Methodology and results of construction company R&D department in energy efficiency in building

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ABSTRACT

To promote the sustainability the building environment is full of opportunities; in particular in Europe with the energy building performance directive and its adaptation in Spain with the new regulation on energy efficiency in building (Código Técnico de la Edificación: CTE). The work on energy efficiency in building could be held since different point of view. In a construction company it exists 2 ways to encourage energy savings:
- Studying the basic project during the phase of competition. This approach lets few time and just permits to give advice but they might be not applied at the execution stage.
- Analysing the project at the beginning of the work phase. The clients, most of the time, approve some modifications during the execution of the building. So, the changes to save energy can be consented with the approbation of the architects.
The studies follow a logical plan: the analysis of the projected design, the analysis of different more energy efficient solutions and the economical-energetic study of these proposed solutions. To make the energetic analysis, simulation softwares are used.

1. INTRODUCTION

In Spain the transposition of the European energy building performance directive: EBPD (European Parliament & Council on energy efficiency of Buildings, 2002) is the new building code called Código Técnico de la Edificación: CTE (Dirección General de Arquitectura y Política de Vivienda del Ministerio de Vivienda & CSIC, 2006). This new regulatory environment pushed the actors of the construction to think more on energy efficiency in building. One of the sectors able to promote sustainability is the construction. They usually support sustainable technologies in the construction site but let the architect and the client work on the building efficiency. The fact is that the project is not fixed during the execution and the construction company, as makes changes in the structure project, can modify the architectural project improving the energy efficiency of the building. The framework and the possibilities are not the same than for the building designers. The construction company needs to respect strict requirements in terms of cost and aesthetic defined by the building project.
In our case the R&D department is the responsible of the energy efficiency field and makes the different studies relating to this subject. During a competition phase, a description of the project is developed and since few time a part of the report is dedicated to energy efficiency. The R&D department works also developing reports including energy saving solutions through the construction phase.

2. METHODOLOGY

2.1 Competition's phase

The construction companies answer to competition through a tender department specialized in building budget development. Singular projects receive a special attention, for example an energetic study of the building. At this stage, the basic project is composed by an architectural and installations report. The level of the building definition depends on the architect, the size of the project or even the client. The time to develop an energetic analysis is short, usually around 3 weeks.
The study is mainly focused on showing that the company is able to develop energetic analysis than finding viable energy efficient solutions adapted to this building. An architectural analysis is done pointing the bioclimatic characteristics of the project. A simple model for an energy consumption analysis is simulated. Usually, the modelling software is DesignBuilder (Tindale et al. 2005). It offers a graphic interface which is utilized to create pictures. According to the competition, some advices dealing with energy efficiency are integrated into the construction company report.
Thanks to this energetic analysis, the construction company will prove to the client that it can build his building using energy efficient technologies and might propose solutions to improve its thermal behaviour.

2.2 Construction's phase

When a building is allocated to the construction company the execution project is available. The execution project includes the architectural and installations projects and the project budget. The period between the reception of the execution project and the construction work's beginning is variable. Fortunately, some changes should be proposed after the start of the construction work. The site manager is the unique contact between the R&D department and the construction site. The energy efficient proposals must be firstly submitted to the site manager and afterwards he has to convince the client to introduce modifications into the execution project. The modifications should not to create new work items in the project budget because it generates complications, like increase of the budget, that hinder the site manager to propose them to the client.

The procedure to present proposals of energy efficient change is firstly; the R&D department analyzes the projected building energy consumption; several research lines are proposed to the site manager; by mutual agreement, it is decided to follow the investigation on selected research lines; a deadline is fixed to make the studies; a final report including the energetic and economic analysis is developed and presented to the site manager; he decides to propose modifications to the client. The final decision is always in the hands of the client to accept or refuse any modifications even if it doesn't have any influence on the budget, the execution time...

2.3 Research lines

The research lines are the building parts or systems which influence the energy consumption of the building and they depend on each project. As the building project is finished, the research lines are limited and the energy efficient solutions are more complex to implement. The three main lines are: bioclimatic architecture, renewable energy and HVAC installations.

The bioclimatic architecture field includes various level of development. As the building is already designed, to vary the orientations and the shape, for example, is impossible. Therefore the analyses are focused on materials and passive systems. Proposed materials need to fulfil the acoustic, condensation, structural requirements of the project materials. The building elements like walls, roofs or windows must be the same dimensions than in the execution project. The only opportunity to decrease the energy consumption is replacing a material by one with a thermal behaviour more adapted to the building. If the passive systems (Santamouris & Asimakoploulos, 1996) already exist their optimization offers interesting proposals easy to implement. The passive systems can be introduced depending on the building project. In this case, the most important requirement is to not change the aesthetic of the façades. Natural ventilation proposals (Allard & Santamouris, 1998) using ventilation grilles, existing ducts or even operable windows are studied. Other options as trombe wall, air-to-earth heat exchanger and green roof are analyzed in some particular cases when the site manager notices a possibility to convince the client.

Solar domestic hot water (DHW) system integration is required, since the 17th of September 2006 (Ministerio de la Vivienda, 2006), in almost each building; photovoltaic (PV) system integration is required since the same date in specific buildings like offices, hospitals, commercial centres according to their size. In the installation project, the solar project is described. The influence of the solar panels in the energy consumption for the building conditioning and their architectural integration are usually not taken in account. The proposals for this technology deal with these subjects. Other renewable energy systems might be proposed like water-to-earth geothermal heat exchanger depending on the willingness of the site manager.

It exists different ways to improve the energy performance in HVAC systems: changing the equipments for more efficient ones (condensing boilers, recovering systems…) or using the energy consumption simulation's results to reduce the nominal power of the heat and cool production equipments.

2.4 Final report contents

The final report contained the study of each proposal including an economic analysis and a cost comparison between the project solutions and the proposal solutions. The used software choice to make the proposal studies depends on various parameters: the time, the complexity of the building and the proposals it selves. Some systems are easiest to implement in one software and conversely. DesignBuilder based on the EnergyPlus algorithms (UIUC, 2004) is used for global analysis of the buildings. TRNSYS (Klein et al., 2006) with TRNFLOW (Hiller et al., 2004) are utilized for passive systems with natural ventilation like atrium and double-façade. Passive techniques using humidity are also modelled in TRNSYS. ECOTECT (March & Square One research, 2005) is used for solar radiation's analysis. In general the studied buildings are singular and large; consequently each software is used to develop the entire analysis. The final results of energy consumption are calculated for one year.

The economic study of the proposals includes the cost of the proposed systems furthermore the energy savings in kW and in €.

The comparison between the project and the proposal cost is very important for the site manager. In the project budget, in fact the construction company can loose money in some work items if the real cost is higher than the presupposed cost. The R&D department looks for these items and finds energy saving proposals to permit to the site manager to propose modifications. The economic conclusion of the proposals is made by the site manager because he is the only person to have the whole information to take the decisions.

3. REAL BUILDINGS STUDY

3.1 Buildings description

The FORESTA office buildings complex (Beroiz, 2006) is situated at the North of Madrid city. These buildings were studied during the construction's phase. It includes eight buildings of three floors. The storeys are open-plan thanks to pillars on the perimeter. Each building is designed to be protected from the sun using pergolas and includes an atrium. The façades are made by structural glazing with different solar control depending on the façade's orientation.

3.2 Building models

The site manager decided to study two buildings. They were modeled firstly in DesignBuilder to define the global energy consumptions. The first planned building energy demand is 15.37 kWh/m^2 per year of heating and 84.11 kWh/m^2 per year of cooling. The second building's energy demand follows the same trends. The conclusion of this initial study is that the cooling demand is more than five times higher than the heating demand. The proposals will focused on reducing the solar gains during summer time.

Sun exposure and shading studies were developed using ECOTECT (Fig. 1).

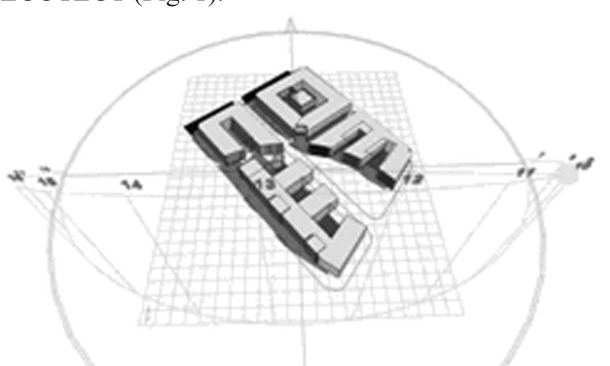

Figure 1: Four buildings the 21 of September at 10:00.

The results of these studies are that the atriums are designed to avoid overheating in three buildings; the shaded area of the atrium in the last building does not reach the 50 %. Concerning the façades, the solar shading systems do not protect the building in summer.

The atrium is a critical part of the building according to its energy consumption per square meter. In one of the building, the cooling demand is over 100 kWh/(m^2.year). A model of the atrium of this building is developed in TRNSYS with TRNFLOW.

3.3 Proposals

Three research lines are proposed focused on reducing the cooling demand of the buildings.

The office façades are made up of double glazing with a coated glass in the exterior pane. The coated glass is a solar control glass, which blocks up to 2/3 of heat by reflecting it to the outside. The double glazing's thermal transmittance is 1.8 W/(m^2.K) and its solar factor is 0.44. The proposed glazing is a double glazing with two coated glass, one to reflect the sun protecting the indoor environment from the solar beam and the other to prevent the losses from the interior to the exterior. Its thermal transmittance is 1.6 W/(m^2.K) and its solar factor is 0.31. Thank to this solution, the energy consumption decreases 8.9 % compared to the projected buildings. Of course, the consumption for heating increases more than 15 % but the consumption for cooling lowers more than 15 %.

The cooling demand is higher in the upper part of the buildings, especially in the last floor. The roof receives the sun beam during the hotter hour of the day. The proposal is decreasing the solar absorptance of the roof covering; less heat will enter into the building. The roof covering was not specified in the project. The usual coverings are gravel or concrete flag. Their solar absorptances are greater than the proposed coverings: white flag or white paint. The results are that the energy consumption for heating increases 3.8 %, the energy consumption for cooling decreases 10.19 %. The global balance of the energy consumption is a drop in 2.2 %.

The sun exposure and shading studies made previously show one building suffers overheating owing to its atrium. A model in TRNSYS is developed to analyse this complex architectural element. Its purpose is to shade the atrium using a temperature and solar beam regulation. When the interior temperature is increasing during sunny days in summer, shading elements will be moved to stop the solar beam and prevent overheating. The atrium will be covered at 50 % to use daylighting for illumination. This proposal influences only the cooling demand because the shading system will only work in summer. The reduction of the energy consumption between May and September is 14.46 %, which supposes a reduction of 2.44 % of the global energy consumption during the whole year.

3.4 Conclusion of the study

The report containing the results of the planned buildings and the proposal studies was presented to the site manager. The period to implement the studies for the real application was short and he decided to not include the proposals at this stage. The proposals will be taken in account in a second phase of development of the building complex extension.

4. CONCLUSIONS

Many barriers hinder the energy efficiency to penetrate in the phase of construction. The cost of the energy efficient solutions is high, the time to study the proposals is short, the site manager is not convinced by the solutions or the client decides to not modify the project. In spite of these barriers, the introduction of energy saving techniques into the built environment during the construction phase is possible. The rise of the consciousness in the construction sector pushed by the authorities in energy efficiency in building will permit a development of private initiative to build in a sustainable way.

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