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INTELLIGENT DESIGN OF CLIMATE RESPONSIVE SKIN IN MODERN BUILDINGS

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ABSTRACT

The climate responsive skin can adapt to changing climates by using intelligent or non-intelligent, active or passive strategies building envelop. This paper reviews the climate responsive skin design cases in modern buildings, and classifies them basing on environment performance and operation mode. The main aim of this paper is to present state-of-the-art of various kinds of climate responsive skin designs and analysis the current status. It is expected that the study helps to provide the reference for the design and application of climate responsive skin in buildings.

Keywords: climate responsive skin, modern buildings, adaptive design

NONMENCLATURE

Abbreviations	
CRS	Climate Responsive Skin

1. INTRODUCTION

The harmonious relationship between architecture and climate is one of the most important themes of architectural design. As the only connection between the building and the outdoor environment, the skin takes a paramount role of regulating the internal environment of the building. Recent years, the development of computer simulation, mechanical engineering, materials science and other disciplines makes the climate responsive skin (CRS) possible. In response to the ever-changing climate, CRS is designed to take the potential range of change into account at the early design. By using different solutions, CRS can solve the conflicting requirements between climate and architecture, and has a great potential in the context of "Green Building" in the world.

For the climate adaptive buildings, the skin has always attracted more attentions. Since 1981, when British architect Michael D first proposed the concept of building skin[1], study on CRS has achieved a great progress: The Delft University of Technology proposed a skin design method of "environment parameterization" in the study of climate-adaptive building interface [2]; Nimish B and Valentina S used a parametric design method to design the multi-layer composite interactive skin and verified its feasibility[3, 4]; Loonen R.C.G.M classified the existing climate adaptive skins and analyzed the influencing factors of climate adaptability[5]; Miao ZT proved the energy-saving advantage of the dynamic skin by simulating the building physical environment[6]; Shi F and Hu C classified the skin design strategy based on different environmental factors in international solar decathlon competition[7]. However, the study of CRS is still not enough, especially lack of data statistics and analysis about their applications in modern buildings. Therefore, this paper collects and summarizes 203 cases to analyzes the application status of different epidermis in modern architecture, understands market bias and provides reference for skin design.

2. CONCEPT AND DEFINITION OF CRS

The difference between CRS and ordinary building envelop is mainly reflected in the design orientation, materials or components. The definition of CRS is a skin that has the ability to reversibly change some of its functions, features or behavior over time in response to changing performance requirements and variable boundary conditions, and does this with the aim of improving overall building performance [5].

CRS usually improve the building performance and reduce energy consumption by taking an intelligent or non-intelligent, active or passive design strategies which

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is based on the targeted analysis and simulation of building indoor environment.

3. DESIGN STRATEGY

The design strategy of CRS can be divided into two aspects, as shown in Fig 1. The one is called Environment Performance Oriented Design. According to the main responding climatic factors: temperature, humidity, wind, natural illuminance, rainwater and so on, CRS can be divided into four categories: thermal adaptation, optical adaptation, wind adaptation, and wet adaptation. The other is called Operation Mode based design. According to its operation mode, it can be divided into: active dynamic skin, passive dynamic skin and non-intelligent dynamic skin.

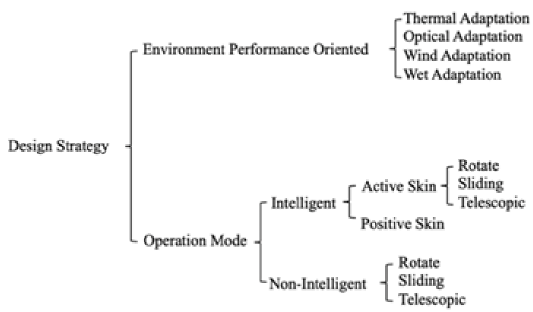
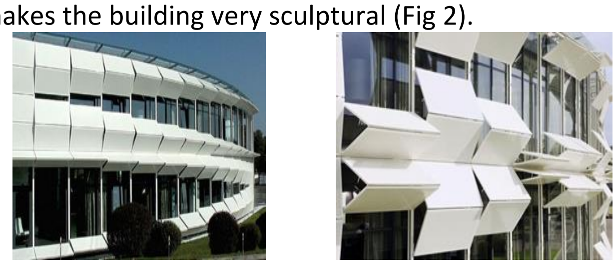


Fig 1 CRS Design Strategy

3.1 Environment performance oriented design

3.1.1 Thermal adaptation

It is known that building energy consumption accounts for about 30% of the total social energy consumption. the building skin plays a big role to reduce the overall building energy use. There are mainly two ways to achieve thermal adaption: regulating solar radiation and changing the thermal performance of the skin. Compared with using high thermal performance skin materials, regulating solar radiation in CRS design is more operational, which is favored by architects. For example, in the Kiefer Technology Exhibition Centre in Austria, the smart skin system can adjust the opening and closing modes according to the climate change and space requirement. Meanwhile, the changing facade makes the building very sculptural (Fig 2).



(a) (b)

Fig 2 Kiefer Technology Exhibition Center

3.1.2 Optical adaptation

Light is the eternal topic of architecture. Only with light could architecture have a sense of time and space. Different light environments give people different psychological feelings. The world-famous Architecture-Arab World Institute uses CRS whose unit is similar to an eye to control light, creating a religious environment (Fig 3). From the perspective of built environmental control, the meaning of optical adaptation is not only to reduce lighting energy consumption, but also to create a comfortable and healthy light environment for people. For example, the Korea Pavilion designed by SOMA uses the change of louver form to control the amount of light for adjusting indoor light environment (Fig 4).

(a) (b)

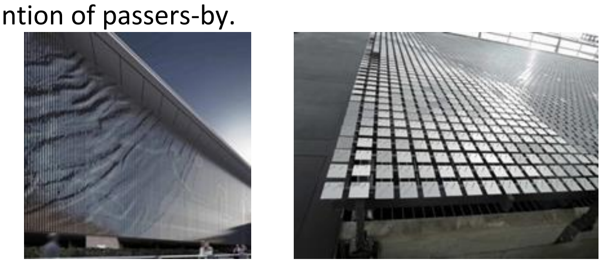
Fig 3 Arab World Institute

(a) (b)

Fig 4 Korea Pavilion

3.1.3 Wind adaptation

The wind adaption of CRS embodies two: aesthetic and wind energy utilization. For example, the Crit Building in the USA uses a large number of aluminum metal sheets on its façade (Fig 5). Due to the ultra-thin metal sheet material, the weight is extremely light. When the wind blows, the building skin can immediately present a ripple flow in the façade which can attract the attention of passers-by.

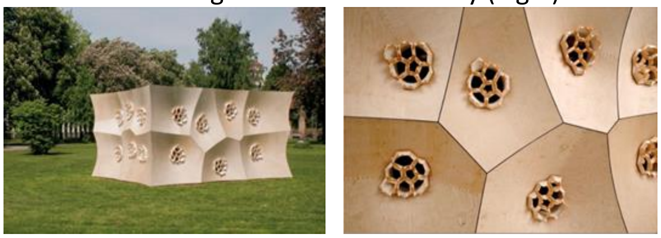


(a) (b)

Fig 5 Crit Building

3.1.4 Wet adaptation

There are not many researches and practices on wet environment adaptive skins. Professor Steffen Reichert of Stuttgart University pays attention to the morphological changes of pine cone in different humidity environments. The building skin can automatically open and close according to different humidity (Fig 7).



(a) (b)

Fig 7 pine wood

3.2 Operation mode design

3.2.1 Active dynamic skin

The active dynamic skin is a comprehensive system consisting of adjustable skin components, climate environment sensors, system control equipment and so on, with a process of intelligent analysis of climate adaptation and procedures for how to change the skin components. According to the change mode of the skin components, the active dynamic skin can be divided into three types: rotation, telescopic and sliding. The rotating skin is usually driven or rotated by an internal fixed rod; the telescopic skin change form by controlling lever expand or stack up levers; The sliding skin can move the unit plate on the sliding bar to open or close building façade. For example, Ai Baha Tower is equipped with a CRS that is created from a traditional Middle Eastern pattern wood grille, combined with dynamic sunshade simulation technology according to the sun's running track. So it can take multiple forms in a day (Fig 8). According to the change mode of the skin components, the active dynamic skin can be divided into three types: rotation, telescopic and sliding. The rotating skin is usually driven or rotated by an internal fixed rod; the telescopic skin change form by controlling lever expand or stack up levers; The sliding skin can move the unit plate on the sliding bar to open or close building façade.

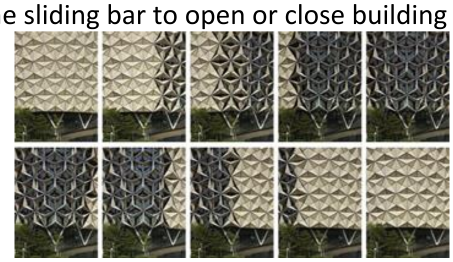


Fig 8 Ai Baha Tower

3.2.2 Passive dynamic skin

The passive dynamic skin mainly depends on the properties of the skin material itself. Although the process of passive dynamic skin is instantaneous and variable, it does not consume any conventional energy. When the external environment changes, the epidermis or epidermal material changes spontaneously without any mechanical system (Fig 9).

(a) (b)

Fig 9 A smart metal that can change shape with temperature

3.2.3 Non-intelligent dynamic skin

The non-intelligent dynamic skin is the traditional CRS. They can also be divided into three categories: rotation, sliding and telescopic according to the change pattern of the components. However, unlike the active dynamic adaptive epidermis, the non-intelligent dynamic skin does not have the ability to judge when and how to change according to climate change, nor does it have the ability to analyze and execute intelligently.

4. APPLICATION IN MODERN BUILDINGS

Compared with the static skin, the other three categories are more representative of modern building technology due to the dynamics. In order to understand the current application status of CRS in modern buildings, 203 cases from Archdaliy[8] and Pintest[9], the world's authoritative architectural case website were collected by ourselves for statistical analysis.

For environment performance oriented design (Fig 10), 92.1% of CRS chose thermal as the climate adaptation factor, of which 97.8% of the thermal adapted skin only focused on thermal environment adaptation, but another 2.2% also pays attention to the adaptation of optical in the meanwhile. According to the geographical location of 203 cases, the thermal-adaption skin is spread all over the world. In addition, 5% of CRS just focuses on the optical-adaption, and most of them are public buildings. Compared with residential buildings, the optical-adaption skin is more valuable in public buildings because of the intensive crowd and high frequency space use. The use of optical-adaption skin in public buildings is also due to the consideration of the space atmosphere, while in residential buildings it is more because of Solar energy utilization. In addition to the light and thermal, about 1% of the adaptable skins focus on wind -adaptation and wet-adaptation, which indicates that it is more difficult to improve the building performance from these two factors.

About the Environment Performance Oriented design (Fig 11), 89% of the CRS works in a non-intelligent dynamic mode, with only 6% active dynamic skin and 5% passive dynamic skin. Therefore, most of the CRS still remain at the stage of non-intelligence. The intelligent dynamic skin is not widely used in worldwide because of its higher cost and more complex technology. Moreover, unlike the durability of non-intelligent dynamic skins, thee components of the intelligence skin are more susceptible to damage, resulting in system paralysis.

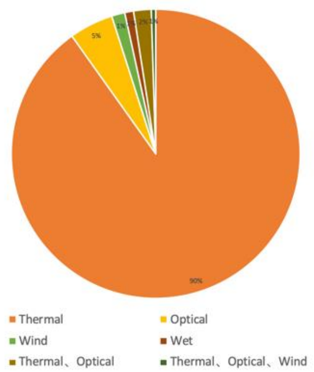


Fig 10 The proportion of different environment performance

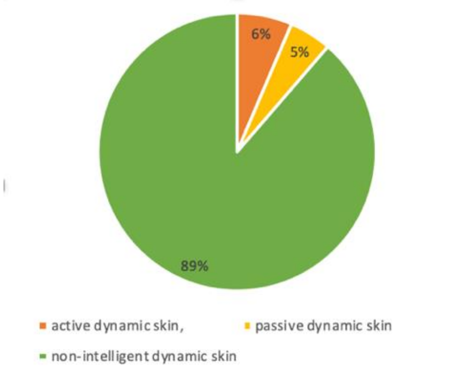


Fig 11 The proportion of different operation mode

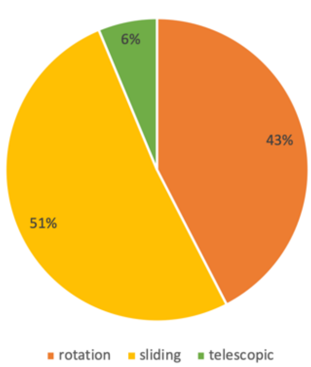


Fig 12 The proportion of different operation mode

About the variation changing mode of the component (Fig 12), 51% of the CRS use sliding component, 43% of the skin use rotation component, and only 6% use telescopic component. Compared with the telescopic component, the composition of the sliding component and the rotation component is relatively simple and convenient to use, while the telescopic component is relatively complicated with higher cost, so the proportion have a big difference.

5. CONCLUSIONS

The CRS is a relatively new field in architecture. Compared with the existing building skin, it increases the building climate adaptability and improves the building Performance. However, due to the relatively complicated technology, the practical application of CRS has not been widely promoted. But it is undeniable that CRS is the future development direction of building skin.

ACKNOWLEDGEMENT

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