

The necessity of explaining the form in the interaction of structure and architecture (case study: Barsian Jame Mosque, Mossali Tehran and Al-Ghadir Mosque)

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Abstract:

Aims: The shaping of form in architecture is the result of various functional, economic, social, cultural, climatic, and environmental factors, as well as construction and stability conditions. Stability plays a fundamental role in the shaping of form and its resistance to environmental factors, as it ensures the overall stability of the architectural form. Therefore, the position and importance of the structure in design and its role in shaping the form is a subject that must be studied due to its significance. Although form is considered the manifestation of architecture, its formation is dependent on and connected to the structure. Thus, the structure and its concepts and methods play a primary role in creating the form. The aim of this research is to provide solutions to enhance the interaction between architectural form and structure by explaining qualitative parameters in the evaluation of buildings.

Methodology: The method of this research is descriptive and content analysis.

Finding: The results show that in traditional architecture, the proportion of type, shape, size, and arrangement of structural elements with the form was well observed. Shape and form relied on each other and ensured each other's stability. The proportion of the structure with the functional needs of the form (dome house, arched elements, corner construction of the three-corner type, kilil-type arches, load-bearing and decorative elements of the pointed type) is in a harmonious and integrated combination with the structural components. In the participation of form decorations, geometric patterns in form decorations were consistent with the geometry of the flow of forces in the structure. However, in the contemporary period, the lack of participation of the structure in the visual expression of the form, the separate and inconsistent design of form and structure, covering and decorating the structure with form elements, and consequently not understanding the behavior of the structure in the building, designing the structure, and even in some cases, the low efficiency of the structure are noted.

Conclusion: In past architecture, the highest duty of the architect was to recognize, understand, and spatially visualize the static and dynamic forces in the load-bearing body of the building, which with complete mastery, precisely specified the proportions and dimensions of the filled and empty parts.

Keywords: Structure architecture form; Interaction architecture and structure

1. Introduction

Interaction or interplay is an action that occurs between two or more entities, objects, phenomena, or processes that have a mutual effect on each other. The idea that the principle of interactivity is based on is that the action of an entity is not only carried out according to its own plans and intentions but also considers the plans and possible reactions of other entities. Based on this, the interaction between form and

structure can be defined as the simultaneous formation of form or structure while considering each other's needs and functions. In other words, the interaction between structure and architectural form occurs in such a way that the architectural design and building structure are harmonized and emerge simultaneously, making it difficult to separate the structure from the architectural form.

Today's architecture in Iran, with the changing desires and needs of users and the transformation of social, economic,

technological, and cultural conditions, is witnessing disorders in the relationship between form and structure. The effects of these disorders can be seen in all aspects, both in architectural education and in the field of design and execution. This issue in education leads to the training of specialists who lack complete knowledge in building design (1). In the field of architectural design, the separation of structural science from architectural knowledge is most evident in its impact on the stability, beauty, and sublimity (semantic value) of buildings. In the field of execution, the relationship between architecture and structure affects the amount of materials used, the complexity of design and construction, and the efficiency of buildings. In today's architecture, the structure is used more as a separate knowledge in the building design process rather than behaving in unity with the form. In some cases, the structure takes precedence over the form, and its manifestation is more dominant than its interaction with the form. In another type of relationship between form and structure, the visual needs of the form take precedence over the structure. This can be seen in the decoration of the structure with historical shapes and forms or in cases where the structure merely serves as a support for the building's covering and is often hidden behind the form (2).

2. Research objectives

The main objective of this research is to explain the role of form in the interaction between structure and architecture. This study aims to examine the role of architectural form in both contemporary and traditional periods to elucidate the interaction between form and structure, and to provide solutions for improving this interaction in today's architecture.

3. Theoretical foundations of the research

A structure is defined as a member or a set of members used to bear and transfer loads. The most important goals include maintaining a stable balance while preserving the predetermined geometric shape and pattern. Another important goal often considered is its optimal operational form. A structure can be described as the ability to create resistance in materials and a set of interconnected building elements that resist dead and live loads and transfer them to the ground. This function of the structure is determined by the science of statics. The structure is the hidden member of the building and ensures its life. Architectural structures are large, fixed, and stationary. Structural requirements include balance, resistance, stability, regularity, attention to material properties, adherence to the path of forces, and geometry (3).

The structure is undoubtedly one of the essential components of architecture. This importance is evident in the construction of various uses and is not specific to one type of space. To have an architectural space, a structure is primarily needed. Therefore, it can be imagined that the structure determines the architecture, but it is easy to see that this is not the case. Many magnificent buildings, such as Gothic churches in Europe and historical Iranian architecture, especially during the Seljuk and Timurid periods, have relied on their architectural form to respond to both

architecture and structure. The structure was not defined separately from the architectural body; rather, both form and structure were employed in the same direction, resulting in beauty as well (4).

Form, in terms of its semantic scope, is an open, general, relative term with various levels and has many definitions in the field of art. Form or shape is the sensory manifestation of a work and an expression that presents itself for judgment. In architecture, form can also be considered the clear manifestation of an architectural work, imagined as the physical entirety of the work formed by the combination of visual elements. Form is the most important and first factor in the visual perception of the audience when encountering an architectural work. When looking at a building, we first recognize its overall form and then understand its details.

On the Importance of Interaction Between Structure and Form Alami and colleagues (2015) conducted a study on structure, form, and architecture [1]. In this research, among the various aspects of form, its structural aspect was considered. In this context, force was presented as an operating system influencing both the architectural and structural aspects of form (5). Ekhlesi and Ghamari (2011) also emphasized the expansion of free forms in architecture, introducing space frame structures as the best structural option for achieving these forms, as they could harmonize with the architecture (6) [2]. The necessity of harmony between structure and architecture has been examined in articles by Zarkesh (2015) [3], Eslami and Hadafi (2011) [4]. Zandieh Vakili, Mahmoudi Kamel Abadi, and Hojjat (2019) explained the qualitative parameters and evaluation criteria for the interaction between form and structure in contemporary Iranian architecture (1, 7, 2) [5]. El-Eqapi and colleagues (2020) studied the coexistence of form and structure in contemporary architecture (8) [6].

In past architecture, the application of structure in the formation of form can be observed in aspects such as harmony (balance and symmetry) in plans and elevations, the use of specific proportions, geometric patterns in two-dimensional and three-dimensional designs, and scaling (9). On the other hand, research in the field of past Iranian architecture reveals the unity between form and structure (2). Conversely, contemporary Iranian architecture, with the changing desires and needs of users and the transformation of social, economic, technological, and cultural conditions, is witnessing disorders in the relationship between form and structure. The effects of these disorders can be seen in all aspects, both in architectural education and in the field of design and execution. This issue in education leads to the training of specialists who lack complete knowledge in building design (1). The comparative relationship between thermal systems and structures was investigated in the research of Hosseinzadeh et al. (2024) [7] (10), Esmaeili et al. (2023) [8] have investigated the most advanced design standardization method for the industrialization of contemporary architecture (11). In the field of architectural design, the separation of structural science from architectural knowledge is most evident in its impact on the stability, beauty, and sublimity (semantic value) of buildings. In the field of execution, the relationship between architecture and structure affects the

amount of materials used, the complexity of design and construction, and the efficiency of buildings. Despite extensive research and studies in the field of past Iranian architecture, the interaction between form and structure, which is one of the main concerns of contemporary Iranian architects, has been addressed in only a few of these studies. Therefore, further studies in this area seem necessary.

4. Explanation of types of relationships between architectural form and structure

Given the limitations and deficiencies in the existing classifications describing the types of relationships between architectural form and structure, and to address the criticisms of these classifications, a new classification of the types of relationships between form and structure is presented here, based on qualitative content analysis. This classification is provided by coding the features that are acceptable in each of these types.

a: Self-Exposing structure in form-imposing structure on form

In self-exposing structures, the structure is often designed to showcase advanced technology or for aesthetic reasons and to express the designer's tastes. In these buildings, the structure is visually emphasized and has an origin inconsistent with the needs of the form. In this case, considerations related to the type, size, shape, and organization of structural elements are mostly determined by visual criteria. The priority of visual criteria in structural design sometimes contradicts the structural logic of the formation of the structure. This issue creates problems that require specific structural responses to solve. In some cases, the self-exposing structure appears to be imposed on the form, and its display does not correspond to the architectural needs of the form for which it is designed.

b: Harmonious structure with form

The best example of this type of relationship between structure and form can be seen in natural objects. In nature, the structure is inseparable from the overall form, and the structure and form of the body arise simultaneously and spontaneously. In this case, the harmonious structure simultaneously expresses architectural ideas, and the technology serves to realize architectural ideas, not the goal of form design. In these buildings, in addition to the presence of a structural sense in the space and the acceptance of structural conditions and needs by the form, the structure helps to realize the spatial and visual ideas of the form by participating in the formation of the form and emerging simultaneously with it.

c: Forgotten structure in form

The advancement of structural technology and the freedom of designers in the stability and construction of buildings, on the one hand, and the use of computers in designing very complex forms, on the other hand, have led to the production of buildings where the form is shaped more based on visual considerations than structural ones. As a result, the overall form of the building does not necessarily relate to

its structural performance. In these buildings, the structure is merely designed as a support for the building's covering, and the forms can be constructed sculpturally without considering structural needs. In these buildings, the architect tends to create a sculptural appearance for the form that has not been seen before and, on the other hand, is functional. To explain the qualitative parameters of the interaction between form and structure, it is necessary first to state the needs of these two and examine how they participate in meeting each other's needs.

Structural Requirements

In a comprehensive classification, structural needs can be categorized into four areas (12): 1. Operational requirements, 2. Construction requirements, 3. Functional requirements, 4. Aesthetic requirements.

Architectural form requirements

In general, the needs of architectural form that the structure can participate in meeting can be categorized into three areas: 1. Semantic requirements, 2. Aesthetic requirements, 3. Functional needs.

4.1 Explanation of Qualitative Parameters and Evaluation Criteria for the Interaction Between Architectural Form and Structure

Based on the specific definition of the interaction between form and structure and the explanation of their needs, the factors influencing the realization of this interaction can be explained as follows:

1 Participation of architectural form in meeting the functional needs of the structure (structural performance). 2 Aesthetic needs of the structure (structural expression). 3 Operational needs of the structure (structural efficiency). 4 Participation of the structure in meeting the functional needs

Based on the above analysis, the qualitative parameters of the interaction between architecture and structure are expressed as follows, based on which the interaction between structure and architecture of the buildings examined in this research is evaluated.

4.2 Qualitative parameters of the interaction between architectural form and structure

As stated in Table 1, the qualitative parameters of the interaction of form and structure architecture are presented as follows:

1 Proportion of the structure to functional needs. 2 Understanding the structural behavior in architectural form. 3 Participation of decorations in higher structural efficiency.

5. Discussion

Analysis of Case Studies:

5.1 Jameh Mosque of Barsian

As seen in figure number 1, mosque and minaret of Barsian are among the most prominent architectural structures of the Seljuk era in Iran. Thanks to the inscriptions on the minaret and mihrab, the exact date of the construction of this building can be determined (491 AH during the reign of Sultan

Table 1. The characteristics and characteristics of the types mentioned in the relationship between form and structure.

	Exposed structure	Structure Consistent with Architecture	Forgotten structure
Proportions of structure to functional requirements	Structural Fit to the Functional requirements of Form Mismatch of Type, Shape, Size, and Arrangement of Structural Elements with Loads	Structural fit to structural requirements Technical knowledge of specific structural points Suitability of type, shape, size and Arrangement of elements with applied loads	Lack of Structural Participation in the Expression of Architectural Ideas Mismatch of Type, Shape, Size, and Arrangement of Structural Elements with Loads
Understanding Structural behavior in Form	Artificial or exaggerated expression of behavior in architecture The behavior of structural elements is completely contrary to the expected structural performance	Understanding structural behavior in form (the Presence of structural sense in architecture) The organization of various architectural components according to the pattern of structural behavior pattern of the building	Failure to understand the behavior of the structure in the form Architecture and structure have a completely separate origin. (Lack of structural sense in architecture)
The participation of ornaments in higher structural efficiency	The decorative or ornamental role of structural elements Low structural efficiency By removing it the efficiency of the structure becomes more	Integration of structure and decoration/ornament with high structural efficiency	Decorations apart from the load-bearing structure No effect of decorations on the efficiency of the structure

Barkiyarūq). The architectural style of Barsian Mosque is Razi, and it is designed as a two-iwan mosque with elements such as a dome, dome chamber, minaret, iwan, courtyard, and mihrab. The Jameh Mosque of Barsian is a standalone chahar-taqi (four-arched) pavilion-like structure built on the ruins of a Sassanian-era chahar-taqi.

Apart from the muqarnas, which forms the main decoration of the mihrab of Barsian Mosque, this mihrab is also adorned with brickwork, stucco, and decorative inscriptions, geometric and vegetal motifs. Architects of this period, instead of hiding the harmonious divisions of bricks under a layer of plaster, aimed to integrate and display the proportions of bricks cohesively. The inscription of Barsian refers to the exclusive flourishing of mosques by believers and their specific and general conditions.

Elaborate brickwork and various patterns and designs are major features of Seljuk architecture. The minaret of Barsian Mosque is a prominent example of the notable minarets of Iran before and during the Seljuk period. In the architecture of this mosque, the number 3 is frequently used, and even the area of the mosque is related to the number 3.

The transitional zone of the dome chamber of Barsian Mosque consists of two octagonal and hexadecagonal layers, which, using arched elements and three-part squinches in the first layer and simple squinches in the second layer, allow the transformation of the square base to a circle for the final dome covering. The amount of stress and deformation created in the building exceeds the tolerable stress, and large deformations occur in the structure. The deformations are up to six meters, indicating the building’s vulnerability to lateral loads.

The transitional zone of the dome chamber of Barsian



Figure 1. A view of Bersian Grand Mosque.

Mosque consists of two octagonal and hexadecagonal layers, which, using arched elements and three-part squinches in the first layer and simple squinches in the second layer, allow the transformation of the square base to a circle for the final dome covering. The amount of stress and deformation created in the building exceeds the tolerable stress, and large deformations occur in the structure. The deformations are up to six meters, indicating the building’s vulnerability to lateral loads.

5.2 Tehran Mosalla complex

According to figure number 2, architectural design of the Tehran Mosalla complex includes 7 domes, with the main dome being one of the largest in the Islamic world. The

height of this dome is 63 meters, and its diameter is 54 meters. The reinforced concrete walls of the dome structure are categorized into three main types: Orthogonal shear walls, radial walls, and semi-cylindrical walls. The low slope of the dome and the crenellations designed at its end enhance its formal power. The dome chamber of Tehran Mosalla is designed in a circular pattern, consistent with the dome's circular layout. The structural elements of the dome chamber are organized accordingly, strongly emphasizing the form of the dome chamber. In Tehran Mosalla, each entrance will have two minarets, an iwan, and a dome with different architecture. The large iwan between the Jameh Mosque and the main minarets is designed as a shell with a height of 72 meters and a span of 110 meters. The iwan has two minarets on either side, each 140 meters high. In this building, the lack of simplicity in the forms and structures used in a complex originally built for prayer is evident. This building attempts to evoke the image of traditional Iranian brick architecture. However, such a number of buttresses in a concrete dome is unnecessary. This dome resembles a fuel or water tank, justifying the high pressure of all these buttresses and arches.



Figure 2. A view of Tehran Mosalla Complex.

5.3 Al-Ghadir Mosque

Al-Ghadir Mosque is formed by combining two rectangular cuboid volumes with varying heights and a prismatic volume with a regular polygonal plan. These volumes are combined in such a way that the tallest volume (the dome chamber) is placed between the two shorter volumes. The men's prayer hall is a cuboid that partially overlaps with the dome chamber. The main volume of the dome chamber is a 12-sided prism with a height of 20 meters. The interior space of the main dome chamber, due to its formal needs, has elongated proportions in height, and the elongation of the pointed arches indicates an important termination point at the top. The octagonal base of the dome is seated with triangulation on the 12-sided prism. Additionally, in Al-Ghadir Mosque, brick and decorative brick patterns such as cross-shaped lattice brickwork, cornice brickwork, and geometric decorations like the use of pointed arches in the walls of the space, which are decorated with wooden frames and colored glass, are used.

Regarding Al-Ghadir Mosque, regardless of the limitations

imposed by the mosque's location on its form, three main factors determine the mosque's form: the direction of the Qibla, the Twelve Imams' Shiite thought, and the desire to reach paradise. Semantically, the form of the dome chamber mainly recalls the space of tomb buildings and roadside towers in traditional Iranian architecture. Functionally, the choice of a polygonal base close to a circle for the dome chamber has created a space that does not emphasize any specific direction. This spatial quality is different from what happens in the dome chambers of traditional mosques; in traditional mosques, entering the dome chamber and the design of the walls, the orientation of the iwan, the prayer hall, and the dome chamber were entirely based on the specific direction of the Qibla.

In the following, selected examples of architecture in this research are reviewed and their strengths and weaknesses in the interaction of form and structure are presented in the tables below.

The results of the evaluation of Tables 2, 3, and 4 show that the dome-shaped Al-Ghadir Mosque building is different from conventional dome forms in terms of structural performance and optimal force flow pattern.. Additionally, in understanding the structural behavior, the dome form and its structure have separate behaviors. Moreover, the impact of the structure on the aesthetic form of this building is reminiscent of tomb buildings, roadside towers, and dovecotes. In the analysis of the Tehran Musalla complex, there is no need for the structural performance with the dome form and the number of buttresses. However, in the arches, the structural performance aligns with the structure in stability. Additionally, the structural forms exhibit exaggerated behavior in understanding structural behavior and a tendency towards magnification and luxury is abundantly observed in this complex. However, regarding the Barsian Mosque, the integration of form and structural elements with each other and in understanding the structural behavior in the form using golden proportions (golden ratio), module, symmetry, and brickwork (the presence of structural sense in architecture) and the integration of structure and decorations and high structural efficiency (geometric brick patterns, brick decorations) can be well and fully observed (Tables 2, 3, and 4).

Finally can ultimately be observed by reviewing the results of the evaluations conducted, showing the lack of interaction between form and structure in the Tehran Musalla complex with the structure imposed on the form and Al-Ghadir Mosque with the structure forgotten in the form. Additionally, in the Jameh Mosque of Barsian with traditional architecture having structural features compatible with the form, the interaction between form and structure occurs in the best way.

6. Conclusion

In past architecture, the highest duty of the architect was to recognize, understand, and spatially visualize the static and dynamic forces in the load-bearing body of the building, which with complete mastery, precisely specified the proportions and dimensions of the filled and empty parts. In this architecture, structure and form had a simultaneous

Table 2. Evaluation of parameters in the interaction of form and structure in case studies of Iranian Architecture. Contribution of Form Decorations to Higher Structural Efficiency.

Parameters	Contribution of Form Decorations to Higher Structural Efficiency		
Case studies	Bersian Grand Mosque	Tehran Mosque	Al-Ghadir Mosque
Assessments	Geometric brick motifs, brick arrays Moqrans decorations, brickwork, plasterworks and written decorations Hadesi and plant motifs in Altars Vault latches	Resemblance to tanks tendency towards magnification and luxury in dome form. Symbolism-exaggeration and luxury in the form of arch	Wide span cover without creating a columns in the space filtering natural light downwards in the form of a dome
Results	Integration of structure and Decoration/ornaments with high structural efficiency	Lack of integration of structure And decoration with high structural efficiency	No impact internal form decoration/ornaments on structural performance and efficiency

Table 3. Structural Suitability to Functional Requirements.

Parameters	Structural Suitability to Functional Requirements		
Case studies	Bersian Grand Mosque	Tehran Mosque	Al-Ghadir Mosque
Assessments	Structural Suitability to Functional Needs (Dome House Form, Arched Structure, Vaulted Cover, and Quadrilateral and Cubic Columns) Ascending Sequence of Load-Bearing Elements from Columns, Piers, and Arches to Squinches and Dome Cracks, and Official Squinches and Karbandi.	No functional need for this number of supports in the form of a dome Lack of simplicity and purity in the religious building in the form of a dome. The form of the arch corresponds to the performance of the structure in stability Covering a wide opening for holding congregational prayers	Wide span cover without creating columns in the space Filtering natural light downwards in the form of a dome Lack of transitional stage between the roof and the base (a distinctive element in traditional dome buildings)
Results	Integration of the form and structural components with each other	Inadequacy of the structure with functional requirements	Structural Disproportion to Functional requirements

Table 4. Understanding structural behavior in form.

Parameters	Understanding structural behavior in the form		
Case studies	Bersian Grand Mosque	Mossali Tehran	Al-Ghadir Mosque
Assessments	Use of golden proportions (golden ratio), measurement(Peymoon), symmetry and brickworks with chalipa patterns, six-pointed Shamseh Optimal use of materials to control load weight, membrane stresses, tensile and bending forces from wind , temperature and the dynamic effects of earthquakes.	Exaggerated behavior in the form of domes and arches Waste in costs, long construction time	Separate emergence of structure and form
Results	Correct Understanding of Structural Behavior in Form (Presence of Structural Sense in Architecture)	Lack of understanding of structural behavior in form (lack of form following the overall structure	Lack of understanding of structural behavior in form (lack of form following the overall structure

and homogeneous genesis, and issues such as the choice of covering type, determination of force movement paths, placement of load-bearing elements, use of selected local materials, and direct intervention of geometry in a

coordinated system in the formation of building forms played a decisive role. Therefore, the presence of the structure can always be perceived as a tangible matter in the spaces of past architecture.

One of the most important reasons for the lack of interaction between form and structure in contemporary architecture can be stated as the separate design of form and structure and the lack of close cooperation between architects and engineers. The design of the structure imposed on the form and incompatible with the functional and semantic needs of the form, or in another way, the lack of participation of the structure in the visual expression of the form, the lack of understanding of the structural behavior in the building, the lack of honesty in expressing structural elements, and the lack of integration of structure and form decorations can be considered as the results of separate and incompatible design of form and structure. Imitation of famous and well-known buildings in creating today's architectural works is often seen as a formal and shape-based interpretation of these buildings. Since the superficial interpretation of these forms is done without considering the construction technology and execution, skills and available facilities, and specific considerations and conditions in the design and execution of the structure, it leads to the separate and often incompatible genesis of form and structure. Additionally, in most cases, the form elements are merely added to the building structure as decoration with the aim of creating a superficial resemblance to prominent buildings. Therefore, it is suggested to avoid mere symbolism of past forms without considering their structural logic and to avoid imposing high costs on the project and long construction times by considering factors such as attention to construction details during the design of complex forms, utilizing the advantages of prefabrication in the production of structural components, maximizing the use of available materials and facilities in the execution of large projects, avoiding exaggeration and luxury in the design of structural forms, and ultimately considering the structural logic of forms seriously from the beginning of the design.

Authors contributions

Authors have contributed equally in preparing and writing the manuscript.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interests

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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