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Şcoala Doctorală de Studii Inginereşti

CONTRIBUTIONS REGARDING THE NEW RESIDENTIAL CONSTRUCTIONS ENERGY EFFICIENCY IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

PhD Thesis - Summary
for the scientific title of doctor in
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PhD in ARCHITECTURE AND URBANISM

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From a practical point of view the objective of the present PhD thesis is that of researching the aspects related to the edification costs and energy consumption of a pilot building, as well as the means to reduce these costs, the behavior of the water-to-water heat pump system used for heating, and the financial efficiency analysis used for cost reduction in terms of electrical energy.

Theoretically, we propose the analysis of the energy-efficient home concept, according to current theories in the field, and we propose a matrix method for the realization of the field study used for identifying the ideal location for such a house.

The subject approached by this study responds to the need of finding solutions to the aforementioned problems and to the need of enhancing energetic performance for new buildings; the thesis comes under the provisions of Europe 2020 strategy and of the National Plans in the Field of Energy Efficiency (NPFEE).

Beside the fact that architecture creates the life-frame for the society, the architecture product as a result of a structured designing process needs to reflect the social needs, not only through its functionality and rationality, but also through the efficiency and sustainability of the constructions itself – through the way it interacts with the environment.

Chapter I – The global and national context of energy consumption

The first chapter of the thesis begins by presenting the importance and actuality of the research topic in the global context, by highlighting the continuous growth tendency of global energy consumption as an effect of accelerated demographical growth.

The importance of the topic and the fact that it is up to date in the global context is also highlighted through the assertions made by the Climate Change and Sustainable Development Expert Group, according to which the current consumption level of populations in developed countries could be supported, with the performance that we nowadays have for the management of global resources, for two billion people at the most. The world population has already reached this threshold in year 1920, nowadays exceeding 7 billion inhabitants. Ergo, at least two more Earth-like planets would be needed in order to sustain living conditions similar to those in developed countries for all people, using the technology available today.

In subchapter 1.2 - The National Context, the big-picture of the Romanian real-estate fund is presented, highlighting the fact that, in the case of most residential buildings build 1961-1980, or after the year 2000, periods of time in which the migration tendency towards ”new urban developments” was higher than ever before, the thermal requirements were either ignored or treated superficially. This is followed by a short analysis of the main energy systems used nationally according to data provided by the Ministry of Energy and by the Ministry of Regional Development, Public Administration, and European Funding.

The second part of the chapter presents the research topic, the main ideas, the aim and objectives of the PhD thesis, as well as the actual phase of the research study. The paper analysis problems related to energy consumption levels of the pilot project, ways of reducing energy consumption, the behavior of certain used technological systems, as well as the financial efficiency that results from applying the measures.

Subchapter 1.4 – The actual stage of the research project in the topic of the proposed thesis, highlights the way the ”energy efficient home” concept was born, both in Europe and in the United States of America, reminding the differences between them.

Chapter II –Performance analysis of an energy-efficient house

This chapter presents selected informative data regarding the functioning principles of this type of homes. The functioning principles will be highlighted, as well as the minimal characteristics that need to be met, stratification of the house covering, and the advantages brought by using under floor heating systems, as they are found in the literature.

Hence, the following will be described: heat demand, primary energy coefficient, thermal capacity, heat transfer coefficient, as well as a few structural features of the main parts included in a house covering destined for energy-efficient homes.

Chapter III – General data and the theoretical approach in designing energy-efficient houses

Following the analysis of global and national energy consumption carried out in the previous chapters, has surfaced the need of applying certain principles and strategies in the case of energy-efficient house design.

The subject of this chapter is represented by endeavoring in the efficient and logical design, which could be adopted even from the early stages of the design process, and through which one could assure a correct relation between the building and the environment, as well as with the local energy resources, technologies and materials.

Detailed analysis techniques and design strategies for energy-efficient buildings presented in this chapter insist upon using distributed energy resources (sun, water, wind) instead of high-end energies (petrol, gas, uranium, coal).

The theoretical approach by Mark deKay and G.Z. Brown was first presented in their work, "Sun, wind and light", which proposes a hierarchic organization in which part of the energy performance is induced by the architectural design of the building. Each level proposes a certain approach of the designing process from the point of view of different conceptual parameters, but that are also interdependent in value, resulting in 5 approach levels, also interdependent, that aim at solving the issues regarding energy and design with minimal facilities and low costs.

In the following pages of the chapter we propose a theoretical analysis method and a conversion of the placement study, which takes into account the criteria that already exist on site, the local resources, and includes them in a matrix analysis system that indicates the ideal location for such a building.

By using a checkered model of the allotment and the local data referring to sunlight and shade conditions, solar exposure rate, draft and air movement patterns, we managed to complete graphical charts representing climate conditions that are typical for either the warm or cold season, and that respect certain time intervals (morning, noon, and evening). These graphic representations are reduced to numerical models (matrix) that by summing up indicate the positions on each allotment that have favorable climate conditions for the building.

The advantage is represented by the limited resources it uses and by the ability to create the computer software that would perform such an analysis.

Chapter IV – An experimental program regarding the technical and economic aspects of building and monitoring of the pilot project

The practical approach of this work is represented by a project designed as a home, realized in 2010 in Giroc, Timis County. The allotment chosen for building the house has a total surface of 645 m^2 with a height regimen of P (ground floor) that occupies an area of 125 m^2.

The complete description of the construction parameters, electric energy consumers, as well as of the heating system characteristics are detailed in subchapters 4.2 and 4.3 of the current chapter.

Throughout this chapter data obtained from the 4-year long experimental program are presented; during these four years in regard to energy consumption in the pilot building was continuously monitored.

Electric energy consumption monitored between 2012 and 2014, as well as maintenance costs in the same period of time are the subject approached in subchapter 4.4.

In the following pages of the chapter, we determine the heat transfer coefficient associated with the elements that constitute the pilot-home, by using direct calculations and by respecting legislative acts in force.

After determining these coefficients, the building's heat demand was calculated – Hypothesis B, as well as the annual electric energy consumptions levels used for heating, and the annual costs brought by the house.

The results obtained are then compared with the energy consumption and maintenance costs during the monitoring period (Hypothesis A – Direct monitoring), resulting in an exact cost estimation for one square meter of heated surface per year.

In the same time, for the calculation used for determining the energetic efficiency, a -5% difference was used in comparison to the reality costs and consumptions.

Subchapter 4.10 approaches edification costs, on work categories, presenting lists of materials and work types and the costs associated to each of them.

For the installations systems part the invoices received for all acquisitions made on behalf of building the home were taking into account.

Chapter V – Technical and economic analysis of hypothesis C and D from the pilot project

Energy expenditure recorded for the pilot Project, as well as the technical and economic data presented in previous chapters, offered a set of information regarding the construction costs and the exploitation costs of the home. The data obtained was then used in order to carry out the analysis of two different scenarios of the pilot project, consisting of energy consumption and edification costs simulations.

Therefore, in order to be able to verify the efficiency of the scenarios, we needed to establish hypothesis based on which these simulations were then carried out. Following the results obtained after these simulations the technical and economic analysis of edification expenditure for each scenario was completed.

During the experimental simulations and while establishing the hypothesis, the following were taken into account:
- keeping the architecture characteristics and specific dimensions of the existing pilot project;
- improving the energy consumption parameters by bringing the pilot-project energy consumption levels as close as possible to those of an energy-efficient home;
- that the solutions found for improving these parameters are feasible both technically, and economically, by using materials that are easy to find on the Romanian market, at accessible prices;

The importance of this evaluation in the designing activity is important because it can aid in estimating energetic performance of certain residential projects depending on the materials chosen for the construction.

The experimental simulation program has the following objectives:
-researching building opportunities for an energy-efficient home in relation to construction materials and efficiency;
- cost analysis for materials used in the building process;
- cost analysis for exploitation depending on the materials used;
- budget identification needed for energetic improvement of the pilot-project.;
- determining the amortization time for cost differences, achieved through savings on energy expenditure.

Therefore, in the case of hypothesis C, the estimation will be made for the situation in which the construction will be conducted under the following conditions:
- ceiling with additional insulation;
- floors elevated above the height of the systematized land (0,5-0,6 m);

These improvement measures have been inflicted because of the fact that in the case of the pilot-project, following the calculations, certain heat loses have been determined, at floor and ceiling level.

Starting from the premises that materials are available, hypothesis D proposes analyzing the energetic and economic efficiency of an identical building with that of the pilot-project, and with the following characteristics:
- a structural configuration based on confined masonry brick structure, belts, beams and reinforced concrete strip foundation.
- wooden framing and metal tiles;
- maintaining the plane geometry and orientation of the pilot-project;
- maintaining the dimensions of structural elements.

A technical and economic analysis will be carried out for each aforementioned hypothesis, as it was previously described in chapter IV, in order to determine the investment costs. These are then compared in chapter VI.

Chapter VI – Economic analysis

Chapter VI presents an economic analysis of the results obtained for each studied hypothesis. The cost-benefit analysis (CBA) of the project targets the financial feasibility analysis through three performance indicators:
- Net Present Value (NPV);
- Internal Rate of Return (IRR);
- Return of Investment duration;

In general, for all types of investments, a financial analysis is always recommended. It is important to understand the length to which the invested capital can be amortized over the years. This can happen either through cash flow generated by an economic activity (selling products/services generated by the investment), or through cost reduction when it comes to maintenance, that are noticeable during the operational period of the investment (as the case analyzed here).

The investment cost necessary for obtaining savings on costs was considered to be an additional cost for each hypothesis (B, C, and D) if compared to hypothesis A.

In order to determine additional costs, table 6.4 summarized the total edification costs, taking into consideration all work afferent to technology implementation for each hypothesis.

The reasoning for which only additional costs were taken into account, is the fact that these costs effectively generate savings through less electric energy consumption, all other costs being identical in each building situations, and therefore having no direct contribution to the analyzed cash flow.

The analysis results confirm the fact that all hypothesis and possibilities represent acceptable investments – with future advantages that are higher than the investment needed in order to create the cost savings – but the D hypothesis leads to a maximization of the investment, compared to the other hypothesis, having the highest internal rate of return (IRR) and the shortest return of investment duration.

Chapter VII – Final conclusions. Personal contribution. Practical application of results. Publications.

In this chapter are presented the final conclusions, obtained as a result of research carried out throughout the study. The analysis results highlight the differences of edification and maintenance costs, as well as the energy consumption for each hypothesis.

The second part of the chapter presents the main contributions made by the author and dissemination and practical application manners for the PhD thesis, through research projects, presentations, and publications in specialty journals.

Thus, the major contributions of the author are as follows:

1. Designing and completing a pilot-building, designed as a home, pilot-building that encompassed the implementation of certain technologies, that already exist on the Romanian market; these technologies use unconventional energy and certain building systems that contribute to lowering the energy consumption.

2. Follow-up of edification costs for building the pilot-project.

3. Direct monitoring and periodic recordings of energy consumption and of maintenance costs for the pilot-building that works on a water-water heat pump.

4. Investigation of issues regarding energy consumption and energy loss associated with the project.

5. Proposing a set of simulation ways that could highlight the differences in the energy consumption reduction, as well as the differences regarding the construction costs, depending on the additional interventions and on the materials used for increasing the efficiency of the pilot-building. Analysis of the proposed hypothesis and comparison of results.

6. Proposing a research direction regarding the orientation and positioning of individual homes on an allotment, starting from the current situation on the site and aiming at reducing it to a simplified numerical model.