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Thermal Performances of a Highly Insulated Building in Northern Italy

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ABSTRACT: The paper discusses the renovation project of an existing building, which was built in the late 40s, and has been transformed into a one family house (mainly) with a private office for the owner.
The original building function was a mechanical factory, and in last 30 years was transformed first into a furniture shop and then into a store. The building was then abandoned for five years and in the last eight was transformed into an experimental office, in which the inhabitants could themselves experiment with the meaning of living in an green building; the last refurbishment transformed once again the use of the building into a residential building.

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Keywords: architecture, refurbishment, simulation

1 INTRODUCTION

This work discusses the thermal performances of a building that has been recently renovated in northern Italy not far from Milan. The original building was an industrial building (built just after the World War II) with very low thermal properties and no thermal equipment. Last year the building has been renovated and has been transformed into a residential building.

In Mediterranean countries, the use of a high level of thermal insulation is not always related to good indoor conditions, while the use of thermal mass, both in external and interior walls, has to be improved.

The balance between thermal resistance and thermal mass is critical in the Mediterranean climate where people can find both conditions of cold winter as well as hot summer.

The use of natural finishing and ecological building materials was another characteristic element of the project and the effect of CO_2 emissions was computed.

The building has been recently completed (few elements still have to be completed and will be finished next September) and it has been used as a residential building since last January.

The simulations have been performed using the software ARCHISUN, SUNREL, ESP-r and the Italian standard (Legge 10/91).

2 ARCHITECTURAL CONCEPT

The building is located at Legnano, a medium sized town of approx. 50.000 inhabitants, not far from Milan in one of the most industrialized areas of north Italy. This area is characterised by the presence of many industries that are deeply integrated in the town.

The existing building was a single volume with an interior height of 4.5 meters. Part of the house is EW oriented, while the office faces south. The original height of the building was extended in order to have both the house and the office on two floors.

Objective of the retrofit was to have an ecological, high in quality and low energy consuming at competitive costs.

Wet technologies (bathrooms, kitchen, heating systems) have been placed to the north-west façade to protect the primary spaces, as well as corridors, storage rooms and stair that face north-east.

The living rooms are located at ground level, while the sleeping rooms are at the first floor. The former building was a single volume about 4.5m high with a conventional roof; the portion of the building at the higher level has been marked using a different morphology and different materials for the finishing. Large sized blocks of cellular concrete (30cm) have been used for the ground floor with plaster finishing ($U=0.43\ w/m^2\ K$) while the exterior walls of the upper floor have been built using large sized blocks in cellular concrete (24cm depth) with an exterior insulation of 10cm in kenaf (hemp) and 2cm wood finishing ($U=0.22\ w/m^2\ K$).

Both old and new roofs have been highly insulated using 15cm of natural insulation (kenaf) and an infra red barrier (from thermal transmittance $U=0.23\ w/m^2\ K$ to $U=0.32\ w/m^2\ K$, the difference depends on the use of different insulation sizes or different infra-red barrier).

The thermal resistance of the intermediate floor is $1.02\ w/m^2\ K$ while the ground floor has a U value of $1.29\ w/m^2\ K$.

The structure of the horizontal slabs is made of wood as well as the main column of the house that is made with a cypress log.

3 ENERGY CONCEPT

The building is quite compact but with no transparent surfaces facing south, this is due to the building regulations and the existing buildings around that made it impossible to plan any passive solar system. The main concept was to use a conservative technique using a super insulated envelope (at least for the Italian standard) with a significant internal mass that could act as a thermal regulator.

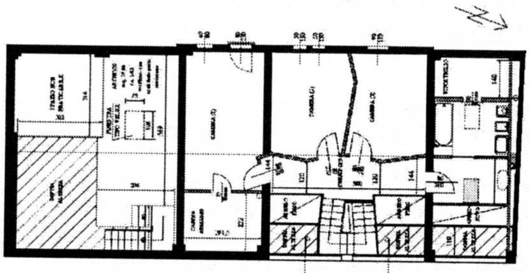

Figure 1: Plan of the building at ground level

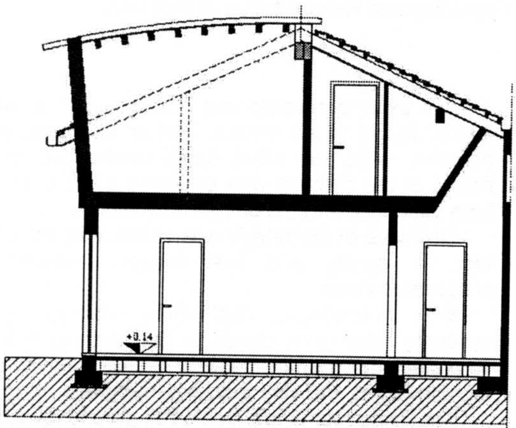

Figure 2: Section of the building

Cross ventilation upgraded in the ground floor by a stack effect (+ 3m) guarantees good summer condition and allows night ventilation techniques.

The global energy consumption of the building is mainly related to space heating (gas burned in a condensing, high efficiency furnace) and to the electrical equipment (electricity). The building is divided into two thermal zones (living – ground floor and sleeping – upper floor) that operate separately. For every room a controller stops the hot water circulation if the interior loads are strong enough to heat the room. The radiators used in the house are single plate, low temperature (45°C) steel slab that reduce the convective interchange increasing the radiating one. The window frames are made in pine wood with double low emission glasses with reinforced insulation and a final U value of about (1.5 w/m^2 K). All windows (except the ones facing north) are equipped with wood, 'Mediterranean jalousies.'

Air circulation under the cover reduces thermal gains in summer and helps in bringing down the surface temperature of the cover. The presence of infra-red insulation improves the efficacy of the insulation with particular effect in summer.

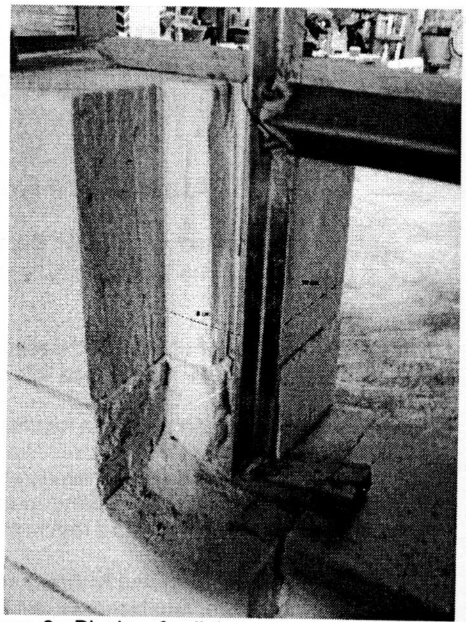

Figure 3: Blocks of cellular concrete 30cm thick

4 PREDICTED BEHAVIOUR

The thermal behaviour simulation of the building has been done with the software Esp-r in order to evaluate the technical system suitability in terms of the ecological criteria and low energy consumption.

The model is represented by 14 thermal zones divided into two floors (8 at ground level and 6 at first floor).

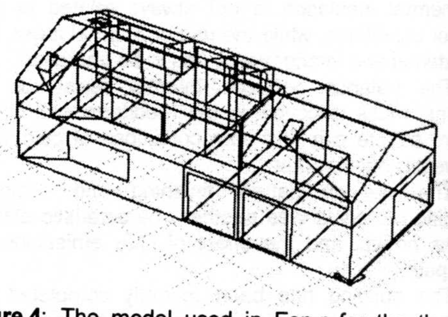

Figure 4: The model used in Esp-r for the thermal simulation

Simulations have evaluated horizontally and vertically for structure.

Horizontal partitions are related to the ground floor, and the slab between the two levels and roofs, is almost flat above the bedrooms and tilted in the other parts.

The differences in the two roofs are 5cm of kenaf more in the flat roof (15cm instead of 10cm).

Regarding vertical structure the idea is to have highly insulated external walls (both existing and new one), while the internal partition are characterised by a massive system – 15-30cm of cave bricks or blocks in cellular concrete.

Cross ventilation is guaranteed by opposite windows in the east and west facades, while a chimney effect is possible through windows located in the high part of the spaces facing west (bathrooms, stairs and resting rooms).

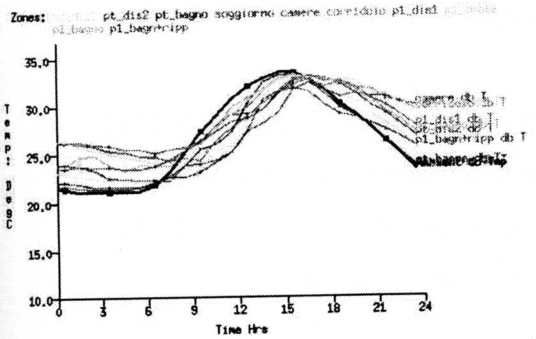

Figure 5: Air temperature in summer with opened windows

Also casual gains have been considered with differences between house and office.

In the house, the presence of four people has been considered weekdays, from 6 p.m. until 8a.m., while during the weekend the presence is continuous.

In the office, the presence of people and equipment for 6 days from 9 a.m. to 7 p.m. is considered, while only the basic functioning of the equipments (computer and security system) is considered on Sunday.

The results of the simulations appear to be satisfactory: in the summer no part of the house requires cooling equipments and even in the hottest period cross ventilation is enough to guarantee comfort conditions.

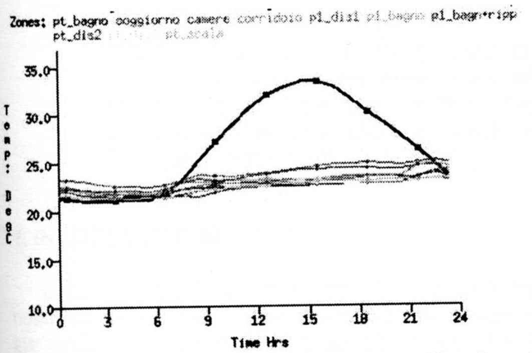

Figure 6: Air temperature in summer with closed windows

The office is the only space facing south, solar protection is less efficient than 'jalousies' and some cooling is desirable to keep the air temperature under 26°C (in the hottest day 1.4 KWh is required - at the moment no cooling system has been planned and a fan with variable speed is the only active technique in summer). During winter the office is reached by direct solar radiation, and this is the space with the best thermal performances (about 35 KWh on the coldest day).

With reference to the house, if no heating system is considered the internal conditions are approximately 10°C higher than the exterior one.

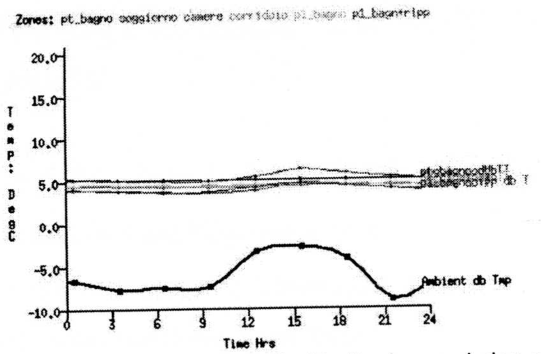

Figure 7: Air temperature inside the house during a cold winter day in free floating regime (the heating system is considered off)

If the heating system is on and the set point is at 19°C from 7a.m. to 9p.m. and off for the remaining hours, the temperature doesn't go lower than 14°C.

In the same period the difference with the external temperature is about 25°C.

In this case the estimated energy consumption on the coldest day is about 51 KWh.

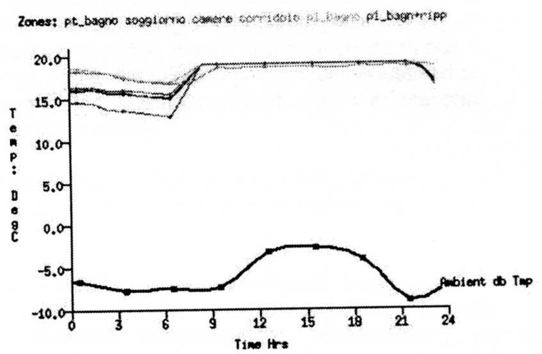

Figure 8: Air temperature inside the house during a cold winter day: the heating system is off at night and is set at 19°C from 7 a.m. to 10 p.m.

5 CONCLUSION

The use of super insulations in buildings has to be considered in Mediterranean countries with reference to high air temperature and strong solar radiation.

The use of good insulation together with significant internal thermal mass gives better results reducing both the necessity of cooling in summer and heating in winter.

The standard for passive houses in the Mediterranean context should be probably considered in a different way, for example defining a minimum of thermal mass, the necessity of cross/night ventilation and the effect of solar radiation on opaque surfaces in summer.