Paper No 644: Energy Efficiency Compared Studies at Master Plan Stage for a New Urban Development in Madrid.

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Abstract

In order to achieve optimum results, energy efficiency of buildings should be first addressed in the pre-design phase. This paper describes the studies carried out in order to improve the energy efficiency of the buildings planned to be built in a large residential-commercial urban development in the north of Madrid. The first analyses are addressed at Master plan design stage, confronting the issue of energy efficient building form. Following selection of four residential and office plots, several mass options, derived from the tight planning regulations for the area, are modelled and simulated in order to compare the results in terms of heating and cooling demand, taking into account each building's surroundings. Once the most efficient mass options are chosen, further studies, centred in envelope materials and building refrigeration and heating systems will be carried out, so the results obtained in all these areas can be used as criteria and specification guides from the early stages of individual building design projects.

Keywords: Energy efficiency, design criteria, mass studies, residential building, office building.

1. Introduction

Energy efficiency of the buildings is often overlooked in the urban planning stage of an urban development, coming into play at best during the building's design phase.

There are a large number of variables playing a role in energy efficiency of buildings, some of which can be effectively worked on at the pre-design phase. This research project focuses on building form and orientation, building envelope materials, and heating/cooling equipment selection as the main areas in which we have decided to work in order to improve the energy performance of buildings. Coming out with a set of specific criteria, to hand out to design architects, addressing each one of these aspects is the main target of this work

2. The Urban Development

The area to be developed is a large amount of land in the north of Madrid, containing the Chamartín railway station that connects the capital of Spain with the north of the peninsula. Plans include the refurbishment of the station, and the burial of the first stretch of rail lines. This will free about 3.000.000 m^2, so 4.200.000 m^2. of dwellings and offices can be built, extending the financial district around Castellana avenue, (the main north-south axis in Madrid) more than three kilometres to the north in what is considered as one of the biggest urban developments going on in Europe right now.

The approved planning document provides redlining for each lot, as well as maximum number of heights, square meters to be built, and lot occupation percentage. However, it does not reflect any requirements regarding materials or plant equipment.

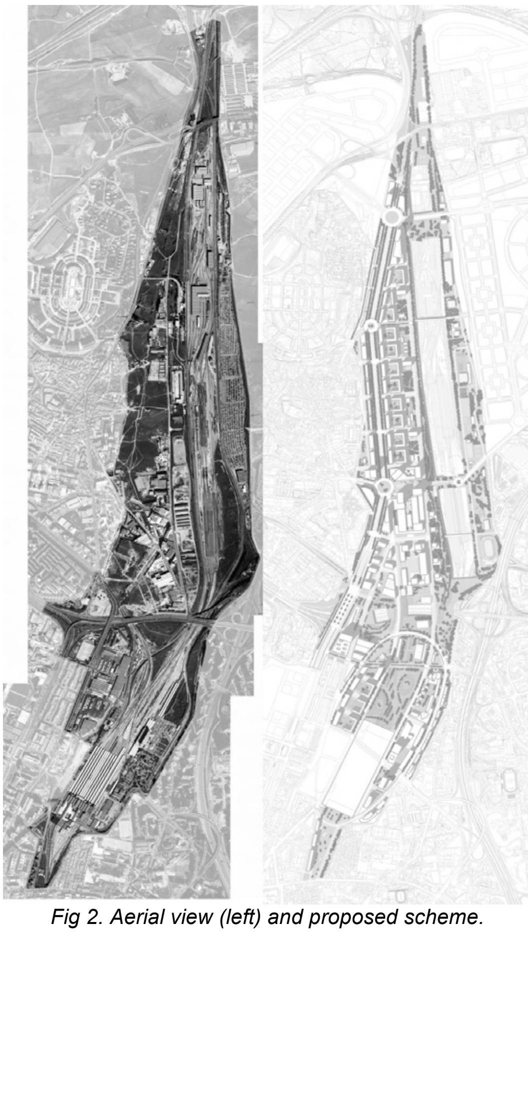

Fig 2. Aerial view (left) and proposed scheme.

3. Methodology

The work was divided in three phases, each one focusing in one of the identified technical targets. In the first phase, covered by this paper, form and placement of the buildings was studied. Envelope materials and HVAC equipment will be considered in next phases.

Four lots were selected (two residential lots and two commercial/office lots), and several mass options were drawn for each lot, taking into account the urban planning restrictions, some of them addressing basic bioclimatic architecture principles. All the mass options, considering their interaction with surrounding volumes were then simulated using Energy Plus, using the minimum or standardised values in Spanish codes for U-values, occupancy patterns, and equipment setpoints. Given the fact that there is no detailed design for the buildings, fixed values were also used for glazed surface percentages and infiltration rates. This way it is possible to assess the impact of massing and orientation decisions in hypothetical buildings, meeting the minimum requirements in Spanish building regulations.

These studies were completed with solar studies for each one of the different massing options, several model sensitivity studies (regarding ventilation rates, glazing percentage, and set point temperatures), and, in the case of office buildings, an additional study was carried out to assess the influence of thickness vs. height, taking into account the influence of an artificial lighting system in the thermal loads of the building. An artificial lighting system was defined, with a target illuminance of 500 lux (standard for general office tasks) with 25 mm. T8 triphosphor fluorescents coupled with a dimming system managed by daylight sensors.

4. Results and Analyses

The simulation results in residential buildings showed clear relationships between building form and energy demand. Due to a relatively low (20%) glazing percentage, maximizing solar gains, and thus, south facades, along with avoiding thick buildings, proved to be key in order to improve energy efficiency. Another evident conclusion of the simulations was to see how the light wells act like “energy sinks”, making much worse, in terms of energy demand, the buildings featuring them.

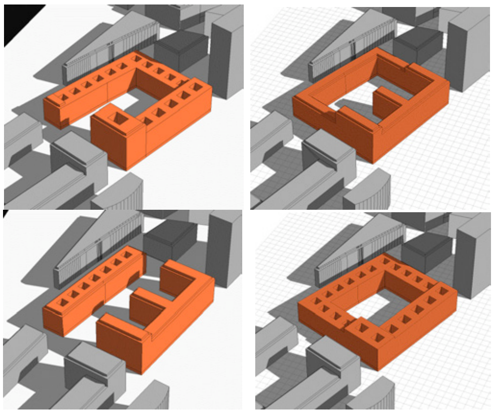

Fig 2. Mass options for residential lot nº 89(Top left to bottom right: base,1,2,4)

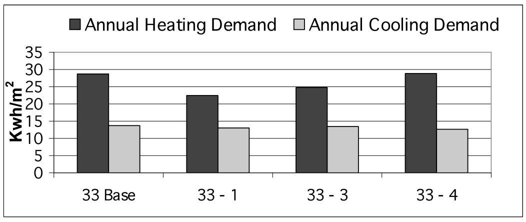

Fig 3. Heating and cooling demands for residential lot nº 33

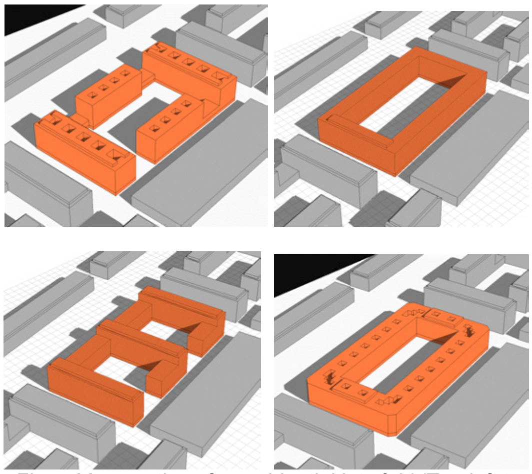

Fig 4. Mass options for residential lot nº 89(Top left to bottom right: base,1,2,4)

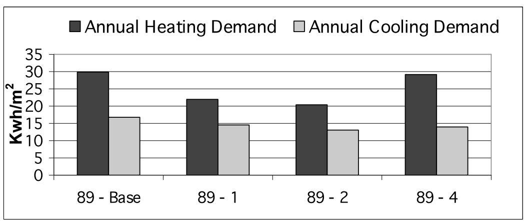

Fig 5. Heating and cooling demands for residential lot nº 89

As a general conclusion for residential buildings, making thinner constructions with big south facades that can take advantage of solar gains, and avoiding light wells were the main criteria recommended to the developers.

Office buildings showed different energy demand patterns. As the illustrations below show, cooling demands are predominant, due to larger glazed surfaces. This is more evident when we take into account the thermal gains from the artificial lighting system.

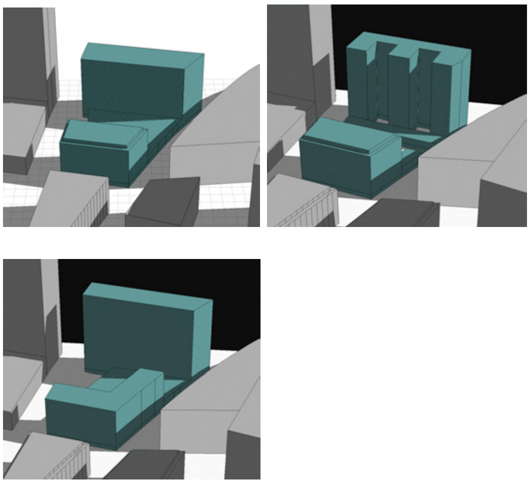

Fig 6. Mass options for office lot nº 89(Top left to bottom: base,2,3)

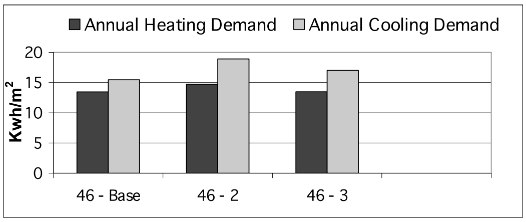

Fig 7. Heating and cooling demands for office lot nº 46

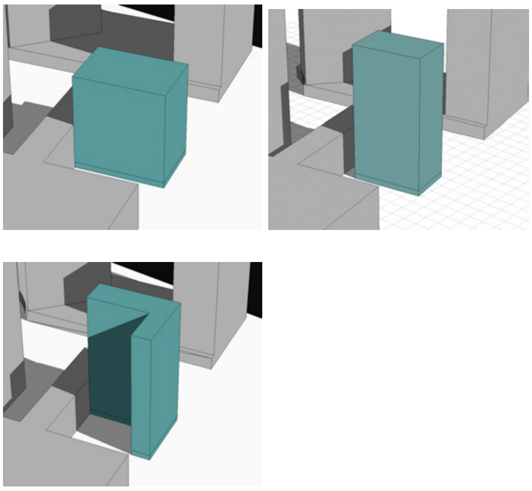

Fig 8. Mass options for office lot nº 76 (Top left to bottom: base,1,2)

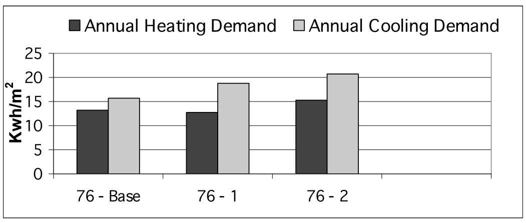

Fig 9. Heating and cooling demands for office lot nº 76 (without lighting system)

As we can see in the following graphs, even with the daylight sensor dimming, the lighting system has a big influence in refrigeration loads for the building in the hot Madrid summer. It is important to note that 75% of the energy used by the T8 fluorescents goes to heat losses. This underlines the importance of a correct lighting design that incorporates a dimming system, not only to reduce the lighting consumption, but to avoid the thermal loads associated to the lighting system.

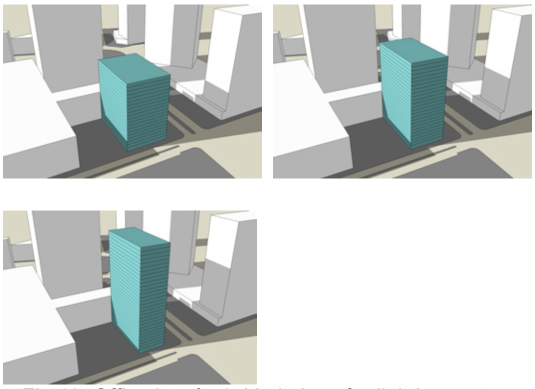

Fig 10. Office lot nº 76: Variations for lighting system analysis

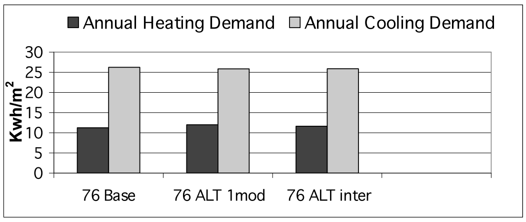

Fig 11. Heating and cooling demands for office lot nº 76 variations(with lighting system)

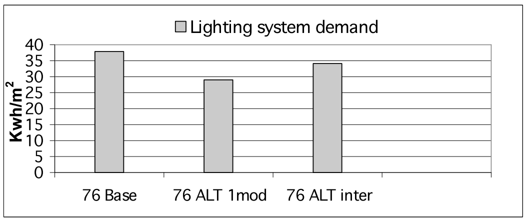

Fig 12. Lighting system demands for office lot nº 76 variations

5. Conclusion

This first phase of the research project has showed how the correct massing and orientation of buildings contributes to substantial energy efficiency improvements.

In terms of demand, residential and office buildings behave differently, due to different occupancy patterns, and mostly because the different percentages of glazing in their facades, resulting in different levels of solar gain, which should lead to different control strategies.

Thick buildings and light wells are features to avoid in residential buildings. This will maximize solar gains in the envelope and will make ventilation of the buildings easier.

Office buildings, more heavily glazed, need thinner plans to take advantage of daylight and to make natural ventilation easier, while protecting

themselves against summer solar gains by the use of solar control devices, more easily implemented in south facades.
In the next phases of this research project, currently underway, several materials definitions for roofs, facades, slabs and glazing systems, as well as heating and cooling systems will be analysed in the most efficient mass options for each plot. The final result will be a book of criteria that design architects will be able to use as a starting point in their designs, always having in mind that more building-specific design solutions will have to be validated in order to achieve maximum efficiency.
Another positive impact lies in the fact that the outcome of the study is having an awareness rising effect in the developers, who have since then revised their targets in order to achieve greater efficiency ratings.

6. Acknowledgements

The authors would like to thank *Labein Tecnalia* and *Desarrollo Urbanístico Chamartín S.A*. for their support in the development of this research project.

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