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Design strategy for the integration of climate-responsive building elements in dwellings

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ABSTRACT

High performance architecture meets both comfort and energy issues to a maximum level. The application of climate-responsive architecture is a strategy that can meet both issues. Climate-responsive building elements are responsive to internal and external climatic conditions and to occupant intervention. They have a combined function as they actively store and transport heat, light, air and moisture as an integrated part of the building structure. The application of climate-responsive building elements in building design practice is still limited. Barriers are their innovative character and the lack of dedicated knowledge on the synthesis of design, building performance and implementation in the design process. They can be overcome by means of a design strategy to assist designers during their design process. Further development of climate-responsive techniques in the integrated design of dwellings, which provide the foundation for a PhD study, is asserted in this paper.

KEYWORDS

Climate-responsive Architecture, Comfort, Energy Performance, Design Strategy, Dwellings.

1. INTRODUCTION

A growing worldwide attention to sustainable development, where the needs of today's generation do not conflict with the abilities of future generations to fulfil their needs, also finds a way in the built environment. Foremost indicated by regulations on the energy performance of buildings.

With aim to reduce the use of primary fossil fuels for building services like heating, ventilation, domestic hot water, artificial lighting and cooling.

The path to sustainability in the built environment is transitional and embraces improving existing techniques and presenting new innovative solutions. Regarding energy reduction this means a transition where buildings become less dependent on fossil fuels by minimising their energy consumption and by retrieving renewable energy resources from their direct vicinity.

But it is important to keep in mind that the fundamental objective of building design is to provide an (efficient) comfortable and healthy environment. The wish for a reduction in energy use is an additional objective that has become of increasing importance in the last decades. High performance architecture should suffice both comfort and energy issues to a maximum level.

There are different strategies that address to reducing energy consumption and providing a comfortable and healthy environment. While most strategies address to only one of these issues, the application of climate-responsive architecture is a strategy that meets both. Further development of climate-responsive techniques in the integrated design of dwellings, which provide the foundation for a PhD study, is asserted in this paper.

2. CLIMATE AND ARCHITECTURE IN PERSPECTIVE

We are surrounded by a built environment. Buildings are essential to human beings for living, working and multiple other activities. According to Vitruvius one of the most fundamental functions of architecture is to provide shelter from the dynamic conditions of our environment. But he also mentioned to concern the buildings' environment as a design parameter: “We must at the outset take note of the countries and climates in which buildings are built”. So architecture initiated from function, local climate and availability of local resources.

In time humanity advanced and so did its architecture, emerging into a craft where aesthetics and impression gained importance. More functions became subject of the built environment and the original function of giving shelter had transformed into providing comfort. Increasing wealth and the development of new technologies catapulted the amount and proportion of the built environment. The desire to control the indoor environment to the occupants best wishes resulted in the implementation of mechanical climate control systems that operate completely separate from the rest of the building. And buildings themselves became completely separated from the (outdoor) environment they were placed in. As Maver (1971) puts it: “One of the most marked trends in architecture over the centuries has been that of replacing the functions of the building structure by engineering service systems”.

3. ENERGY AND COMFORT

This trend resulted in buildings to be significant energy consumers by the 1970s. Due to shortcoming of fossil fuels and accompanying raises in pricing, energy saving in the built environment became since then of progressive concern. In more recent years the environmental impact of burning fossil fuels increased our conscience on this topic. Building design practice in most developed countries is nowadays subjected to governmental regulations on energy performance (the use of primary fossil fuels for heating, ventilation, domestic hot water, artificial lighting and cooling) and CO_2-emissions in order to address the importance energy-saving. But despite these efforts the built environment still demands a lot of energy. Up to 40 percent of total energy demand in the EU is related to the built environment (European Communities, 2005).

It clearly shows that building systems were designed from the single objective of providing optimal comfort while energy-efficiency was not considered at all. It seems that at a time where consuming energy did not ring a bell on resource depletion and environmental damage, comfort became a synonym with high energy consumption. This is by no means necessary (Roulet, 2001). From studies it has become clear that the mechanically controlled indoor environments that are completely separated from the outdoor environment can even be far from comfortable and healthy (Mahdavi and Kumar, 1996). On the other hand it is good to realise that low-energy design of buildings, where no attention is paid to comfort and health, can as well become non-sustainable due to higher energy use of occupant's to compensate for the discomfort (Nicol and Humphreys, 2002).

4. STRATEGY TO SUFFICE BOTH ENERGY AND COMFORT ISSUES

The key to suffice both comfort and energy issues in one design is the generation and development of new ideas on accomplishing comfortable and healthy environments in relation to energy use.

A starting point for buildings to become minimal energy consumers is by minimising their energy-demand. This is generally seen as the first step of the Trias Energetica, a three-step (design) strategy for sustainable design and construction (Lysen, 1996). The first step is followed by steps of applying renewable energy sources and optimising building system efficiency.

Considerations for buildings to become comfortable include realisation of an 'open barrier' between the indoor and outdoor climate (make use of solar and natural ventilation strategies) and allowance for human intervention in climate control to satisfy subjective needs (Fountain *et al.*, 1996; Mahdavi and Kumar, 1996).

Both strategies combined, by exploring the boundaries of energy demand reduction with a focus on establishing comfort, an optimised situation can be achieved by demand control and adaptive buildings. Comfort is provided when needed and delivered where needed, while buildings react to changes in the conditions of indoor and outdoor climate.

5. CLIMATE-RESPONSIVE BUILDING ELEMENTS IN AN INTEGRATED BUILDING CONCEPT

An adaptive building is a building that is able to adapt or react to changes in the environmental conditions. Building elements that specifically address to this feature are called climate-responsive building elements. In this context climate-responsive refers to responsive to internal and external climatic conditions and to occupant intervention. Therefore climate-responsive building elements actively store and transport heat, light, air and moisture. They form an integrated part of the building structure (e.g. roof, wall, floor, foundation). By responding to changes in dynamic conditions climate-responsive building elements contribute to maintaining a comfortable environment with an improved energy performance. The use of climate-responsive building elements more or less reverts to the original combined role of a building structure to meet both the function it was created for and to provide comfort.

For optimal performance on both comfort and energy issues, a potential design solution is an integrated building concept where climate-responsive building elements are combined with passive energy strategies, and sustainable building systems for climate control.

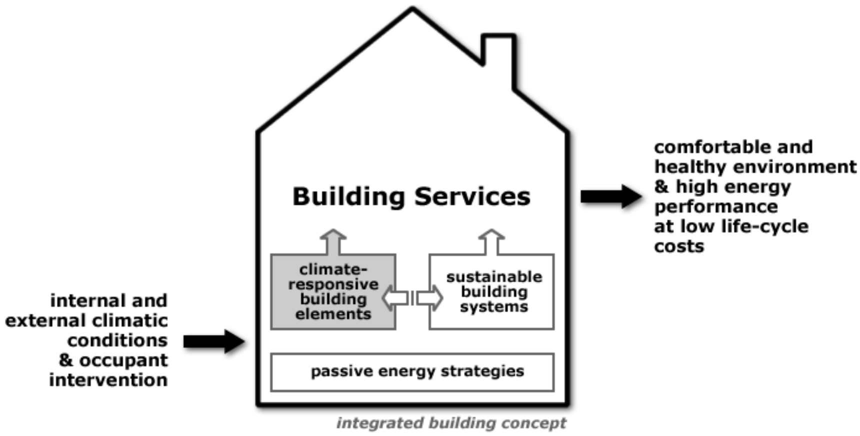

Figure 1.1 Integrated building concept.

The development and application of climate-responsive building elements are considered as essential in the transitional path towards a sustainable energy economy in the built environment.

6. EXAMPLES OF CLIMATE-RESPONSIVE CONCEPTS

The increasing concern of environmental performance of buildings has activated innovation of new techniques and strategies of climate-responsive concepts. A selection is presented here for illustration purposes.

Thermal mass systems

Thermal mass is defined as the mass of a building that is actively used for the storage of thermal energy. This storage ability can be used for both heating and cooling purposes. In fact every part of a building, the structure, the envelope and even the furniture in it, can function as a device of thermal storage, although functional use desire design considerations.

Heat from sun radiance can be directly stored in construction elements like floors and walls. In some climatic conditions this effect can be further improved by putting a ventilated glass layer in front of a sun-faced wall. This concept is called a Trombe wall. Furthermore thermal mass systems can also be used to store or remove waste heat, for example through core activation of concrete floor elements.

Earth coupling systems

Earth coupling systems use the earth's large thermal storage ability to provide heating or cooling to a building. The ground source is able to supply the system with an all-year round constant temperature. The exchange of thermal energy can be established by direct contact of a well-designed building ground floor slab with the soil underneath or indirectly by using a transport medium (water or air) that cycles between the building and the ground beneath it.

An energy-efficient ventilation system can be obtained by use of an earth coupling system, in which air from outside is cooled or heated through a series of embedded ducts prior to using the air to ventilate the building. Another concept is that of so-called energy piles. They differ from ordinary construction piles while they combine the function of supporting the structure with the function of a heat exchanger. Energy piles are manufactured with integrated ducts or pipes in which a transport medium carries heat between the building and the underlying soil.

Dynamic insulation

Dynamic insulation is the concept of the combined use of conventional insulation and heat exchange characteristics of an outer wall in order to preheat fresh ventilation air. The heat loss through the outer wall can be partially recovered. An air flow can be led through special constructed cavities within the wall or by leading it to a permeable insulation layer. This last method is also referred to as a breathing wall.

Phase change materials

Phase Change Materials are defined as materials that encounter a phase change at a certain constant temperature. The idea is to take advantage of their ability to accumulate heat during their melting phase. For use in the built environment there are a couple of materials that change phase at temperatures near ambient temperature.

7. RESPONSIVENESS OF BUILDING ELEMENTS

Responsive means that a building (through climate-responsive building elements) reacts to a certain stimulus with some kind of rational or logical behaviour. In the case of climate-responsive building elements, the dynamic conditions of external and internal climatic conditions and human intervention are the stimulus. The exchange of energy between the building and its environment is treated with respect with to supply and demand.

Responsiveness in this context implies some sort of intelligent reactive or perhaps perceptive behaviour to dynamic conditions in order to comply with comfort demands without the direct need for fossil fuels to compensate for the lack in energy supply by natural resources. The topic of climate-responsiveness in the context of energy and comfort in buildings is ambiguousness because different levels of responsiveness can be distinguished.

Within this research, climate-responsive is defined as controlled and desired adaptable behaviour to the changes in external and internal climatic conditions and occupant intervention.

8. STATE OF THE ART IN APPLICATION

The conscience of sustainable architecture (or likewise strategies like green, ecological or bioclimatic architecture) led to the adoption and implementation of climate-responsive concepts into different projects. In many cases with notable success. Although climate-responsive concepts are available for some time now, their application in building design practice is still limited. This goes especially for residential projects.

The reason why climate-responsive techniques nowadays are not widespread implemented into building design, with dwellings in specific, is presumably caused by its innovative character. Innovation in architectural practice is mainly obstructed by financial, technical and psychological issues, an easily satisfied client, incompetent designers and conservative building standards (Intrachooto and Horayangkura, 2007). While residential projects are in general more restricted to aspects of time, effort and money than non-residential projects, their application is even more obstructed.

Furthermore climate-responsive concepts lack dedicated knowledge on aspects of design, building performance and design process in order to successfully implement them to their full potential into building design of dwellings. They can be overcome by means of a design strategy that assists designers during their design process on the selection and implementation of climate-responsive building elements in their final designs.

9. DEVELOPMENT OF A DESIGN STRATEGY

It is known that building design is a very complex practice. Final building design has to meet a variety of design objectives (such as comfortable indoor climate, healthy environment, life-cycle costs, resource use, environmental loading, functionality and architectural expression) that interrelate with each other. In order to achieve high performance in the end-result, all design objectives need to be satisfied to a maximum level. This demands consideration of all objectives from the very early stages of the design process, full understanding of the interrelationships between the different design objectives and close cooperation among all designers (architects and technical designers) of the design team in an integrated design approach where all available knowledge is shared (International Energy Agency, Solar Heating and Cooling Programme Task 23, 2003).

Effective use of climate-responsive building elements demands implementation in the very early stages of the design process as well. The designer should be familiar with its existence and with the potentials and limitations in order to use them with maximum benefit in the design fields of comfort and energy performance. The actual decision on using climate-responsive techniques should be based on contribution to total building performance. What do we expect from our final design and to what extend can climate-responsive building elements contribute to our design objectives on comfortable environments and energy performance?

To structure these aspects of knowledge on design and building performance on the application of climate-responsive building elements, a design strategy can be of help. Through a step by step approach on how to suit all design objectives in the final building design in the best possible way. A suitable design strategy provides the right information at the right time to help all designers make performance-based decisions in every stage of the design process. It provides feedback to previous stages in the design process to identify and solve possible conflicts with decisions made earlier.

10. OBJECTIVES

Climate-responsive building elements have potential in different building concepts and climates. So far the efforts that have been made to introduce climate-responsive techniques in building design are located in a wide variety of climates, but consist mostly of non-residential projects. This has been explained from the fact that residential projects are generally more restricted by aspects of time, effort and costs when compared to non-residential projects. Therefore the barrier for implementation in residential building concepts, or dwellings, is large. But their potential is too.

The objective of the research presented in this paper is to gather knowledge on the synthesis of design, building performance and design process related to the implementation of climate-responsive building elements in building design. With specific focus on design of dwellings. The next step is to transform this knowledge into a design strategy that assist designers during the entire design process in making performance-based decisions on the integrated application of climate-responsive building elements in their final designs.

11. APPROACH

The synthesis of design, building performance and design process concerning integrated use of responsive components is expected to result in a combined improvement of comfort and energy issues in the design of dwellings. This synthesis is derived from detailed analysis of existing and new climate-responsive concepts, their design integration in integrated building concepts, their effect on total building performance obtained through building energy simulations and design considerations with respect to various decision moments along different stages of the design process.

An important factor for successful implementation in final building design is to dedicate this knowledge to the design process with the aim to assist designers in the performance-based selection of climate-responsive concepts throughout the entire process. Key-issue is knowledge-sharing and communication between different designers in the design team. This is where current knowledge fails.

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