The application of smart materials in building facades

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ABSTRACT

Buildings represent one of the main sources of energy consumption and carbon emission. This issue leads many researchers to investigate various ways to overcome the problem and identifying ways to respond to climate change and the environment. Recently, smart materials have gained attention in scientific research, especially in industry and engineering applications and lately in the architectural field. This paper aims to review previous studies that addressed the concepts of utilizing smart materials in building facades. This research paper reviewed and categorized specifically smart materials and their applications in building skins. In addition, it discussed materials that have structural and physical properties to generate energy, movement or kinetically adapt in real time to environmental changes for a better performance.

Key words : Smart materials, Building façade, Sustainability, Energy efficiency

Introduction

A rapidly changing environment such as the one we find ourselves in is affecting building users as well as building performance. Despite the fact that the climatic characteristics have variable parameters, traditional façades are largely static; so, we use large amounts of energy in order to control internal comfort. Omrany et al. (2016) indicated that energy consumption for space heating and cooling makes up 60% of the total consumed energy in buildings.

Lately, the research in smart materials has been developed in many areas, such as industries, medicine engineering and recently in the field of contemporary buildings. Loonen et al. (2013) and Al-Obaidi et al. (2017) stated that there are many studies mainly focused on the use of smart materials in the design of building envelopes for achieving a better response to climate changes. Pesenti et al. (2015) stated that to obtain an adaption in architectural systems, smart materials could be considered as a key role through different levels: (1) molecular scale as polymers, (2) surface scale as shape memory alloys (SMAs); and (3) system scale to integrate with a facade system as a whole in providing cover for the building (Cimmino et al., 2016).

This approach will help to build elements to mimic natural systems and reduce the need to use mechanical and electrical systems in buildings. This is a step forward to make future buildings more responsive and adaptive to their environment. As a result, this paper will review a series of studies on the concept of smart materials, types, classifications, and systems used in architectural applications as well as discuss the advantages and future ideas for the development of these applications.

Smart materials

López et al. (2017) stated that the difference between traditional materials and smart materials is the
former classified as homogeneous in composition and the reaction with external influences, however, the latter is responsive to external stimulus in order to control temperature changes or solar radiation such as electrochromic glass with glazing material in curtain walls, windows, shading devices and more applications. Addington and Schodek (2005) stated that smart materials possess “embedded technological functions” that involve specific environmental responses, operating either through internal physical property changes or through external energy exchanges, and define the characteristics of smart materials as: “immediacy” (real-time response), “transiency” (responsive to more than one environmental state), “self-actuation” (internal intelligence), “selectivity” (a response is discrete and predictable) and “directness” (Dewidar, Mohamed, and Ashour, 2013). However, Fiorito et al. (2016) stated that this technology is difficult to be defined and classified, many applications in architecture depend on architect needs, and hence there are many types and definitions for this new technology as well as new applications with the innovative concept of design.

Types and properties of smart materials

Usually, the kinetic architecture developed through mechanical and electronic sensing as well as actuating and regulating devices, resulting in a non-energy-efficient architecture (Wigginton and Harris, 2009). It seems clear that it would be very difficult to achieve adaption purpose by means of inert traditional materials. It is worth mentioning that in order to take advantage of the properties and the installation of smart materials, one must find approaches to move in understanding natural mechanisms (El-Ahmar, 2011).

Al-Obaidi et al. (2017) stated that smart materials are capable of stretching, folding or bending, depending on the environmental stimulus such as shape memory alloys (SMA), shape memory polymers (SMP), piezoelectric materials, magnetostrictive, electrostrictive materials, and electroactive polymers (Elattar, 2013). Furthermore, the molecular compositions of smart materials control and produce a performance on the level of material form, to interact with environmental influences such as humidity, temperature, light, and carbon dioxide (Lopez et al., 2015). Sung (2007) indicated that smart materials can be varied in terms of the type of installation such as wood, metals, fibres, tissues, and fabric thicknesses. Researchers at Clemson University have developed deployable wet-responsive fibrous materials based on the spontaneous unfolding of tree leaves. This model demonstrates the ability of the leaves in trees fibres to absorb moisture and respond to the transformation of the self-energy to curvature (Hoefnagels et al., 2007).

In architecture, smart materials can be classified based on their actions. Addington and Schodek, (2005) stated that smart material can be categorized according to their performance as the following: (1) Property-changing: fundamental response variation of material to specific internal or external motivation such as thermochromic (response to heat), thermotropic (response to light), magnetorheological (response to electricity) and Shape memory (response to heat). (2) Energy exchanging: responses can be computationally controlled or enhanced such as photovoltaic (response to heat and light), thermoelectric or stimulation by electric current based on a thermal difference at both ends of the surface of the material, piezoelectric (response to electricity) to produce a deformation (strain), photoluminescent responses to radiation energy from the ultraviolet spectrum (or electrical energy for an electroluminescent), and finally electrostrictive responses through magnetic field that alters the inter-atomic distance through polarization which produces elastic energy – strain. This strain deforms or changes the shape of the material.

Smart materials in architectural applications

Façades and building envelopes, which form the outer skin of buildings, are the interface between interior space and the exterior environment. It plays an important role in heat and light exchanges. Its performance affects occupant comfort and productivity, energy use and running costs, and some of these systems have more than one element to respond and adapt to external environment changes (López et al., 2017). The theme of “Adaptive Building Envelopes” is dedicated to a relatively new technology. Adaptive or dynamic facades can optimally adapt properties such as heat, light, humidity, air and many more to ever varying climatic surrounding conditions as well as user demands. Compared to traditional facade systems, this technology can contribute significantly to optimizing the energy efficiency of modern buildings.

Climate Adaptive Building Shell (CABS) repre-
sents one of the architectural systems that adapts itself to function as a building skin and adapt its behavior to meet users’ needs to reduce the overall energy demand (Fiorito et al., 2016). This system utilized smart materials such as shape memory alloy (SMA) in envelopes to respond to the environment exchange by using its form to adapt to environmental changes (Pesenti et al., 2015).

On the other hand, there are few systems that adopt the concept of biomimetic approach, which integrated biological systems with smart materials in architectural applications: The idea is to learn the mechanism of natural systems (plant, animals, insects and even bacteria) then transfer this concept to architectural systems. Badarnah and Kadri (2015) introduced an adaptive wall concept that acts as a water-harvesting system by adopting the concept of biomimicry, that use bumpy mounds and grooves to exhibit capillary action for distributing water over the wall surface to collect water droplets through the bumpy surfaces as shown in Figure 1 (a). In addition, Holstov, Bridgens and Farmer (2015) presented the pine model as a biomimicry system, due to the ability of pine cone to respond and adapt to humidity, which opens and closes, in response to changes in humidity and weather. Holstov, Bridgens and Farmer (2015) suggested the idea to utilize smart materials similar to pine cone movement to form the architectural envelope of a building as shown in Figure 1 (b).

Conclusion

The application of smart materials in the field of architecture mainly depends on the ability of these materials to change their shapes and characteristics based on passive form, under the influence of external stimuli such as humidity, temperature, solar radiation, light, air movement and pollution. This paper noticed that the research in this field is still open for further studies and advanced solutions, researchers are still searching to solve existing problems. The study found that the potential of smart materials relies solely on their structural and physical properties that must remain stable in their different configurations to generate movement or kinetically adapt in real time to environmental changes. At the end, this study found that a continuous development in this area would open new possibilities to achieve adaption in architectural design.

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References


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