

Bionic Architecture and its Practical Applications in Housing (with a Focus on Enhancing Physical and Mental Well-being)

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Abstract:- In recent years, drawing inspiration from nature has entered the field of architecture to facilitate the pursuit of a comprehensive architectural approach. The aim of this research is to enhance the levels of physical and mental well-being in housing through the identification of practical components of bionic architecture. This qualitative study was conducted through interviews. Based on the research findings, environmental factors, comfort, satisfaction, socio-economic components, and the most important elements should be taken into consideration by architects in designing bionic housing.

Keywords: *Bionic Architecture, Sustainable Architecture, Physical and Mental Well-being*

Introduction

In recent decades, with the onslaught of industrial and technological approaches to architecture and urban planning, cities worldwide, particularly in developing societies, have undergone significant transformation, and contemporary Iranian architecture is no exception to this. It is now entirely clear that there is no practical knowledge or theory that can be realized without specific expertise. Housing, as the primary space where most of a person's life is spent, plays a role in creating health (both mental and physical) in the lives of all individuals. It is self-evident that a healthy society is contingent upon having healthy individuals within families and within the confines of housing. [1] The opinions of experts and scholars (sociologists, psychologists, designers) indicate that the design of a comfortable and functional environment can have a significant impact on improving the quality of life and mental health of the residents. [2] In the current climate of urban development, the importance of environmental quality, socio-economic aspects, and the most basic needs of residents in urban areas, especially in housing design, is emphasized. The integration of nature, architecture, and human beings can create harmony and balance in the built environment, leading to an improved quality of life. [3 and 4]

On the other hand, the science of bionics, as an emerging field and one of the top three sciences of the present world, can bridge the gap between the use of new technologies and the creation of tranquility in housing. Transferring biological criteria to architecture requires discussion of common ground between architecture and biology. Their goal is to use bionics as a tool in architectural design. Common issues in the field of architecture and biology have not yet been fully explored. Today, many individuals worldwide are striving to discover these commonalities, and many of these efforts have led to successful advancements in the field of architecture. [5 and 6] Solving some architectural problems can only be achieved through innovative solutions. Nature-inspired paradigms can foster creativity and innovation in the architect's mind. The first step in using biology in architecture, or in other words, "bionics" in architecture is when the need for innovation arises, especially in cases such as designing architecture for new environments, issues that cannot be solved with conventional knowledge, better communication between architecture and the surrounding environment, and achieving better quality of life. In all of these cases, nature assists architects in providing answers to their architectural needs. The transition from nature to architecture is a completely logical process because natural patterns, over the years, have now presented architects with the best adaptation strategies in various conditions. Based on the information presented in this

research, we aim to address the question of which bionic components can be effective in optimizing housing architecture.

Bionic Architecture

What is now referred to as bionic architecture or biomimetic architecture is the result of efforts by architects who, with a fresh perspective on architecture and structures in natural forms, seek to address human shortcomings in construction. Given the energy and natural resource crisis, architects are striving to find a solution to this crisis and conserve energy by adopting a new approach to architecture and structures through the science of bionics. The culmination of these teachings is bionic architecture. The goal of bionic architecture is to achieve a conventional architecture with sustainable principles that harmonize with nature. Intelligent emulation of examples and mechanisms from natural organisms is a part of bionics, in which nature is used as a basis for solutions whose efficiency has been proven. [7]

Bionic architecture is a modern approach in the contemporary world that leverages sustainable solutions from nature to address human problems. To solve the problem of excessive extraction of materials from the environment, which is a destabilizing factor in the construction and architecture industry, the optimal use of materials in nature is explored and revisited. Natural structures, like human bones, gradually extract their own materials from the environment. The simulation of a pre-fabricated intelligent structure with the ability to self-destruct and self-repair, which grows over time by absorbing materials from its surrounding environment, is presented. The waters of the Persian Gulf and Lake Urmia are faced with an excessive salinity crisis. The extraction of salt, as complementary materials, from saline water and the return of water with lower concentration, ensures the environmental sustainability of this construction method. [8]

Research Method

This study was a qualitative research. In the present research, the initial questionnaire (non-experimental descriptive tool) was designed using a survey method.

In this research, after examining and inferring the practical components of bionic architecture through studies and interviews with experts in this field with the aim of achieving the content goal table, the questionnaire structure was developed. Interviews with experts were conducted to understand the perspectives and tendencies of bionic architecture in residential buildings in Iran, which is an important step in the tool development stage.

The framework of the interviews is based on theoretical backgrounds. All interviewees had similar qualifications such as membership in the faculty of state universities, a history of research-related activities, guidance on relevant theses, and desirable professional experience in the field of architectural design.

In the first step, a summary of the research introduction and its objectives was prepared by determining the areas of questioning and sent to the interviewees. Then, the opinions of the interviewees were reviewed, adjusted, and edited to provide the basis for designing and refining the inferential indices from the relevant literature and components related to the conditions in Iran. In the next step, the questionnaire was designed.

Results

In Table 1, the initial observations and perspectives of the interviewees are provided.

Table 1 presents the topics discussed by the interviewees (emphasis, tendencies).

| Opinion | Emphases | Trends | Scope of Topics |
|----------|---|---|--|
| Number 1 | Necessity of revisiting past experiences, looking at nature according to worldview and culture, social and technical development, role of basic | Historical perspective, goal-oriented, holistic approach, environment-focused | Holistic perspective, form and content, education, planning, flexibility, social participation and development, alignment of structure with needs, creating awareness and motivation, nature as the main issue |

| Opinion | Emphases | Trends | Scope of Topics |
|----------|---|---|--|
| | education, pollution and consumption reduction | | |
| Number 2 | Quantitative approach to elements, comfort as the main axis, topical fluidity, building efficiency, enhancing livability | Technical perspective, environment-focused, climate | Technological advances and evolution of experiences, indigenous architecture, energy, economy, education, land and water conservation, building efficiency, life cycle, climate impact on comfort |
| Number 3 | Macroscopic view of the subject, social development, emphasis on location-based elements and residents' needs (participation), environment enhancement through design | Behavioral and social perspective, design context | Program-oriented, hierarchy from macro to micro, inclusivity, location-centric, alignment with needs over time, attention to program scale and integration |
| Number 4 | Economic, engineering and technology, flexibility, systemic view and interaction of components, design issues and feedback, waste reduction | Technical and specialized view, systemic approach | Interaction of overall and individual components, comprehensive thinking, economy, waste, alignment with needs, efficiency, society-environment interface, sustainable design process, feedback evaluation, residents' economic capability |

Interpretation of Interview Analysis

Preparing a content goal table is one of the crucial steps in research, especially in the tool design phase. To this end, the content obtained from the interview analysis is presented in Table 2 as a content framework. This will serve as the basis for designing the research questionnaire.

Table 2 Table of Objectives and Approaches in Interview Content

| Approach/Content on the Scale of Thesis Topic | |
|---|---|
| Economic | Planning and budgeting in all areas/ Economy as a driving force/ Creating economic incentives/ Capital return and profit assurance/ Cultivating awareness of short-term economic costs/ Forward-looking economy (life cycle costs). |
| Technical and Aesthetic | Existing technical infrastructure/ Alignment of technical factors with societal needs/ Emphasis on vernacular architecture/ Introducing new methods in construction, technologies, and related professions/ Engineering decision-making/ Software analysis prior to construction/ Feedback-oriented software systems/ Utilizing innovative green methods. |
| Social | Access to facilities, services, and infrastructure/ Fair use of services and facilities/ Social presence of individuals and shaping of the place identity/ Social integration through education and awareness/ Attention to unique social issues of the context. |
| Functional | Responsiveness/ Tailoring form to match physical and content-related needs/ Health/ Development and evolution of open spaces/ Interaction with the surroundings/ Easy |

| Approach/Content on the Scale of Thesis Topic | |
|---|---|
| | access to public transportation and pedestrian access/ Alignment with environmental changes. |
| Enhancing Architectural Quality | Improving performance and durability of structures/ Using elements of bionic architectural aesthetics (curvature, balance, proportions, and unity). |
| Comfort | Thermal comfort, visual comfort (lighting and radiation)/ Hygienic and psychological comfort/ Considering the needs of different individuals/ Resident satisfaction/ Duration of residence/ Improving communal spaces/ Security. |
| Macro (Environmental) | Reducing energy consumption/ Renewable energy sources/ Water conservation/ Recycling of materials/ Hidden energy of materials/ Pollution reduction/ Resource consumption reduction. |
| Efficiency (Effectiveness and Efficiency) | Changing benchmarks in line with technological advances and evolving experiences/ Post-occupancy feedback and evaluation of buildings/ Building maintenance management/ Building life cycle management: Exterior appearance, functional equipment and accessories, structural aspects of the building, and repairs and maintenance/ Maximizing resource utilization efficiency/ Ensuring performance reliability. |

In Diagram 2, the most influential components in bionic architecture from the perspective of experts have been gathered.

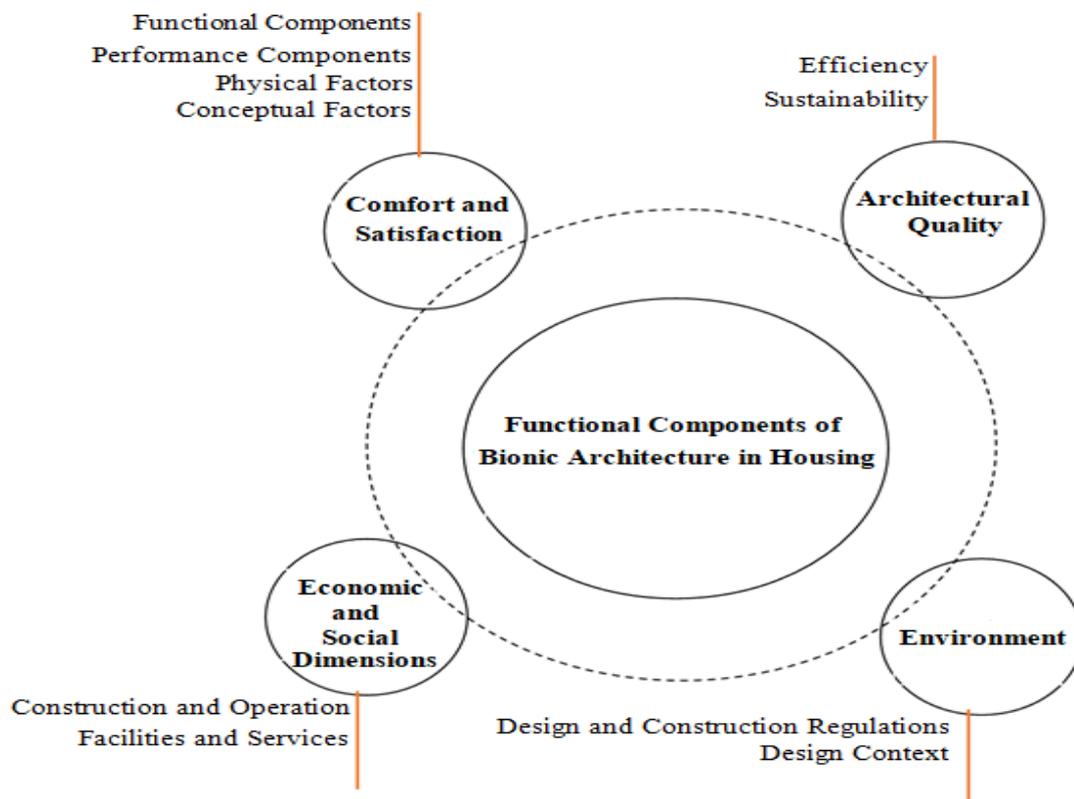


Diagram 2 Substantive and Practical Emphases of Bionic Architecture in Housing from Interviews with Experts.

Table 3 Operational Components of Bionic Architecture.

| General Category | Bionic Components | Application in Housing | Comments |
|------------------------|------------------------|---|--|
| Physical Components | Curvature | Changing the natural rigid shape into pleasant and humanized forms | Reducing the rigidity of volumes enhances a sense of tranquility for residents |
| | | Nonlinear architecture, convex and curved (inducing weightlessness and softness feeling in an individual) (Mahdavinejad, 1391,p. 86) | Making comfortable and intimate corners for meeting and chatting, solitude and privacy |
| | Balance and harmony | Compliance with axial order | Symmetry and order in design causes tranquility in residents |
| | | Active balance between natural activities (harmony) | |
| | Proportions | Observance harmony between length, width and height of the space with function and harmony in the space | Observing golden ratios in housing |
| | | Human scale and flat and low spaces (not inducing feeling of inferiority), not designing floors vertically | Height causes fear and low height causes feeling of suffocation |
| | Unity (coherence) | Using minimalistic organic and primary materials (elements put simply together) | Making opportunities for different experiences via various spaces (inducing curiosity), space flexibility (individual's choice to create function) |
| | | Building in a natural landscape and the view over natural landscapes from the building | |
| | | Forms spread on a horizontal plane to understand space and attention to the horizon (horizontal planes aligned to the ground) (attention to the horizon) | Readability of the space causes tranquility |
| | Conceptual | Inducing special meaning (using ideas and concepts in design to induce this feeling) and symbols in the building | Sacred concepts cause tranquility in residents |
| Performance components | Openness (open system) | Proper day light (no need for artificial light during day), enough light in spaces during night for resting and personal and social interactions (soft light), electro- | Housing flexibility causes tranquility in residents, increasing members and no need for movements |

| General Category | Bionic Components | Application in Housing | Comments |
|-------------------|---|--|---|
| | | optical layers, electro chromic materials | |
| | | Individuals joining the nature through openings | Open (yard) and semi-open (porch) spaces architecture, presence of nature in three facades of individual's life space |
| | | Moving from the outside world towards inside and complete dependence to the inside world | Variety of natural intra-environments variables causes variety in spaces |
| | | Semi-permeable membranes (adaptive permeability), Temporary structures like air curtains." | Emergency access of the building to the outside space - Independence in energy consumption (solar panels) |
| | "Limitation - Space and time of death and revival." | "Permanent and temporary residences - Residency construction scales." | "The scale of the residence is determined based on comfort, security, and infrastructure needs." |
| | | "Recycling of materials" | "Given the limitation of resources, recycling will lead to the comfort of residents in the long run." |
| | Order | Minimizing ambiguity | Order in the environment accelerates its perception and at the same time gives it attraction that encourages people to discover it |
| | | Geometric or structural order (related to proportionality) based on mathematics. | Map scales - Observance of aesthetic principles. |
| | | Hierarchy | Separation of public and private spaces, crossing a sub-space to get to private spaces, spatial continuity, ease of perception of spaces (readability of spaces causes tranquility) |
| | | Performance order | Order in spatial hierarchy (activities sequence), order in construction stages causes better final quality and tranquility for residents |
| Energy processing | Ecological design, energy (radiant, thermal, electricity) control | Maintaining thermal energy (prevent waste) | |

| General Category | Bionic Components | Application in Housing | Comments |
|---|--|---|--|
| | | Climate design | Designing residence aligned with local climate |
| | Reaction to environment | Using sensors to prevent unforeseen reactions (erosions, slides, earthquakes) | Movement of the residence or its components, using self-repairing materials |
| | | Stimulating senses | Stimulating five senses: via natural elements such as water, colored and fragrant plants, scent of soil, touch (visual and real) of plants, soft and rough materials, etc. |
| | | Presence and intervention of users during design and construction process | Interviews and questionnaires, and space users' knowledge of relaxing factors, knowing users' mood and needs, and increasing individual's sense of belonging |
| | Reaction to environment | Using smart materials | |
| Homeostasis and metabolism | Controlling comfort parameters: temperature, humidity, ventilation, light, magnetic radiations | Execution of smart building management system | |
| Promotion of comfort and satisfaction | Comfort in internal spaces | All of the factors in "openness" component | |
| | | Providing fresh air and proper ventilation | |
| | | Providing hygienic comfort | Controlling contamination factors |
| | Access | Access to infrastructure, facilities and services | |
| | | Access to public transport | Paths functionality |
| | | Accessibility for people with disabilities and the elderly. | |
| | | Access to physical components, accident prevention and safety in operation | |
| | Sociopetality of open spaces | Opportunities for presence and participation in multifunctional spaces | |
| Social development and expansion of recreational spaces | | | |

| General Category | Bionic Components | Application in Housing | Comments |
|----------------------|-------------------------------------|--|--|
| | | Sense of belonging and residents' participation in promoting the environment | |
| | | Safety and increasing security in using environment | |
| Construction quality | Durance | Proper use of physical components (first part of this table) | Physical and meaningful qualities through harmony with design (proportions, concepts, etc.) |
| | | Proper maintenance of building | Maintenance planning, residents' awareness of use and maintenance, proportionate equipment and residents' budget |
| | | Compatibility | Flexibility, compatibility with climate conditions |
| | Efficiency | Construction productivity | Waste reduction, safety in execution |
| | | Residents' productivity | Smart equipment, proper open space, maintaining energy |
| | | Costs and efficiency feedback | Planning resource supply, performance and costs of equipment |
| Environment | Promotion of environment conditions | Reduction of soil damage | |
| | | Reduction of fossil fuels usage | |
| | | Water management | |
| | | Promotion of ecology | |
| | | Waste reduction | |

Conclusion

It is clear in the history of architecture that it began by directly seeking inspiration from nature or borrowing ideas from it for construction. However, with the advancement of technology and its impact on human life and architecture, architects now have various tools at their disposal for drawing inspiration from nature. Nature provides endless sources of inspiration, which can contribute to the mental and emotional well-being of humans. Additionally, utilizing natural structures can foster constructive interaction between the structural elements and architectural forms. The integrated approach to shaping structures inspired by nature involves in-depth attention to natural structures and analyzing structural forms. Through the use of parametric software and structural analysis, architectural forms in harmony with nature can be achieved.

While it's undeniable that technological advancements have made significant contributions to architecture after the industrial revolution, a strictly industrial approach has distanced humans and their living spaces from nature. In some cases, architectural outcomes have even resulted in a conflict between human life and nature. Until the

principles of emulating nature as part of a continuous cycle are properly understood, it remains only a fragment of an interpretive process, accompanied by a wealth of information related to construction conditions. However, a nature-based approach, rooted in exploration and research, possesses genuine and accurate qualities, which are the interpreters of how they should be emulated. Natural phenomena typically exist in an optimized state, and bionics represents a continuous quest for optimization in human-made technology and environment. The concept of optimization in nature, and how it shares similarities and differences with similar concepts in industry and technology, warrants serious research. Hence, the utilization of natural patterns and elements with a technological perspective (bionic architecture) can be one of the ways to enhance the quality of residential architecture.

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