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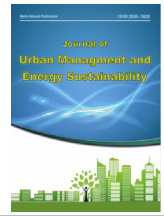

ORIGINAL RESEARCH PAPER

Evaluation of smart materials application in optimizing energy consumption in office buildings (Case Study: cold and mountainous regions of Iran, Tabriz)

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ABSTRACT

The reduction of energy resources, as well as the high costs of using renewable resources, as well as the increasing destruction of the environment and global warming, have caused the advanced countries in the world to deal more with the energy crisis. Considering the economic and environmental effects of high energy consumption in the building sector, sustainable design and development in architecture seems to be essential, one of the important ways to save energy in the building industry is to design a smart building and use smart techniques and materials. The aim of the current research is to evaluate the role and application of smart materials in optimizing energy consumption in office buildings in cold and mountainous regions. The research method is analytical research and it is applied on purpose. Accordingly, a building with administrative-service use in the region of Tabriz city was simulated in certain dimensions and field data was evaluated using the design builder and Energy plus software. The findings are that the use of smart concrete instead of ordinary concrete can reduce the high amount of energy consumption in the building and regarding the amount of heating energy used in this simulation, which is practically the most effective part of the results, as can be seen in the coldest days of the year, the maximum difference in the amount of energy required reaches 22.5%, which can significantly save energy consumption.

Running Title: Smart materials application in optimizing energy consumption in office buildings

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INTRODUCTION

Since the beginning of history, human beings have always taken initiatives to organize the environment around them to meet their basic needs. He has sought to create a livable environment to meet his physical and spiritual needs. Even today, with the use of new materials and all technological facilities that are economically, costly and environmentally polluting, it can be seen that in some cases the comfort and peace are not provided, which today with the introduction of sustainable architecture, an attempt is made to solve this problem. The reduction of energy resources, as well as the high costs of using renewable resources, as well as the increasing destruction of the environment and global warming, have caused the advanced countries in the world to deal more with the energy crisis. A crisis that most originates from energy consumption in urban buildings (Yu et al., 2018). Since in developing countries more than 40% of the total energy consumption belongs to the building sector, therefore, according to the emergence of new technologies, the process structure of energy consumption should also be examined (Wang et al., 2019). Many of the energy sources in the world that humans are using are non-renewable energies that the inhabitants of the biosphere are required to use more rationally. Half of the world's people live in cities, and this urban life requires the consumption of a significant amount of energy. According to the statistics of various institutions, the amount of urbanization with its increasing growth will cause this amount of consumption to increase by 2050 and reach 80% of the total energy consumption (Wang, 2015). The program for changing energy sources is based on five axes, according to which the largest amount of urban energy consumption takes place in buildings (Nagamoto et al.,2015). For this reason, to optimize energy efficiency in the city, buildings will be the main focus. Since today the issue of energy and environment is considered the most important focus in urban issues, which is discussed at the macro level, in terms of the type and production of energy consumption, and at the medium and micro level, the amount and manner of its consumption. The reflection, emission and absorption of solar radiation is determined by the properties of urban materials and the heat capacity and heat islands. Compared to natural materials such as dry soil, sand, and artificial materials such as brick, concrete, steel, stone, increase the heat storage capacity in urban areas. The expansion of urbanization has changed the type of land cover and impervious materials such as asphalt and construction materials have replaced natural soil, and these impervious materials and surfaces are important factors affecting thermal comfort and the environment. Urban materials are selected by architects, designers and urban planners based on various needs, such as safety, longevity, cost and environmental considerations (Schrijvers et al., 2016). Most of the materials used in cities show different changes in albedo with the passage of time, for example, the abode of concrete and colored stones decreases with the passage of time, but asphalt becomes brighter and its albedo increases over time (Snoeck et al, 2021). The results of studies conducted in Athens show that by using materials with high albedo on a large scale, the air temperature can be reduced by 20 degrees (Xu et al., 2018). The use of urban materials with high albedo, in addition to reducing the effects of heat islands, can have positive and negative environmental effects. So that if materials with high albedo are used only to reduce the ambient temperature, the amount of vegetation cover will be less and, in this case, thermal stress and humidity reduction and other cases mentioned in the absence of vegetation cover will occur (Schrijvers et al. 2016). Considering the economic and environmental effects of high energy consumption in the building sector, sustainable design and development in architecture seems to be essential, one of the important ways to save energy in the building industry is to design a smart building and use smart techniques and materials. Smart buildings have this capability. By changing the environmental conditions, they have shown a reaction to the changes and provide security and peace for the residents of the building in the direction of sustainable development. The use of new technologies to reduce the consumption of non-renewable energy and the storage of basic energy is one of the major topics that They are proposed in sustainable architecture.

Smart materials are a new term for materials and products that have the ability to understand and process environmental events and react accordingly. In other words, these materials have the ability to change and are able to reversibly change their shape, form, color and internal energy in response to the physical or chemical effects of the surrounding environment. If we classify materials into three groups of non-intelligent, semi-intelligent and intelligent materials, the first group, i.e., non-intelligent materials, do not have the above specific characteristics, semi-intelligent materials are only able to change their shape and form for a time or a period of time in response to environmental influences. Change a little, but in smart materials, these changes will be repeatable and reversible. Smart materials are also known as "flexible" and "adaptable" materials, and this is due to their special feature in adjusting themselves to environmental conditions. (Addington, 2020) Materials used in cold and mountainous climates must have good capacity and thermal resistance to maintain the heat of the building in its interior. Therefore, in the traditional system, most of the time, the body of this building is made of stone (or wood, straw mortar, clay and brick) and the roof covering is made of wooden beams and straw to act as thermal insulation. Strong and heavy stones and materials are used for the foundation of the building, and in some places, Chinese chairs with heavy materials are used to prevent moisture, although the buildings in these areas are generally built on the ground. Therefore, according to the topic of climate and the topic of using smart materials in the construction industry, we need to examine and look at the local approach of using this type of materials.

Energy Consumption

The topic of energy is considered one of the most important and fundamental discussions on the sustainable development approach. About 70% of the existing buildings in the cities are residential, constantly facing the challenges of energy supply and controlling the consequences of its consumption, hence attention and revision in the process of production, consumption, and solutions to deal with the energy crisis and pay attention to the climate in Cities are inevitable. Since energy provides the power and movement for modern life, energy conservation (less energy consumption) and energy efficiency (reduction of energy waste) can expand energy supply sources and promote economic development. Therefore, energy efficiency and the use of renewable energies are the two main pillars of sustainable energy (Brown et al., 2015). The residential sector is one of the main factors in energy consumption and greenhouse gas emissions (Green House Gases), representing 25% of the total electricity consumption in OECD countries in 2012 (Jayalath et al., 2016). According to the Energy Information Administration (IEA, 2021), in the United States, most of the energy located in housing is used for space heating and electrical appliances. In Iran, the share of the household sector in energy consumption was about 31% in 2018, which has increased by about 180% from 2000 to 2018, and the amount of carbon dioxide gas produced in the household sector has increased by 1.6 times during this period. (IEA, 2021). Also, according to the energy balance sheet of 2016, Iran's final energy consumption per capita in agriculture, domestic, commercial and public sectors, transportation and industry is 3.3, 2.2, 1.5 and 1.5 times the world average, respectively. About 37% of the country's electrical energy consumption is used in residential buildings, of which about 60% is the building's heating and cooling sector, which is 22% of the country's total energy consumption (IEA, 2021). With rapid economic development and urbanization in the past few decades, it is predicted that the total urban population will reach 66% of the world population by 2050, leading to higher energy demand (UNEP, 2015). In addition, increasing household income and improving living standards will be a serious threat to efforts to respond to climate change. The two main and basic solutions that are effective in achieving energy sustainability can be considered the use of renewable energy sources (technological dimension) and the second is optimizing the consumption of non-renewable energy (environmental dimension). Making the use of non-renewable energy efficiency refers to a set of actions and activities that lead to reducing dependence and consumption of fossil energy. These materials usually become a final carrier with a final energy after being transformed several times. The consumer arrives. They are used in daily life, they require secondary energy, that's why the construction of refineries and electric power plants, as well as large dams, is considering infrastructure measures and very important in the economy of a country (Ibid). Most of the energies used by humans are non-renewable energies. This type of energy has two main weaknesses, one is that the source of such energy is limited and its resources will be exhausted at some point, and the other is that this type of energy is produced from fossil fuels, which are the biggest polluters of life. It is environmental (Yang et al., 2018).

New Materials in architecture as smart application

Smart materials are in the process of discovering new materials. Historically, the discovery of smart materials dates back to the 19th century, but at that time, the necessary technology to produce products, as well as human knowledge in order to understand people's needs and match new materials with the needs, did not exist in today's form (Addington, 2020). While in the present era, especially in the last three decades, with the advancement of technology and the improvement of human knowledge, it is possible to expand and develop these materials in various sciences, and their use has become very widespread in the world. Vocabulary related to architectural materials in the world has changed significantly since 1992, because for the first time the term "smart materials" was popularized in all fields. Because of the glamor that smarts materials have, we often forget the origin and beginning of the formation of these materials. The first documents and roots were related to the science of alchemy, which was found in the writings of the early 300 BC. After alchemy, metallurgy was a technology used by the Egyptians and Greeks. But in this era, many philosophers were worried that these experimental studies were not obtained from a fundamental scientific theory. The misconception that has been formed about the science of alchemy in the minds is related to the magicians and tricksters of the late Middle Ages. (Sun et al., 2020) in all eras, alchemy has been related to the change of shape and state of metals, and it has mostly been concerned with changing the appearance and more specifically the color of the object. In such a way that in a period changing the color of various metals to purple, which is a luxurious color, it was as desirable as searching and finding gold was important. In the 19th century, magic and sorcery flourished to transform one object into another. One of the famous findings in this the course was an inflatable book (Sun et al., 2020). This book was made up of white pages and pictures, which are variable. At first, magicians used a special trick and skill to display only the white and empty pages of the book. After that, a warm breath would be blown on the pages and the pictures on the pages would be displayed. In this work, it was thought that the photos appeared on the pages by blowing. This book can be considered as an idea for the warm colors used in modern materials today. For a basic introduction to smart materials and materials, their practical and concrete examples in everyday life are first examined, then their definition and characteristics, as well as the types of smart materials, are presented in detail.

Basic characteristics of smart materials

The most unique features of these smart materials and technologies, either the molecule of the composite material or the system, are the following:

• Adaptability in the sense that they have the ability to respond to local conditions.

• Self-motivation in the sense that this intelligence is inside these materials and not outside them, which means they do not need a computer program and complex controller and operator systems.

• Selectivity in the sense that their response is distinct and predictable.

• Direct in the sense that the response is located in the same place as the incoming stimulus.

Urgency, self-compatibility, motivation, selectivity and directness are the distinguishing features of smart materials from conventional materials. If these features are used in the form of materials classification, smart materials can be divided into 2 groups (Wang et al., 2018):

1. Smart materials with the ability to change internal properties: this group can also be divided into several categories, materials that change

color and materials that change binders and...

2. Smart materials with the ability to exchange energy: this group also includes the following: light-emitting materials, electricity-producing materials, and energy-storing materials.

3. Smart materials with the ability to exchange nature: super absorbent polymers and water or gas storage are among this category of materials.

Since these first and second groups are more widely used in the field of architecture, we will limit ourselves to examining only these two groups. Here, it is necessary to point out that all objects and their surroundings have a certain amount of energy, when the energy level of the objects is the same as the energy level of their surroundings, it is said that the matter is in equilibrium. This means that there will be no exchange of energy. But if the substance is at a different energy level than the energy level of the environment, a potential for energy exchange is created. In this way, the input energy raises the energy level and the output energy causes it to return to the initial level and the state of balance. (Addington, 2021).

In conventional materials, the incoming energy manifests itself as an increase in the internal energy of its body, which is usually in the form of heat, but smart materials have the ability to convert energy into more useful forms (Sun et al., 2020). In general, existing building materials, both traditional, natural and synthetic, are classified according to their characteristics, including appearance, texture, chemical composition, mechanical and physical properties, environmental effects, etc., but in the classification of smart materials, in addition to considering Having the above characteristics, other properties that are specifically related to distinguish smart materials from traditional materials have also been considered. In fact, the proposed classification of smart materials is based on the following three properties (Zhang et al, 2015). (Tab. 1)

Table 1: The first and second groups of smart materials and their examples (Addington & Schodeck, 2005)

Types of smart materials	Input	Output
Type 1 smart materials with the ability to change properties		
Thermochromic	Temperature change	Color change
Photochromic	Light	Color change
Mechano-chromatic	Transformation	Color change
Chemo-Chromic	Changing the chemical environment	Color change
Electrochromic	Change in electric potential	Color change
Liquid crystal	Change in electric potential	Color change
Particles	Change in electric potential	Color change
Electro logical	Change in electric potential	Change in adhesion and stiffness
Magneto Logical	Change in electric potential	Change in adhesion and stiffness
Type 2 smart materials with one-way energy exchange capability		
Electroluminescent	Change in electric potential	Light
Photoluminescent	Light	Light
Thermochromic	Temperature change	Light
Photochromic	Light	Change in electric potential
Type 2 smart materials with two-way energy exchange capability		
Piezoelectric	Transformation	Change in electric potential
Thermochromic	Temperature change	Change in electric potential
Electro restrictive	Change in electric potential	Transformation
Magneto Restrictive	Magnetic field	Transformation

Common usage

Smart materials are mostly used as sensors due to their reaction to environmental stimuli. However, they can play an effective role in all building systems such as systems, facades, lighting, structures and facilities. It should be noted that what has been made possible by the use of smart materials in different urban contexts, whether old or new, etc. In the table below, some examples of the most widely used smart materials in various building systems, which are mostly used in the construction industry, are presented, regardless of the sensors. (Tab. 2)

Table 2: Some examples of the common use of smart materials in buildings

Capability	All types of smart materials	Input	Application in building
Type 1 smart materials with the ability to change properties			
With the ability to change color and visual features	Thermochromic	Temperature	Thermochromic glass Thermochromic concrete Thermochromic cement
	Photochromic	Light	Roof windows, wall windows
	Thermochromic	Temperature	Roof windows, wall windows
	Electrochromic	Change in electric potential	Window
	Liquid crystal	Change in electric potential	Windows and interior partitions (flat surfaces)
	Particles	Change in electric potential	Windows and internal partitions (curved surfaces)
With the ability to change the difficulty	Electro logical	Change in electric potential	Masonry structure and cable structures
	Magneto Logical	Changing the magnetic field	Masonry structure and cable structures
With the ability to change adhesion	Self-cleaning materials	Light	Building facades
	Self-cleaning glass	Light	Builder window
Type 2 smart materials with one-way energy exchange capability			
With the ability to emit light	Electroluminescent	Change in electric potential	Internal partitions
	Photoluminescent	Light	Separating curtains
Electricity producer	Photovoltaic	Light	Supplier of building electricity and able Use in combination with windows Electrochromic

But those materials that are used in the facade system mostly assign to the architect's design process. Therefore, the classification of smart materials that can be used in the building is as follows; (Tab.3) The summary of research results related to the ingredients of smart concrete types is given in the table below.

Table 3: Smart concrete and ingredients

Smart concrete	Ingredient
Self-compacting concrete	Pea gravel + sand + stone powder + super-lubricating water and viscosity modifiers
Self-expanding concrete	Expanding compounds such as expanding cements or expanding additives can be used to make expanding concrete.
Self-curing concrete	LWA light sand curing materials are pumice and SAP superabsorbent polymers. SAP can absorb water up to 1000 times its weight.

Self-sensing concrete	In general, an active filler is used. The concrete matrix of the sensor itself is usually Portland cement. Conductive fillers are mainly composed of carbon, metal and polymer materials, among which carbon and metal fillers are the most used.
Self-healing concrete	Self-healing concrete is also called self-healing concrete or self-sealing concrete, and the essence of this concrete is that it provides the necessary binder that can fill cracks in case of damage. In general, self-healing concrete is divided into two categories: self-healing concrete are independent
Self-leveling concrete	Polyethylene fiber is composed of polypropylene fiber and polyacrylonitrile fiber or metal fiber and concrete, it can adjust its pore structure and thermal performance. It has thermal conductivity and thermal capacity (especially considering the temperature outside the air to prevent tumbling.
Self-compacting concrete	Self-damping concrete improves its damping properties through the introduction of functional fillers such as latex, polymer MWCNTS fibers or multi-walled carbon nanotubes, silica fume (SF), methyl cellulose (MC) and the power of graphite.
Exothermic concrete	Self-heating concrete produces heat by applying voltage to concrete based on Joule's law. Electrical fillers such as carbon fibers, steel fibers, nickel powders and graphite are added to the concrete composition for heat transferability.
Self-sacrificial concrete	To prevent the corrosion of reinforcements from the sacrificial concrete coating as a node, use sacrificial concrete that contains fibrous cellulose.
Self-cleaning concrete	To obtain self-cleaning concrete, two strategies are usually used: superhydrophobic and photocatalytic. Conventional concrete is porous, so it has the ability to absorb water, which is called hydrophilic. For sealing, sealing materials such as Penetron Admix are added to the concrete mix. Materials such as oil, nano particles, waterproof polymers are added to concrete so that concrete has self-cleaning properties.
Self-conforming concrete	Gypsum cement materials with the main materials of gypsum, vinyl polymer and hygrometer carbohydrates and water are used to print 3D concrete samples.
Self-draining concrete	Self-draining concrete is mainly composed of cement paste and uniform coarse aggregate. The concrete skeleton is formed with coarse materials and they are connected to each other with a limited amount of cement paste.
Transparent concrete	It is a material with solar energy that traps solar energy during the day and emits light at night. The whole process is done without electricity.

Smart concrete, as an innovative technology in the field of building materials, injects a new evolution for building materials despite the challenges. The development of smart concrete will promote the application of concrete to a wider perspective and bring enormous economic performance. However, as an emerging technology, research on smart concrete is still in its early stages, and the following are necessary before it can be used on a large scale. Be resolute

1. The characteristics of functional fillers are the main factors to achieve smart concrete. Therefore, it is very important to explore and exploit more suitable functional fillers. Nanotechnology and bionic techniques may inspire the search for more efficient functional fillers.
2. The mechanical properties and durability of smart concrete need deep analysis. The study of smart concrete in the multiaxial stress state is necessary, because the existing research is always limited in the range of uniaxial stress, which is far from engineering applications. In addition, the effect of various environmental factors on the performance and durability of smart concrete should be further investigated.
3. Although there are many explanations and reasonable prediction models, the mechanism of smart concrete is ambiguous due to the complex system of smart concrete in multi-component, multi-phase and multi-scale properties. Therefore, to describe and predict the behavior of concrete, a more accurate constructive model based on advanced laboratory facilities and numerical analysis is required.
4. The lack of a specific standard for testing smart concrete has made its design difficult and limited its applications. Therefore, a standard method providing guidance and standard specifications for the research and use of smart concrete is necessary.
5. In general, smart concrete is inherently an interdisciplinary subject that includes bionics, biology, physics, chemistry, engineering and

materials science, and civil engineering, etc. Therefore, scientific cooperation and interaction between researchers with different specialties is of particular importance to conduct further research. Regarding smart concrete, it is necessary to use smart concrete, it is a logical choice to maintain the sustainable development of concrete structures and the development of smart infrastructure. There is no doubt that smart concrete will bring a deep revolution in the field of building materials and infrastructure. Its wide applications will have beneficial effects on the future. The society will leave the economy and the environment.

Features of cold and mountainous climate in Iran

The Alborz and Zagros Mountain ranges separate the central regions of Iran from the Caspian Sea in the north and the Mesopotamia plain in the west. There are also individual mountains in the center and east of Iran, including Mount Taftan, Shir-Kuh, and... Western mountains, whose western slopes the mountain ranges of the central plateau of Iran and the entire Zagros mountains are among the coldest regions of the country. The general weather conditions of this area are as follows:

• Extreme cold in winter and mild weather in summer

• Huge difference in air temperature between night and day temperature

• Heavy snowfall

• Low air humidity

The average air temperature in the hottest month of the year in this climate is more than 10°C and the average air temperature in the coldest month of the year is less than -13°C. Temperature fluctuations during the day and night are also more in the mountainous areas. In this climate, the valleys are very hot in summer and mild in winter. The amount of sunlight in this region is high in summer and very low in winter. Winters are long, cold and hard, and the ground is covered with ice for several months of the year, and spring is short-lived and separates winter and summer. The cold of April continues. Throughout this region, from Azerbaijan to Fars province, winters are extremely cold. In these areas, the amount of rainfall is low in summer and higher in winter, and it is mostly in the form of snowfall. Continuous snow covers most of the peaks. There is always snow at altitudes above 3000 meters and these mountains are the source of rivers and aqueducts in the country. The snowfall in the north and northwest of the region is more than the southeast. Despite the abundant rainfall, the humidity in this climate is low, and the western mountain range, like a dam, prevents the humid Mediterranean air from penetrating into the Iranian plateau and keeps the air humidity only on its slopes. Unlike the northern regions of Iran and the coasts of the Caspian Sea, where the concentration of air is high due to the low land and rainfall in the cold climate, this concentration is less and this reduces the use of natural air conditioning.

MATERIALS AND METHODS

Sample evaluation

Climatic and environmental features of Tabriz

Geographical location

The city of Tabriz is the capital of the East Azarbaijan province, located in the west of East Azarbaijan province and at the extreme east and southeast of Tabriz Jolgeh, and with an area of about 1200 square kilometers, it is the third largest city in Iran after Tehran and Mashhad. This city is located in the geographical position of 38 degrees and 8 minutes north latitude and 46 degrees and 15 minutes east longitude in the northeast corner of a plain with an area of 46929 square kilometers, at an approximate height of 1350 meters above sea level. Tabriz has an area of 2,167.2 square kilometers, which covers 4.76% of the area of the province, and for this reason, it ranks twelfth among the cities of this plain, surrounded by mountains and hills, with a gentle slope to Lake Urmia in the west. From Lahat, the relative location is 619 km northwest of Tehran and 150 km southeast of the border city of Jolfa, from the north to Shabestar city, from the northeast to Ahar city, from the east to Heris city and Bostan-Abad city, from the south to Maragheh city, from the southwest is limited to the city of Esko and the northwest to the city of Shabster, and it consists of two central parts centered on Tabriz city. (Iranmanesh et al, 2020). Its geographical location with all physical, economic and human factors, especially with the political and cultural borders in the Azerbaijan region and with its internal and external communication routes, and the direction of the roads from the valleys and the extension of Iran's nationwide railway from it. The location gives four roads to the city (Abbasi and Shakiba, 2020). (Fig. 1)

Figure 1: Geographical location of Tabriz city Source: Author

Climate

Tabriz topography is a high and mountainous territory with a cold and dry climate, which has long and cold winters and short and moderate summers. The topographical position of the natural bed of the city of Tabriz and its location in a wide valley which is limited from all directions except the west and northwest to the steep slopes and the surrounding mountains, has made this city, in addition to following the climatic characteristics resulting from the natural location of the Tabriz plain, to some extent, it depends on the specific quality of the location of the city bed. The climate of Tabriz is dry steppe with hot and dry summers and cold winters. The winter cold is influenced by the high altitude and mountainous topography of the region. The climate of this city is dry and hot in summers; Although the heat is adjusted due to the proximity to Sahand Mountain and the presence of many gardens around the city. The average temperature of Tabriz in July (the hottest month of the year) is 25.4 degrees Celsius, in January (the coldest month of the year) it is -2.5 degrees Celsius, in April it is 10.5 degrees Celsius and in October it is 14.1 degrees Celsius. Centigrade and the annual average temperature is 11.9 degrees centigrade. The average annual rainfall of Tabriz, like most cities in Iran, is very small and about 330.1 mm per year. Usually, during the summer season, the amount of rainfall is very small and it rarely rains. The climate of Tabriz is dry steppe with hot and dry summers and cold winters. The winter cold is influenced by the high altitude and mountainous topography of the region (Tahbaz et al., 2012). Due to the presence of low air humidity and rainfall of about 280 mm per year, and due to its height above the sea level, Tabriz jolgeh witnesses cold and long winters and hot summers. Constant winds with bitter cold that blow in this area are the effect of local winds. The prevailing and usual winds in Tabriz are east and then northeast and these two directions are the main directions of air flow in the city. Southwest and west winds are in the next stage (Tahbaz et al., 2012). The most days of frost in Tabriz are 155 days and the last days of frost are 52 days and on average this city has 107 days of frost. As mentioned in the research methodology, in order to simulate the effect of using smart materials on the amount of energy consumed in order to avoid the interference of other factors such as complexity in thermal volume and thermal zones as well as various and different facilities and equipment used in Residential buildings, a room with fixed dimensions and changes in material are considered for this purpose. The mentioned room has dimensions of 5 meters by 8 meters with an area of 40 square meters and a height of 3 meters, which has two windows with a height of 1 meter and a width of 2.40 meters on the south side, and a door with standard dimensions on the north side.

Energy consumption in the office building

Office buildings are considered to be one of the biggest energy consuming sectors in most societies. It is very important to pay attention to building technologies to save and optimize energy consumption. The amount of energy consumed in each building depends on factors such as the amount of air penetration and the difference in the desired temperature of the building. And the environment outside the building in different days of the year depends on the heat transfer coefficient of the building walls and the orientation of the building. In the following, the background of the research in the field of thermal comfort, type of climate and architecture of walls and building materials and building air conditioning systems has been examined. They consume more energy. The energy consumption in office buildings depends on the location and dimensions of the building, lighting systems, air conditioning systems and the number of equipment used in that range between 100 and 1000 kilowatt hours per square meter. Studies conducted in the United States America shows that the average intensity of energy consumption in office buildings is 300 kilowatt hours per square meter, of which about 70 percent is used in the lighting and air conditioning sector, while it is 72 in Britain and 60 in Canada. is the percentage (Lombard, 2008) (Fig. 2)

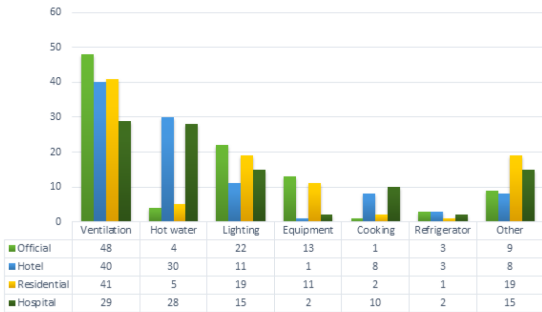

Figure 2: Energy consumption in different building sectors in the world (Lombard, L, 2008)

Evaluation of energy simulation software in buildings

In the field of sustainable design, there are also software's for energy calculations, and the analysis of energy-related topics can be done in the building sector since the 60s when the first energy simulation software's were produced until now, the power and efficiency of these software in Performing more complex calculations. Generally, energy and building software can be classified in four areas: fluid thermal analysis, lighting and acoustics. In addition, energy simulation software are tools that have been created to predict the behavior of building energy consumption in accordance with the way of providing comfort in a period of one year and with various reporting capabilities. Construction science today is in coordination with soft experts. Software and information technology has provided many tools called simulation software to evaluate the performance of the building before its implementation. Energy simulation software is among these tools that have been created to predict the behavior of building energy consumption according to the way of providing comfort in a period of one year and with various reporting capabilities. The three main functions for this type of tools are It can be imagined that the prediction of energy consumption is a very complex collaboration between elements, design, climate, users of ventilation and lighting systems, and only by using energy simulation software can all the factors interfering in the process be evaluated to prevent defects. Mainly in the design, the architect needs to calculate the energy consumption of the building in the early stages of the design process. Energy simulation programs allow designers to make reliable predictions of the building performance based on weather conditions and other influencing parameters have authority

Methodology

According to the proposed road map, the current research goes through different steps to achieve the result. In each of these steps, a strategy is used. The current research is quantitative research. In this research, which has an explanatory and correlational approach, interpretive-historical strategies are used in the step of reviewing the subject literature, simulation in the step of variable test and logical reasoning, and descriptive statistics in the step of analyzing the variable test and presenting the research result. The research method in this study was based on scientific research and simulation. The best and at the same time the most convincing way to establish a scientific relationship is a careful experiment in which the influence of latent variables is controlled. It means to test the active change of x and observe its effect on (Wang et al., 2018) The testing tool of this research is simulation by means of thermal software, which was used to search for the temperature effect of different conditions according to the inner and outer layers of the two shells and the number of walls in these two layers. Energy has been consumed. The simulation in this research was done using Design Builder software, which is a software for building thermal analysis and measures the impact of environmental factors on the building. The capabilities of this software include calculating the total energy consumption of the building, calculating the amount of heating and cooling of the building, imaging solar radiation on windows and other surfaces, calculating daylight factors, and displaying the position of the sun and the path of the sun relative to the model in every day and hour. Be This software can calculate the amount of energy consumed per hour, day, month and year based on weather information and help the design team to make design decisions based on real information. The validity of Design builder software has been proven in many previous researches. By referring to the main page of the website of this software, it can be seen that the results of the simulations by entering the characteristics and weather data of different regions are completely valid and recognized in the decision-making authorities of England. SBEM Approval) In order to mention examples of previous research with the help of Design builder software, we can refer to the study of the behavior of office buildings from the point of view of energy consumption, where the ways of achieving energy efficiency by evaluating the effect of various architectural indicators such as the orientation of the level of openings in Different facades, canopies, natural ventilation and air exchange rate through leakage on the energy consumption of buildings, using energy modeling (with Design builder software) has been obtained (Nasrollahi, 2011). Also, with the help of the analyzes of this software, the amount of heat loss of the building roof has been calculated by taking into account various types of roofs, such as roofs, two-shell roofs, pond roofs, and green roofs, according to the critical points of the results, existing facilities, and construction costs. The most suitable technique was selected and its thermal wall was also designed (Mehgani et al., 2019). By using Design builder simulation software, the thermal behavior of the building can be changed according to the main variables under investigation, such as the type of orientation, the type of materials, the type and dimensions of the windows, and thermal simulation has been done for each of these variables. It is possible to calculate what changes will occur in the cooling and heating load of the building. Finally, according to the graphs extracted from this software, the data is analyzed. The method of this research has been done in two stages, the first stage includes collecting information and simulating the current state of the desired building, and the second stage includes simulating the building in the optimal state.

DISCOSION AND FINDING

Simulation of the building in the current state

In this regard, the building with the dimensions of 20.40 x 15.30 meters and the height of each floor is 3.5 meters has been considered as a sample model. The orientation of the building is northeast-southwest. (Fig. 3)

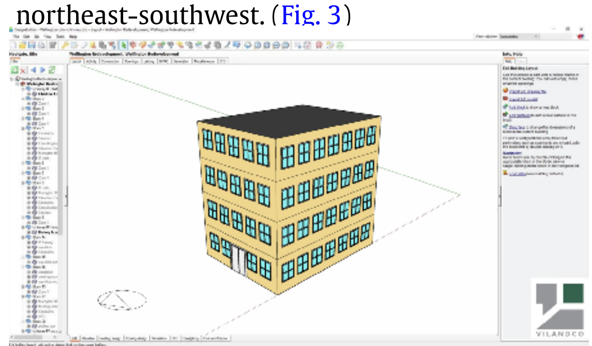

Figure 3: Modeling the office building in Design Builder software

RESULT AND CONCLUSION

At this stage, the current specifications of the building are given to the software and simulation is done and its results are displayed in the form of a diagram. The analysis of cooling loads and heating loads of the building was continued. Diagram 3-1 shows the amount of cooling load and diagram 23 shows the total amount of heating and cooling load of the sample model in this geographical direction. The vertical axis is the total amount of cooling and heating load based on kilowatts per hour. It should be noted that the unit of energy consumption in the software is Kwh.

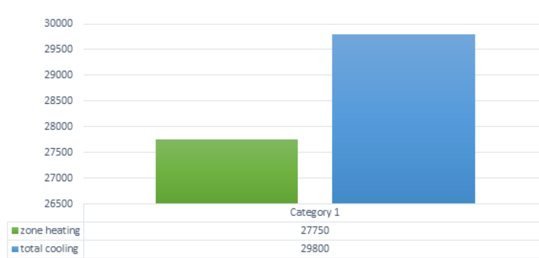

Figure 4: The heating and cooling load of the building

The required cooling load is 29,800 kilowatts per hour and the required heating load is 27,750 kilowatts per hour. According to diagram 3 the total amount of cooling and heating load is 57550 kilowatt hours.

After defining and determining the materials and modeling the sample, the simulation specifications are completed and executed. It should be noted that in all the simulated cases, the numerous variables in the software simulation are fixed and without changes in each case. Therefore, as mentioned, completing the data and defining the structure of the walls was done in Energy Plus software, and the final evaluation was based on the outputs taken from Energy Plus, which will be analyzed in the form of tables and graphs in the next section.

Simulation results

In the simulation part, the basic criteria on the layering of the surrounding walls, which is explained by the Asher standard, is considered. In this standard, three different types of concrete have been used to evaluate and compare the amount of heating and cooling heat transfer of these three types of concrete. In the first case, the concrete proposed by Asher standard, in the second case, the concrete proposed by the Iranian Engineering System Organization under topic 19, and in the third case, the thermal chromic intelligent concrete. In the following, the results of the simulation of these three modes can be seen.

Table 4: Comparing the amount of annual heat energy transfer in the modes of using thermochromic concrete, concrete topic 19 and concrete proposed by Ashera standard in the peripheral wall with layering of Ashera standard 55

	Heating (Thermal energy transfer) [J] (monthly)			Cooling (thermal energy transfer) [J] (monthly)		
	Normal	Ashree	Thermo-	Normal	Ashree	Thermo-
January	2965161255	2914582773	2309870665	0	0	0
February	1982660282	1932858850	1523337377	0	0	2579367.304
March	1149724683	1119451087	897073147.1	7123760.156	3999668.538	29906607.27
April	489162333.2	454349876	369615029.6	66790594.82	51224402.95	111763710.6
May	75347381.53	60435693.31	58076173.56	485227488.9	461325156	508913959.5
June	3809346.197	574176.8034	2355021.488	1073958590	1053929684	998932159.9
July	0	0	0	1520290268	1501982155	1376151132
August	0	0	0	1585497149	1568175984	1424056668
September	0	0	0	1057816856	1036907859	1017018636
October	139751396.6	114528014.2	110432532.6	445246393.6	435917582.1	490960044.5
November	921873971.6	865826605.1	716683424	68581547.99	56632822.23	121093080.9
December	2411803214	2359459157	1868165157	0	0	2922.868325

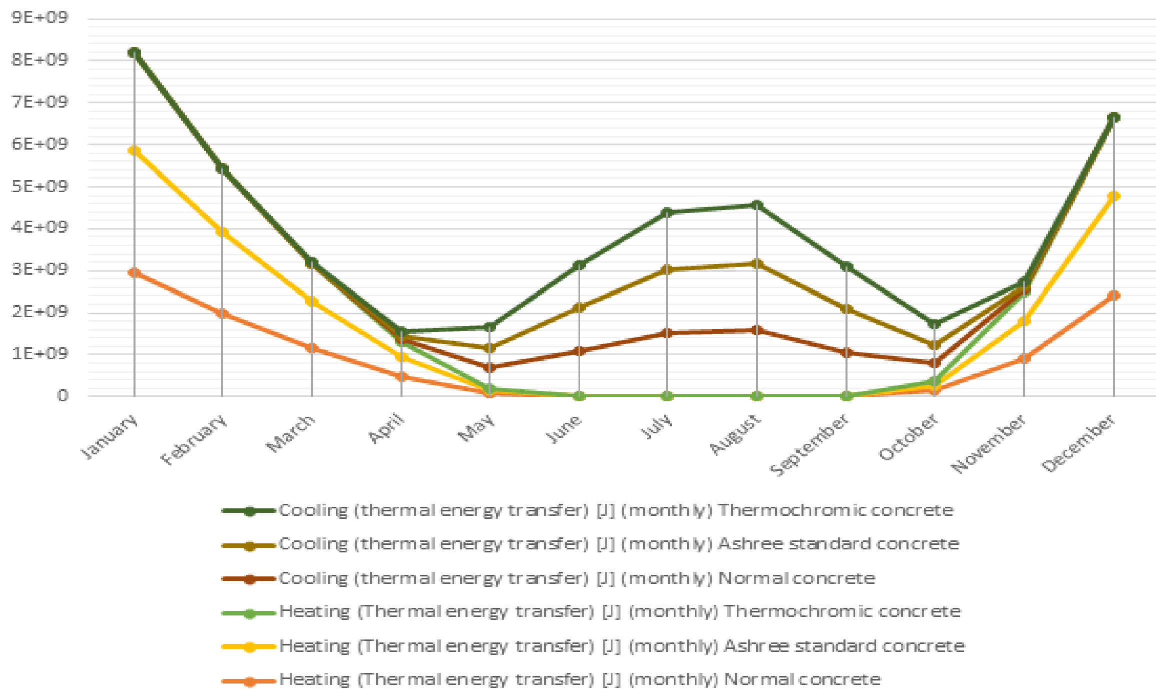

Figure 5: Comparing the amount of annual heat energy transfer in the modes of using thermochromic concrete, concrete topic 19 and concrete proposed by Ashera standard in the peripheral wall with layering of Ashera standard 55

The final evaluation based on the simulation results generally indicates the positive effect of using thermochromic concrete on the amount of energy consumed in the building to achieve thermal comfort. But in the analytical view of the obtained results a significant difference has occurred in the amount of energy consumption in the simulated unit. This importance comes from the fact that in the first case, the walls are in the form of a single layer of concrete and no other intervening factors such as insulation, cladding, facade and any internal and external layers have any effect on the performance of these materials, and only heat transfer and wall capacity. Concrete has been tested. In the cooling energy required in this room, according to the climatic characteristics of the evaluated region, which is the cold and mountainous climate with the geographical location of Tabriz city, in Four months of the year, due to the lack of need for cooling, no change has been achieved. This is also true regarding the need for heating during the four months of the hot season. But from June to September, the room with concrete walls made of thermochromic materials reduced the amount of cooling energy required by almost 50%, which is a significant figure. Therefore, it can be said that if a single-layer concrete wall is used in the building (which can happen in workshop environments), the amount of cooling energy needed is halved and it has a significant savings.

In terms of the heating requirement of the test chamber, the difference and distance is much more significant. In the coldest months of the year (December to February), the use of thermochromic concrete has reduced the use of heating energy to a quarter or almost 25%. Considering that this region has a cold climate and the main need is heating, it can be seen that the performance of using these materials is quite favorable in terms of reducing the need for heating. In the following, to make the test conditions more realistic and to evaluate the condition of residential buildings, peripheral walls with standard layers have been used in the simulation. The standard used is Ashera 55 standard mode for thermal zone in cold and dry climate where the only variable factor in all three modes of night construction is only concrete materials used. In one case, the recommended concrete in Ashera 55 standard, in the other case, the concrete used in the suggested table of topic 19, and finally, thermochromic concrete extracted from Energy Plus standards were used.

Regarding the amount of heating energy used in this simulation, which is practically the most effective part of the results, as can be seen in the coldest days of the year, the maximum difference in the amount of energy required reaches 22.5%, which can significantly save energy consumption. It is considered heating. It is necessary to explain that the mentioned number was defined during the peak of cold and in a period of almost one month, and this amount had a significant downward trend in the time interval of 2 months before and 3 months after this point, to the extent that with the change of season and the arrival of the heat period, the amount of consumption in all three modes and naturally the distance between the modes tends to zero. The simulation results indicate the amount and type of impact of using a certain type of smart materials on the amount of energy consumption in the building, which can be changed and generalized with different modes. In future researches, it is possible to use other materials for evaluation and simulation, and to consider other coating modes and standards for evaluation. There is also the possibility of simulation in specific residential units with different facilities and equipment, which is based on this research and can be done in the future.

According to the results of the simulation and the use of samples of input materials to the software environment, as well as the description of the findings, some things can be stated as a general result of the specialized simulation. As it is known, as a material with low heat transfer and lighter volumetric weight, economical, concrete has been widely used in global construction. It will still remain an essential and superior building material for a long time to come. Concrete is constantly being developed and exploited. The inherent capacity of smart concrete can be achieved by combining traditional concrete with active functional fillers or improving the composition of raw materials. In fact, smart concrete, as an innovative technology in the field of building materials, despite the challenges, injects a new evolution for building materials. The development of smart concrete will promote the application of concrete to a wider perspective and will bring enormous economic performance.

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