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The Usage of Nanomaterial in Building Constructions in Hot and Dry Climate (Case Study: IRAN, South East)

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Abstract. Materials are one of the significant properties of building construction. In special region with specific climatic characteristics, such as south east of Iran, nanomaterials play an important role for bioclimatic design in architecture. In this field the major question is that which kinds of nanomaterials are the best choices for building construction in hot and dry climate of Iran? To achieving this aim, the used research method is logical argumentation with librarical searching and physical studies. As a result nanomaterials are categorized in two groups. One of them is less compatible with this climate whereas the other one are completely suitable for this region. So they are suggested to use more for climatic design in hot and dry region of Iran.

Keywords: Nanomaterial, bioclimatic design, hot & dry climate, architectural design, south east of Iran.

1. Introduction

In our technology-oriented ages, architecture is beyond the luxurious eye-catching constructions. What makes an architecture masterpiece is not limited solely to form; truly, the building relation with users and environment is an effective factor in its evaluation. Climatic principles consideration in construction design plays an important role in achieving sustainable ecological developments. These principles affect material selection as well as the form. Efficient energy use, environmental pollution reduction and buildings' running costs decrease are some of the advantages of applying appropriate materials.

Nanotechnology power in controlling matters on the nanometer-length scale makes it as a leading science which is about to change the world. Construction industry is not an exception and is completely affected by the transition which nanotechnology caused in improving and developing material characteristics. New generation of materials with more efficiency, better performance and different physical and chemical properties from conventional ones are the results of nano-scaled researches on materials.

Application of nanomaterials in bioclimatic housing is an undeniable part of the journey towards achieving sustainable architecture goals.

2. Questions and Inference Mechanism

2.1. QUESTIONS

- What are the characteristics of hot and dry climate which affect the selection of nanomaterials?
- Which kinds of nanomaterials are the best choices for building construction in hot and dry climate?

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2.2. Research Method

Research approach is logical argumentation and applied techniques are descriptive analysis complemented with comparison between introduced technologies with society needs. Information gathering method is librarical searching and physical studies [5].

3. Bioclimatic Architecture in Iran

Climatic circumstances mainly affect the human life and inattention to them can leads to an unendurable life. Bioclimatic architecture can serves mankind through the comfort that it has the ability to provide. What makes the climate of a region to be categorized as hot and dry is particular condition of solar radiation, air temperature, humidity, perception and vegetation. IRAN's geographical location between latitudes 24 and 40N and longitudes 44 and 64E and its limitation to Caspian Sea and Persian Gulf is the cause of vary climate all over this country; but hot and dry rejoins form the majority parts of IRAN. Blowing winds from south east and north east to equator, these regions which include subtropical ones are dry. Direct solar radiation is intense and it could provide 700-800 Kcal/h/m^2 energy on flat surfaces and also the arid lands aggravate it. In summer days the temperature of earth surface is about 70C and at nights it's reduces to 15C. The temperature of air is less and changes between 15-20C and 40-50C. Not cloudy sky, lack of humidity, fog and dust storms in afternoons and wide range of temperature fluctuation are some other characteristics of these regions. [1]

The main concern of Iranian traditional architecture used to be improvement of the climate conditions for people. Providing humidity by enclosed courtyards with trees, ponds and planted surfaces and concentrating the life spaces to these courtyards is the main approach of Iranian architectures. Adobe used to be conventional materials appropriating to the hot weather. Compactness in form and layout, minimization in the number and size of openings, high level windows, dome roofs, wind towers, persiennes are another contrivances for hot-dry climate constructions.

Despite indoor thermal comfort, the outdoor environment needs attention. Buildings can affect the outdoor climate beside the meteorological elements; the compact texture of the hot dry cities is a response to the not suitable weather through providing maximum shade and minimizing heat gain and sun exposure.

Bioclimatic architecture has applicable solutions for hot and dry climate all around the world. The main architectural design features of buildings which can play an important role in providing thermal comfort are mentioned in the following table.

Table 1. derived from Stay Cool by Holger Koch-Nielson [2]

Feature	Methodology	Solutions
Roof	Have thermal and ventilation requirements Prevent from hot air trapping Do not have sand blocking surface	Ventilation openings Appropriate sloping orientation Composite roofs
Floor	Increase thermal storage capacity Increase overall ventilation potential	Cellars Undergrounds Heavy weight constructions
Walls	Control exposure to solar radiation Balance temperature variation Reduce heat gain	High thermal mass Operable ventilation openings Shading provisions Insulation materials Minimization of east facing walls
Shading devices	Avoid absorption and re-radiation of the heat Prevent reflection Avoid hot air to be trapped	Proper orientation Proper size Proper location Low heat storage and reflective materials
Natural ventilation and cooling devices	Cool and dust free the air before entering Cool building structure Cool internal spaces	Wind tower Roof devices Evaporative cooling

Openings	Prevent direct sunlight Prevent reflected light from ground Provide Maximum use of indirect light Diffuse internal light achievement Use stack effect to cool down the structure	Small openings High-level openings Below roof ventilation openings

4. Materials

Materials significance in life quality of human being is undeniable. The assertion of this notion is in the interaction of materials with indoor and outdoor environment. Consequently appropriate selection and appliance of materials are important issues.

Fernandez (2006) declares a classification for common materials used in building constructions:

- Metals: Ferrous/ Non ferrous
- Polymers: Thermoplastics/ Thermosets/ Elastomers
- Ceramics: Fired clay/ Concrete/ Stone/ Glass
- Natural Materials: Wood/ Natural fibers/ Biopolymers/ Earthen materials
- Composites: GFRP/ CFRP/ Fiberglasses/ Others [3]

What make differences between materials and lead to efficient usage of them in some cases and inappropriateness in some others is their performance characteristics which must be investigated on a rational basis include the following:

- Structural serviceability: Natural forces/ Strengths
- Fire safety
- Habitability: Thermal properties/Acoustic properties/ Water permeability/ Hygiene/ Comfort/Safety
- Durability: Resistance to wear/ Weathering/ Adhesion of coatings/ Dimension stability/ Mechanical properties
- Compactibility
- Environmental Considerations: Safety/ Natural resources/ Energy consumption/ Durability

Materials are directly exposed to natural phenomenon like wind, rain and solar radiation and also to unnatural ones like air pollutants. Thus the amount of effective solar heat gain is affected by the kind of material which is used for the building. As a result, it could be mentioned that in hot and dry climates the main property of materials which must be considered is thermal property and subsequently insulative property; although other properties, most importantly environmental impacts must not be neglected.

5. Nanomaterials

According to NSET definition of nanotechnology, it refers to research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1-100 nanometer range, to provide a fundamental understanding of phenomena and materials at the nanoscale.

The properties of matter at nanometre-scales are governed by a complex combination of classical physics and quantum mechanics. [6]

The goal of most nanotechnologies researches is formation of new combinations or alteration in existing materials. The following are some of the nanotechnologies achievements in the field of materials:

- Lotus-Effect self cleaning nanosurfaces: The knobbly hydrophobic surface of this facade coating makes water rolls off and washing away dirt deposits. Air humidity is required.
- Photocatalysis self cleaning nanosurfaces: Dirt decomposition by the catalyst and the hydrophilic surface makes it easy to be washed. UV light, oxygen and air humidity are the requirements. In contrast with Lotus effect surfaces, its transparency provides an applicable coating for glasses.

- Easy-to-Clean nanosurfaces: On these water and oil repellent surfaces, water runs off in droplet format and washing away grimes. No UV requirement makes its application more than facades.
- Air-purifying nanomaterials: Their application is in reducing pollutants by means of breaking down them to constituents but they are not substitutes for air ventilations. They are used for both indoor and outdoor air quality improvement through paints, textiles, road surfaces and etc.
- Vacuum insulation panels (VIPs): The entirely air-evacuated characteristic of these thermal insulators makes them much thinner and more efficient than the conventional ones. They can be applied for floors and walls as their high cost, limitation in cutting and efficiency reduction by humidity must be mentioned.
- Aerogel thermal insulators: The air molecules disability to move between aerogel pearls contributes to thermal and sound insulation. Proper daylight transmittance is another beneficial characteristic of them.
- Phase change materials additives: These materials reduced temperature fluctuations due to the latent heat is used for transition between solid and liquid phases and thus helps with temperate regulation. They reduce energy consumption for heating and cooling.
- UV protection coatings: UV sunrays affect the appearance and stability of materials. These transparent nanomaterial coatings do not degenerate themselves and provide lasting protection.
- Solar protection coatings: The combination of these coatings and electrochromatic glasses raise the need of blinds or curtains as they provide partial shading through darkening glass although they do not completely eliminate the visual contact with outside view.
- Antireflective coatings: Improving solar transmission, these coatings increase efficiency of photovoltaic systems.

Fragrance capsules, anti-fogging, fire proof, anti-graffiti, anti reflective, anti fingerprints and abrasion-resistant coatings are some other nanomaterials that make changes in architectural world through their specific properties. [4]

According to the different characteristic of nanomaterials, the most efficient ones in hot and dry climates are Easy-to-Clean nanosurfaces, Vacuum insulation panels, Aerogel thermal insulators, Phase change materials additives, UV protection and Solar protection coatings.

Away from climatic reasons, the other nanomaterials can be applied due to their significant properties in reducing air pollution, increasing safety and many other advantages that they bestow to our world but the Lotus-Effect self and photocatalysis self cleaning nanosurfaces cannot be used because of lack of air humidity in these regions.

6. Discussion and Conclusion

Evaluation of nanomaterials in purpose of bioclimatic architectural design is different in each climate, according to information about hot and dry region of Iran, all of mentioned nanomaterial could use in variant situations. But the important point is preparing an evaluator system that can give score to appropriate material for this climate.

For giving score to rapport of the material with hot and dry climate, system must consider the climatic features of this area. Such as amount of sun rising, amount of air humidity, range of temperature changes and etc. In evaluation, scores from A to D show the efficiency of these kinds of materials in south east of iran climate.

Following table is final assessment for mentioned kinds of nanomaterials. A & B scores are more compatible with this region. And C & D scores are less suitable for this climate.

Table 2. designed by authores

Material	Function	Score

Lotus-Effect self cleaning nanosurfaces	Cleaning façade and surfaces It needs air humidity	D
Photocatalysis self cleaning nanosurfaces	Dirt decomposition for facade and surfaces UV light, oxygen and air humidity are needed	B
Easy-to-Clean nanosurfaces	Water and oil repellent surfaces and facade	D
Air-purifying nanomaterials	Reducing air pollutions Indoor and outdoor air quality improvement	A
Natural ventilation and cooling devices	Thermal insulator Efficiency reduction by humidity	A
Vacuum insulation panels (VIPs):	Thermal insulator	A
Aerogel thermal insulators	Thermal and sound insulator	A
Phase change materials additives	Reduced temperature fluctuations Thermal insulator	A
UV protection coatings	Coatings to not permit degenerate material which is affected by sun rays	B
Solar protection coatings	Shading for interior spaces	A
Antireflective coatings		C

According to assessments and studies in this essay, nanomaterials for the purpose of architectural design are categorized in two categories. The first one is the materials that are not exactly appropriate for hot and dry climate of Iran. So, for this group building builders must not use these materials in south east of Iran and such area with climatic similarity of hot regions of Iran.

Whereas in second group there are lots of features that are suitable for hot and dry climate and should be used for this region.

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