Design process for integrated concepts with responsive building elements

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ABSTRACT

An integrated building concept is a prerequisite to come to an energy efficient building with a good and healthy IAQ indoor comfort. A design process that defines the targets and boundary conditions in the very first stage of the design and guarantees them until the building is finished and used is needed. The hard question is however: how to make the right choice of the combination of individual measures from building components and building services elements. Within the framework of IEA-ECBCS Annex 44 research has been conducted about the design process for integrated building concepts with responsive building elements. The (Dutch) Toolkit Sustainable Residential Buildings is one of the examples of tools for an integrated design process.

1. INTRODUCTION

1.1. From component to concept

Efforts to minimize the building energy efficiency over the last decades have focused on efficiency improvements of specific building elements and building services equipment Significant improvement have been made and most building elements and equipment still offer opportunities for efficiency improvements. However this approach seems to reach its limits.

The performance of individual elements is often heavily depending on the performance of the system they are part of. I.e. the performance of a heat pump depends on the performance of whole heating and cooling system which consists of a source, a distribution and a delivery part. The performance of a well insulated window no longer only depends on the insulation level of the glazing, but also on the window frame, the spacers etc.

But also the system level approach is not longer appropriate. Buildings have become integrated concepts in which advanced systems work together to reach an optimal performance in energy, comfort and health. And particularly on the overlapping field of building technology and building services, the responsive building elements, lies a great future potential to achieve the next steps in energy savings.

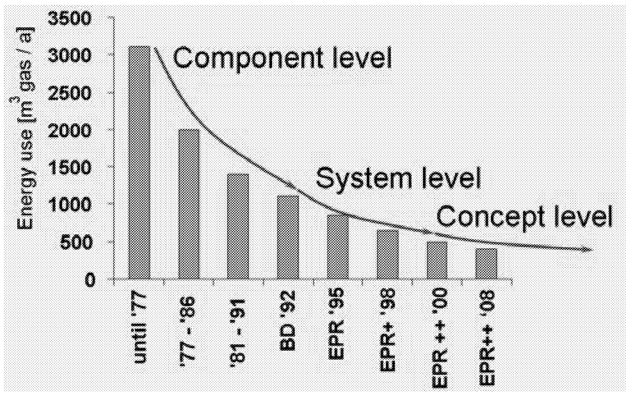

Figure 1. Increasing energy demands lead to requirements on a concept level

Responsive in this context means the ability to dynamically adjust physical properties and energetic performance according to changing demands from indoor and outdoor conditions. This ability could pertain to energy capture (as in window systems), energy transport (as air movement in cavities), and energy storage (as in building materials with high thermal storage capacity).

With the integration of responsive building elements and building services, building design completely changes from design of individual systems to a design of integrated building concepts, which should allow for optimal use of natural energy strategies (day lighting, natural ventilation, passive cooling, etc.) as well as integration of renewable energy devices.

In order to address some of these issues an international research effort has been initiated. IEA-ECBCS Annex 44: "Integrating Environmentally Responsive Elements in Buildings" is a task-shared research project initiated by the IEA implementing agreement Energy Conservation in Buildings and Community Systems (ECBCS). The project runs for 4 years from 2005-2008 and involves about 25 research institutes, universities and private companies from 14 countries around the world.

1.2. The classical way

Before the advent of modern design practices, buildings were protected from the inclement weather or designed to take advantage of daily and seasonal climatic rhythm and fair weather through orientation and strategic placement of entrances and windows. Similarly, the use of natural lighting was planned into the building design. Architects utilized a number of design features such as atriums, light shelf's, or narrow building designs to bring natural lighting into building interiors. Other techniques were also used to keep buildings comfortable in the summer, ranging from finishing the building exterior in light colors to introducing natural ventilation via thermal stacks. In contrast modern construction seldom considered orientation, building shape, day lighting features or passive cooling techniques. Clearly, there was a need for architects to consider the implications of building design on the resulting energy use. This ultimately required the development of a process that emphasized the use of passive (i.e., weather integration) and active (i.e., mechanical systems) techniques to meet all comfort needs.

1.3. Modern times

Nowadays we, have improved and modern building materials, but above all, are able to measure and control the performance of the buildings and building services with an advances building management system (BEMS). These BEMS give buildings there "intelligence" and play a crucial role in promoting an optimal performance of buildings with its building elements and building services in terms of energy, comfort and indoor air quality depending on the required indoor conditions and depending the present climatic outdoor conditions. For the design of these buildings we have access to a large number of advanced design and simulation tools to predict and design the performances, served by highly educated specialists.

The difficult question is however: how to make the right choice and combination out of a large pile of individual measures from building components and building services elements, with respect to all disciplines involved.

2. INTEGRATED BUILDING CONCEPTS

Integrated building concepts are design solutions in which an optimal environmental performance is realized in terms of energy performance, resource consumption, ecological loadings and indoor environmental quality. It follows that integrated building concepts are design solutions that maintain an appropriate balance between optimum interior conditions and environmental performance by reacting in a controlled and holistic manner to changes in external or internal conditions and to occupant intervention that develop from an integrated multidisciplinary design process, which utilizes a three step approach for optimization of energy efficiency (Trias Energetica) and includes integration of human factors and architectural considerations.

2.1 Principles of Integrated Building Concepts

An integrated building concept however includes all aspects of building construction (architecture, facades, structure, function, fire, acoustics, materials, energy use, indoor environmental quality, etc…).

It can be defined to consist of three parts:
- the architectural building concept;
- the structural building concept and;
- the energy and environmental building concept.

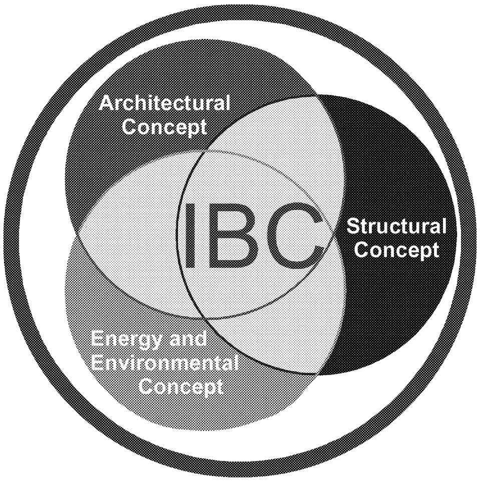

Figure 2. Integrated building concepts: a combination various concepts

This corresponds to the different professions involved in the building design and each concept is developed in parallel by the three professions using their own set of methods and tools - but in an integrated design process leading to an integrated solution – the Integrated Building Concept.
In Annex 44 an Energy and Environmental Building Concept is defined as: “Integrated design solutions where responsive building elements and energy-systems are integrated into one system to reach an optimal environmental performance in terms of energy performance, resource consumption, ecological loadings and indoor environmental quality”.

3. THE INTEGRATED DESIGN PROCES

3.1 The traditional design

The design process that once was done by the architect who covered all design disciplines, has evolved into a fragmented and sequential process, carried out by a number of separate disciplines and served by a group of specialists. An often sequential way of working leads to solutions that focus on adjusting and correcting the implicit “design failures” of the architectural design. Today, the construction industry is in the early stages of a revolution to reinvent the design process that was used before the advent of HVAC equipment. Therefore a more integrated and structured approach, much more interaction and co-operation, clear goals and quality control is needed to bring the design process to a successful ending. Only an early interaction between all disciplines that together design the building concept leads to a low energy building with a good indoor climate, with the incorporation of the architectural and constructional concepts. Especially in these days where buildings become increasingly complex and have to fulfill a lot of requirements.

3.1 The integrated design

Design teams, including both architects and engineers, are formed and the building design is developed in an iterative process from the conceptual design ideas to the final detailed design. Building energy use and HVAC equipment size cannot reduced without the use of sophisticated technologies, but only through an effective integration of the architectural and HVAC designs. The integrated design approach achieves this improved energy utilization due to the relationship between the building, its architecture and the HVAC equipment. Besides this the integrated design approach also achieves an improvement in the environmental performance of the building, as well as fewer construction problems and lower costs.
In the integrated design process the expertise of the engineers is available from the very beginning at the preliminary design stage and the optimization of the architectural and HVAC designs can start at the same time as the first conceptual design ideas are developed. The result is that participants contribute their ideas and their technical knowledge very early and collectively. The concepts of energy and building equipment will not be designed complementary to the architectural design but as an integral part of the building very early.

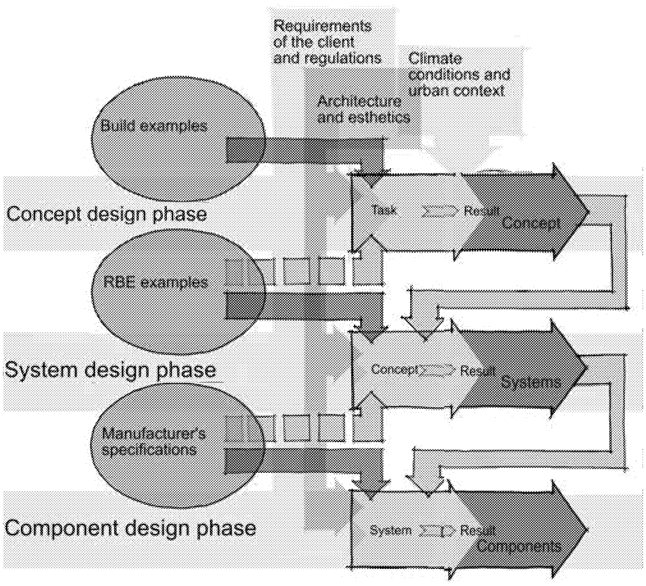

Figure 3 Integrated design process

3.3 Implementation barriers

A number of barriers appear when the borderline between architecture and engineering is crossed and the design process contains a lot of challenges to the persons or groups who participate in the process.

Architects belong to the humanistic arts tradition while the engineer belongs to a technical natural science tradition. This often creates problems for architects and engineers working as a team, as the communication between the two groups rely on a common language and in this case the languages are at the outset very different.

The integrated design process is a holistic method that intertwines knowledge elements from engineering with the design process of architecture to form a new comprehensive strategy to optimize building performance. This implies evaluation and weighting of very different building performance characteristics that often are non-comparable, which requires willingness from all participants to reach acceptable compromises.

The goal of integrated design is an improved and optimized building performance for the benefit of the building owner and the occupants. Changes in design process and methods will require investment in education and will always be more expensive for the designers in the beginning. Therefore it cannot be expected that architects and engineering consultants will be the main drivers for these changes unless the building owners and clients recognize the benefits and are willing to contribute to the investments needed to implement the changes.

4. DESIGN STRATEGY

In order to reach an integrated technical design solution and to develop an Energy and Environmental Building Concept it is necessary to define and apply a certain design strategy. In Annex 44 the design strategy is based on the method of the Trias Energetica method described by Lysen (1996). This Trias Energetica approach has been extended within the Annex 44 work with technologies that will be applied, depending on the design step, see figure 4.

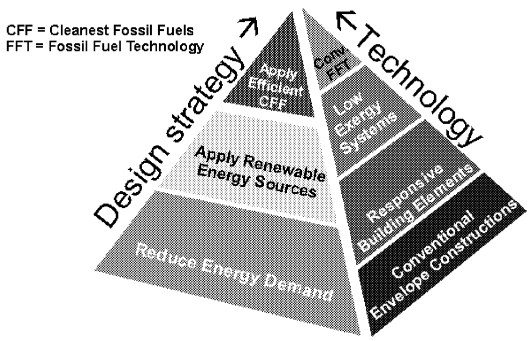

Figure 4. Illustration of Annex 44 Design Strategy and corresponding Technologies

The left side of the pyramid shows the design strategies, and the right side of the pyramid shows the technical solutions in each of the steps. The figure clearly positions the responsive building elements as a technology that falls in the first step "reduction of energy demands" as well as in the second step "application of renewable energy sources".
An integrated design strategy, starts at the bottom of the pyramid and applies the strategies and technologies as follows:

- *Step 1. Reduce Demands*

Optimize building form and zoning, apply well insulated and air tight conventional envelope constructions, apply efficient heat recovery of ventilation air during heating season, apply energy efficient electric lighting and equipment, ensure low pressure drops in ventilation air paths, etc.

Apply Responsive Building Elements if appropriate including advanced façades with optimum window orientation, exploitation of daylight, proper use of thermal mass, redistribution of heat within the building, dynamic insulation, etc.

- *Step 2. Utilize renewable energy sources*

Provide optimal use of passive solar heating, day lighting, natural ventilation, night cooling, earth coupling. Apply solar collectors, solar cells, geothermal energy, ground water storage, biomass, etc. Optimize the use of renewable energy by application of low exergy systems.

- *Step 3. Efficient use of fossil fuels*

If any auxiliary energy is needed, use the least polluting fossil fuels in an efficient way, e.g. heat pumps, high-efficient gas fired boilers, gas fired CHP-units, etc. Provide intelligent control of system including demand control of heating, ventilation, lighting and equipment

The main benefit of the method is that it stresses the importance of reducing the energy load before adding systems for energy supply. This promotes robust solutions with the lowest possible environmental loadings.

5. TOOLKIT SUSTAINABLE RESIDENTIAL BUILDINGS

5.1. Toolkit application

An example of a practical application and tool for an integrated design approach has been made in the Netherlands with the Toolkit Sustainable residential buildings (Hameetman & De Haas & Van der Aa, 2006). The call for a toolkit came from the building sector where the conclusion was drawn that inventing the wheel for every new building project leads to unclear design targets and financial budgets, an uncontrolled development process, large failure costs, exceeding of budgets etc. An important point of departure at the beginning of the development of this Toolkit was that energy is not the only and certainly not the most important selling point for new houses, but the integrated quality, formed by a lot of items, is important. So, first of all the location, the safety, the visual performance, the flexibility, the accessibility, etc. are the items people select there house on. Meanwhile there is a large interaction between all these items and a number of them influence the comfort and energy quality of the building. Therefore so called quality profiles were made, from which the quality aspects of a dwelling can be defined in the very early stage of the development. Under these quality aspects health, comfort and energy defined, among 4 quality aspects for the location and 12 quality aspects for the building. Per quality aspect 3 levels of ambition can be chosen. Based on the level of ambition it is possible to zoom in until the level of detailed requirements to apply.

Once the quality level is defined one can chose out of a list of applicable concepts that has been selected from a list of 300 already calculated integrated building concepts. The calculated items are among others energy performance targets, energy consumption, CO2-emission, investment costs, exploitation costs etc.

The concepts have been designed based on an integrated design strategy following the Trias Energetica. For 30 often applied concepts an extended work out and full description with targets, process issues, crucial aspects, technical and financial (costs and exploitation) aspects, quality control etc has been made. Together with the focus on energy, health and comfort also specific attention has been paid to the application of sustainable materials and industrial and flexible building.

The Toolkit in practice shows to fill in a need for information in the building sector in the early stage of the project development. It removes uncertainties and gives a guidance for an integrated design.

The large building development companies and contractors pick out their “own” concept and improve and standardize this in co-operation with co-makers.

At this moment a number of new Toolkits are ready or under development. The Toolkit sustainable renovation of residential buildings is launched and the Toolkit Sustainable office buildings will be launched at the end of 2008.

5.2 Cost-benefit of energy measures

One of the most important questions in design process of the energy saving buildings is the cost-benefit relation of individual measures. As the interaction between the individual measures in an integrated design concept is big, this questions is not easy to be answered. Increasing the insulation level of a building, decreases the heating demand. How much, however depends i.e. on the thermal inertia of the building and the efficiency of the heating system. On the other hand an increase of the insulation level will effect the cooling load during summer. This means that for integrated building concepts it is quite complicated to determine effects for individual measures.

Based on the simulation results of the 300 integrated concepts for residential buildings an analyses has been made about the spread in cost versus energy performance of the various concepts. Reference point is the legal level of the building regulations (zero additional costs). The analysis is given in figure 5.

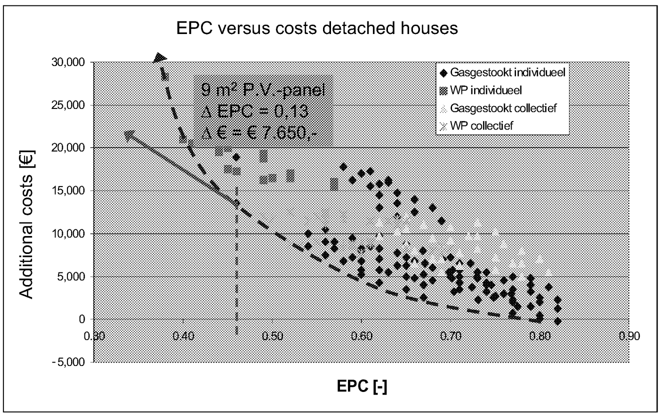

Figure 5. Additional cost versus EPC for integrated concepts

Based on this spread a line can be drawn that represents the most effective concepts. The gradient of the line is increasing as the energy performance requirement are increasing. From this it can be seen that the law of diminishing returns counts is applicable for piling up energy saving measures. For solitary measures that do not have an interaction with other measures (i.e. photovoltaic's) depending on the tangent line of it's cost-benefit relation it can be determined at which level this technology is beneficial to apply.

6. CONCLUSIONS

Within the framework of IEA Annex 44 research has been conducted about the prerequisites for an integrated design. This has resulted in a new description of the design process and methodology and also makes clear that new tools are needed. The Toolkit Sustainable Residential Buildings is one of the tools that gives means for a new approach.

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