Energy efficient ventilation systems and components in sport facilities

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ABSTRACT

Building industry is often regarded as a mature and traditional sector, in which the technological development is not so accelerated as in other cases.
The increasing costs for electric energy, heating and climatization, the dramatic environmental issues draw the attention of professionals and experts to those technological solutions, components and devices which are going to represent the immediate future of engineering practices. The attention was drawn to a 16 900 m^3 sport facility building with 800 seats to be built in the East sector of Rome, one of the districts in which is higher the needing of social services and sport facilities. This installation is devoted to volley, basket and other sport activities which are becoming popular. The study is focused on the energy performance of the envelope and the system for climatization if more sustainable technologies and materials were adopted to run the installation. Solutions like a better orientation, a new kind of brickwork, a better choice of the glazing surfaces, new concept for heating and cooling are already known or available on the market, but the traditional attitude of designers or professionals, the insufficient information of public bodies devoted to control and other factors affecting these techniques are obstacles to their diffusion. Prudential evaluations of the introduction of these solutions lead to a minor primary energy consumption of 30% as a basis. The facility is run by Municipality, then a 10 years amortization period is perfectly tolerable, expecially if the operation of the building is foreseen to be at least 30 years.

1. MAIN ADOPTED SOLUTIONS

1.1. Masonry

Traditional

Concrete brickwork
The experience of buildings of the past of the Italian building stock give values between 1 and 1.2 W/m^2K with a density which in some cases might rise up to 1500-2500 kg/m^3.
In the study, obviously the actual traditional masonry was adopted, and assuming an overall heat exchange coefficient of 0.43 W/m^2K.

Advanced

High performance bricks are foreseen to be adopted in this case. This class of materials which is commercially well identified, includes in the mass of the component small air cavities not interconnected among them which are obtained mixing in the clay small polystyrene spheres (or sawdust). During the high temperature heating phase, the spheres become cavities (max. 2.5 mm dia) combining together insulation and structural characteristics together. Normally, the elements are studied also as far as the number and shape of the holes (50-70% of the volume); they are placed perpendicularly to the thermal perturbation, to minimize thermal flow. The adoption of these materials does not require further layers of insulation (external, internal).
Production in Italy in 2004 arises up to 1 300 000 t
Densities are around 450-650 kg/m^3, heat transfer coefficient 0.65-0.7 W/m^2K, acoustic
specification 46-48 dB.
The overall heat exchange coefficient is calculated in 0.39 W/m^2K.

Final result

The aspect of the adoption of a more advanced masonry might result in a prudential energy saving of 10%.

1.2. Glazing

Traditional

The overall heat exchange coefficient for a double 3 mm glass glazing is about 4.5 W/m^2K.

Advanced

Electrochromic glazing permits dynamically changes of a window's thermal, solar and visibile transmittances by applying small amounts of electric current to an electrochromic film affixed to the glass.
The tension to be applied is very low, 1÷1,5 V and this results in a migration of part of the ions from the storage layer (IS), through the separation zone (ion conductor IC), to the electrochromic layer (EC). The actual status can be kept for 24 hours without extra energy.
Energy absorption is registered only during the transition phase (Maccari, 1999).
Designs can incorporate manual or automatic actuation through devices such rheostats, thermostats, photocells etc. Several electrochromic technologies are under study,

including a design using electrically conductive layers of film that exchange ions when a voltage is applied.3. These devices are today still very expensive, some figures estimated in 200 €/m2 the actual selling prices in the current year.

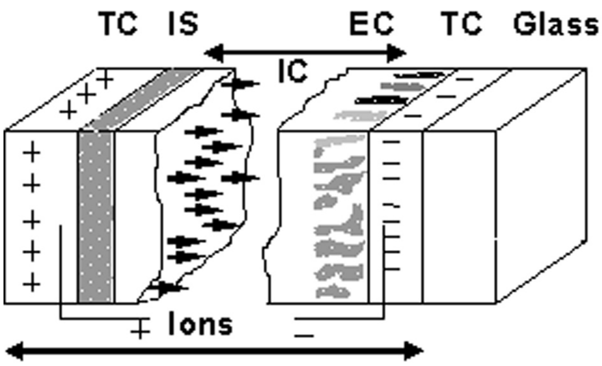

Figure 1 Electrochromic glass

These devices are evaluated to be able to reduce the peak cooling loads from 10% to 30%. The heating energy savings are estimated up to 30% (Emerging Technologies, 2004).
The heat exchange coefficient is specified (DIN 52619) for some commercial products in 1.60 W/m^{2}K.

1.3. Lighting
Advanced
The adoption of fluorescent ball resistant lamps was considered, having prismatic diffusers with 80 W power each. The Italian standardization is differentiated into three classes of lighting for sports like basket, soccer, volley, i.e. 750 lux for high level competitions, 500 lux for regional competitions with a low number of spectators, 200 lux for local competitions with no spectators. In this case a 500 lux level is adopted. The power to be installed is around 16 W_e/m^2.

1.4.Heating and cooling loads
Traditional
The estimation of thermal loads was performed on the basis of the methods which are explained in the literature (ASHRAE Fundamentals, 1993) which are the framework also of models and software which are commercially commonly available.
The loads were estimated by hourly periods, through the concepts of CLTD method. We understand that more modern instruments were implemented in these last years in the literature, but the order of magnitude of the involved quantities was well characterized for preliminary design, this one is actually sufficient to achieve the authorizations of the public bodies to start with the realization of the project. The heating load, evaluated during the sport event, with a building made with traditional technology, gave a value of 552 kW. The cooling load, under the same conditions, gave a value of 514 kW.

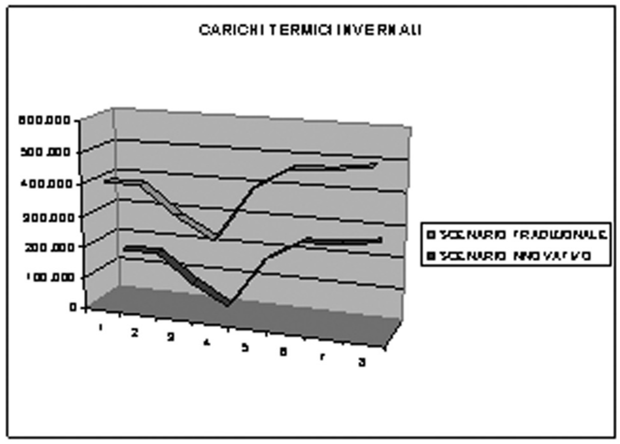

Figure 2 Heating loads

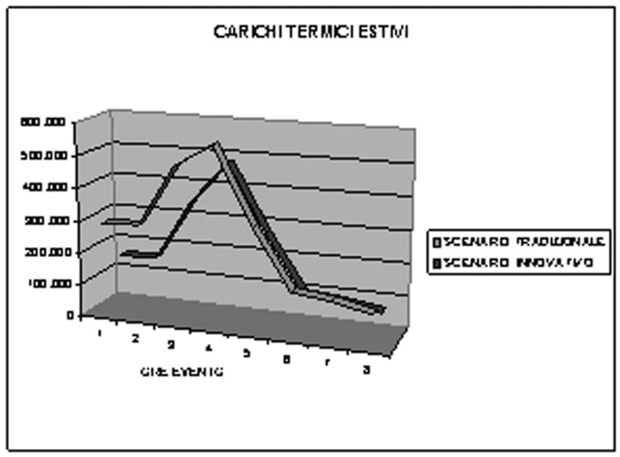

Figure 3 Cooling loads

Advanced
The heating load, evaluated during the sport event, with a building made with advanced technology, gave a value of 264 kW. The cooling load, under the same conditions, gave a value of 480 kW.
Final result
A reduction of the heating loads of 48% and a 13% for cooling loads was assessed.

1.5.Climatization system
Heating
Traditional
Heating of volumes and spaces is usually achieved in the country through hot water circulation at 70- 80 °C, to keep the indoor temperature at the value of 19-20°C. The efficiency of the heat generators for this cathegories was recorded about 85% at the turn of the century, meanwhile the new installations are supposed to easily achieve 93% (AICARR, 2007). Therefore, even the adoption of traditional but updated technologies may

result in a remarkable improvement.

Advanced

It is apparent that the best solution is to decrease the temperature at which the thermovector fluid is circulated, i.e. from those mentioned above up to values of 75° -60°C and so decreasing up to 40°-30°C in case of radiant panels. This concept, can be achieved only by means of condensation components. These heaters are able to use also the energy stored in the latent heat of the fumes, the temperature of the exhaust gas is far lower than the conventional components (from 230°-270°C up to 40°-65°C), then this portion of sensible heat can be saved also with the percentage due to the minor radiant dispersions because of the lower operating temperatures. All these amounts easily raise the savings up to 30%.(Viessmann, 2006)

Since the investment cost is still high, these devices are not yet common in the country, recent evaluations give still values of the national market about 5%.

Final result

Our prudential evaluation of 30% of savings in heat production during the cold season supported also from data from a main supplier is easily achievable.

Cooling

Traditional

The traditional cooling system includes a section for the thermovector fluid production, (delivery temp. 7°C, return temp. 12°C, ΔT = 5 K) which is usually operated through a chiller which for high capacities is of the centrifugal or screw type.

Conduction and operation is performed at fixed point, i.e. all the quantities (flowrates, pressure, temperature) are fixed and in general the system is on-off.

The ventilation system is an all-air one and is based on the principle of mixing ventilation; this kind of technology requires for air distribution at least 1÷3 $W_e/(l \cdot s)$, the highest figure for not so efficient designs, the lowest for good engineering (Liddament, 1995).

The aspect of the final delivery devices also has to be considered. Traditional grilles and louvers have an air distribution efficiency which can be assumed about 0.6 ÷ 0.7 (i.e. to deliver 10 l/s to the breathing zone of a defined room, a flow rate of 14 l/s should be considered in the calculations).

These air amounts are obviously of outside air, for good IAQ purposes.

Advanced

The direction to which technology moves is toward variable fluid and air volume circulation systems (VAV).

The thermovector fluid flowrate is adjusted in the secondary loop (i.e. from the heat exchanger to the final devices), according to the actual energy requirements and this is the first aspect which the designers obviously take into consideration, but in these last years the variable flowrate is under consideration and study in the primary loop also, i.e. from the chiller to the heat exchanger (Vio, 2004). However, if the attention is focused on the variable flowrate in the secondary loop only, a minor energy amount for fluid circulation is required for pumping purposes, less friction losses are recorded.

As far as the chillers are concerned, values of 5÷6 COP for centrifugal or screw type impellers is a normal value considering the evolution of these machines from the ‘90s up till now.

A remarkable diffusion of the scroll technology is recorded also.

Figure 4 Scroll compressors

Figure 5 VAV air distribution devices

Because of operation at partial loads, a prudential COP value of 4 was adopted, then two chillers having an overall capacity of 480 kW_f are estimated.

As far as the cooled air distribution is concerned the concept of the system foresees the displacement ventilation mode. In this mode, the buoyancing effect of the heated air is exploited. Cold air is delivered through grilles placed at low level, below the seats of the spectators, at a temperature lower than the room one, $\Delta T \approx 8$ K and the vertical air flow around an occupant having a normal body temperature results in a very efficient removal of the pollutants.

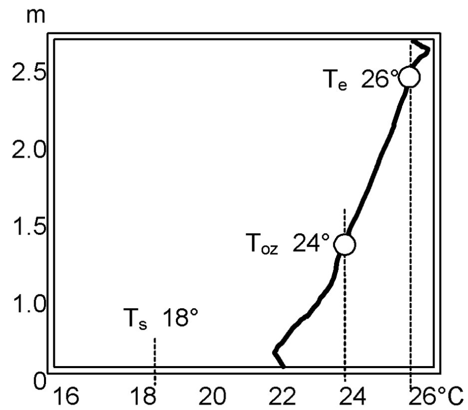

Figure 6 Displacement Vent.Temp. profile

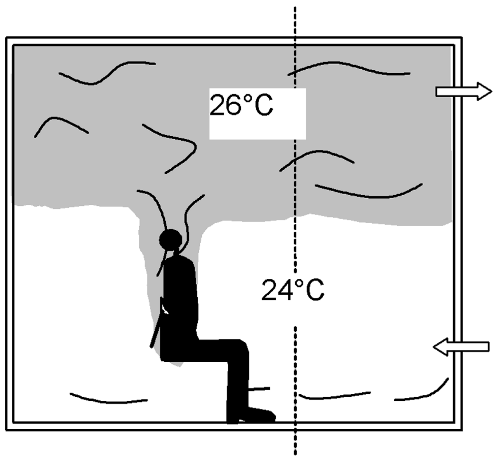

Figure 7 Air distribution flowpath

The position of return air grilles is at high level and is independent from the position on the horizontal plane. Under these conditions (amb. 25°C 50%), the total air to offset all the thermal loads was evaluated to be 6 achs. (Building volume 16 800 m^3).

Furthermore, the adoption of high efficiency final devices for air distribution should be obvious. In normal conditions, some types of modern devices (helicoidal anemosthats, etc.) can achieve a delivery efficiency of 0.9. To have just an idea of the investment cost, we assume for this system typology about 150 €/m^2.

Final result

The final evaluations give an 11% for minor uses of electric energy, to which savings for less delivered air in case of events in which the occupancy is not complete should be added. With the previous number 1÷3 $W_e/(l \cdot s)$, considering 22 events per year, a 20% of yearly electric energy saving is easily achievable.

2. CONCLUSIONS

All the evaluations were aligned in terms of primary energy, i.e. in toe, 42 GJ = 1 toe and assuming for the electric energy the value of the Italian grid heat rate, 9.63 MJ/kWh_e.(The required energy from the national mix to obtain an electric kWh), in the *traditional scenario* a consumption of 7 toe was found, while in the *innovative technologies* one a value of 4 toe was assessed, resulting then in a decresing of the energy consumptions around 43%. It is apparent that a remarkable energy conservation is achievable when innovative solutions are explored. To obtain this result, some border conditions should be fulfilled.

• professionals and designers should be aware of trends of the market, since the majority of the technicians working with the Public Bodies are very traditional.

• In the tenders for public facilities emphasis is placed to the lowest cost, this prejudices a quality design and induces to poor execution.

• The energy conservation culture should drive effectively all the technical choices, very often this aspect is disregarded, attention is focused on the investment cost and not in the exercise cost.

• Amortization periods should be shortened, from 10-15 years to 2-5, to enable technologically innovative solutions attractive for the market. The aspect in this case will be strongly accelerated if PV (Photovoltaic Generation) autoproduction will be considered too. The incentives system promoted by the government is very advantageous. The energy brought to the market is paid up to four times the actual distribution price.

• Standardization in the country is finally considering energy certification to be produced in the building market; every building will be classified on the basis of an energy index per square metre, this will result in a consideration of more modern aspects of the energy uses than the previous norms.

REFERENCES

ASHRAE 1993 Non Residential Air Conditioning Cooling and Heating Loads, Handbook Fundamentals, Ch. 26 pp.1-65

Electrochromic Glazing (2004) Emerging Technologies & Practices ACEE.

Maccari, A. (1999) Materiali Elettrocromici, Workshop April 4, pp. 1-4.

Liddament M., A. (1999) A Guide to Energy Efficient Ventilation l 4, pp. 1-4.

Vio, M. (2006) Evoluzione dei circuiti idronici nella centrali frigorifere, Proceedings, Conference Evoluzione tecnologica per il risparmio energetico nella climatizzazione ambientale, Catania October 25, pp.321-345.

Viessmann (2006) Notiziario Tecnico, Tecnica della Condensazione pp. 1-23.