.26	432.94	5266.03	2991.65	198.96	8415.29	5995.17	1609.28
Case 4°	6642.46	4300.99	274.02	8365.59	6245.95	1547.20	8249.08	5754.34	1490.25	9357.63	6920.01	2535.22
Case 5°	4242.27	2010.46	0.00	6873.96	4889.39	511.52	6656.44	4019.74	454.96	8460.04	6011.71	1609.35
Case 6°	4154.47	2216.08	12.63	6251.55	4576.83	664.18	7130.74	4733.41	954.79	7419.38	5389.49	1613.78
Case 7°	6130.47	4146.44	439.53	7392.31	5565.96	1548.50	7314.63	5221.57	1553.05	8088.85	6051.86	2280.86
Case 8°	4171.02	2216.38	12.63	6306.97	4581.42	665.10	6135.66	3903.94	607.44	7459.12	5409.39	1613.97
Case 9°	5818.40	4003.39	514.80	6860.98	5186.23	1500.03	6814.46	4922.76	1544.64	7487.31	5609.53	2146.36
Case 10°	5460.94	3716.63	1055.99	6552.45	4952.50	1418.03	6476.16	4611.02	1405.68	7246.00	5398.41	1958.42
Case 11°	5503.10	3614.84	1050.06	6840.09	5105.12	1337.65	6742.80	4667.49	1322.77	7743.73	5700.68	1956.20
Case 12°	5336.66	6951.59	6903.99	6951.59	5106.11	1322.77	6903.99	4668.05	1322.77	7766.60	5708.96	1956.26

Table 2: Primary energy analysis for heating (H_{eat}, kWh) for the twelve cases of facades.

Cooling [kWh]

	South			West			East			North		
	Milan	Florence	Palermo	Milan	Florence	Palermo	Milan	Florence	Palermo	Milan	Florence	Palermo
Case 1°	519.73	907.76	1651.09	688.08	1034.23	2348.83	672.17	1447.16	2283.56	30.69	211.97	792.74
Case 2°	1892.85	2312.13	2841.99	2206.75	2516.00	4052.64	2181.17	3248.79	3962.74	484.21	797.67	1401.92
Case 3°	3786.70	4640.05	5608.35	4624.43	5185.82	7957.79	5224.40	7358.30	8516.51	967.28	1607.85	2728.58
Case 4°	864.76	1374.48	2212.54	1085.18	1522.33	3221.04	1072.71	2114.04	3157.52	85.85	366.92	1033.14
Case 5°	865.09	1374.66	2225.76	1085.63	1524.62	3336.91	1073.03	2119.77	3237.45	85.86	366.97	1033.23
Case 6°	2044.40	2688.81	3507.43	2620.70	3126.09	5393.42	2368.42	3921.08	5077.34	450.24	923.93	1733.31
Case 7°	377.34	703.01	1417.06	559.05	882.77	2103.89	523.69	1265.67	2039.78	15.91	158.22	693.69
Case 8°	377.40	703.44	1417.44	559.52	883.26	2145.05	523.87	1266.44	2054.02	15.91	158.24	693.82
Case 9°	240.84	464.10	1164.26	362.55	647.72	1677.27	317.58	915.25	1581.49	0.00	89.70	558.14
Case 10°	1022.03	1337.73	1818.49	1287.72	1540.09	2757.48	1254.69	2047.67	2669.14	226.66	456.50	916.39
Case 11°	1892.92	2312.41	2868.47	2204.09	2513.60	4090.96	2180.63	3248.59	3992.27	484.59	798.28	1413.60
Case 12°	422.89	682.12	1177.31	506.30	749.16	1736.90	453.99	1047.39	1676.28	43.38	179.84	566.29

Table 3: Primary energy analysis for cooling (C_{ool}, kWh) for the twelve cases of facades.

3. CONCLUSIONS

The research Abitare Mediterraneo has involved companies, leaders in the engineering and production of facades: Schueco, Metra, Permasteelisa, Focchi, Cotto Imprunetta, Palagio Engineering. The advice of industrial companies has improved the technological solutions of the production process and of the construction phase. The smart façade prototype was developed and realized by DAVINI, a Tuscan company. The advice of the industrial companies has improved the technological solutions of the production process and of the construction phase. The façade system has a thermal break frame by Schueco and glass panels by Pilkington. This choice allowed us to reduce the cost of the smart façade, bringing it, without PV panels, to 850,00 €/m2. This cost is the same as that of a traditional double skin. The Domino Facade 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. The research has showed that is possible to realize dynamic façade systems that can change their technological configuration during the year, decreasing the energy needs of the building for heating and cooling.

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