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Smart Material Systems and Adaptiveness for Beauty of Modern Architecture

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ABSTRACT

The past decades have witnessed a growing interest in the knowledge acquisition of smart materials and their applications in different fields, especially in the field of architecture and building technology. Smart materials may not be relatively new, but researchers work to develop smart materials and compose a system that controls and guides the materials to create a living environment with more adaptive qualities and less negative impacts. To conduct an in-depth research on the outstanding performance of architecture decorative material in the areas of technology and art at certain historical times, this article mainly studied the modern architecture. The smart material of architecture decoration is a substantial foundation for the existence of architecture beauty, and reflects the traditional concept of different schools and culture in the areas of architecture materials and constructive technology. The research aims to explore the qualities and advantages of smart material systems in the field of architecture, to better understand the impact smart material systems have on the design and construction processes, and to explore the way to create architecture with better adaptive characteristics, to ultimately reach the state of ‘‘adaptiveness”, providing the optimal environment for the users, reflected on the structural, climatic, and architectural performances.

Keywords： modern architecture, Smart material, Adaptiveness, Smart system

1. INTRODUCTION

The field of smart materials has witnessed a great development in the twentieth century, and this development became more rapid with the start of the new millennium. This paved the way

towards the development of architecture itself, and reshaped the way designers and construction specialists think.

The many different functions smart materials can achieve led to the composing of smart material systems. These systems are composed of a number of smart materials and can do multiple functions as well as being able to sense the change that triggers the actuation.

The basic structure of modern architecture in some cities like Harbin consists of wood, brick and ferroconcrete. Woods, bricks and stone are the main materials for decorating the architecture, and plaster decoration is commonly for the external side of the architecture. The "new art" campaign in Harbin popular in this period initiated traditional handicraft, so the decoration of architecture commonly took the iron decorative elements as the first choice, which was perfect combination of technology and art for decoration. The decorative materials mentioned above outstandingly reflect the unique beauty of modern architecture decoration through different construction technique according to their own characteristics, and add unique appreciation value to the architecture of this emerging city in modern times. Wood is a kind of natural material, which can be applied to the partial decoration of the architecture after being processed by artisans. It's a unique material language praising simple architecture and the beauty of nature. In modern times, the brick was a widespread architecture material in cities. In the early stage, most of the brick architectures were the residential blocks for employees of the Middle East Railway, which consist of brick wall and one-store double slope roof which was made by wood. According to research conducted in some cities around the world, 89.5% of them were constructed with bricks. Stone is the traditional material of west architecture. There are less stone to be exploited in the North area of China, and the cost is very high. Therefore, in modern times, the only architecture with stone decoration in Harbin was the original office building of Middle East Railway Bureau which is the office building of Harbin Railway Bureau now.

Another material used in modern architecture is plaster. Plaster means the gypsum slurry decorative art and using lime mortar, mixed mortar, polymer mortar, hemp fibred mortar and paper strip mixed lime mortar to decorate the surface layer of the architecture.

The great potentials new technologies of smart materials and smart material systems have can dramatically change the process of design and construction. As they develop and integrate more and more in applications of architecture, it becomes clear why they should be considered at the early stages of the design process, and not only as an application.

In the age of technology that we live in, and with the many different aspects of technology that are available to be exploited, developing architecture from the way of thinking to the process of design becomes crucial, as creating better architecture should be the drive that pushes the development of technology, not acting only as a projection of what is available.

2. SMART MATERIALS AND SMART MATERIAL SYSTEMS

2.1. Definition of smart materials

In the field of smart materials, a variety of terms are used to refer to materials or even systems that imply materials that are considered to be smart. Examples of that are adaptive systems, responsive materials, computational materials, smart systems… etc.

With the recent development in material technology, a more recent definition of smart materials describes it as:

"A material which has built-in or intrinsic sensor(s), actuator(s) and control mechanism(s) whereby it is capable of sensing a stimulus, responding to it in a predetermined manner and extent, in a short appropriate time and reverting to its original state as soon as the stimulus is removed".

2.2. Smart materials classification system

In 2005 Addington and Shodek introduced the new system that classifies materials according to the way they function dividing them into: (Fig. 1)

Type 1 – Property Change Material Types

Type 2 – Energy Exchange Materials Types

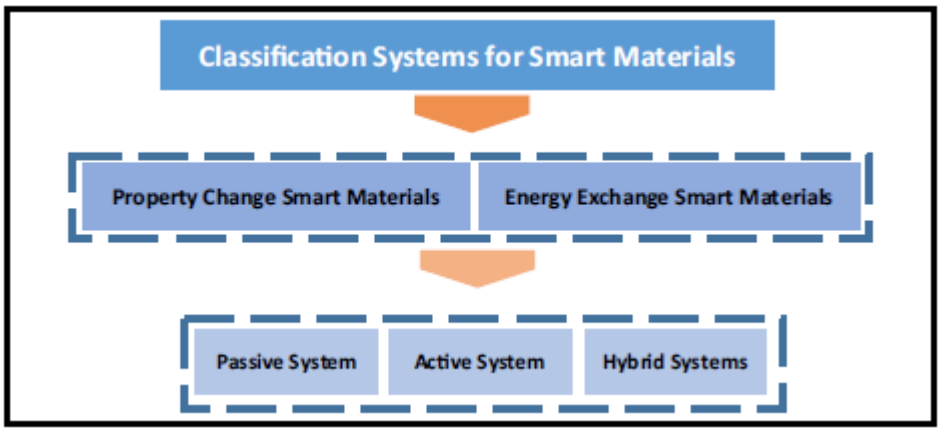

Fig. 1. Classification for smart materials [The researcher].

2.2.1. Type 1 – Property change material types

These are the smart materials that experience changes in one or more of its properties in a response to a direct external stimulus. These changes are direct and reversible and no external

control system is needed to direct such changes. An example of that is a photochromic material that has the ability to change color when exposed to ultraviolet radiation.

2.2.2. Type 2 – Energy exchange materials types

This type includes smart materials with the ability of energy transforming from one form to an output energy of another form. It can also do its job in a direct and reversible manner. An example of that are electro-restrictive materials that transform electrical energy into mechanical energy and thus results in a change in shape. It can be reversed to its original form easily in the same manner.

2.3. Smart material systems

A smart material has the ability to do one function, however, by composing materials together a system is created. The system can do multiple functions as well as being able to sense the change that triggers the actuation. Smart material systems are classified based on how the system responds to the stimuli. They are passive, active and hybrid systems. (Fig. 2) shows the types of smart material systems and (Table 1) explains their different properties.

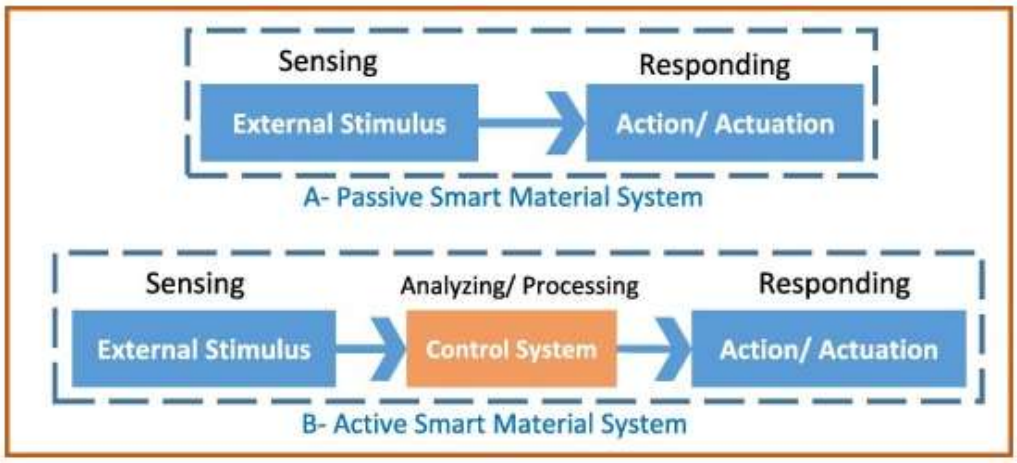

Fig. 2. A – Passive smart material system, B – Active smart material system

Table 1. Properties of active, passive and hybrid smart material systems

Characteristic	Type of smart material system		
	Passive system	Active system	Hybrid system
Detection	Material sensor	System sensor	Material and system sensors
Output	One-on-one output	Variable outputs	Variable outputs
Reaction	Direct reaction	Controlled reaction	Direct and controlled reactions

3. ADAPTIVE ARCHITECTURE

Adaptive architecture is a vast concept and an umbrella that holds a wide array of derivatives mentioned below. Each one of them is used to refer to a certain state, especially those that are concerned with the applications of adaptive architecture. The term "Adaptability" refers to the willingness of a building to carry features of adaptive architecture. All Architecture has some level of adaptability, like a window that can be opened for ventilation or a curtain that is used for privacy or protection. The second term is "Adaptation" which refers to the process of how the adaptive element functions to create the act of adapting. "Adaptivity", which the term "Adaptive" is derived from, refers to a building having one element of adaptation or more. Adaptive buildings are different in their components and elements of adaptation, some imply basic elements that require human intervention to function; and some are very advanced pre-programed elements that work by their own and offer better results.

"Adaptive Architecture is a type of architecture that has the ability to alter its physical properties (form, shape, color, texture, acoustic, etc.) in a predefined/programmed/designed way to adapt to changing external and internal environmental stimuli (temperature, humidity, wind, sound, radiation, etc.), users activities and needs, and social contexts".

3.1. Design strategies of adaptive architecture

Based on the published works of Schnadelbach in the field of adaptive architecture, design strategies were derived to represent the important aspects of the design palette of adaptive architecture and are defined as: Mobility, Prescription, Re-use, Timescales, Automation and design for Human Intervention and Inhabitant focused – independence.

3.1.1. Mobility

Mobility is considered as one of the main design strategies in a building to allow for better response to changes around it. Most projects of architecture are fixed to a single location. However, in adaptive architecture, mobility is inspired by related mobile infrastructures like caravans, boats, trailers and even spaceship designs to develop the building to response to the 'inhabitants' needs. The result is a building that is transportable and truly mobile and adaptive.

3.1.2. Prescription

There are two overall strategies that can be distinguished when level of prescription of the potential building adaptations is considered. The first is that things are left open, the building framework is designed in a way to cope with the largest possible amount of conceivable adaptations inside the building.

3.1.3. Re-use

This strategy revolves around re-usability and standardization. A building can be designed with each of its components made in a way to fit that particular building project. In most cases of buildings design, some form of standardization must be found, this leads all the way to pre-fabricated buildings have nearly all of its components standardized.

3.1.4. Timescales

Design of adaptation must take into consideration the time scale of when to expect the function of adaptation. Usually, timescales for adaptive architecture are designed to be very short, where the responses of adaptation are rapidly reflected to the affecting stimuli, such as the case when a user interacts with a smart phone or a computer. Other cases experience slower timescales when the adaptations spans through the whole day, where adaptations of the building are driven by the patterns and daily routines of the inhabitants.

3.1.5. Automation-human intervention

The selected level of automation is one of the important strategies of adaptive design. Adaptive buildings are designed specifically for inhabitants' intervention. In such cases, people can move, rotate and reposition elements of architecture which are designed for such purpose, it doesn't matter if this is manual or with the assist of a power system.

3.1.6. Inhabitant focused – independence

In this final strategy, the space of design also uses a method that can address what level the building is independent from its inhabitants. In adaptive architecture adaptations are related to the inhabitants in one way or another, adapting to their requirements, no matter if directly, or indirectly adapting to object or the environment itself.

4. THE MODERN BUILDING CLASSIFICATION SYSTEM

The modern building classification system was created as a way to decide how and to what extent adaptive characteristics are visualized in the designed and built projects. It is based on and developed from the work of Brand, 1994. Later, it was adopted by researchers in the architecture and built environment fields. According to this classification, the building system is divided into building components. The system also focuses on the "Open Building principle", where dividing the building system into subsystems greatly enhances adaptivity. The components of the building system are:

1- %1 Structure: is the first component of the building system. It determines the shape of the building and its level of stiffness.

2- %1 Outfit: is the second component that holds the exterior finishing elements. This comprises all the elements that are attached to the structure of the building including the elements of the façade, skin, roofing elements and additive elements like shutters or balconies.

3- %1 Infill: is the third component of the building that contains all the elements that make the interior of the building, like walls, ceilings, and floors, including bearing and non-bearing walls.

4- %1 Services: is the fourth component of the building. This component includes the installations of the building whether mechanical or technical. Examples are ventilation systems, air control, heating, sensors network, wiring and piping systems, etc.

5- %1 Interior: is the component that includes all the elements that are used to decorate and make the building comfortable for living. Interior elements are considered attachments to the building and can easily be changed or renewed.

6- %1 Ambient: is the last component category of the building system. Ambient tends to focus on the sensual experience of the building system. It is not a physical component, but depends on space and the experience it offers. Aspects of ambient are the results of the five mentioned tangible components.

5. PRACTICAL STUDY

The aim of the practical study is to test the impact of smart material systems on the adaptive architectural environment. The practical study starts by defining the suitable architectural settings for the study, then discussing the procedure applied on the settings as follows:

1- Choice of architectural settings

2- Procedure

3- Analysis of the examples according to the aspects of the adaptive design strategies

4- Comparative analysis

6. CONCLUSIONS

1- As technologies of smart materials developed, smart materials have been integrated together in buildings to create smart material systems. These systems function inside the architectural built environment in order to provide better adaptive performances for the users.

2-Adaptive design strategies, and the building system are the main two axes that form the theoretical framework. In the practical side of this research, Smart material systems are the third key factor and its role must be clearly determined in the adaptive building.

3-The theoretical framework uses the interrelations of adaptive design strategies and smart material system that are applied on the building system to provide a better understanding of the role smart material systems has on level of adaptivity of the building system, and how can they develop from being directed on the building system as an application into being considered while considering the adaptive design strategies at the early stages of the design.

4-There is a direct relation between the increasing use of smart material systems and the increase in adaptivity score of the building. A higher level of adaptivity in the elements results from a higher number and the use of more than one type of smart material systems.

5-The level of adaptivity also increases with the use of smart material systems. A higher level of adaptivity in the elements results from a higher number and the use of more than one type of smart material systems.

6- All kind of materials comply with their own destiny. In other words, they should fulfill their duties in some certain form. They have integrated colors and textures. Secondly, materials are not chosen for easy treatment or satisfying life needs.

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