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The sustainability of adaptive envelopes: developments of kinetic architecture

Marta Barozzi[1*] , Julian Lienhard[2], Alessandra Zanelli[3] and Carol Monticelli[3]

[1]Politecnico di Milano, Architecture, Built Environment and Construction Engineering Department (ABC), Campus Leonardo, via Bonardi 9, 20133 Milano, Italy

[2] str.ucture GmbH, Lindenspürstr. 32, 70176 Stuttgart, Germany

[3] Politecnico di Milano, Architecture, Built Environment and Construction Engineering Department (ABC), Campus Leonardo, via Bonardi 9, 20133 Milano, Italy

Abstract

The paper presents an overview of adaptable envelopes and shading systems applied in contemporary architecture; it offers a study of different design approaches and a brief analysis of exemplifying case studies. The aim of the research is the gathering of built examples relevant to outlining a state of the arts of adaptive façade systems and also understanding their environmental performances. Nowadays two different trends emerge in building development. On the one side the new challenge is given by the possibility to reconfigure the new spaces following environmental changes and users needs, while on the other the focus is on the increase of efficiency and the optimisation of materials for reducing energy consumptions in constructions. The building envelope is the primary subsystem through which external conditions and environmental changes can be regulated and therefore acquires great relevance in the development of new approaches to sustainable building solutions. In this review paper several examples are shown and compared, understanding the search for dynamics applied in architecture and the effectiveness from an environmental sustainability point of view.

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* Corresponding author. Tel.: +39-02-2399-5135.
E-mail address: marta.barozzi@mail.polimi.it

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1. Introduction

According to the Physical Institute in Maldegem, building façades are responsible for more than 40% of heat loss in winter and for over-heating in summer, which is making the employment of air conditioning systems necessary to guarantee an appropriate internal comfort. For this reason the building sector records the highest amount of energy consumption, even greater than industry and transport. The ES-SO Studies "ESCORP-EU 25" confirms that more than the 40% of the total primary energy consumed in all of Europe occurs in the building construction and building management field. With an accurate design of the façade details and an efficient shading system, office buildings in middle Europe could easily work without high energy-consuming cooling systems. The use of adaptive shading systems could contribute to reduce the energy demand of buildings in 2 ways: thanks to the supplementary thermal resistance in closed position, they may reduce the heating energy demand in wintertime while in summer, they protect the façade from solar heat gain, reducing the need for cooling energy. Following these premises, in Europe, the energy consumption of building construction could potentially be reduced by 10% for oil consumption (approx. 41 million tons) and around 111 millions tons for CO_2 production per year [1]. In 2011 the market related to the façade design and construction has reached a total of 12 billion Euros invested worldwide in the sector, 6% of which are appointed to shading systems. This underlines the potential that lies in the field of innovative façade shading systems.

Current trends in architecture go in the direction of dynamic and adaptive building envelopes, which reconfigure themselves to meet external and internal changes in climate and user behavior. Despite recent developments and some landmark projects, the market is, where applicable, still dominated by traditional blinds and shutters. These systems however fail at high wind speeds and are restricted to planar façades and rectangular grids. However, contemporary high rise architecture shows a trend towards complex curved and triangulated façade systems. This trend is particularly present in the Middle East, where external shading devices would seem essential.

To face these energy problems there are two suitable approaches which may be distinguished. On the one side there are mechanical shading devices, while on the other there are chemical solutions in so-called switchable reflective glazing. In the first case additional mechanical elements are added to the exterior or interior of facade or integrated in the façade complex (double skins) and help to regulate the light reflection and the solar radiation through mechanical movements and controlling procedures (mechanical approach). In the second case innovative types of glasses are used, which change their optical properties in relation to external variables i.e. solar radiation, application of low DC-voltage (electrochromic glass) or by using hydrogen (gasochromic) [2]. Here the adaptation method is based on chemical alteration of a material layer within the glass, allowing the integration of the adaptable system directly in the glazing plane (chemical approach).

As a combination of mechanical and chemical approaches it is possible to point out a third research trend which focuses on material systems, in which adaptive performance is based on material behavior. Most commonly known as shape memory or smart materials those systems react to environmental stimulus changing one or more of their proprieties (chemical, mechanical, electrical, magnetic or thermal). Changes are direct and reversible and do not require an external source of energy to activate the system [2,3]. This is the most significant characteristic of shape memory materials which make their application interesting in the field of sustainable building components. Even if based on different technologies, all approaches pursued the principle of adaptability.

2. Common definitions in adaptive shading

Before introducing the case studies of adaptive façade systems, some definitions are made. To describe the division between architectural exterior and interior there are several expressions. The term façade traditionally describes the vertical plane of the construction, while the term envelope, recently widespread, refers more generally to the total building enclosure. The expression building skin initially underlines the distinction between the cladding and the structural part, but has more recently been associated with conceiving the envelope as an intelligent environmental system [4] able to exchange energy, material and information [5]. To reinforce this tendency Wigginton and Harris in their book Intelligent Skins state "the skin operates as a part of an holistic building metabolism and morphology, and will often be connected to other parts of the building, including sensors, actuators and command wires from the building management system" [6].