ND MODELLING FOR SUSTAINABLE ENVELOPES

The sustainable dimensions of envelope design

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Abstract. Sustainable development issues are currently the driving forces in many building projects. The building envelope is critical for the architectural expression as well as large parts of the environmental performance. This study tries to investigate the advantages of multidimensional computer aided modeling and simulation for a sustainable facade design approach. A first step towards nD modeling for sustainable design is to establish a list of parameter which are used as design criteria: Environmental performance, thermal visual and acoustic comfort. Computer simulation and analysis of different building elements can help to determine the performance according to a set of design parameter. Environmental impacts due to energy consumption are an important parameter but it is believed that comfort criteria need also to be accounted for.

1. Introduction

Different countries have developed their specific vision of how to incorporate sustainable development particularly to the built environment. This is a great chance to revalue existing building design and try to find a sustainable solution by optimizing the building envelope in order to enhance not only its energy efficiency but also to provide comfort in the building.

Computer simulations are typically carried out in order predict the performance of a planned building. Since there are a number of design criteria there is normally the need to run different simulations with different tools but the same model.

The computational power has rapidly increased which gives the opportunity to run a number of simulations with a number of design options.

But there is still a distinct procedure missing. Sustainable development issues are currently the driving forces in many building projects. The building envelope is critical for the architectural expression as well as large parts of the environmental performance. Currently, advanced facades are being evaluated and tried to implement in order to reduce the environmental impacts of buildings.

1.1. SUSTAINABLE BUILDINGS

The OECD project identified five objectives for sustainable buildings (John, 2005):

- Resource efficiency;
- Energy efficiency (including greenhouse gas emissions reduction);
- Pollution prevention (including indoor air quality and noise abatement);
- Harmonisation with environment;
- Integrated and systemic approaches.

In Hong Kong, the Chief Executive made clear in his 1999 Policy Address that Hong Kong follows the framework for sustainable development (HKSusDev, 2004). The Sustainable Development Department Hong Kong is working on formulating a Hong Kong specific strategy.

1.2. SUSTAINABLE BUILDING ENVELOPE

The US Department of Energy has a clear ‘Roadmap’ to the Building Envelope design within the next 15 years which is closely linked to other ‘Roadmaps’ that incorporate visions for 2020 on lighting and HVAC systems. The building envelope ought to be (DOE, 2004):

- Affordable
- Durable
- Energy-positive
- Environmental
- Healthy and comfortable
- Intelligent

The building envelope includes all the building components that separate the indoors from the outdoors. The envelope of the building consists of the exterior walls, the roof, floors, windows and doors. In addition to giving the wall the desired appearance, the envelope must withstand the stresses to which it is exposed and also must protect the enclosed space against the local climate. It also acts as a climate moderator. Designs for exterior walls for buildings have seldom been developed in a systematic, rational way (John, 2005).

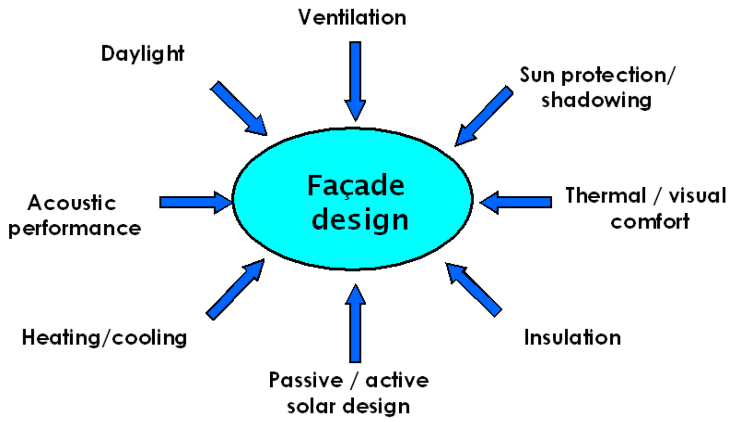

Figure 1: Integrated façade – nD modeling

An intelligent façade (IF) is defined as "a composition of construction elements confined to the outer, weather-protecting zone of a building, which performs functions that can be individually or cumulatively adjusted to respond predictably to environment variations, to maintain comfort with the least use of energy" (Wigginton, 2002.). This can also be named a climate responsive façade.

A number of technologies may be used to achieve energy-saving goals such natural ventilation, night-time cooling, natural lighting, buffer zones or solar assisted air-conditioning. This requires an effective interaction between the façade and the building.

Advanced Integrated Façades (AIF) gathers all the concepts and establishes a tight connection with building energy and control systems.

Summarizing an AIF is, from architectural and technical point of views, in tune with the physical and climatic conditions of a particular location. It is a building envelope exhibits adaptive characteristics, it has a dynamic behaviour provides the basic functions of shelter security and privacy of conditioning energy flows in their various forms, in order to minimize consumption. Being tightly connected to the building energy and control systems an AIF has to contribute to environmental sustainability and make the building a structure with climatic sensitivity. Figure 1 illustrates a possible concept of integrated façade design where several building elements and systems are integrated into the façade design.

There are opportunities and barriers of design and implementation of integrated building concepts across all disciplines. But there is a lack in describing integrated building concepts, processes and tools, and related experiences with designing and implementing responsive building elements very often strongly relate to the issues and questions from different projects and experience which may not be easily adopted.

2. Objective

This study tries to investigate the advantages of multidimensional computer aided modeling and simulation for a sustainable facade design approach. In order to be environmental and energy positive the façade related energy consumption has to be minimized. At the same time health and comfort have to be addressed. A climate responsive façade design can further enhance the sustainable façade design. The concept is illustrated in Fig. 3.

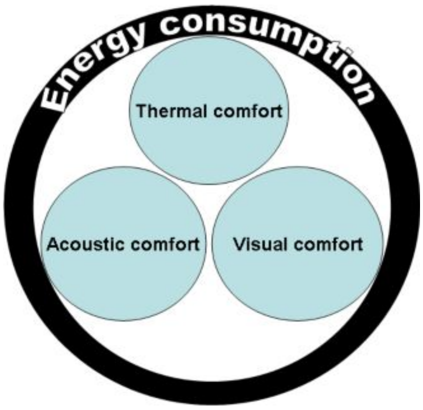

Figure 2: nD modeling objectives

Within the energy consumption modeling different comfort dimensions have to be met. The design of a double-skin façade system was used exemplarily to explain the different dimensions of modeling.

3. Methodology

A first step towards nD modeling for sustainable design is to establish a list of parameter which are used as design criteria. Focusing on the façade design of a building as the architectural and aesthetical most sensitive area of a building a list of parameters is proposed that help to evaluate the sustainable value.

Table 1 Parameters for integrated façade design

Parameters	Calculation	Outcome
Energy performance	annual energy consumption	kWh/m^2
Visual comfort	daylight factor, sunshine duration	DF, daylight autonomy
Thermal comfort	Ta, Tr, RH, v, MET, clo	PMV, PPD
Acoustic comfort	intrusive noise reduction, Reverberation time	R, trb

A simple office room was chosen to run a series of simulations. The room was divided into 11 different working zones. Then, different window systems were analysed and the results can be compared. The first model was using dynamic building simulation (TRNSYS, 2004) to determine the annual energy performance of the room. The calculations are based on hourly weather data provided by Meteonorm.

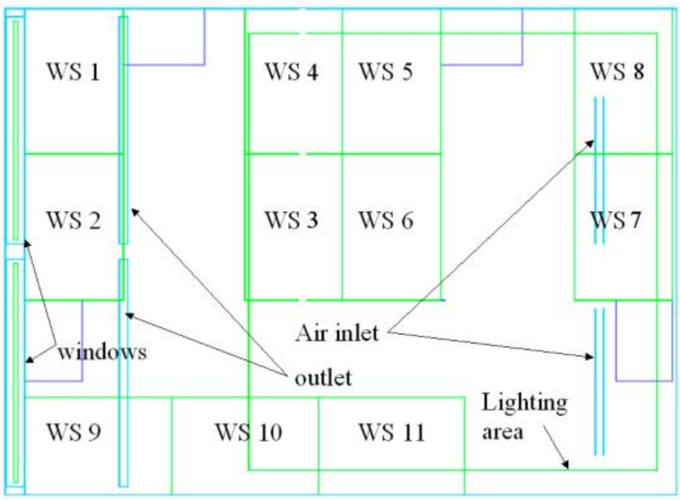

Figure 3: Office room plan

The second model was used to establish Thermal comfort in the different zones. It is defined in the ISO 7730 standard as 'that condition of mind which expresses satisfaction with the thermal environment' (ISO_7730 and EN_ISO_7730, 1991).
Especially in ventilated or air-conditioned spaces not only the set-point temperature is an important design criteria but other environmental factors play an important role. Fanger (1970) related Thermal comfort conditions to the following four environmental factors (Fanger, c1970.) and there are two physiological factors that affect an individual's thermal comfort:

- Dry bulb temperature (Ta)
- Mean radiant temperature (Tr)
- Relative humidity (RH) / partial water vapour pressure in Pa (pa)
- Air movement (v)
- Metabolic rate (MET)
- Clothing level (clo)

The third model was a used for visual comfort simulation. There have to be considered at least two issues; daylight and glare. The use of daylight can be expressed as daylight factor which is the fraction of outside illuminance to indoor illuminance. The Glare Index (GI) as well as Guth's visual comfort probability (VCP) of the façade system will be calculated in the near future (Osterhaus, 2005).

The final model was acoustic simulations in order to establish the acoustic performance of the façade of the room. Results will be reported elsewhere.

4. Results

The various simulations show different results depending on the purpose of the optimisation process. Not all of them can be shown here.
These different parameters show the strength of an integrated approach through nD modelling. It could be demonstrated that an optimised window system with a ventilated double-skin façade can not only help to reduce the annual energy consumption of the building but also improve thermal comfort at the work space (Haase and Amato, 2005).

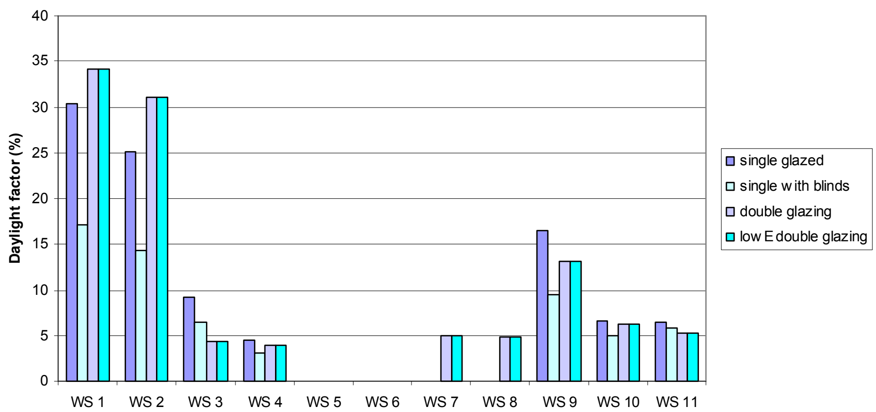

Figure 4:Daylight factor distribution

The detailed analysis of the façade system shows the daylight factor distribution in the room for the 11 different work spaces. It can be seen that daylight factor distribution can play an important role in determining visual comfort within a room.

5. Conclusions

Sustainable building involves considering the whole life of buildings, taking environmental quality, functional quality and future values into account. Sustainable building design is therefore the thoughtful integration of architecture with electrical, mechanical and structural engineering resources.

Computer simulation and analysis of different building elements can help to determine the performance according to a set of design parameter. Environmental impacts due to energy consumption are an important parameter but it is believed that comfort criteria need also to be accounted for. Planned work for the future includes

- Opening the façade for Natural ventilation: Weather data analysis showed already that during hot summer months the potential for NV are limited. However, an increase in airflow can provide a potential for comfort improvements.
- Solar assisted extract air device: The opportunity of solar assisted ventilation will be examined in detail.
- LCA of different façade systems: Sustainable building involves considering the whole life of buildings, taking environmental quality, functional quality and future values into account. Sustainable building design is therefore the thoughtful integration of architecture with electrical, mechanical and structural engineering resources. An extended version of life cycle assessment (LCA) might help to establish objective benchmarks and design criteria for the integrated design process with a nD modelling approach (Wong and Amato, 2003).

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