

# The Creation of Sustainable Architecture by use of Transformable Intelligent Building Skins

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**Abstract**—Built environments have a large impact on environmental sustainability and if it is not considered properly can negatively affect our planet. The application of transformable intelligent building systems that automatically respond to environmental conditions is one of the best ways that can intelligently assist us to create sustainable environment. The significance of this issue is evident as energy crisis and environmental changes has made the sustainability the main concerns in many societies. The aim of this research is to review and evaluate the importance and influence of transformable intelligent structure on the creation of sustainable architecture. Intelligent systems in current buildings provide convenience through automatically responding to changes in environmental conditions, reducing energy dissipation and increase of the lifecycle of buildings. This paper by analyzing significant intelligent building systems will evaluate the potentials of transformable intelligent systems in the creation of sustainable architecture and environment.

**Keywords**—Transformable, Sustainable architecture, Intelligent building system, Environment condition

## I. INTRODUCTION AND DEFINITIONS

**T**RANSFORMABLE architectural units can be used in order to control the environmental conditions inside of a building. They can either be controlled by an operator when it is required, or they may interactively moderate the environmental condition of the architecture in terms of light, humidity and heat. Most of the transformable buildings are operated manually or automatically by means of a driving system and are usually transform from a fully deployed configuration to a fully retracted state. This indicates that in the case of sudden environmental changes, the transformable structure is not able to respond until it is instructed by an operator. In recent years the application of computer control systems has enabled architects and designers to actively monitor and moderate the environmental conditions of the buildings.

CIB Conference (Tampa, Florida) in 1994 defined sustainable architecture as “creating and responsibly sustaining a healthy built environment, observing the demands of ecology and optimal energy use without over-exploitation”. This simply means a building should be in harmony with nature to reduce the harmful effects of architecture as much as possible [5]. Sustainability means protecting and continuing the genius loci, and working within the required limitations and possibilities. Sustainability of the building is sublimated to sustainability of the place [8].

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Therefore, if we accept that sustainable design is one of the main necessities in today's architecture, this paper investigates how this issue can be properly responded by use of transformable intelligent systems.

## II. INTELLIGENT BUILDING

The word ‘intelligent’ and the American term ‘smart’ was first used to describe a unique type of buildings at the beginning of the 1980s [9]. The concept of intelligent building presents the strongest level of communication among the building's systems. The term “building systems” refers to all systems that operate a building like HVAC, mechanical, structural, access control, safety and security, building management, lighting, maintenance, local networking, and energy management. The intelligent building concept presents control and management by a building's systems and users using computer abilities to achieve users' needs, which may include productivity, efficiency, energy savings, entertainment, delight, and comfort, return investment, and low life cost [7].

Thus, defining intelligent building should not be limited to specific achievement as the required achievement may change from one party to another and from time to time. EIBG (European Intelligent Building Group) defines intelligent building as “a building that maximizes the efficiency of its occupants and allows effective management of resource with minimum life costs.” Atkin defines an intelligent building as a “building that knows what is happening inside it and outside it and can decide the most effective way to create the right environment for users on time.” In this definition, Atkin describes an intelligent building as a live body that can decide (output) on the basis of the information that it receives (input). Responding on time is essential in an intelligent environment; most outputs or responses needed in certain time [2].

## III. POTENTIAL AND ADVANTAGES OF INTELLIGENT BUILDINGS TOWARD THE SUSTAINABILITY

A building with a responsive skin system can make a significant contribution to the reduction of energy dissipation in buildings, and assist in maintaining and improving internal comfort levels [5]. In the absence of the user, even for short periods, the intelligent skin is able to operate the building fabric automatically for maximum efficiency, even when it is unoccupied. The brain of the intelligent building can be programmed to learn how to do this [9]. On the other hand potentials of the intelligent structure have numerous advantages toward the new method of architecture spaces which have flexibility and ability to be developed. Proper perception of new technologies about intelligent systems and their application could reach us to the sustainable architecture.

Transformable and flexible spaces and construction with minimum damaging to the living environment could help us to access to the sustainability.

The rest of this paper by analysing the main examples in the area of building skins describes and evaluates how the application of computer technology and transformable intelligent elements can create architecture that is able to respond to what is expected today and what is wishing for the sustainability and suitable architecture in the future.

#### *Case Study 1: Transformable intelligent walls*

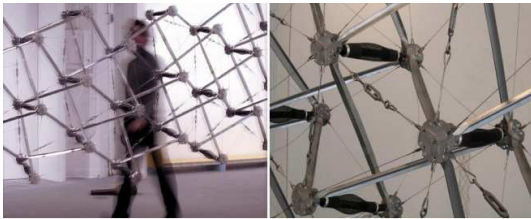


Fig. 1 A detail and a full-scale module of Sterk's actuated tensegrity structure

Fig. 1 shows a full-scale prototype of Sterk's actuated tensegrity structure. When the two outer layers of this structure, consisting of tensile members, are replaced by membrane fabric, the tensegrity structure is converted to a functional architectural component that can protect and shelter people from environmental conditions. The resulting architectural structure is able to interactively respond to environmental changes, if it is embedded with a smart controlling system. This system consists of several actuators that connect the apex of each tensegrity module, a processor, a sensor and a power supply. Changes to the internal or external conditions are received via sensors, then processed through processors that tighten or loosen the entire structure through the actuators.

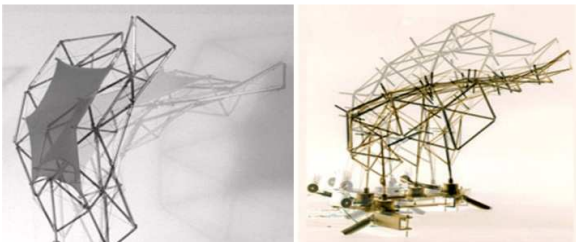


Fig. 2 Responsive wall designed by Kinetic Design Group at MIT University

The kinetic wall project designed by P. Brayent at Kinetic Design Laboratory, MIT University, represents a responsive architecture that can respond to human movement and environmental changes including light, shade and wind [3]. This wall includes a triangulated network of compressive rods (some rods are inevitably in tension) integrated with a membrane and is operated by a computer controlled system (Fig. 2). In this project, the integration of structural and architectural elements with embedded computational devices makes it a live

architectural body that can change its shape, yet it is able to retain its stability and rigidity.

#### *Case Study 2: Headquarters of Merck Serono in Geneva, Switzerland*

The new headquarters of Merck Serono in Geneva, Switzerland designed by Jahn Murphy is a great example of a building that innovatively incorporates a moveable roof in order to moderate the environmental condition of the building (Fig. 3). The new buildings were designed in such a way technologically to show the innovative approach of the Merck Serono Company as a world leading company in the biotechnology field. The new buildings not only can harmonize respectfully with preserved existing industrial architecture, but they use a high level of sustainability and create a new way of working in a new environment. The new design helped the company to bring together all disconnected division and to create a new continuous environment both physically and visually, so that collaboration and spontaneous interaction between workers is fostered [1].



Fig. 3 The new headquarter of Merck Serono in Geneva

The careful contemplation of this building shows that transparency, dynamism, visibility and the application of the state-of-the-art technology in terms of material and construction were the key issues in its design. These factors have allowed the building to not only respect to the existing building, but also to dynamically respond to changes in the environmental conditions and also to make a friendly, interactive working environment. The building is free of air conditioning. In the warmer summer months, water from Lake Geneva will be used to chill spaces, a manufactured rain cloud in the atrium humidifies the large space, and the roof of the forum opens to release heat.

The roof of the forum in open state enables even at summer temperatures a comfortable climate in this area and also transform the forum space from the inner to the outer space. A hydraulic system is used to operate the roof. The roof can be rotated from a fully closed state to a fully open configuration by means of hydraulic system and it is also able to be stabilized in different states during rotation. The movable roof is a unique example of transformable architecture in which the operation of the roof, create a dynamic and viable environment for its users (Fig. 4).



Fig. 4 The Transformable roof of the new Merck Serono Headquarter

### Case Study 3: Responsive skylight

Responsive skylights are examples of dynamic transformable architecture that can optimize thermal and day light conditions. Such a project has not yet been built but as it is shown in figure 5 a series of transformable skylights could be assembled to generate a responsive transformable roof. Each skylight unit consists of eight individual panels affixed to a structural aluminium frame. Each panel consists of three layers including a photovoltaic cell layer, a shading film, a moisturizing barrier and a plexi-glass layer (Fig. 6).

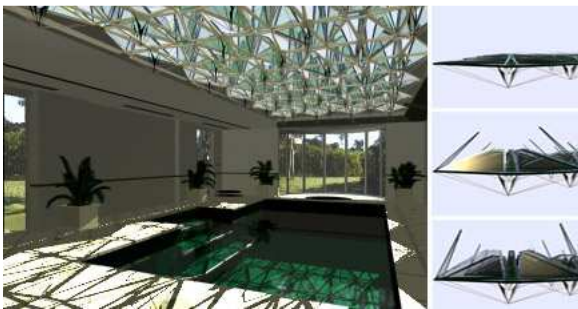


Fig. 5 A computer model of the Responsive skylights designed by The Kinetic Design Group at MIT University

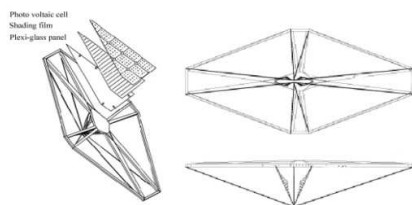


Fig. 6 Details of an individual module of responsive skylights

This network of skylights is operated by means of sensor devices and sliding actuators attached to the aluminum framing. A series of cast aluminum supports and steel tension cables stabilize each transformable unit separately. Primary design considerations are to utilize natural daylight in the space and to take advantage of natural ventilation. Consequently, it reduces energy cost. This project reveals the great advantage of transformable frame structures for intelligent kinetic skylights that can automatically control the environmental condition of architecture.

The application of sensor devices allows the roof to be transformed in a controlled manner during the course of the day. Transformable architectural elements can also be used in different shapes and sizes to create responsive modules that can provide architecture with natural light and the desired ventilation without interfering with the functional, instructional or working visibility of buildings. A prototype that was designed by G. Magnoli and his colleagues at the MIT House of the Future is an example that shows how individual transformable units can be manipulated separately, so that the building can take advantage of the effective and desired natural light and ventilation during the course of a year (Fig. 7) [6]. This proposal consists of four transformable roof units, each consisting of a series of curved transformable beams covered by a number of plates. The outer beams are hinged at intermediate points to outer columns and the beams of the two internal transformable roofs are hinged to the internal columns. Each roof panel consists of a flexible, highly-insulating membrane covered by silicon photovoltaic cells from an outer skin and a capillary heat exchanger system (using water as heat exchange medium) from the interior side.

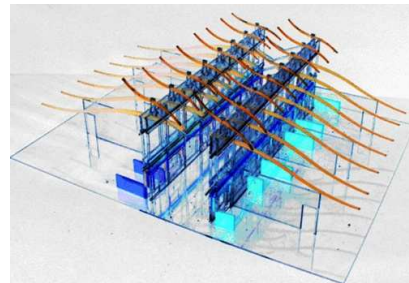


Fig. 7 An axonometric view of a responsive kinetic roof

Fig. 8 depicts how this responsive kinetic roof can be transformed in order to adapt to environmental changes. During the summer, the transformable panels rotate toward and block the sun allowing cross ventilation. In the winter they open to the sun allowing more light and heat to penetrate the building. The configuration of the roof during summer nights allows cool night breezes to enter. The roof is closed during winter nights to retain warmth inside the building [1].

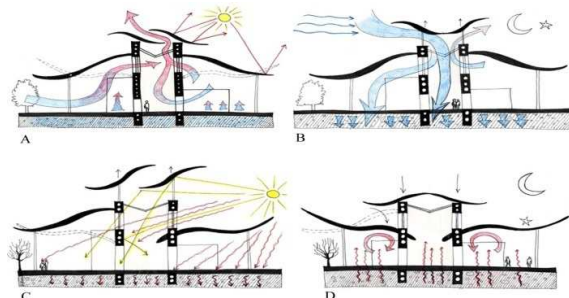


Fig. 8 Different configurations of the responsive kinetic roof during a course of a year A) Summer day, B) Summer night, C) Winter day, D) Winter night

## IV. CONCLUSION

Intelligent architecture has been developed rapidly in recent years. Although, research and development work in this important area of architecture is still in its infancy, the examination of the existing projects and the build examples reveals the great advantages that architecture can gain from smart structure technology. Intelligent transformable architecture is capable of reacting to and interacting with the users and anticipates and adapt to behavioural patterns.

Intelligent systems are architectural spaces and objects that can physically reconfigure themselves to meet changing needs. In these systems, computer systems will interpret functional circumstances and direct the motor-controlled movements to change responsively and adaptively to better suit changing needs. The potential and advantages of these intelligent systems can provide sustainability in different aspects. Indeed, appropriate use of these potentials in architecture can results in convenience spaces and access to wider choices in creation of architectural sustainable spaces. This paper shows that intelligent skins and materials separately or with the combination of movable structures can help designers in the realization of more sustainable buildings.

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