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Architectural Engineering and beyond

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Abstract

Various design drivers influence the architectural engineering design process, such as architectural criteria or multiple environmental impacts. Most of these conditions are time dependent, which leads to the challenge that the building system should be able to respond to or interact with these circumstances, in order to create high-performance systems. This leads to the overall framework of "adaptive" or "bionic" systems: in natural systems the integration of several disciplines and functions is self-evident. In contrast to traditional technical artefacts the understanding of natural systems makes clear, that the distinction between different disciplines leads not to optimum results – in natural systems, which are optimized over millions of years, the integration and adaptation of different function is self-evident. Understanding these systems is a major scientific interest, since we can learn about their uses as structural or functional devices. Further on highly interesting is the adaption of thermal systems or functions which can influence the building physics of buildings. The framework of this paper is to develop new concepts with a holistic and sustainable approach and this can be achieved by the consequent introduction of adaptable building systems. Buildings and construction industry are one of the main consumers of energy in the world, but these new concepts will lead to environmental friendly, sustainable solutions by reducing the mass and energy demands of our built environment. Apart from reducing the embedded energy by using lightweight systems it is aimed to develop zero emission buildings, e. g. by using smart skins to control heat and light transmission through the building envelope. The objective of this idea is to study these concepts and to develop them further, in order to save our environment. The paper presents examples where the concept of adaptation can improve the performance of building systems at different aspects.

Keywords: architectural engineering, adaptive systems, smart materials, performance, energy, design driver.

1. Integration and Adaptation

The design process in architecture and engineering involves various methods to develop the shape, the topology and the materials of a building. Obviously this depends on the type of

building, the boundary conditions and lots of other aspects, such as architectural, technical, ecological, social or economic concerns. Consequently there is an interesting interaction between the above mentioned design drivers and design enablers, such as new materials, new tools, new manufacturing processes, which will be within the focus of the presented architectural engineering research.

The overall framework of this research driven "Innovative and integrative design" will be the area of "adaptive" systems, with focus on natural systems, where the above mentioned integration of several disciplines and the possibility to adapt is self-evident. This research easily integrates and links adjacent fields such as building envelopes, climate design, simulation tools and interactive architecture. Further on new material developments are going to be studied and evaluated how they can have impact to the research.

Adaptive processes can be driven by many drivers, currently following sub-topics are under investigation: user-building interaction, solar strategies, day light, acoustics, wind, energy gain & storage and structural aspects. Of course further topics or combination of multiple drivers can be considered as well.

2. Context – Adaptive material systems in Architectural Engineering

The previous described ongoing and future research projects are covered by the overall framework "Adaptive Material Systems" and shall lead to answers to following questions:

- Responding to user and environmental impact
- Interaction with user
- Structural control
- Environmental control
- Improve overall performance
- Application of new materials
- Computational modeling adaptive behavior
- What happens if architecture becomes alive?

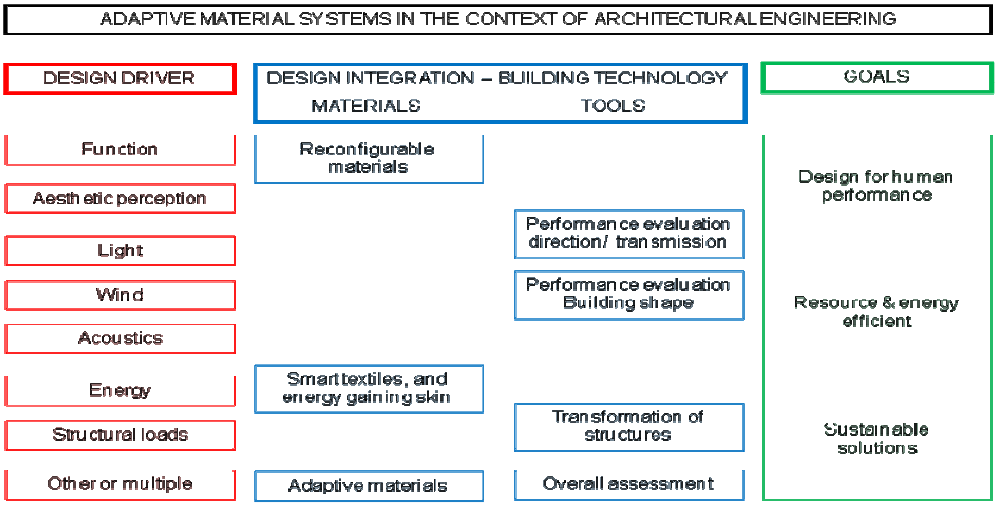

Figure 1: Overall context

3. Design drivers

Various design drivers can influence the design process, which are briefly described in following six case studies.

3.1. User-building interaction

Obviously the interaction of the user and the building plays a crucial role for the performance of any building object – but why has the building to be static while the user is not ? The use of new materials is one possibility to create adaptive architecture, which can react or interact with the user.

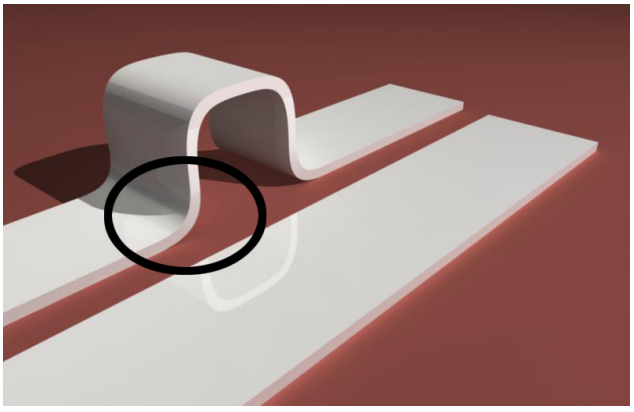

Figure 2: Adaptable dynamic material based on shape memory polymers, Lelievield [6]

The on-going research project „Realisation of adaptive architecture with the use of dynamic materials " [6] deals with this issue and investigates the use of shape memory alloys and polymers and its application to reconfigurable objects.

Further on the use of these shape memory materials, which belong to the group of smart materials which are able to change their geometry (as a result of temperature changes), can be seen in combination with flexible textiles as well - these "smart" materials posses an interesting characteristic: they can remember their original shape and can transform at a specific transition temperature. This actuating effect can be used when shape memory alloys are integrated, e. g. woven into fabric materials, in order to change the surface geometry of them. Recent studies, carried out by Leenders [5] propose this idea applied to fashion products. Figure 3 shows two samples of these textiles with two different states each: extended at the top and contracted at the bottom of the figure. Possible applications in buildings could be the shape reconfiguration of curtain wall elements in order to allow variable space separations and various lighting or ventilation conditions, without any requirement of mechanical joints, which would lead to much more resilient building components.

Figure 3 Smart textile employing shape memory wires, Leenders [5]

3.2. Solar strategies

Apart from the material, the geometry and topology of a building influences substantially the way how light can be transmitted and directed into it. Similar to other design drivers light is nothing static and it has to be investigated how kinetic building components can improve the building performance in that sense.

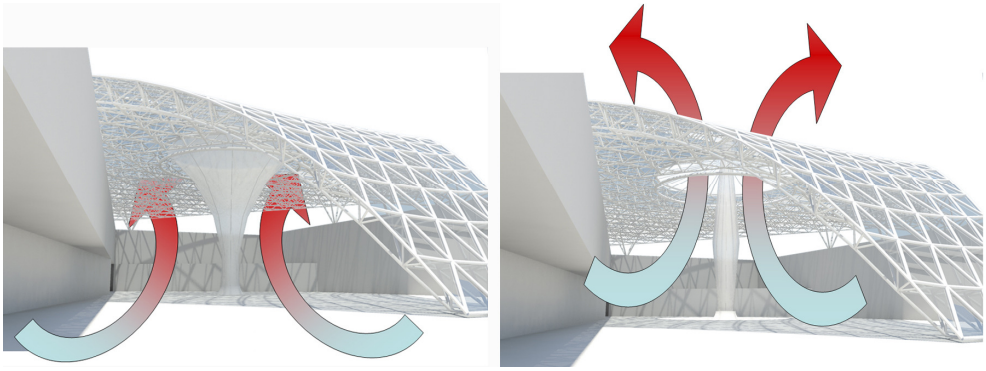

Figure 4: Deployable structure controlling solar strategies, Turrin [10]

Deployable structure affecting stack effect-related air flows for passive achievement of summer and winter thermal comfort in a semi-indoor space. This latter was originally designed by Open Project Office

This topic is covered by the research project "Reconfigurable structures for passive solar strategies" by Turrin [10] with the development of reconfigurable roof systems and its application to the design process using parametric tools.

3.3. Wind

The interaction of wind of building is a well established research field in architecture and engineering, but mainly deals with the passive (although dynamic) response of the building. Future work will focus on buildings which actively react to this environmental impact.

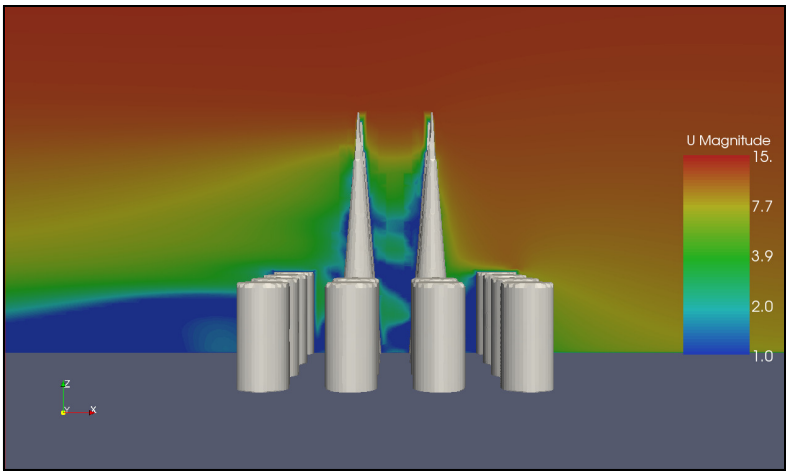

Figure 5: Wind simulation (© H. Plomp)

The current wind research at TU Delft considers following aspects in relation to wind: urban situation, structural behaviour, façades and internal conditions. Further on the "Impact of building shape and its surroundings to the wind performance" is studied using large-scale numerical models. Further details are described in Teuffel et. al. [9]. The time dependency of wind events makes clear that adaptive building components or systems can improve the overall building performance, as previous described by Teuffel [8].

3.4. Energy

Nowadays the public awareness of an excellent energetic performance of buildings is evident and shall drive architects and engineers to develop and apply high performance building components. While the structural performance of textile materials, such as PVC-coated polyester or PTFE-coated glass fibres provides excellent performance regarding lightweight and wide-span criteria, unfortunately the performance evaluation regarding thermal or energy aspects in the context of building physics, such as insulation, heat storage or acoustics, shows only poor quality.

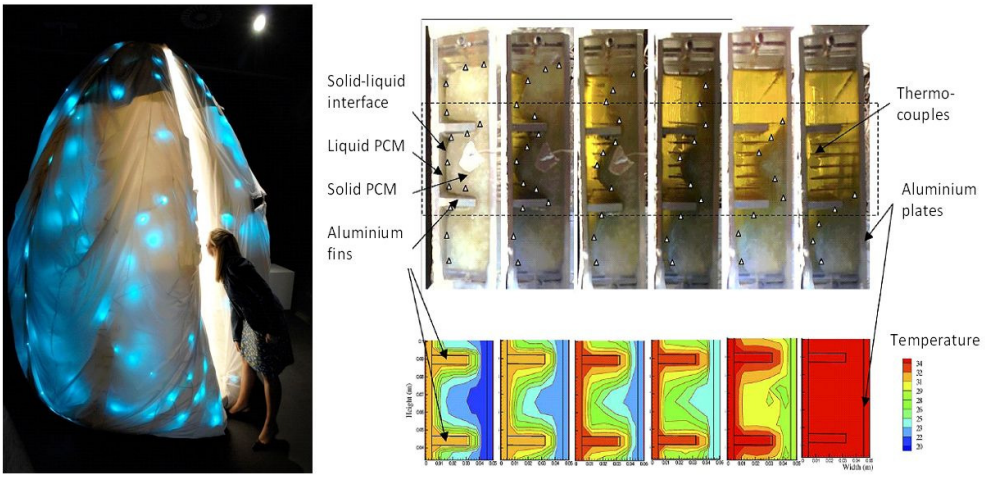

Figure 6: Left: Corpform pavilion (Architect: Markus Holzbach, Structural engineer: Teuffel Engineering Consultants, Photograph: Frank Vinken), right: Integrated PV-PCM layers, Huang et. Al. [4]

The research project „Smart Skins" shall deal with the development of multi-functional materials for building envelopes, with the focus on textiles, which can fulfill different criteria, such as architectural, structural and environmental control. Through the integration of different elements, such as flexible solar cells, phase change materials or nano- and aerogels high performance building components will be established (Holzbach [3], Braun [1]).

3.5. Day lighting

Current research also looks into the utilization of day lighting as a design driver – the geometrical and topological optimization of large span structures is studied and described by Heinzelmann [2].

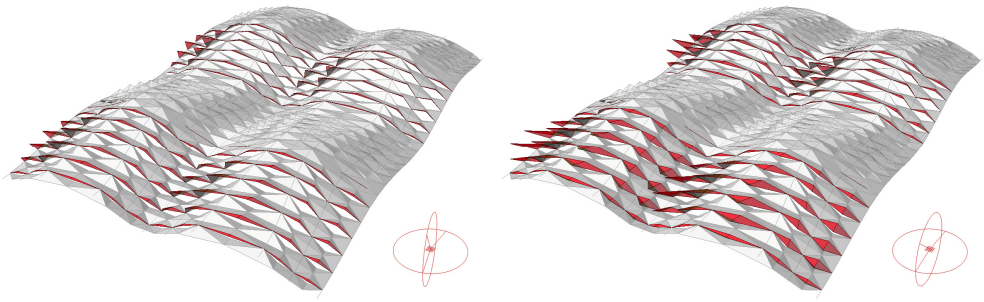

Figure 7. Shading extensions, left Amsterdam operating from the 15.05, right Abu Dhabi operating the whole year, Heinzelmann [2]

3.6. Structural control

In structural engineering the consideration of dynamic loadings is well established, but mainly limited to passive systems. The introduction of adaptive components into structural systems can substantially improve its performance in terms of serviceability and load carrying capacity. Further on the topic of resilient engineering is considered as well. The research project "Transformation of structures" does focus on structural issues of transforming or reconfigurable systems, which are subject to highly invariant loading conditions, such as high wind loads or seismic events, Sobek and Teuffel [7].

4. Conclusion

The framework of this vision as proposed is to develop new concepts with a holistic and sustainable approach and this can be achieved by the consequent introduction of adaptable building systems. Further on the design and development of adaptive systems requires naturally the integration of architectural, structural and building services, which makes it an appealing foundation for the approach "Architectural Engineering and beyond".

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