Architectural Dimensions and Beyond

www.adb.reapress.com

Arch. Dim. Bey. Vol. 3, No. 3 (2026) 231–242.

Paper Type: Original Article

Conceptual Framework for the Application of Self-Regulating Biomimetic Materials in the Development of Building Envelopes Adapted to Climate Change in Iran's Mountainous Regions

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Citation:

Received: 18 December 2025 *Revised: 07 February 2026* *Accepted: 22 April 2026*	Kazemi, M., & Sabouriasl, P. (2026). Conceptual framework for the application of self-regulating biomimetic materials in the development of building envelopes adapted to climate change in Iran's mountainous regions. *Architectural dimensions and beyond*, 3(3), 231-242.

Abstract

The accelerating pace of climate change, the increasing dependence of buildings on energy resources, and the necessity of reducing environmental impacts have highlighted the need to redefine the role of materials in contemporary architecture. In this context, bio-inspired self-aware materials, as an emerging approach in building technology, draw inspiration from the adaptive processes of living organisms to enable the development of responsive building systems that are coordinated with environmental conditions. This study aims to investigate the capabilities of bio-inspired self-aware materials in shaping adaptive building envelopes and to propose a conceptual framework for enhancing architectural adaptability in the mountainous climate of Iran. The research methodology is based on a descriptive–analytical approach and a systematic review of scientific literature related to bio-inspired architecture, smart materials, and climate-responsive design. The findings indicate that natural mechanisms observed in examples such as the insulating structures of animals inhabiting cold regions, the hygromorphic movement of pine cones in response to changes in humidity, the adaptive patterns of mountain plants, and the cellular organization of organisms resistant to harsh environmental conditions can inspire the development of materials capable of regulating heat exchange, controlling moisture, modifying physical properties, and restoring their performance. Based on the analyses conducted, the proposed conceptual framework consists of four stages: identification and sensing of environmental stimuli, organization of the material's internal properties, generation of an adaptive response, and maintenance or restoration of envelope performance. This framework can provide a basis for developing innovative approaches to the design of building envelopes in the mountainous regions of Iran and can contribute to advancing architecture toward greater sustainability, flexibility, and responsiveness to environmental changes.

Keywords: Self-aware materials, Bio-inspired materials, Adaptive architecture, Climate-responsive architecture, Mountainous climate of Iran, Smart building envelopes, Architectural sustainability.

1 | Introduction

The building sector is considered one of the largest energy consumers worldwide and contributes significantly to greenhouse gas emissions. Over recent decades, sustainable architectural approaches have sought to reduce

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https://doi.org/10.48314/adb.v3i3.68

the negative environmental impacts of the built environment through energy-efficiency optimization, the use of renewable resources, and improvements in building envelope performance. However, the increasing complexity of contemporary climatic challenges has demonstrated that the use of static and passive materials is no longer sufficient to meet the requirements of future buildings [1]. In response to this challenge, the concept of self-aware materials has emerged as one of the most significant and rapidly developing fields in materials science and architecture. In addition to responding to environmental stimuli, these materials are capable of sensing surrounding conditions, regulating their functional behavior, and, in some cases, activating self-healing processes. Such capabilities enable buildings to evolve from passive structures into dynamic systems that can adapt to their surrounding environment [2].

On the other hand, nature has developed highly efficient strategies for environmental adaptation over billions of years of evolution. Living organisms employ complex yet energy-efficient mechanisms to respond to variations in temperature, humidity, solar radiation, and environmental stresses. Biomimicry, as an interdisciplinary approach, seeks to identify these mechanisms and translate them into engineering and architectural solutions [3]. In contemporary architecture, one of the most important fields of application for biomimicry is the development of adaptive building envelopes. Recent studies have demonstrated that bio-inspired building envelopes can dynamically regulate energy, light, moisture, and airflow exchanges, thereby reducing building energy consumption [1].

The significance of this issue is particularly pronounced in the mountainous climate of Iran. A substantial portion of the country encompasses mountainous regions, including West Azerbaijan, East Azerbaijan, Ardabil, Kurdistan, Hamadan, Chaharmahal and Bakhtiari, and parts of Khorasan. These regions experience long winters, substantial diurnal temperature variations, snowfall, frequent freezing conditions, and considerable solar radiation at high elevations. Such climatic conditions contribute to increased energy consumption and accelerated deterioration of building materials. Therefore, the development of bio-inspired self-aware materials can provide an effective strategy for enhancing thermal performance, increasing building durability, and reducing dependence on mechanical systems in the mountainous climate of Iran.

2 | Problem Statement

Conventional building materials used in the mountainous regions of Iran generally exhibit fixed and non-adaptive behavior. These materials maintain relatively uniform performance regardless of environmental changes and, consequently, cannot effectively respond to severe climatic fluctuations. Recent studies indicate that the building envelope is the most critical component in controlling energy exchanges between indoor and outdoor environments and plays a decisive role in reducing building energy consumption [4].

In contrast, many living organisms are capable of regulating their environmental conditions through adaptive mechanisms. For example, the fur structure of the polar bear helps reduce heat loss; pine cones open and close in response to changes in humidity; and certain alpine plants employ natural antifreeze mechanisms to survive under extremely low temperatures. These strategies represent examples of natural self-regulating systems that can provide a basis for the development of next-generation building materials [1].

Despite significant advances in the fields of smart and bio-inspired materials, a comprehensive and context-specific framework for the application of bio-inspired self-aware materials in the mountainous climate of Iran has yet to be developed. This research gap highlights the necessity of the present study.

3 | Theoretical Foundations of the Research

3.1 | The Evolution of the Concept of Materials in Contemporary Architecture

Throughout the history of architecture, building materials have primarily been regarded as passive elements whose main functions were to bear loads, separate spaces, and protect occupants. With the emergence of advanced technologies, the concept of smart materials was introduced into architectural discourse. These materials are capable of responding to stimuli such as temperature, light, humidity, and pressure [5].

Over the past decade, researchers have moved beyond the concept of "smart materials" and introduced the notion of self-aware materials. Self-aware materials not only respond to environmental stimuli but are also capable of sensing environmental conditions, regulating their functional behavior, and, in some cases, restoring or repairing their own performance [6]. This transformation has shifted the role of materials from static elements to dynamic and adaptive systems, an issue that has become particularly important in the design of building envelopes.

Adaptability, or economic efficiency, is among the most widely adopted strategies for advancing sustainable development by improving material and energy efficiency. Although related approaches are not explicitly limited to the effectiveness of technical systems, they primarily focus on enhancing energy efficiency through technological solutions [7].

3.2 | Biomimicry and the Transfer of Knowledge from Nature to Architecture

Biomimicry is an interdisciplinary approach that studies natural mechanisms and translates them into human technologies [8]. It defines biomimicry as a process of learning from nature rather than exploiting nature. According to recent studies, over approximately 3.8 billion years of evolution, nature has developed highly efficient strategies for energy management, temperature regulation, water storage, structural resistance, and environmental adaptation [2].

In architecture, biomimicry can be categorized into three primary levels:

Level 1. Form-based inspiration

At this level, the external form and morphology of living organisms serve as the basis for design. Examples include:

Table 1. Form-based Biomimetic inspiration in contemporary architecture.

Number	Biomimetic Inspiration	Example	Architect / Designer	Key Feature	Image	Description
1	Shell-inspired structures	Sydney Opera House, Australia	Jørn Utzon	Thin-shell geometry with high structural strength and optimized material use		One of the most famous examples of the application of shell geometry in contemporary architecture.
2	Flower-inspired building envelopes	Lotus Temple, India	Fariborz Sahba	Radial spatial organization and natural daylighting inspired by the structure of a flower		One of the prominent examples of biomimetic architecture inspired by the form and geometry of flowers.
3	Tree-inspired towers	Supertree Grove, Singapore	Grant associates	Solar energy collection, natural ventilation, rainwater harvesting, and functions analogous to natural tree ecosystems		One of the world's most prominent examples of artificial trees in sustainable architecture and design.

Level 2. Process-based inspiration

In this approach, the way natural systems function is used as a model. Examples include:

I. Natural ventilation in termite mounds.

II. Moisture regulation in plants.

III. Self-healing mechanisms in bones.

Level 3. Ecosystem-based inspiration

This argument is considered the most advanced level of biomimicry and seeks to establish interaction between the building and its environment. According to recent studies, this level has the strongest connection with sustainable architecture and climate-responsive architecture [2].

4 | Iran's Mountainous Climate and Design Requirements

4.1 | Climatic Characteristics

A mountainous climate influences a significant portion of Iran. The mountainous regions of western and northwestern Iran include:

I. West Azerbaijan.

II. East Azerbaijan.

III. Ardabil.

IV. Kurdistan.

V. Kermanshah.

VI. Hamadan.

VII. Chaharmahal and Bakhtiari.

The following climatic conditions characterize these regions:

I. Long and cold winters.

II. Frequent frost events.

III. Significant diurnal temperature variations.

IV. Intense solar radiation at high altitudes.

V. Snowfall.

VI. Seasonal cold winds.

These conditions lead to increased building energy consumption and reduced durability of many conventional building materials.

4.2 | Challenges of Building Envelopes in Mountainous Climates

Studies indicate that approximately 50–70% of heat transfer in buildings occurs through the building envelope. Therefore, the performance of the building envelope plays a decisive role in energy consumption [4].

The main problems associated with conventional building envelopes in mountainous regions include:

I. Heat loss.

II. Thermal bridging.

III. Moisture infiltration.

IV. Frost-induced cracking.

V. Degradation caused by UV radiation.

VI. Performance deterioration over time.

5 | Systematic Review of the Research Literature

5.1 | Environmentally Responsive Materials

The study by Ortega Del Rosario et al. [9] showed that responsive materials are capable of reacting to temperature, light, wind, and humidity, thereby improving the energy performance of buildings. The study also emphasizes that the development of responsive materials still faces challenges related to scalability and sustainable production [2].

Table 2. Comparative analysis of previous studies in the fields of biomimicry, smart materials, and adaptive building envelopes (source: authors).

Study	Year	Research Field	Research Approach	Key Finding	Limitation
Benyus [10]	1997	Biomimicry	Theoretical	Introduction of the concept of biomimicry	Lack of direct architectural applications
Addington and Schodek [5]	2005	Smart materials	Analytical	Introduction of a new generation of smart materials	Lack of focus on climate-specific applications
Pawlyn [11]	2011	Biomimetic architecture	Theoretical–applied	Transfer of natural patterns and strategies into architecture	Lack of investigation into self-aware materials
Badarnah [12]	2017	Biomimetic building envelopes	Case study	Development of environmentally adaptive models	Limited focus on building envelopes
Abdullah and Al-Alwan [13]	2019	Smart materials	Case study	Investigation of the role of responsive materials in buildings	Lack of investigation into biomimicry
Del et al. [1]	2022	Adaptive building envelopes	Systematic review	Identification of natural mechanisms transferable to architecture	Lack of focus on cold-climate regions
Xia et al. [14]	2022	Self-healing materials	Experimental	Improvement of material durability	Lack of architectural investigation
Ortega Del Rosario et al. [9]	2023	Responsive materials	Review	Introduction of emerging responsive materials	Lack of a climate-responsive framework
Verbrugghe et al. [2]	2023	Biomimetic architecture	Comprehensive review	Classification of biomimetic approaches and methods	Lack of focus on Iran
Present study	2026	Self-aware biomimetic materials	Conceptual framework development	Development of a model specifically adapted to the mountainous climate of Iran.	Requires experimental validation

The analysis of the table above indicates that previous studies have primarily focused on one of the following three areas:

I. Biomimicry in architecture.

II. Smart materials.

III. Adaptive building envelopes.

However, research that simultaneously addresses self-aware materials, biomimicry, adaptive building envelopes, and the mountainous climate of Iran within an integrated conceptual framework remains very limited. This research gap highlights the need for a comprehensive framework that can establish a connection between biomimetic principles, self-aware materials, adaptive building envelopes, and the specific climatic conditions of Iran's mountainous regions.

5.2 | Biomimetic Building Envelopes

Del et al. [1], in a comprehensive review of biomimetic building envelopes, demonstrated that the adaptive mechanisms of plants have significant potential for application in building technologies. The findings of this study identify six primary functions for adaptive building envelopes:

I. Temperature regulation.

II. Light control.

III. Moisture management.

IV. Ventilation.

V. Energy control.

VI. Environmental protection [2].

5.3 | Self-Healing Materials

One of the most important areas in the development of self-aware materials is self-healing materials. These materials are capable of repairing cracks and surface damage without external intervention. Recent studies indicate that the use of microcapsules, shape-memory polymers, and biological materials can enhance building durability [6].

5.4 | Biomimicry in Climate-Responsive Building Envelopes

A review of studies published between 2018 and 2025 indicates that three natural models have been among the most widely applied in the design of building envelopes:

I. Pine cones.

II. Termite mounds.

III. Polar bear fur.

These three natural models demonstrate a particularly strong correspondence with the challenges associated with cold and mountainous climates.

6 | Comparative Analysis of Natural Patterns for Iran's Mountainous Climate

The identification and evaluation of biological patterns are essential steps in the development of self-aware biomimetic materials. Natural systems have evolved sophisticated mechanisms for responding to environmental conditions such as temperature, humidity, solar radiation, moisture, and mechanical stresses. These mechanisms can provide valuable models for developing adaptive building materials and responsive building envelopes.

In the context of Iran's mountainous climate, the transferability of biological patterns should be evaluated according to their ability to address specific climatic challenges, including low temperatures, freeze–thaw cycles, moisture infiltration, strong solar radiation, snow loads, and thermal fluctuations. Accordingly, this study compares selected biological patterns based on their natural characteristics, biological functions, potential architectural applications, and compatibility with the climatic conditions of mountainous regions in Iran.

Table 3 presents a comparative assessment of these biological patterns and identifies their potential suitability for integration into self-aware materials and adaptive building envelopes.

Table 3. Comparison of the transferability of Biological patterns to self-aware materials in Iran's mountainous climate (source: authors).

Biological Pattern	Natural Feature	Biological Function	Architectural Application	Compatibility with Mountainous Climate
Polar bear	Hollow fur	Heat retention	Adaptive thermal insulation	Very High
Pine cone	Opening and closing in response to humidity	Moisture regulation	Kinetic and responsive façade	High
Termite mound	Natural ventilation	Temperature regulation	Breathing building envelope	Moderate
Alpine plants	Cold resistance	Frost resistance	Anti-frost building envelope	Very High

Table 3. Continued.

Biological Pattern	Natural Feature	Biological Function	Architectural Application	Compatibility with Mountainous Climate
Lotus leaf	Self-cleaning surface	Pollution and contaminant repulsion	Self-cleaning façade coating	Moderate
Snake skin	Surface structural changes	Regulation of heat exchange	Adaptive thermal façade	High
Human bone	Strong porous structure	Weight optimization	Lightweight and high-strength materials	High
Spider silk	High strength with low weight	Load-bearing capacity	Lightweight composites	Moderate
Seashell	Strong layered structure	Mechanical resistance	Stress-resistant façades	Moderate
Cactus	Water storage	Moisture management	Moisture-absorbing façades	Low

The results of the table indicate that patterns inspired by polar bears and alpine plants have the greatest potential for application in the mountainous regions of Iran.

To further clarify the potential advantages of self-aware biomimetic materials, their performance can be compared with that of conventional and smart materials across a set of key functional and environmental criteria. Conventional materials generally exhibit fixed properties and limited interaction with their surroundings, whereas smart materials are capable of responding to specific environmental stimuli. Self-aware biomimetic materials represent a more advanced approach by integrating environmental responsiveness with biomimetic principles, adaptive behavior, functional recovery, and potentially learning capabilities.

The comparison considers key criteria including temperature and humidity responsiveness, self-healing capability, climate adaptability, energy consumption, durability, learning capability, environmental interaction, biomimetic inspiration, and suitability for mountainous climates. This comparative framework provides a clearer understanding of the potential contribution of self-aware biomimetic materials to the development of adaptive building envelopes, particularly under the demanding climatic conditions of Iran's mountainous regions.

The results presented in the following table demonstrate the progressive transition from passive materials toward increasingly responsive and adaptive material systems.

Table 4. Comparison of the performance of conventional materials and self-aware Biomimetic materials (source: authors).

Evaluation Criterion	Conventional Materials	Smart Materials	Self-Aware Biomimetic Materials
Response to temperature	None	Limited	Advanced
Response to humidity	None	Moderate	Advanced
Self-healing capability	None	Limited	High
Climate adaptability	Low	Moderate	High
Energy consumption	High	Moderate	Low
Durability	Moderate	High	Very high
Learning capability	None	None	Potential
Environmental interaction	Very Low	Moderate	Very high
Biomimetic inspiration	None	Limited	Comprehensive
Suitability for mountainous climates	Moderate	High	Very high

7 | Research Methodology

The present study is fundamental–applied research conducted using a qualitative approach. The research methodology is based on a Systematic Literature Review (SLR) and qualitative content analysis.

The main objective of the research is to identify the key components contributing to the development of self-aware biomimetic materials and to propose a conceptual framework for the design of adaptive building envelopes in Iran's mountainous climate.

8 | Proposed Conceptual Model

8.1 | Rationale for the Model Development

A review of the research literature indicates that most previous studies have focused on only specific capabilities of smart materials. Some studies have emphasized thermal responsiveness, while others have focused on shape change or self-healing. In natural systems, however, these functions operate in an integrated manner.

Accordingly, the proposed model in this study is inspired by the logic of biological systems, in which environmental sensing, internal adaptation, responsive behavior, and functional recovery operate as interconnected processes.

8.2 | Model Structure

The proposed model consists of four main layers, which are presented and described in the following table.

Table 5. Structure of the proposed research model (source: authors).

Layer	Description	Parameters / Functions	Biological Inspiration	Examples of Adaptive Responses
Layer 1: environmental perception	This layer is responsible for receiving and detecting environmental information.	Environmental parameters: temperature, humidity, solar radiation intensity, wind speed, snow load, air pollution	Sensory receptors and environmental sensing mechanisms in plants and animals	Detection of environmental changes and monitoring surrounding conditions
Layer 2: intra-material analysis	At this stage, environmental data are interpreted, and an appropriate response is determined.	Detection of changes, comparison with previous conditions Selection of an appropriate response	Information-processing mechanisms and nervous systems in living organisms	Internal adjustment of material properties in response to environmental stimuli
Layer 3: adaptive response	At this stage, the material modifies its behavior in response to environmental conditions.	Modification of heat-transfer coefficient, surface color change, opening and closing of pores, moisture absorption control	Adaptive behavior of pine cones and environmentally responsive plants	Dynamic modification of thermal, optical, and moisture-related properties
Layer 4: functional recovery	This layer is responsible for maintaining long-term performance and durability.	Self-healing, structural regeneration, increased durability	Self-healing mechanisms observed in bones, skin, and other living organisms	Restoration of damaged material properties and preservation of long-term performance

9 | Findings and Analysis

9.1 | Thermal Capacity of Biomimetic Materials

Studies indicate that a substantial proportion of energy consumption in buildings located in Iran's mountainous regions is associated with winter heating [15]. Under such conditions, patterns inspired by polar bear fur can improve the thermal performance of building materials. The porous structure of polar bear fur creates layers of trapped air that reduce heat transfer [16]. If this characteristic is transferred to building materials, heat loss and associated energy consumption could be significantly reduced.

9.2 | Moisture-Control Capacity

One of the major challenges in mountainous regions is the frequent occurrence of freeze–thaw cycles. Moisture penetrating building materials during cold seasons can lead to cracking and reduced durability. An examination of the pine cone demonstrates that this structure can respond to changes in humidity without requiring external energy [5]. This characteristic can provide a basis for designing humidity-responsive building façades.

9.3 | Self-Healing Capacity

One of the most important characteristics of self-aware materials is their ability to recover functionality. Recent studies on self-healing materials indicate that the use of microcapsules, shape-memory polymers, and biological compounds can repair microcracks and minor damage [6]. In Iran's mountainous regions, where buildings are exposed to significant thermal stresses, this capability can contribute to extending the service life of building envelopes.

9.4 | Climate Adaptability

Conventional materials generally exhibit fixed and non-adaptive behavior. In contrast, self-aware materials can adjust their performance according to environmental conditions. For example:

Table 6. Seasonal adaptive responses of self-aware Biomimetic materials under winter and summer climatic conditions.

Winter	Summer
Increased thermal resistance	Increased ventilation
Reduced heat exchange	Reduced solar heat gain

Such capabilities can improve the building's overall energy performance and reduce dependence on mechanical heating and cooling systems.

10 | Discussion

The findings indicate that the development of self-aware biomimetic materials could initiate a new transformation in climate-responsive architecture in Iran. Unlike conventional materials, which generally exhibit static performance, these materials possess dynamic behavior and can actively interact with their surrounding environment.

From a theoretical perspective, the most significant contribution of the present study is the transfer of the concept of biological adaptation into the field of building-material design. In this approach, material is no longer considered a passive component; rather, it is regarded as an integral part of a living and adaptive system.

The results further indicate that the following biological patterns have the greatest potential for application in Iran's mountainous climate:

I. Polar bear.

II. Alpine plants.

III. Pine cone.

IV. Cold-climate reptile skins.

These biological patterns can serve as a basis for developing the next generation of adaptive building envelopes in Iran.

10.1 | Research Innovations

I. Development of a dedicated conceptual framework for the development of self-aware materials in Iran's mountainous climate.

II. Establishment of a connection between biomimicry and climate-responsive architecture.

III. Classification of the functions of self-aware materials into four levels.

IV. Identification of natural patterns compatible with the climatic conditions of Iran.

V. Development of a model for adaptive building envelopes based on biological systems.

10.2 | Research Limitations

I. Limited availability of indigenous studies in Iran.

II. The emerging nature of the concept of self-aware materials.

III. Limited practical and industrial data.

IV. Lack of extensive full-scale building applications and real-world prototypes.

10.3 | Suggestions for Future Research

I. Development of laboratory prototypes of self-aware biomimetic materials.

II. Simulation of the energy performance of these materials in the cities of Urmia, Tabriz, and Ardabil.

III. Design of adaptive building envelopes based on the pine cone model.

IV. Development of self-healing materials specifically designed for cold climates.

V. Investigation of the potential integration of artificial intelligence and self-aware materials in future buildings.

11 | Conclusion

The present study was conducted to investigate the potential of self-aware biomimetic materials for developing building envelopes adapted to Iran’s mountainous climate. The findings obtained through an SLR and comparative analysis of biological patterns indicate that the next generation of building materials will move beyond materials that merely serve structural or enclosure functions toward materials capable of perception, response, adaptation, and functional recovery.

An examination of research trends over the past decade indicates that the transformation of materials from conventional substances to smart materials and subsequently to self-aware materials represents one of the most important pathways in the development of future architecture. Within this approach, material is no longer regarded as a passive element but rather as part of a dynamic system capable of adapting to its environment. This perspective is particularly important in climates characterized by severe environmental stresses, such as Iran’s mountainous climate.

The analysis of biological patterns demonstrated that many living organisms have developed highly efficient strategies for coping with harsh climatic conditions over millions of years of evolution. Polar bear fur, pine cones, alpine plants, termite mounds, and porous bone structures are among the examples with significant potential for transfer to building-material technologies. These mechanisms can be employed in the development of building envelopes capable of thermal regulation, moisture control, natural ventilation, self-healing, and climate adaptation.

The findings indicate that the major challenges faced by buildings in Iran’s mountainous regions include thermal energy loss, freeze–thaw cycles, moisture infiltration, thermal stresses, and environmental degradation. Self-aware biomimetic materials can respond actively to these factors, improve building performance, and reduce dependence on mechanical systems.

One of the main contributions of this research is the development of a four-layer conceptual framework consisting of:

I. Environmental perception.

II. Intra-material analysis.

III. Adaptive response.

IV. Functional recovery.

This framework demonstrates that the development of self-aware materials is not limited merely to the incorporation of sensors or smart technologies; rather, it requires a fundamental reconsideration of the nature of materials and their interaction with the environment.

From the perspective of sustainable architecture, the application of self-aware biomimetic materials can contribute to:

I. Reducing building energy consumption.

II. Extending the service life of building envelopes.

III. Reducing maintenance costs.

IV. Enhancing users' thermal comfort.

V. Improving building resilience to climate change.

From a theoretical perspective, the present research attempts to bridge the existing gap between studies of biomimicry, smart materials, and climate-responsive architecture, while providing a foundation for the development of a new generation of building materials in Iran.

Ultimately, it can be argued that the future of climate-responsive architecture lies not merely in the increased use of mechanical equipment, but in the development of materials that, like natural systems, are capable of perceiving their environment, learning, adapting, and regenerating themselves. Such materials can provide the foundation for the emergence of smart, resilient, and energy-efficient buildings in the coming decades.

12 | Scientific Contributions of the Research

12.1 | Theoretical Contributions

I. Development of the concept of self-aware materials within climate-responsive architecture.

II. Integration of the biomimetic approach with building-envelope design.

III. Proposal of a new theoretical framework for adaptive materials.

12.2 | Practical Contributions

I. Providing appropriate solutions for cold-climate regions of Iran.

II. Contributing to the reduction of building energy consumption.

III. Enhancing material durability under harsh climatic conditions.

12.3 | Technological Contributions

I. Establishing a foundation for the development of next-generation building materials.

II. Supporting the design of smart and adaptive building envelopes.

III. Creating a basis for integrating artificial intelligence with materials science.

Authors' Contributions

All aspects of the research and manuscript preparation were carried out by the author. The author has read and approved the final version of the manuscript.

Funding

Not applicable.

Data Availability

All data supporting the reported findings in this research paper are provided within the manuscript.

Conflict of Interest

The author declares that they do not have any conflict of interest.

Consent for Publication

The author confirms consent for the publication of this work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants performed by the author.

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