Typology of the "Internal Form-Structure" Drawing upon Argan's Formal Approach

(Case Study: Historical Bridge-Caravanserai in Iran)

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Abstract

In the process of defining the nature of architecture, three elements recur which are indispensable components of architecture: type, function, and structure. The three can be related to the three attributes produced by Vitruvius, i.e., strength, utility, and beauty. As defined by Guilio Carlo Argan, the term 'type' applies to various levels including the formal composition, structure, and ornamental elements. In his opinion, linking typology to the technical structure turns it into a rigid foundation for formal research. Thus, the type becomes the internal structure of a form, or an element which encompasses unlimited form variations, transformation, and correction in its structure. The main questions of the research revolve around the typology of bridge-caravanserais (bridges with residential spaces) in Iran, and the idea of maintaining the continuity of old architectural traditions to employ them to meet the new requirements of such buildings. To this end, the present study attempts to provide a proper typology for the ten bridge-caravanserais under study drawing upon the levels of typology put forth by Argan. Moreover, the study examines the void space of these bridge-caravanserais as a habitable space, and also the structural function they have in decreasing the pressure of vaults and improving the resistance of bridges. Using a descriptive-analytical method, the data were collected through library and field studies. The typological findings introduce 4 different types of bridge-caravanserais. Being the most prevailing type, the first one has its spatial components (rooms) at the columns of the bridge. This type is categorized in two groups based on the number of floors (one or two floors). In the second type, rooms are located on the columns; the third type has the rooms flanking the bridge as the entrance; and the fourth type is a combination of other types.

Keywords: Typology, Argan's theory, bridge- caravanserais of Iran, structure-architecture interaction.

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Introduction

References to typology in ancient writings from about two thousand years ago can be seen in the works of architects and other scientists. Vitruvius in his famous work entitled Ten Architectural Books (from about 2000 years ago) has grouped different types of Greek buildings, including houses, temples and public buildings (Memarian, 2010: 196). In all studies conducted in the world of architecture, a type refers to a group of architectural components with a physical aspect (architectural spaces, structures, decorations, materials, etc.), which is achieved by a specific mechanism in the process of collection and categorization. This organization is based on common climatic elements, common geometric shapes, common genetic codes (genotype), and anything that can in some way represent a type so that other members of that particular type can be better identified (Memarian and Dehghani Tafti, 2017: 26). In the nineteenth and twentieth centuries, a group of scientists, like Durand in "Art and Science of Architecture", and Clark and Paz in "Analysis, Criticism, and Ideas Shaping Architectural Masterpieces", used formal typology to categorize different buildings based on the shape of their plan. (Tabatabai Zavareh et al., 2018: 103). De Quincy was one of the greatest theorists before the modern movement, whose views have influenced the foundations of typology today. In the Dictionary of Architectural History, published in 1844, he discusses types and models. In this book, a type is a design, a schema or an aesthetic, metaphysical and epistemological classification that has the potential to affect the mind of the artist, but a model is an object or idea that can be imitated and repeated as a methodical approach, used in design. In 1960, Argan provided theoretical support for De Quincy's ideas in the field of morphological and typological memory. For Argan, typology is not only a classification and statistical process. He believes that it also exists in a series of typologies, analysis and simplification of the physical functions of a building (Tafti Architects and Peasants, 2017: 23). These concepts can be used to help understand the nature of issues in the cognition phase, to draw an outline for formulating solutions in the design phase, and to find a benchmark for choosing best options in the selection phase. In many cases, the designer is confused in defining the problem. Common design types or solutions show the designer how other people deal with similar issues and can be the basis for facing new problems. Therefore, in this article, by selecting 10 examples of historic bridge-caravanserais in Iran, we will try to analyze and simplify the ideas of Argan in relation to such buildings and suggest some general solutions for designing them in the future.

Research Questions

What is the place of interaction between structure and formal composition in the discourse and theories of types and typology with morphological aspects and formal approach?

What are the types of spatial components (rooms) in the historical bridge-caravanserais of Iran?

Definitions

Types and typology

The word typology is derived from the word 'type', which is originated from 'Topos' in Greek and 'Typos' in Latin. In English, it is equivalent to the words model, exemplar, form, class, symbol, and character. This word has been combined with other words and has created new compound words. For example, the word archetype refers to the initial pattern, attribute and nature (Memarian and Tabarsa, 2013: 104). According to John Lang, a paradigm refers to a specific design or a specific type of built space. The first prototype is basically anything in architecture and open space that has become a model or standard example. Generic solution is a combination of design principles that is used as a unit of a large group or category of problems (Lang, 2009: 69). According to Rapaport, "typology is an attempt to place a set of complex objects in a regular set to achieve greater generality for cognition and planning" (Seyedian et al., 2017: 17).

Bridge-caravanserais

Iranians are the forerunners of transforming the concept of a bridge from a mere transportation route and linking it with other

side activities. As Borman writes, the bridges of the capital and important cities of Europe have no place for resting (Homayoun, 1969: 71). A bridge-caravanserai is a type of bridge that, in addition to the functions of supplying water and carrying a path, has the function of proving a residential space with a construction management process in order to reduce construction in unfavorable suburban conditions. This is achieved in a process of evolution culminated during the Safavid era (Farshid Nik and Afhami, 2010: 57). The evolution of settlements can actually be considered as the evolution of the optimal use of space. Of course, this evolution is also linked to the evolution of form and technical history (Farshad, 1983: 286).

Research Background

Combination of Transportation and Residence in the Bridge-caravanserais of Iran

Throughout history the construction of roads and highways has been one of the signs of the flourishing of civilizations, and bridge construction has been considered as an evidence of prosperity and progress of road construction (Parsi, 2007: 78). In Iran, because of the Silk Road, many roads were built and accompanied by their side facilities such as bridges for crossing natural obstacles and caravanserais for providing a resting place and responding to the needs of travelers. In the first examples, at the end of construction process, side walls or blockers were built to hide the empty spaces. Gradually, in the construction process, different applications were considered for these empty spaces (Bustani, 2001: 380). Kashkan Bridge, which was constructed in the Sassanid period and reconstructed in the fourth century AH, has rooms in the empty spaces of its foundations that are connected to each other. Moreover, the architect of this bridge has built a room and a place for keeping animals in the space on both sides of the sharp arches (Ibid: 143). Regarding the aesthetics of its body, a length of about 325 meters, a height of 26 meters and a width of 11 meters, has made it necessary to use an advanced lightening method. In order to show the strength and sturdiness of the bridge, the facade of these empty spaces has been covered, and a solid and majestic appearance has been created for it (Sajjadi, 2003: 261). In the Timurid and Ilkhanid periods, it was customary to add buildings on both sides of the bridges. At that time, Tabriz was considered as one of the important highways on the Silk Road. In Ajichai Bridge, rooms were built at the base of the bridge, which was used as a caravanserai resort (Delavaleh, 2001: 151). Prior to the Safavid period, we do not see any extensive experience regarding building bridges within cities, and most bridges were built on the suburban routes or across the rivers and valleys. Perhaps the most important event of this period is the emergence of urban bridges. Examples of these bridges in Isfahan are considered as masterpieces of bridge construction and architecture. The importance of these bridges is not only because they are located in the center of the city, but also because they are used as urban spaces. Bridges in Isfahan were not only used to cross the river, and instead of keeping people away from water, they provided them with a good place to stay and enjoy the flow of Zayandehrood (Parsi, 2007: 78). The ideas that shaped the Khajoo Bridge based on the principles of architecture (functional, structural and physical system) have been a continuation and evolution of previous ideas. In fact, the Khajoo Bridge is the result of paying attention to these principles along with the emergence of creativity that previously existed in the historic buildings of the region. Furthermore, the structure of Iranian bridges, the existence of many functions, the ability to respond to different needs, and most importantly the way human beings used them and dealt with different aspects of life, especially their recreational needs, were influential in the construction of this bridge (Moravej Torbati et al., 2013: 68).

In the Afsharid and Qajar periods, the construction of bridge-caravanserais continues, but there is no innovation in these experiences. Perhaps the only evidence remained from the bridges of Afsharid period is a photograph taken by Nasreddin Shah Qajar's special photographer from Arghavanshah Bridge, located in Kalat Naderi, with the caption: "A soldier's place is

built at the two piers of the bridge, and three military rooms are on the bridge" (Mokhlesi, 2000: 76). Bridge-bazaars of Tabriz are also a continuation of this idea. Some of these bridges, which were the economic centers of the city, date back to the period of Nasreddin Shah. Most likely, with the prosperity of Tabriz Bazaar during the Qajar period, people tried to use the space on the bridges as a market, and as a result, bridge-bazaars were built. However, it seems that these bridges were only bridge-bazaars, not roofed bridges. Another important reason for this idea is that the roof domes of these bridges need supports on both sides to stand still, and a thin ridge on both sides of the bridge cannot withstand their weight. Therefore, the existence of cells on both sides was necessary for resistance (Navari et al., 2009: 107). In general, the factors affecting the formation of bridge-caravanserais are as follows:

- Water supply: This factor can be considered as the first reason to build bridges and caravanserais together and combine them together.
- Saving materials: By having empty spaces inside a bridge pier, in addition to lightening the structure, material consumption has been decreased. Moreover, the combination of bridges with caravanserais, which means the combination of two buildings with each other, should be considered as an important economic motivation in shaping bridge-caravanserais.
- Structural issues of bridges: One of the factors that made it possible to use the spaces inside the structure for housing are the special methods used by Iranian architects.
- Creating suitable climatic conditions: In the studied bridge-caravanserais, it can be seen that in temperate climates, the connection with nature has increased, in the samples that have been constructed in cold regions, this connection has been minimized, and in samples located in the hot and dry climate, such as Khajoo Bridge, this connection and use of nature has become a turning point in design.
- Responding to aesthetic aspects: This factor has always been the focus of Iranian architects, which is culminated in the intercity bridges of Isfahan, for example in Khajoo Bridge and Si-o-se-pol. In these bridges, despite the general function of a bridge to keep people away from water, there is a connection with the flow of river that creates aesthetic pleasure (Farshidnik and Afhami, 2010: 64).

In order to classify different habitable spaces in the historical bridges of Iran, before entering into the discussion of theoretical foundations, we will discuss the methodological background of researches conducted on the subject of typology and morphology in the field of architecture.

Typology and morphology in Architecture

The results of contemporary research in the typology discourse show many contradictions in defining the nature and concept of types and typology in architecture as a simple and general picture that represents a group of buildings. In these definitions, some viewed them in formal aspects and some others have focused on their conceptual and intuitive dimensions (Table 1).

Shape is a tool of architectural expression, but some architectural researchers have equated it with every aspect of architecture. Their view of the subject is quite formal. Here, the shape is considered in its geometric sense. Formal approach in architecture has a history of two hundred years (Memarian, 2010: 9). In the early nineteenth century, Durand used formal typology to classify different buildings based on the shape of their plan (Memarian and Dehghani Tafti, 2017: 23). The use of typology in the study of architecture continued earnestly until the early twentieth century. About two hundred years after Doran, Rob Krier followed his method and interpreted typology as a way to unify the architectural form of cities. The result of his work was the classification of historical buildings based on the type of shape and their changes (Memarian, 2010: 9).

The idea of classifying buildings based on their similarities has been practiced in Iran for about three decades. In general, the function of the building, the shape of the plan and a similarity between a particular building element has been the basis of typology in the studies conducted in Iran (Memarian and Tabarsa, 2013: 106). It seems that providing a clear framework to achieve types is the main problem of these studies.

	Theorist	Theory on Type and Typology	Area of emphasis in the definition and nature of type
Material, physical and morphological aspects	Durand (1830)	Classification of basic forms, formal composition, quantitative and mechanical definition	Formal aspects and its composition
	Walter Gropius (1920)	Application of the concept of prototype in mechanical reproduction of industrial and architectural products	Formal aspect and its abundant reproduction
	Muratori (1948)	A set of physical components representing a group of objects, historical-evolutionary perspective	Material and physical nature and determinism, attention to the course of time
	Argan (1960)	Analysis and simplification of the configuration and physical functions of the building	Formal and functional aspects
	Kaninja (1963)	A simple and general picture in the minds of past architects as a representative of a group of buildings, historical-evolutionary perspective	Material and physical nature and determinism, attention to the course of time
	Rossi (1966)	An intermediary tool for formal analysis	Morphological and formal aspects of the building and anti-historical stance
	Rob Krier (1975)	An Explanation of the continuity of form and structure, form composition as well as styles, forms and types of classical architecture independent of the concept of development and evolution	Formal aspects, historical stance
Immaterial, metaphysical and conceptual aspects	De Quincy (1844)	An aesthetic, metaphysical and epistemological classification or schema	Intangible, non-physical and mental aspects
	Aymonino (1965)	Understanding the sustainability of a particular type in the evolution of cities	Functional aspects and contradicting the formal aspect of type
	Ardalan and Bakhtiar (1973)	Archetype as a reality in the world represented in different forms	Originality with semantic and metaphysical aspects
	Monto (1978)	A basis according to the intrinsic and structural similarities of a group of distinct objects, a means of relating the past to the future including context and culture	Formal, physical, conceptual and immaterial aspects
	Colquhoun (1981)	Knowledge of past solutions that is accompanied by aesthetics, needs and experiences	Intuitive, metaphysical, and past experiences
	Standman (1983)	Presenting both genetic and physical types in the form of explanatory graphs for understanding cultural and social issues	Cultural and social aspects and morphology

T1. Different contemporary theories on the definition of type, typology and its nature (Memarian and Dehghani Tafti, 2017).

Based on the existing theories in the discourse of typology, the view of Argan – analysis and simplification of the configuration and physical functions of the building with emphasis on functional and formal aspects– has been used to classify habitable spaces (rooms) in the historical bridges of Iran.

Research method and Collection of Statistical Population

In this study, in order to analyze the formal approach of Argan in the historical bridge-caravanserais of Iran, a descriptive-analytical method was adopted. The data and basic information of the study were collected by library studies (study of documents, books and articles) and in some cases, by redrawing the plans. The research tried to study and present an analytical typology of historical bridge-caravanserais in Iran in a statistical population of 10 samples from the Sassanid, Timurid and Safavid periods. According to the evidences extracted from travelogues, books and documents, these samples are among the few bridges that had a place for residence. After examining and explaining the formal approach of Argan theory, the samples were accurately evaluated. At the beginning, for having a better comparison and identification, the visual documents of the samples were put together in tables and examined descriptively. Then, in order to achieve the objectives of the research, the typological levels of Argan, including shape composition, structure and decorative elements, were compared and analyzed.

Theoretical Principles of the Research

Explaining the formal approach based on Argan theory

Although a single definition can be found for a type, in practice it has found different definitions depending on the views of the researchers who define it. A type is a schema in which the common features of a group of buildings can be seen. The main question here is where to find these common features. Can they be found in the type of materials; in the format of the plan; in the shape of the covering; in common climatic conditions; in the number of floors; or in other features. Each researcher has chosen one of these features for their typological work. These views can be categorized into formal and semantic views (Memarian and Tabarsa, 2013: 106).

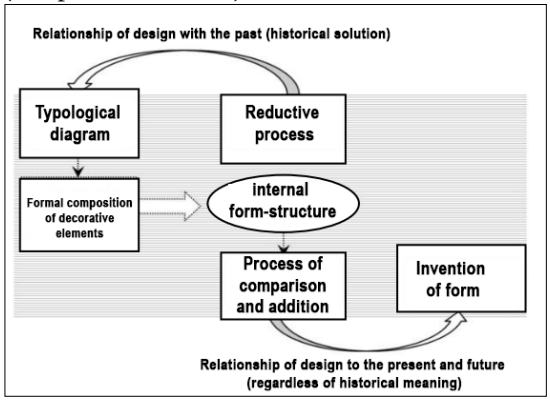
In defining the nature of architecture in the

postmodern discussion, we are repeatedly confronted with three elements, none of which can be excluded from architecture: type, function, and structure. These elements can be related to the three attributes produced by Vitruvius, i.e., pleasure (beauty or ideal shape), utility (function or habitation), and strength (durability). A type is mostly related to two other terms: to function through functional types [building] and to construction through a variety of building systems. Meanwhile, typology can be considered as general architectural solutions. In this way, a type may be something as Derrida has called "architectural architecture" (Nazbit, 2014: 72). Some postmodernists, including Argan, avoid choosing between imitation and innovation in the creation of form by acknowledging that a collection of different pre-existing types exists. Innovation plays an important role in the design process because types are too general (and out of style) to be imitated. A type thus becomes the "internal form-structure" or a principle, which have the possibility of infinite form variation and modification in its structure (Argan, 1963: 565). Types (against the judgment and selection of a particular historical building as a pre-existing example) provides a logical and valuable starting point from which a design method can be devised to create metamorphosis (Nazbit, 2014: 72).

In Quatremère de Quincy's definition of type and model mentioned earlier - and Argan presented his theory based on his view - a model is something that should be repeated as it is. A type, however, is something "in which any artist can conceive works of art that may have no resemblance". "This is what has happened in architecture. In every country, the art of regular building is born of a preexisting source. Everything must have an antecedent. Nothing, in any genre, comes from nothing, and this must apply to all human inventions." This primary principle is the nucleus with which the developments and subsequent changes of forms are coordinated." In the definition of De Quincy, in which type is defined as "more or less vague", three aspects of type assume prominence; type is against model, type is conceived as the result of a long tradition (everything must have an antecedent); and a type is able to change (altered, modified, and evolved) (Leupen, 1997: 133). The role of an architect is to transform the ideal or nature [of a building], which is the very type, into a physical model. Sola Morales calls this process as design figuration. Others combine the typological ideal with practical aspects of construction techniques, sometimes taking into account the characteristics of local buildings in the area. Guilio Carlo Argan, an Italian art historian whose theory opens the space for the development of new types, suggests to combine type and construction to form a new starting point for design (Nazbit, 2014). (73) According to Argan, who revived the writings of Quatremère de Quincy in the 1960s, it is the "internal structure of a form" (internal form-structure) that unites works based on the same type (Leupen, 1997: 133). In his view, type is an abstract concept of a set of buildings and is derived from the characteristics of their common structures. "In the process of comparison and formulating each of the shapes for determination of type, specific features of buildings are omitted and those which remains are elements that create the unity of these collections. Therefore, a type is represented as a diagram, which is reached in the process of reduction, and is related to the totality of the shape changes in the common basic form. If a type is the result of this recursive process, the resulting basic form cannot be considered a framework of pure structures, although it can be thought of as an internal or original form-structure that carries within itself infinite deformations and even structural modifications in relation to the type itself." In contrast to the functionalist understanding of type, Argan redefines type in relation to experience and tradition. In his definition, features related to typological design are dominant –features that are only implicitly present in the definition of De Quincy. Argan therefore emphasizes the distinction between two moments in architectural design: the moment of the process of type formation and the moment of form specification (Figure 1).

Argan describes the process of formation, the phase in which the type is specified and

developed further, as a "process of comparison and addition". Here the basic form common to a series of buildings is derived by reducing that series, and is rendered as a typological diagram. This basic principle, the internal form-structure, contains the possibility of endless variations in from and even of structural modification. once chosen as the foundation for a design, according to Argan, the typology diagram loses its historically determined meaning to become available for the further development and form specification of that design. In the second moment, form specification or invention, the design transcends the typyological diagram and with it all solutions credited to the historical type. This invention of form is the designer's answer to the specific demands made of the design (Leupen, 1997: 138).



F1. Typological diagram based on Argan's Theory (Source: Authors).

For Argan, types almost like prototypes are reduced to a basic common form with perfectly distinctive formal and functional features from the specific works of a culture. His theory makes it possible to create new types parallel with social, cultural and technological changes. Thus, in Argan's view, type is a principle and rule that makes diversity possible rather than a priori set of fixed entities. According to him, a type is applied at different levels such as shape composition, structure and decorative elements. Argan concludes that linking typology to technology will make it a solid foundation for formal research.

Selection of Research Typology Criteria based on Argan theory

Study of physical elements (shape composition, structure and decorative elements) in Bridge-caravanserais

The definition of Argan in this study is the criterion of developing a typology for different bridge-caravanserais of Iran. In his definition, a type is applied at different levels such as shape composition, structure and decorative elements. Based on the proposed definition of type, documents of 10 bridge-caravanserais –a few examples that contain spaces for residence– from the Sassanid, Timurid and Safavid periods were studied, and their formal composition, structure and decorative elements are examined and analyzed (Table 2).

Perhaps, this much interdependence that exist between structure and architecture in bridges cannot be found in any other type of building. One of the important structures determining the shape of a bridge is pier. Bridge piers used to have two parts: The lower part that was into the water and the upper part that formed the main body of the bridge. In designing, the lower part was called "breakwater" and depending on the water dynamics, it was designed in a triangular shape with sharp points or with a semicircular shape (Parsi, 2007: 81). In some cases, this lower part had a polygonal shape. Although there are different types of arches in Iran, only a few of them, including *Holochin* or *Biz*, gothic, *Chamana* and four-section arches, were used in bridges. To flatten the surface of the bridge, it is necessary to fill the recess behind the arches or between the arches of the bridge spans and piers. This way the pressure on the piers is minimized, and landslide can be avoided. To do this, some trenches, called *Kano* or *Keno*, were excavated on the piers, and often perpendicular to them. In addition to preventing arches from slipping, Kano was also considered as a good earthquake-resistant structure (Mokhlesi, 2000: 105). Konos were very influential in the shape and beauty of the bridges and were sometimes used for decoration. On some of the bridges, for both structural and aesthetic reasons, Kanos were built on two floors.

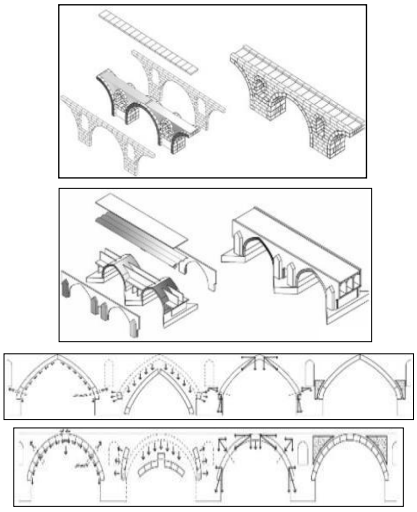
		Bridge-caravanserais of Iran										
		Anbouh	Manjil	Jouei	Si-o-se Pol	Khajoo	Kashkan	Mashir	Shahrestan	Ajichay	Poldokhtar
General features	Location	Roudbar/Anbouh village	Manjil/Sefidroud	Isfahan/Zayandehroud	Isfahan/Zayandehroud	Isfahan/Zayandehroud	Tarhan-Shapourkhast Road	Shiraz-Booshehr Road	Isfahan/Zayandehroud	East Azerbaijan/Talkhehroud	Mianeh-Zanjan/Ghezelozon River
	Period	Safavid	Safavid	Safavid	Safavid	Safavid	Sassanid	Safavid and Qajar	Sassanid, Daylamites, Seljuk, Safavid	Ilkhanate or Timurid	Timurid
	History Reg.	-	-	1305	110	111	335	2411	889	-	87
	Length	60	-	147	295	131.5	320	130	105	100	120
	Width	7	-	4	13.75	11.65	20.23	10.5	4.25-5	5	10
Structure and formal composition	Plan type	1-floor 1-span	-	21-span	-	-	12-span	6-span	11-span	16-span	3-span
		2- floor -	7-span	-	32-span	21-span	-	-	-	-	-
	Breakwater	-	Triangular	Triangular	Semicircular	Triangular	Semicircular	Triangular	Semicircular	Semicircular and Triangular	Triangular
	Materials	Pier: Stone and Sarooj	Stone and Sarooj	Cut stone and Sarooj	Stone and Sarooj	Large stones	Large cut stones	Stone and plaster	Stone and Sarooj	Carved tombstone, cut stone, river rubble	Rubble, cut stone and Sarooj
		Body: Brick and plaster	Brick and plaster	Brick and plaster	Brick and plaster	Brick and plaster	Crushed stone, brick and plaster	Brick and plaster	Brick in the roof, adobe in the body	Brick, stone and plaster	Brick and plaster
	Roof of spans	Chevron	Chevron	Chevron	Chevron four sectional	Chevron	Chevron	Chevron	Circular	Chevron	Chevron
	Corridor	Hidden -	1-floor	-	2-floor	2-floor	1-floor	-	1 floor above piers	-	1-floor
		Visible 1-floor								1-floor	
	Room construction	On piers	Inside piers	In the middle of bridge between piers	Wide corridors in the lower floor; a corridor, a small porch and rooms in the upper floor	Long corridors in the lower floor; sidewalk, rooms and a recreational resort in the upper floor	Several connectable rooms on piers; rooms and a place for animal on the two sharp sides of the bridge	In two entrances of the bridge	A toll-house in located across the north (bridge entrance)	In piers	Inside piers
	Signpost	-	-	-	-	-	-	Has	-	-	-
	Back support	Has	-	Has	Has	Has	None	Has	None	Has	Has
Decorative elements	Parapet	In balconies facing the river	Has	Has	Has	Has	Has	Has	Has	Has	Has
	Epigraph	-	-	-	-	-	Kufic script	-	-	-	Naskh script in the brick epigraph and Nastaliq script in the stone epigraph
	Decorations	None	None	None	Without specific decorations	Tiling in the roof and paintings in the rooms	None	None	None	Tombstone engraved with Quran extractions and flowers	None

T2. General features, formal composition, structure and decorative elements of Bridge-caravanserais under study.

Laying shafts on the bridge piers was another way to control landslide by dividing the thrust force of arch spans in two vertical and horizontal forces. The vertical force is offset by the reaction force of the foundations, but visible components such as a narrow-column shaft are used to reduce the horizontal compressive forces, creating an additional force. The construction of a support on the foundations was another way to eliminate the thrust force from the arches (Mokhlesi, 2000: 111).

In some of the bridges, the tasteful architect, in order to reduce the pressure of the arches and at the same time use the space on both sides of the sharp arch, constructed a room and a place for keeping animals that was accessed by a staircase. (Mokhlesi, 2000: 109). Structural features the type of materials, and the special methods used by the Iranian architects are among the important features that have created empty spaces inside the Iranian bridges and led to the functional utilization and the possibility of using them for housing. Moreover, omitting the need for supports and anti-thrust forces that were

made possible by the use of sharp arches instead of Roman curved arches (Figure 2) and also the negative factor of this action (i.e. the increase of the height of the arch and the creation of space that needs to be filled in the distance between the two arches) led to a change in the structure of bridges and the use of empty spaces. In addition to creating a usable space, this action also increased the resistance of bridges against the forces caused by floods and earthquakes by reducing the pressure of the arches on the piers (Farshidnik and Afhami, 2010: 64).



F2. Comparison of Iranian and Roman Arch in providing empty spaces (Source: Farshidnik and Afhami, 2010).

Although in various architectural works, we see many valuable decorations and designs created by Iranian architects with the help of bricks and tiling, except for a few examples, tile and brick is not used as decorative elements in bridges; and architects tried their best to use simplest solutions available for decoration. For example, they created several holes or jutted some bricks for making contrasts of light and shade (Table 3) (Mokhlesi, 2000: 118).

Proposed Typology according to the Research's Basic Definition of Type

The concept of a bridge-caravanserai is the use of empty spaces within the bridge structure in order to permanently access to rest inside it" (Della Valle, 1991, 151). In Manjil Bridge, under the bridge and inside water resources, reduce construction in suburban unfavorable conditions, avoid expensive installations and meet the need for roadside care. The construction of these bridges was made possible by the structural system of Iranian architects in the construction of bridges. This structural system advocated the consumption of less materials and lightweight structures in the construction of bridges by having hollow spaces inside the structure. Over time, and in the course of their evolution, bridge-caravanserais responded to more functional needs, and by exploiting different climatic conditions and aesthetic qualities, they provided continuous experiences culminating in the Safavid period. The continuation of experiences in the classic architecture of Iran has always existed in a traditional way. The preservation and continuation of these traditions in order to meet new needs is the basis for the recreation of original works, which are at the same time accepted by society. According to Argan, a type can become the internal structure of a form or principle that includes the possibility of endless variations in from and modification in its structure. The internal structure of the form can be shown in the form of a diagram, which is taken from the common structural features of a set of buildings and reached in a reductive process of elimination and comparison of the special properties of the building. According to this definition, by examining and analyzing the empty space as a usable space in the studied bridge-caravanserais and the role of their structures in reducing the pressure of the arches and increasing resistance against incoming forces, these bridges can be typologized according to the location of the rooms (usable empty spaces) (Table 4).

Type 1: Spatial components (rooms) inside the piers

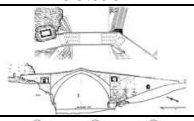
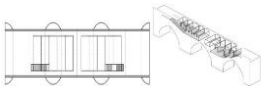
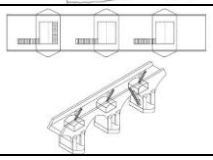
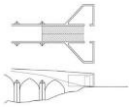
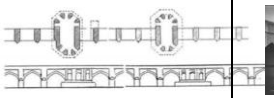
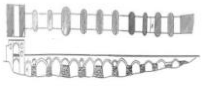
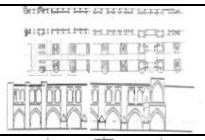
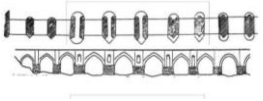
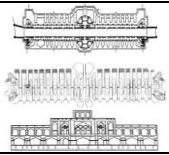
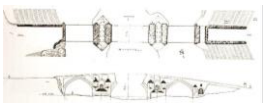
In this type, rooms are located in the bridge piers. In Ajichai bridge, these rooms were used as caravanserais. Pietro Della Valle wrote about the creativity of Iranian architects in Ajichai Bridge: "One of the spans has a small room so that travelers can

most of the piers, rooms have been built with domed roofs. There is also a kitchen which

can be descended through a small staircase to reach the water. In fact, these rooms were like caravanserais and used for stopping and resting of travelers. In the travelogue of Mirza Mohammad Hossein Farahani, a historian of the time of Nasereddin Shah, it is written that these rooms were used as customhouses. In fact, the bridge has been completely transformed into an inn with welfare facilities, and the connection between nature and space answered functional and aesthetic problems. In this bridge, we can see the beginning of the formation of the idea of bridges as a space with two floors and two different functions. Each of the inner-city bridges can be considered as the point of evolution of one of the ideas used in the outer-city bridges. Joui Bridge can be considered a repetition of the idea of Manjil Bridge, but in this case, the spaces of the room have become an influential element on the form and have changed the appearance of the bridge.

Type 2: Spatial organs on the bases in the space between the two sharp arches

This type is evident in bridges where the rooms are placed on the bridge piers in the empty space between the two sharp arches to reduce pressure. In Kashkan Bridge, the empty space on the bridge piers has created several interconnected rooms. The architect of this bridge has built a room in the space on both sides of the sharp arches. In Anbouh bridge, which was built with only a wide and high span, arched rooms are located on top of the foundations to lighten the load of the foundations and save materials. The rooms and small openings below the level of bridges were used as inns and lodges by caravans (Bustani, 2001: 143). Anbouh bridge shows a very important evolution in the view of the bridge as a place of residence. In both rooms constructed for this bridge, not only the features of the shelter have been considered, but also the constructed rooms have porches at the entrance of the east and west walls, so that the view of the room can be used for residents. Furthermore, it is clear that the construction of living spaces is not only for using empty spaces, it is a part of the bridge design process. This is evident in establishing a connection with both sides of the bridge, combining open and semi-open spaces and providing access from the bridge surface, which seem to have evolved more in Manjil Bridge (Farshidnik and Afhami, 2010: 62).

Case study	Plan and perspective elevation	Picutre	Case study	Plan and perspective elevation	Picutre
Anbouh			Kashkan		
Manjil			Mashir		
Jouei			Shahrestan		
Si-o-se Pol			Ajichay		
Khajoo			Poldokhtar		

T3. Analysis of 10 Bridge-Caravanserais based on plan and perspective elevation (Source: Authors).

Type	Location of rooms	Example		
First type (or two subtypes with one and two floors)	Inside piers	Two-floor	Manjil	Connecting the rooms with small staircases down to the water Increasing the connection between nature and space to answer functional and aesthetic problems The beginning of the idea of having two-floor bridges with two different functions
		One-floor	Ajichai	Construction of rooms on a number of piers to be used as caravanserais
			Joui	Repetition of the idea of Manjil Bridge (connecting rooms via staircase down to the water) Transforming room spaces into an influential element on the form and the appearance of the bridge
			Poldokhtar	The two middle pillars of the bridge with Gothic-style surfaces and a room in the middle
Second type	On the piers between two sharp points of vault	Kashkan		Multiple interconnecting rooms in the empty space inside the bridge piers
		Anbouh		Having a balcony with the possibility of using the view Living space as part of the bridge design process Connecting the both sides of the bridge, combining open and semi-open spaces and providing access from the bridge surface
Third type	On the two sides of the bridge to have a better connection with riverbanks and to act as entrance	Moshir		A combination of beauty and engineering Better connection of the room with the riverbank and definition of entrance Weight from the rooms: increasing the force on the bridge to react to the water thrust force and ensure the beauty of the bridge
		Shahrestan		Repetition of Moshir idea
Fourth type	A combination of other types	Si-o-se Pol		Repetition of ideas of Ajichai, Moshir and Shahrestan The evolution of the bridge entrance in Iranian architecture and its transformation into an index element Arranging and combining functional elements and creating a space for communication to the lower parts of the bridge: Functional organization
		Khajou		Organizing the bridge as an element beyond function The middle space called Biglarbeigi Going beyond the linear structure of the bridge and providing numerous visual and spatial experiences

T4. Proposed typology of research based on Argan's definition (Source: Authors).

Type 3: Rooms on both sides of the bridge as entrance

The rooms are located on one or both sides of the bridge for better communication with the riverbank, in terms of architecture and structure. Moshir Bridge is a combination of aesthetics and engineering. Here, the weight of rooms, in addition to increasing the force applied to the bridge to counteract the thrust of water, also provides the beauty of the bridge. Shahrestan Bridge located across Zayandehrood, with eleven spans and a road office can show a picture of the structure of Moshir bridge.

Type 4: Combination

In this type, in the structure of the bridge, the rooms are seen as a combination of the previous two or three types. In Khajoo Bridge, the presence of a middle space called *Biglarbeigi*, going beyond the linear structure of bridges and having various visual and spatial experiences are the turning point of an evolutionary process. The structure of the bridge system is a repetition of the ideas in Ajichai Bridge (rooms inside the foundations), Moshir and Shahrestan (rooms on both sides of the bridge) and shows the evolution of the bridge entrance in Iranian architecture and its transformation into a significant element. Arranging and combining functional elements and creating a space for communication to the lower parts of the bridge can be considered as organizing the function of providing passage in bridges.

Conclusion

According to Argan, linking typology to technology will make it a solid foundation for formal research. The type thus becomes the "internal form structure" or principle that includes the possibility of endless variations in from and modification in its structure. Argan's attitude is generally related to the design process and the production of works. In this approach, the typology stage shows the relationship between design and the past, and the innovation stage (design) indicates the relationship between design and the present and the future. These concepts can be used to help understand the nature of issues in the cognition phase, to draw an outline for formulating solutions in the design phase, and to find a benchmark for choosing best options in the selection phase.

In this study, in order to investigate the formal approach of Argan in the bridge-caravanserais in Iran, 10 examples of historical bridges that contain spaces with the use of habitation were analyzed. Findings indicate that these bridges fall into for types:

(1). Spatial components (rooms) are inside the bridge piers. This type is divided into two subtypes depending on the number of floors. (2) Spatial components are on the bridge piers in the space between the two sharp arches. (3) Rooms are on both sides of the bridge as entrances. (4). There is a combination of the previous two or three types.

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