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Low cost passive cooling system for social housing in dry hot climate

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ABSTRACT

The low energy approach should be the key concept in any long-term strategy aiming to build sustainability. For Madrid climate, action should be taken to reduce energy demand for heating and cooling in residential buildings.

The performance of a passive cooling system was developed as a part of design work for the project of a low cost residential building. The passive cooling systems incorporate a solar chimney and precool the air by using the sanitary area of the building. The natural ventilation is enhanced with the help of the solar chimney and fresh air is cooled down by circulation within the sanitary area. The application of this system to the living rooms of a low cost residential building was evaluated and implemented. This cooling system incorporated to a residential building is the third prototype developed since 1991 by the designers. A model was developed to allow to predict the temperature of the air in the living room. The performance of the passive cooling system was evaluated based on the energy balance for a typical summer day.

To reduce the energy demand in winter, a new design and window orientation has been developed and evaluated using DOE-2 simulation tool. The building has been constructed and monitored during 2006–2007.

1. Introduction

The residential sector accounts for more than 30% of final energy consumption in the European Union and is expanding, a trend which is bound to increase its energy consumption and hence also its carbon dioxide emissions [1]. Indeed, the use of conventional air-conditioning systems has a big influence on the electricity peak in summer. In order to reach the best environmental–thermal conditions within a building having lowered conventional energy consumption, during the summer period, it is advisable to make use of passive cooling strategies, including the reduction of the cooling loads of the building.

In Madrid the climate is hot and dry during the summer and cool during winter period. Moreover, daily thermal amplitude is high, more than 15 °C in summer. So, traditionally, people use night ventilation as the main strategy of natural cooling. During daytime, windows are closed and are protected from direct solar radiation. However, due to internal gains and heat transmission through wall and roof, daytime ventilation is required to improve indoor air quality and to remove the heat. However, if outdoor air temperature exceeds the thermal comfort limit, it is necessary to precool it.

Pre-cooling of external air before entering the building can be achieved by natural means, like circulation of the ventilation air though the sanitary area. Soil temperature at a few meters depth, is lower than mean daily outdoor air temperature and significantly lower than usual outdoor daytime air temperature.

Due to the fact that the ground exhibits high thermal inertia, temperature at a certain depth is almost constant along the year, 15 °C for Madrid area.

A solar chimney is used to increase natural ventilation through living rooms. In the solar chimney air is heated up in contact with a surface, which absorbs solar radiation. Heating enhances the pressure difference between inlet and outlet of the chimney, thus increasing the rate of natural ventilation significantly.

Design temperature for winter is −3 °C but average temperature in January is +5 °C and usually dry and sunny. Design strategies for winter are high-insulated walls and windows orientated on south and southeast facades for optimisation of solar gains.

2. Urban and site context

This building is the result of the wish of the EMV (Empresa Municipal de la Vivienda de Madrid) to progress towards higher

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energy efficiency in their social housing promotions. This 30-apartment block is located on an existing plot of land in an old district in Madrid.

The shape, dimensions and orientation of the plot seem to predetermine a rectangular-type of building with longitudinal axis in a north–south orientation.

3. Design strategy

The design strategy, considering the conditions of the plot of land and the cost constraints due to social housing project, is based on optimisation of solar gains through the windows located on south and east oriented facades in winter and uses external shadows by trees (Fig. 1) at the west façade and solar protection on east and south windows.

Day ventilation in summer is provided with pre-cooled outside air by circulating through the sanitary area of the building located 6 m below grade. During daytime, when outside air temperature is greater than inside temperature, a solar chimney provides driven force to air movement through the rooms. During nighttime when outside temperature drops below inside air temperature, the air movement is also guaranteed by the natural ventilation system.

The building design is organized with the living rooms in a vertical line located on the east and south orientations (Fig. 2).

The layout of the rooms allows the design of two chimneys connected through the living room of each apartment (Fig. 3).

The chimney (left line) connects the sanitary area of the building with the low part of the living room and the right one connects the upper part of the living room of each apartment with the solar chimney located on the roof of the building (Fig. 4).

The pieces used for the construction of the chimneys are prefabricated low cost SHUNT, A-47N of common use for bathroom ventilation.

Fig. 1. West façade.

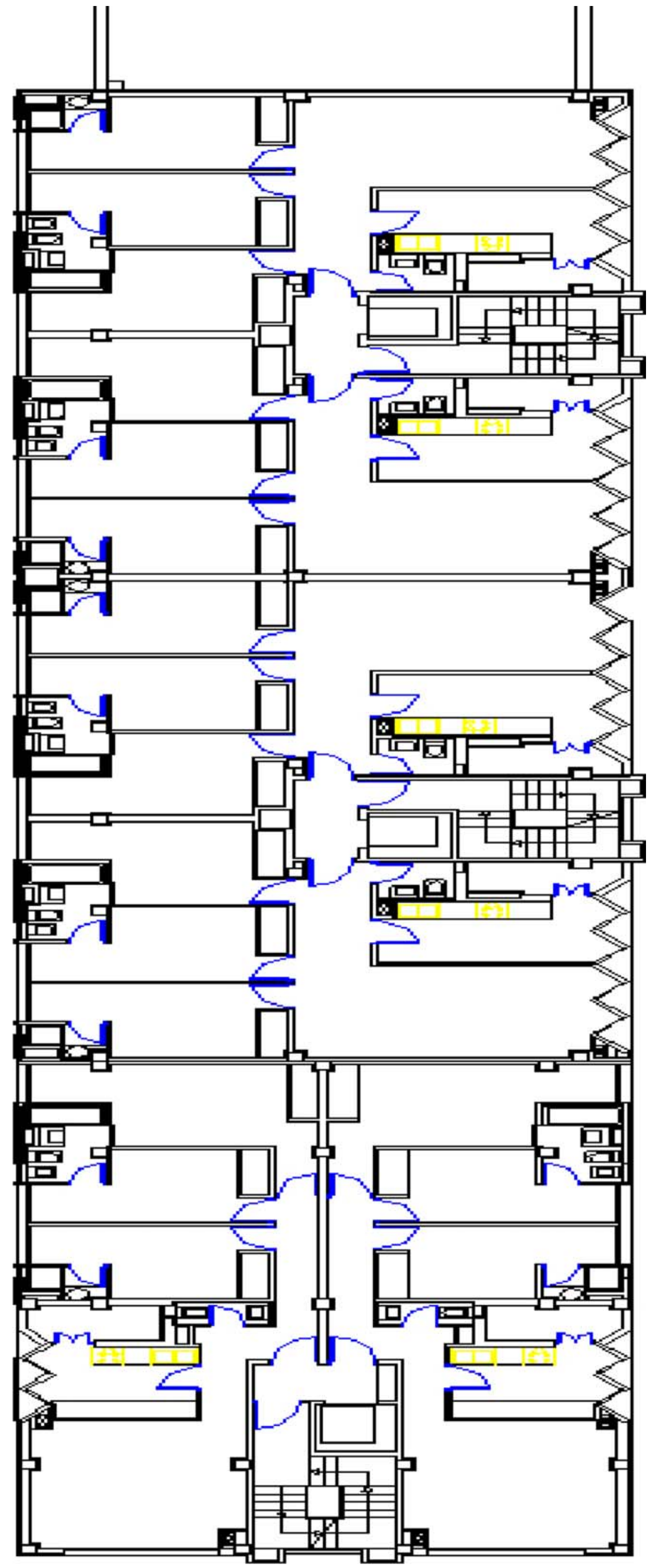

Fig. 2. Ground plan of the building.