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Effects of Passive Cooling and Intelligent Architecture on Sustainability of Buildings in Hot Arid Climate

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Abstract. Today, one way to reduce the energy consumption for cooling and ventilation units is to exploit passive cooling techniques. Therefore, this paper tries to find the influences of the combination of intelligent buildings with passive cooling on sustainability. The paper, at first, reviews the hot, arid climate, and the solutions and techniques used to provide human comfort in Iran. Afterwards, it is attempted to update those techniques with employment of new technologies and intelligent architecture, and therefore achieving thermal comfort passively. Consequently, this synthesis can be an effective way to reduce energy consumption, which is a step towards sustainability. This research is based on the library studies and descriptive methods. Its result with the goal of sustainable architecture tries to improve the relationship between human, nature and architecture.

Keywords: Climate Hot Arid, Intelligent Architecture, Passive Cooling, Sustainability.

1. Introduction

Providing human comfort at a minimum time and under control on the one hand and the necessity for using energy resources on the other hand has led buildings, which are products of technology, to form according to occupants' needs. In this regard, applying technological parameters in order to construct buildings intelligently, may cause an increase in this capability. Intelligent architecture, which is a new approach to the future of constructing buildings, with providing a secure, comfortable and responsive environment is an instrument to achieve sustainable architecture. Buildings which can adapt themselves to an inner and outer environment so to provide thermal comfort. There are lots of definitions of the term "intelligent architecture", but generally it can be defined "The balance between the feeling comfort of the occupants and the energy consumption". This issue is one important factor of sustainable architecture.

2. Sustainable Development and Sustainable Architecture

Today, after decades of neglect to this issue in Iran, concerning about the future of energy with respect to the domestic issues of the day seems important. Providence to energy is one of the topics that has structural relation to sustainable development and overall cohesion of the countries of the world. In other words, there is no country to have a policy on energy sector without taking other countries of the world into consideration and find it as an optimal policy. This close cohesion arises out of direct connection with the environment, widespread energy influence on the world life and thus, the fact that the environment policies subject is a global issue. To clarify the subject, it is necessary something to be mentioned:

- First of all, nowadays, it is proved that sustainable development is not possible unless the amount of carbon dioxide gas produced in the world is kept at the lowest level.

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- Secondly, energy is the most important factor affects the amount of carbon dioxide.
- Third, the control of the carbon dioxide to achieve an improved environment is a global matter and, no country can implement an individual policy on it.
- Forth, energy is a derivative commodity and, no one can investigate it without taking the tools of using it into account that includes a very broad spectrum of activities. The demand of the sustainable development is to achieve a sustainable economy and one aspect of this sustainable economy in the natural capital sector is that the amount of carbon dioxide gas should be kept at the lowest level. Today it is proven that if the amount of the carbon dioxide gas should be kept at its lowest level, there is no choice except for keeping it at its lowest level in the energy sector.[1]

The goal of societies in addition to the physical life, is to provide or continue a sustainable development. Sustainable development is a revision attitude towards tradition and modernism, and tries to find a conciliation solution between these two. In 1983, in a meeting in Norway, sustainable development was defined as "*a development that can meet the current demand of the world's countries without endangering future generation to meet their needs*."[2]

Thus, according to the above description, in the field of building industry, sustainable architecture is being raised, which is a general phrase applied to describe the design of the resistance buildings in terms of technical, materials, ecological and environmental. Resistance can be met with:

- Sustainable technology and materials (elements)
- Sustainable resources
- Sustainable environment (Table 1)[2]

Table 1: Component for sustainable architecture [2].

ELEMENTS	RESOURCES	ENVIRONMENT
Durable	On- Site condition	Healthy
Economic	Cost- effective operational/life cycle	Habitable
Low maintenance	Accessibility	Social capacity/Normative
Recycle	Natural forces (Desirable)	Safty and security (Protective)

3. Hot Arid Climate and Traditional Thermal Comfort Solutions

The country "Iran" is a part of the great plateau of Iran, which has a central plateau, too, and this plateau has different climatic zones. One of them is hot, arid climate which receives almost no rain for at least six months of the year, hence it is very dry and hot. Thus, cooling is the most remarkable issue for providing thermal comfort in this region.

As Eiraji and Akbari Namdar, [2011] in "*Sustainable Systems in Iranian Traditional Architecture*" described, "*Traditional architects in Iran, tried to use convection and evaporation in their design, and certain wind and water play the main roles in this way of design and by this way, some sustainable systems and equipment such as wind catcher known as "Badgir" and ponds build inside the house known as "Hozkhaneh" were presented to Iranian valuable architecture*."[3] In addition, there were some other ways that our ancestors used to make their living place comfortable. They are listed below:

- High thermal capacity of the materials.
- Compaction of the buildings and shading.
- Reducing the number and area of the openings.
- Building orientation (south to southeast)

4. Definitions of Intelligent Architecture

A first group of definitions relates the intelligence of a building envelope, and architecture in general, to the skillfulness and rationality of the people who design, use and maintain it. A typical example of this type of definition is given by Kroner, who identifies three main areas of concern for intelligent architecture: [4]

- Intelligent design. “The design process must respond to humanistic, cultural and contextual issues; exhibit simultaneous concern for economic, political, and ecological sustainability at both the local and global scale.”; and [ibid]
- The appropriate use of intelligent technology. “Integrating intelligent technologies with an intelligent built form that responds to the inherent cultural preferences of the occupants is a central theme in intelligent architecture.”[ibid]
- The intelligent use and maintenance of buildings. “For a design to be intelligent it must take into consideration the life cycle of a building and its various systems and components. Although an intelligent building may be complex, it should be fundamentally simple to operate, be energy and resource efficient, and easy to maintain, upgrade, modify, and recycle.”[ibid]

4.1. Responsive to the Environment

The manner in which the envelope is able to adapt to changes in its environment, is a third dimension of intelligence in building envelopes. Intelligence may be related to the responsive performance of the building envelope, “the design and construction of which forms the single greatest potential controller of its interior environment, in terms of light, heat, sound, ventilation and air quality.”[5]

Of particular importance is the manner in which intelligent technology is able to adapt to the needs and preferences of the building users.

Magnoli et al. explore the design of DNA for responsive architecture, where “the primary motivation of the design lies in creating a design solution that is flexible and adaptive at any scale, and at instances, responsive and intelligently active with respect to the changing individual and climatic contexts As in any ecosystem, a fractal, coherent, continuous fluctuation at every scale of the system is vital.”[6]

4.2. Typologies in Responsive Architecture

Dynamic systems in architecture are receiving a growing interest from researchers likely to be the result of accessible technology and inspirations from dynamic systems in nature and the surrounding environment.

The unfolding potential of such systems reveal many intriguing questions related to architectures perception of being, all the way to designing and assembling explicitly defined multi-rotational robust joints. Listed investigation areas thus frame a larger spectrum of specific research areas into one towards performance based responsive systems in architecture.

1. Material Systems: The development of physical kinetic systems or the like are often developed within structural and mechanical engineering and material sciences.

2. Informational Systems: The development of physical sensor systems, which to an increasing level can observe and send continuous information further to a processing system, which then actuate into behaviours passing information back to the environment.

3. Processing Systems: The development of physical processing systems, which filter and decide from large amounts of sensor information and stored information. These are often associated and developed within computational sciences.

4. Behavioural Systems: The development of logic and behavioural gestures, patterns and systems, often associated with artificial intelligence sciences based upon computational and neurological sciences. [7]

4.3. Smart Materials

Shape- changing smart materials include materials and products that are able to reversibly change their shape and/or dimensions in response to one or more stimuli through external influences, the effect of light, temperature, pressure, an electric or magnetic field, or a chemical stimulus. Among these, there are materials and products that are able to change their shape without changing their dimensions, and other materials and products that retain their shape but change their dimensions. [8] (Table 2)

Thermostrictive, piezoelectric, electroactive and chemostrictive smart materials are those that are currently of the greatest interest in the field of architecture, due to their availability, predicted long-term stability and other factors.” [Ibid.]

Table 2: Smart Materials

Smart Materials	
Types	Sub-Type
Shape-Changing Smart Materials	Thermo strictive
	Electroactive
Color and Optically Changing Smart Materials	photochoromic
	Thermochoromic
	Electrochoromic
Adhesion-changing Smart materials	Photoadhesive
Light-Emiting Smart materials	Photoluminescent
	Electroluminscent
Electricity- Generationg Smart Materials	photoelectric
	piezoelectric
Energy- Exchanging Smart Materials	Heat storing
	Gas/Water storing

5. Some Suggested Solution

According to the above subjects, there are some solutions to be suggested to integrate the two aspects (traditional patterns and the intelligent technology) which lead to reducing energy and its other positive consequences. They are mentioned below:

5.1. High Thermal Capacity Materials

Today due to the demand for using the most rentable space of the buildings, lowering the dead load and cost efficiency of the buildings and with the help of technology, according to the authors "*Addington and schodeck*" described "*many materials can exist in several different physical states – gas, liquid or solid – that are known as phases. A change in the temperature or pressure of a material can cause it to change from one state to another, thereby undergoing what is termed a 'phase change'. Phase change processes invariably involve the absorbing, storing or releasing of large amounts of energy in the form of latent heat. A phase change from a solid to a liquid, or liquid to a gas, and vice versa, occurs at precise temperatures. Thus, where energy is absorbed or released can be predicted based on the composition of the material. Phase-changing materials deliberately seek to take advantage of these absorption/release actions.*" [9]

5.2. Shading and Ventilation

In hot, arid climate, giving attention to the expansion of shading and preventing direct ventilation helps to provide thermal comfort. Integrating this traditional pattern with intelligent technologies will lead to the use of panel control systems in the envelope of the buildings. Hence, according to Sinopoli, that is mentioned below applies these solutions will lead to the control of smart ventilation, daylight and shading. He claims that "*one approach to the lighting control system is the use of intelligent controllers. These controllers are distributed throughout a facility and manage downstream relay panels.*

Photoelectric controls are designed to strategically use daylight to reduce the need for artificial lighting, a process called "daylight harvesting." [10]

Ventilation is used to maintain a satisfactory environment within enclosed spaces. The environmental criteria controlled may be:

- Temperature: Relief from overheating
- Humidity: Prevention of condensation or fogging
- Odor: Dilution of odor from smoking, body odor, processes, etc. [Ibid.]

5.3. Lowering the Openings

One another thermal comfort factors is to lower the number and area of the openings in the skin of the buildings. However, today's modern architecture demand is to make buildings transparent. Thus, for solving the contradiction between architectural demand and the fully glazed needed buildings, it is possible to apply photochromic glazing units. According to Ritter in the field of photochromic materials, "*Photochromic materials (PC), photochromics and UV-sensitive materials are materials or components that are able to reversibly change their colour in response to light."*[8] *Photochromism describes the reversible conversion of materials or components between two forms A and B, each with different absorption spectra*. [ibid]

In addition to the above mentioned solution, there are some other kinds of executive tasks possible, without the need of technology, to be done such as the orientation of the building which must be chosen properly, designing the building around a central yard and building a pond so to provide the needed amount of humidity in this arid climate. What is more, is that for example by designing double skin façade systems for the building envelope, it can take the advantage of natural indirect ventilation along with other benefits derived by this system.

6. Conclusion

By utilizing intelligent technologies and traditional patterns with respect to the following items it is concluded that doing some revision to the traditional architecture as a thesis and modern architecture as an anti-thesis may lead to a synthesis that could be called "sustainable architecture".

- Reduction in energy consumption
- Providing thermal comfort
- Utilizing renewable energy
- Cost efficiency of the buildings (in occupation stage) and efficient building spaces
- Time efficiency (if designed properly)

7. Reference

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