International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

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PAPER ID: 11A03P

USES OF NEW/SMART MATERIALS IN THE GREEN BUILDING WITH SUSTAINABILITY CONCERNS

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ARTICLEINFO

Article history:
Received 28 June 2019
Received in revised form 01 November 2019
Accepted 11 November 2019
Available online 29 November 2019

Keywords:
Smart building systems; Green architecture; Green roof; Green design; Sustainable environmental architecture; Smart energy management; Architecture technology.

ABSTRACT

Due to the importance of energy in green buildings, one of the most critical solutions to achieve a sustainable environmental architecture that tries to cope with nature instead of overcoming it and use of renewable energy instead of fossil fuels. Smart architecture and building systems can reduce energy consumption as well as provide desirable comfort to residents of the green building. The widespread and growing need of the community to buildings and housing, the necessity of using new construction systems and modern materials to increase the pace of construction, light-weighting, increasing service life and also buildings` retrofit against earthquakes have been proposed more than ever. Solving problems such as long run time, poor service life, high cost of building construction, environmental issues, and existing pollution in today's cities requires a public determination and fundamental changes in the type and use of materials, building systems, and architecture. The need to achieve such an ideal is to apply technology again to produce smart and new materials that guide the ecological behavior of the building towards smart energy management; this means the application of materials that best adapt to environmental changes. The use of smart materials reduces energy consumption in green buildings with a sustainable development approach that was reviewed and investigated using a descriptive-analytical method.

Disciplinary: Architecture Engineering (Sustainable Architecture).

1. INTRODUCTION

Building and living have changed dramatically over the past two decades. In fact, it can be stated that in our times, the increasing population and urban life, along with the excessive energy consumption and pollution caused by human activities, is a great problem in environmental protection, so the green architecture is one of the important architectural currents. Green and sustainable titles are indeed the attributes that characterize the existence of adaptation to the environment and persistence in a built subject, such as a building. Each community should be

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supported by the present and future residents. In this regard, the building designing and construction should be done in such a way that it is compatible with a sustainable and smart environment and with the use of state-of-the-art technologies. A sustainable and green building is set along with nature to further exploit the environmental facilities and provide human comfort. A sustainable and green building is regulated and controlled using sophisticated and integrated systems. The architectural design, in addition to the beauty and function of the spaces, tries to use the natural factors and resources such as renewable energy (e.g., solar energy, geothermal energy, and the wind) and plants to regulate environmental conditions and for the welfare of beneficiaries. Green architecture arising from sustainable architecture and development is the result of human need today against the consequences of the industrial and consumption of the present era. Protecting the world's natural resources, immunity from air pollution and other environmental pollutions, protection of the ozone layer, physical and mental health, the future of humanity has been one of the issues discussed in this regard, and its necessity has become more and more evident as a global task. (Modaresi, 2019)

This study amplifies the use of smart materials, aiming at the reduction in energy consumption. This study highlights the harnessing of the mentioned structural and building components through which there will a drastic decline in energy loss. In the first step the study tries to define sustainability, then it puts effort on to describe the sustainable design and related principals.

2. SUSTAINABILITY IN ARCHITECTURAL DESIGN

Sustainability is meant to meet the needs of today's generation without sacrificing the ability of future generations to meet their needs (Mohammad, 2013).

In this definition, two critical concepts of prospecting and maintaining resources have been considered. The next generation has a right upon today's generation and requires duty for today's generation to endow the earth in full health to the next generation. To preserve resources, it is necessary for today's generation to protect all renewable and non-renewable resources (Keikha, 2018). Sustainable development is a kind of development that improves human health and ecological systems in the long run. This definition emphasizes the continuous process of moving toward healthier natural and human communities (Kasmaee, 2012).

2.1 SUSTAINABLE DESIGN

The proposed definitions for sustainable design are sometimes more focused on the idea of environmental sustainability concerning architecture, including a sustainable building is a kind of building that has the least adverse effects on the natural environment over the life of the building as well as regional and global deployment. The principle of sustainable design is based on the fact that the building acts as a minor part of the peripheral nature and a part of the ecosystem and is set in the life cycle. The concept of sustainability in architecture can be translated into the vision and design of future construction, not only with the physical sustainability of the building but by the sustainability and preservation of the planet and its energy resources (Keikha,2018).

Thus, it seems that sustainability is based on a pattern where available materials and resources are deployed more efficiently before being wasted or ignored. In other words, sustainable design is focused on building capability to integrate environmental and atmospheric factors and transform them into spatial qualities, comfort, and form. According to the principles of humanization, sustainable architecture is of particular importance regarding the quality of the interior spaces of the building. Undoubtedly, the desired quality is not suitable regardless of nature, suitable lighting of spaces, and air conditioning. Besides, since the sustainability and persistence of the building per se are considered as a phenomenon, high-quality construction, using long-lasting materials must also be considered. It is possible to achieve such conditions using systematic design, efficient management, and the application of the latest technologies concerning building materials (Kiomarsi and Ahmadipour, 2001).

2.2 SUSTAINABLE DESIGN PRINCIPLES

Location recognition: Sustainable design is posed by a cognitive site because if we are sensitive to the delicate spatial issues, we can settle without degradation. Knowing the location, such as the direction of light, helps the design and protects the environment and even facilitates access. Relationship with nature*:* In designing the site, whether within the city or in the natural environment, it has a coordinated design with nature to return to environmental life, and the effects of design help us have a natural space. Knowledge of natural processes*:* There is no waste in nature, production of an organism provides food for the other, and in other words, natural systems have a closed loop. By working with living processes, we respect the needs of the species, and by a design that can put itself in the cycle of nature, we return the design to life. Understanding environmental impacts*:* Sustainable design is an attempt to identify the environmental effects on the site evaluation. Negative environmental impacts can be mitigated by impressible energy efficiency, structures` technology, and sustainable materials` selection. Understanding people: Sustainable design should pay attention to a wide range of cultures, generations, religions, and the habits of people who use or inhabit it, which needs to be responsive to the needs of the people and the community (Husseini, 2011).

2.3 THE PRINCIPLES OF GREEN ARCHITECTURE

2.3.1 CONSERVATION OF ENERGY

Each building must be designed and constructed to minimize the need for fossil fuels. The necessity of adopting this principle in the past can undoubtedly be denied according to the types of construction. Perhaps due to the great variety of materials and technologies in contemporary times, such a principle in buildings has been forgotten. Now, using different materials with different combinations of them, they change the buildings of the environment according to the needs of the users (Hamideh,2018).

2.3.2 WORKING WITH THE CLIMATE

Buildings should be designed to be able to use the climate and local energy resources.

The shape and the deployment of the building, as well as the placement of the interior spaces, can be in such a way that it causes the height of the comfort level inside the building and at the same time can reduce the fossil fuel consumption by proper insulation of the structure. Both processes are overlapped and have many common points.

2.3.3 REDUCING THE USE OF NEW RESOURCES

Each building should be designed to minimize the use of new resources and to create a source for building other structures at the end of its service life.

Although the orientation of this principle is similar to the other principles referred to the new buildings, it must be noted that most of the resources available in the world are employed in the current built environment, and it is necessary to repair and upgrade the existing structures to reduce environmental impacts, which is of equal importance to the creation of new structures. It should also be noted that there are not enough resources to create built environments in the world that can be used to reconstruct every generation of buildings. A green process may consider the judgment of this subject on available resources only. These changes should be welcomed if the resources required to change a building be less than the resources required to destroy and restore it. However, this does not lead to a lack of respect and commemoration of the historical significance of the structure. Moreover, these structures may also have other values that are required to pay attention to them. (Lahiji, 2018)

2.3.4 HAVING RESPECT FOR USERS

Green architecture respects all the people who use the building. This principle appears to have little relation to pollution caused by global climate change and the destruction of the ozone layer. However, the green process in the architecture that includes respect for all common resources in a complete building does not exclude humans from this collection. All buildings are made by humans, but in some structures, the fact of human presence is respected, while in others, an attempt is made to reject the human dimension at the construction site. (Lahiji, 2018)

2.3.5 HAVING RESPECT FOR THE SITE

Each building has to touch the ground in a calm and light way.

"The building should touch the ground in a quiet and light way," said Australian architect Glenn Murcutt, a feature of the interaction between the building and the site, which is essential for the green process, and of course it has broader characteristics. The building that consumes energy greedily, generates pollution and is alienated from its consumers and users; thus never it touches the ground in a gentle and light way (Torabi and Roshan, 2015).

2.3.6 HOLISM

All green principles require participation in a holistic process to create the built environment.

It is not easy to find buildings that have all the basics of green architecture since green architecture is not yet fully understood. A green architecture must include more than one individual building block and must include a sustainable form of the urban environment. The city is a creature beyond the building complex; in fact, it can be viewed as a collection of interacting systems - systems for living and recreation that are molded in the shape of structured forms. With a closer look at these systems, we can map the face of the future city (Torabi and Roshan, 2015).

2.4 THE BENEFITS OF A GREEN BUILDING

- ✓ It satisfies the needs of its inhabitants.
- ✓ It provides health to its residents with satisfaction, productivity, and gayety.
- ✓ It requires the measured use of sustainable architectural solutions, construction with non-toxic materials, effective use of materials obtained from sustainable natural materials, relying on the sun on daylight, thermal and electrical energy, and recycling materials.
- ✓ An architectural synthesis of these solutions in a building, which is an honor to its users and is in the service of the natural world (Najafi, 2002).

Some aspects of green architecture are:

- ✓ Increased comfort, ability to live and productivity
- ✓ Improved durability, quality, and maintenance
- ✓ The sustainability of the internal environment

- ✓ Money savings by reducing the cost of life
- ✓ Understanding the options of high-performance solar buildings
- ✓ Choosing the field of green building materials to play your role to help protect the environment

2.5 GREEN MATERIALS

Avoid using those chemicals that destroy the ozone layer in mechanical and insulation equipment.

Use the building materials obtained from the site. Transportation is important both in energy consumption and in public pollution.

Use waste materials that can be recoverable in the cycles of nature, such as cellulose insulation, homasote, plywood, the tiled floor made from ground glass, and recycled plastic in the form of timber and flooring.

Search the authentic wood products. Use exclusively guaranteed timber which was obtained from controlled forests.

Avoid using substances that are polluting with gas: They release the base solvent of color and oil, glues, carpet, scrap wood, and many other building materials and products, formaldehyde, and volatile organic VOC compounds (Zhou, 2012).

The main features of the smart architecture are:

- Adaptable
- Dynamic and Mobile
- Flexible and consistent with the environment
- Reactive and responsive (Turkgizi and Farokhzad, 2013).

In this paper, it was tried to name some materials that are compatible with green and sustainable architecture that only two of them have been analyzed.

3. SMART MATERIALS

Smart materials are materials and products that can understand and process environmental events and react favorably to it. In other words, these materials are capable of change and can change shape, form, color, and internal energy in a reversible manner in response to the physical or chemical effects of the surrounding environment. If we classify the materials into three non-smart, semi-smart, and smart materials, the first group, i.e., non-smart materials, do not have the above particular characteristic, the semi-smart materials can only change their shape and form for once or for a while in response to their peripheral effects; however, in smart materials, these changes are repeatable and reversible. Smart materials are also known as "flexible" and "adaptive" materials, and this is due to their particular feature in adjusting themselves to environmental conditions. The effective chemical and physical variables introduced below are the stimuli that smart materials react to.

1. UV-ray light: The ultraviolet and visible part of electromagnetic rays
2. Temperature: The temperature changes that make a physical system like a human body.
3. Pressure: Pressure difference created in a region
4. Electric field: The field created around an electric charge.
5. Magnetic field: The field created around a magnet or a mobile electric charge

Chemical environment: The presence of a particular element or chemical compound such as water (Kiomarsi and Ahmadipour, 2001).

3.1 TYPES OF SMART MATERIALS

The existing building materials including traditional, natural, and artificial, are classified according to their characteristics such as appearance, texture, chemical composition, physical properties, environmental effect, and so on. However, smart materials are classified based on other properties related specifically to differentiating between smart materials and traditional materials. In fact, the proposed classification of smart materials is based on the following three properties:

1. The capability of changing internal properties:
    - Anamorphic smart materials
    - Halochromic smart materials
    - Delinking smart materials

2. Energy exchange capability:
    - Smart materials emitting light
    - Smart materials producing electricity
    - Energy-saving smart materials

3. The ability to change and exchange internal materials:
    - conductive smart materials

3.3 POWER CONSUMPTION REDUCTION WITH SUITABLE UTILIZATION OF SMART MATERIALS

3.3.1 THERMAL EXPANSION SMART MATERIALS

This type of material has some inherent property that enables them to react in response to changes in ambient temperature around the environment. Temperature variations may have an inactive effect so that the material continuously adjusts the state of its internal temperature with its natural state through the outer shell and if they have an active effect, a kind of active heating is created using an electric field through contact.

An example of thermal expansion materials (TEM) is expandable materials that have an expansion coefficient. However, their most important application in architecture is for heating thermostats for building services as well as specific drivers in greenhouses and in building facades to control and manage energy. The other applications of them are in the ventilation system of the building rooms. The system works in such a way that the system is open or closed in certain temperatures to provide suitable space ventilation conditions. They can also be designed as components of the ventilation system in the building facade by lifting or dropping parts of the roof cover automatically. The application of this type of smart materials in building decreases the amount of energy consumption to a considerable extent by producing proper ventilation of the need for complex systems and excessive spending (Saanei and Masudi, 2008).

3.4 HALOCHROMIC SMART MATERIALS (SMART MATERIALS WHICH CHANGE COLOR)

These materials can change their color or visual characteristics in response to one or more external stimuli. Due to their stimulus, these materials include various types. Some of them, which have been considered in many architectural applications include photochromic, thermochromic, and electrochromic materials (Michelle, Britain, 2005).

Currently, much attention has been paid for photochromic materials (PC) by the architects. Although the application of these materials was primarily due to their beauty aspect (because of the color spectrum they created in front of the light) (Figure 1), researchers did many research on these materials so that they can use this product for other functions such as reducing energy consumption or temperature changes of these materials. The electrochromic materials are also used in the architecture of the electro-optic glasses. These materials can change their visual characteristics, i.e., their transparency by exposure to solar radiation (Axel, 2007).

Figure 1. Windows made from photochromic glass

3.5 ENERGY-SAVING SMART MATERIALS

Transparency and heat capacities can be used simultaneously. Whenever the temperature of the interior of the building is higher than the outside, a bidirectional flow is established. The radiation energy is transmitted into space, whereas the internal thermal energy is driven outward. Changes in the amount of glasses' adsorption finally affect their net conductivity and change the balance mode of these currents. Many materials, such as photochromic, thermochromic, thermotropic, electrochromic material, liquid crystals, and suspended particles` system can be used in building smart windows. In many cases, the smart materials used in windows can be used interchangeably, for example, the electrochromic materials, the liquid crystal, and the materials with suspended particles are all used in controlling the conduction of light and heat, the highest difference in these materials is caused by the electric current (Kienzl, 2002).

These materials and products are capable of storing energy in themselves, whether explicitly or implicitly, such as the form of light, heat, hydrogen, or electricity, which also have the reversibility capability. Thus, these materials are capable of storing energy in different ways. However, among these smart materials, heat storage has gained more attention. These materials have a kind of inherent characteristic, which enables them to store energy as heat or cold (vs. heat) as latent energy (Michelle, Britain, 2005).

3.6 THE MATERIAL APPROACH IN ARCHITECTURE

The selection of materials to use in architecture has always been based on many different criteria. Function and expense play an implicit role; however, the final selection is often based on facial appearance, beauty, ease of construction due to the skill of the human force, local or regional access, as well as materials used in the facades of nearby buildings. A lot of advanced materials were created to provide the fastest visual facade and thus, the most appropriate tool for the presentation in and out of the building. As a result, today's architects often think of materials as part of the design mix by which materials can be chosen and accepted as structure or combination or visual levels. It is in such a climate that many have reached the approach of smart materials.

3.7 SMART MATERIALS IN ARCHITECTURE

Smart materials are often investigated to achieve a rational development of the path of development and expansion of materials toward greater selection and specialization of the performance. For many years, an architect had to accept to work with standard materials such as stone and wood and to design regarding the constraints of these materials, while during the twentieth century, he could have started to choose or manage the characteristics of high-performance material, especially to find the defined needs. Smart materials even grant additional specifications because their properties can be modified and thus respond to unsustainable needs. For instance, photochromic materials (with the spectral transport feature) change color when they are exposed to light. The entering light of the strongest surface area since the buildings are always confronted with changing conditions; the ability to respond to multiple states more than optimal in just one case has presented smart materials as a reviewable material for the design. As a result, we can start to find out many suggestions about how smart materials substitute for more common building materials (Mondal, 2008).

Although the cost and availability of conventional building materials are limited by smart materials, the implementation steps tend to follow the model that the new material has traditionally been introduced into the architecture, first through obvious examples (such as thermochromic materials and electrochromic doors), and then by fully distinguished proved projects, such as the Barasari restaurant, Diller Scofidio's work, and Seagram Building by Ludwig Mies van der Rohe (Figure 2). Many architects think that building surfaces and exterior walls and facades that are generally made of smart materials may automatically move their design from a lifeless box to an interactive corridor. Indeed, conditions such as variability and the interactive state have become the standard elements of the architect’s dictionaries, as far as the technologies and necessary materials are superior to the practical and economic reality of most construction projects. For the inclusion of smart materials in a principled practice with conventional construction materials, the architects principally have tried to incorporate conventional standard building materials. Common standard building materials are immobile and tend to resist the forces of the building. Whereas, smart materials are dynamic so that they can respond to conditions in the fields of energy. With a smart material, we need to focus on what we want to do on that material, not on what we want it to look like. Recognizing smart materials needs to be a more simple and superficial understanding of material properties. There should also be a full and acceptable awareness of the underlying physical and chemical reactions of these materials with the environment surrounding it (Husseini, 2011).

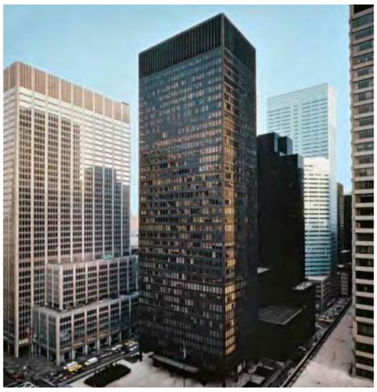

Figure 2. The exterior view of the Seagram Building by Ludwig Mies van der Rohe.

3.8 REVIEWING THE PROPERTIES AND APPLICATION OF SMART MATERIALS CONCERNING ARCHITECTURAL NEEDS

One of the biggest problems in the use of smart materials in architectural design is that a limited number of materials and systems are under the influence of the same environmental effects, for example, the use of smart materials in controlling heat transfer via convection through building cover may negatively affect the transit rate and influence of the light day. Furthermore, since the majority of the machines in the building have a high level of integration, it is difficult to optimize the performance of smart systems without affecting the system size or eliminating the balance of the control system (Arbabi and R’afati, 2012).

3.8.1 SAVING THE OPERATING COSTS OF SMART MATERIALS IN ARCHITECTURE

When asked about the cost of smart materials, all the architectural engineers and consultants can compute its cost. Anyway, the real price of smart materials is calculated from the volume of capital and the cost of building and setting it. The building value, the investment value, the value of executive activities is the highest volume of costs associated with smart materials, and since the building management systems greatly reduce operating costs, it not only will save money to the investor but also spend the lowest cost for construction (K.C.W).

3.9 ARCHITECTURAL DESIGN PLATFORM IN CONTEMPORARY TIMES

When the common claim is that architects design space, the fact is that they build surfaces. This particular advantage of surfaces causes the use of materials in two main directions. Second, since architecture is synonymous with the surface and materials of that surface, we inherently consider the materials as two-dimensional (i.e., two-level). The result is that we tend to consider materials in large 2D rows, i.e., outer covering, internal covering. More recent attempts to use smart materials in architectural design, the word ‘2D surface’ or identity and a simple continuous purpose of smart materials are kept as substitutes or alternatives for many conventional materials. For example, many recommendations have been made to replace standard glass curtain walls or electrochromic glasses that completely cover the facade of the building (Golabchi, 2011).

3.10 THE EFFECT OF SMART MATERIALS ON GREEN BUILDINGS

ETFE environmental features

Energy consumption in the ETFE sheets production process is very low, and its full structure has a weight range 50-90% less than the similar structures made with other materials. It is comparable with other properties of weight. Structural systems, however, require more protection to maintain coverage. A part of the structure is made of recycled materials, and at the end of the life of each project, the entire system can be returned to the construction site for recycling. Long life-cycle and low construction and maintenance cost, makes ETFE a suitable solution in sustainable architecture. The architect of the structure can use the daylight and thermal cycle to change the features of the structure and function of the building. These capabilities and facilities make ETFE a unique group (Gorji and Aboutalebi, 2009).

Air dryers: Wind pumps can easily be equipped with air dryers to attract air moisture into the pads. This arrangement is recommended for high humidity environments (Gorji and Aboutalebi, 2009).

Fire: The ETFE sheet has a low combustion capability and is self-extinguishable. Pads evacuate the fire automatically in the event of fire because the mass of hot air causes the ETFE sheet to accumulate and recede from the heat source, thereby allowing the fire to exit. Since the amount of materials available in the roof is insignificant, molten sheet droplets do not fall during the fire (Gorji and Aboutalebi, 2009).

Acoustic: A sheet roof is relatively transient in terms of acoustic insulation, meaning that the sheet acts as an acoustic absorbent for the room and increase the understanding of sounds in an internal environment (Gorji and Aboutalebi, 2009).

Heat insulation: The U-factor of a three-layered standard pad is equivalent to 1.96 kW/m, which is much higher than that of three glass layers when used horizontally (i.e., the glass producers present figures for the vertical glass that significantly increases the numbers). The characteristics of pads' insulation can be improved by adding self-covered layers (Gorji and Gorji, 1994).

Persistence: ETFE sheets are not affected by UV waves, environmental pollution, and atmospheric conditions. This material is tested both in the laboratory or in the outside environment; no erosion or resistance reduction was observed. ETFE sheets do not become fragile over time and do not lose color. This material is predicted to be more than 40 years old (Gorji and Aboutalebi, 2009).

Construct: The ETFE is built by a construct from steel frames, and no support structure is required. To achieve broader craters, the membrane can be reinforced by adding cables (Gorji and Aboutalebi, 2009).

The water, air, and water vapor insulation: The pads' material (i.e., Fluoropolymer sheets) alone acts like water, air, and water vapor insulation.

3.10.1 THE APPLICATION OF PHASE-CHANGE MATERIALS ON THE GREEN ROOF

Vegetation on the roofs, the green roof, is used as a passive technique to reduce buildings energy consumption and improve air quality around them. This is possible through the conservation of heat in winter and preventing direct sunlight and creating shade and cooling in summer. Control and management of surface water, energy conservation, reducing heat islands effect in cities, and increasing service life of roofs is one of the reasons for the importance of this issue. However, in most cases, the use of the green roof itself does not have a significant impact on energy consumption because storing nightly cold for daytime use and vice versa cannot save long-term heat from the sun at night. In this regard, the need for materials that can store thermal energy in the long run and significantly, among which are phase-change materials that improve the green roof efficiency by storing latent heat. By minimizing heat transfer in winter and creating shade and cooling in summer, the green roof leads to a reduction in the total heat load required for the building, and the addition of phase-change materials to the inner layer of the building increases these positive effects (Arbabi and R'afati, 2012).

3.10.2 GREEN ROOF'S THERMAL PERFORMANCE

The heat flux transfer of the green roof is controlled through four mechanisms:

1) Shading, 2) Thermal insulation, 3) Evapotranspiration, 4) Thermal mass

Overall, the total amount of radiation absorbed by the green roof is approximately reflected 22%, about 6% is absorbed by the evaporation of plants and soil, and only 13% is transferred to the soil (Sam C. M., 2009).

The thermal effects of the green roof can be divided into two aspects:

The direct effect on the building (i.e., the internal effect): In this case, the heat transfer problem is through the roof with the interior, which reduces the energy consumption of the building by reducing this heat exchange and preventing waste.

The indirect effect on the surrounding environment (i.e., the external effect): In this case, the heat transfer problem from the rooftop to the surrounding environment leads to the reduction of urban heat islands and finally decreases the city's temperature, which will reduce the temperature reduction required for cooling to significantly reduce the energy conservation data. In calculating the thermal performance of the green roof, the type of vegetation, and the soil bed of the plant seem to have been affected by parameters (Torabi and Roshan, 2015).

4. CONCLUSION

Today, buildings are a form of technology; they adapt to technology and take advantage of it. Building as a structure, once it controls technology, becomes smart. The main purpose of using smart materials in a building is the storage of energy, proper and optimized utilization of facilities and the return of initial capital. Besides, considering the finitude of energy resources and the destructive effects of the immethodical consumption on the environment, we can also contribute to the global community, using new technologies, in reducing energy consumption. In the green building, using smart materials leads to reduced costs, which is much higher than the construction costs. It also reduces the adverse environmental effects and the approach of society towards sustainability criteria. Today's complex life, on the other hand, requires all these technologies, and on the other hand, it should try to maintain the environment and reduce energy consumption. Therefore, the methods described in this paper concerning the design and implementation of buildings are an effective step in reducing energy consumption in the building sector. Therefore, the reviewed examples in this study indicated that the facades should be better equipped and designed in such a way that they may be able to deal with the wind, rain, and humidity. Thus, the deployment of a method that does not create a limitation in addition to proper energy efficiency in the architectural design and building facade is considered one of the essentials in the design of buildings. In addition to taking positive points in the field of aesthetics, the ETFE panels` system has many unique capabilities, including thermal and acoustic insulation that plays an important role in reducing noise pollution. One of the most important systems studied in this research was phase-change materials which can save energy consumption by 20% if selecting its correct type, and in addition to natural ventilation, reduces the dependency of the building to the use of mechanical equipment.

From the outcomes of this study, the effective ways to reduce energy consumption in the building is the use of new construction materials and technologies are listed below:

Areas that new materials reduce energy consumption in construction:

- Optimization of existing materials and products
- Weight-loss and volume of materials and building elements (light-weighting)
- Reduction in the use of raw materials and energy
- Reduction of production steps/Reduction in the need to maintain and maintenance cost
- Increased speed of construction/ Dynamic economics
- Increased service life/Retrofit of buildings against earthquakes
- More efficient use of materials/Reduction of carbon dioxide emissions
- Prevention of damage/Conservation and preservation of natural resources
- Recycling capability/Plasticity
- More comfort

4. AVAILABILITY OF DATA AND MATERIAL

Data used or generated from this study is available upon request to the corresponding author.

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