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The Isfahan's inhabited arch bridges

Les ponts habités d'Ispahan

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## **ÉTUDE DES PONTS HABITÉS À ISFAHAN**

### **STUDY OF INHABITED BRIDGES OF ISFAHAN**

Ispahan est l'une des villes historiques qui se trouve au centre d'Iran. La ville est célèbre pour sa belle architecture islamique, ses ponts couverts, ses mosquées uniques et ses minarets. Cela a fait d'Ispahan le titre de "la moitié du monde" dans la culture populaire. Les cinq ponts historiques Zayandeh Rud à Ispahan sont un chef-d'œuvre de l'architecture iranienne, conçus non seulement pour le passage des individus, mais aussi pour traverser les confins de ce monde. La compréhension des valeurs matérielles et immatérielles existant dans les ponts historiques d'Ispahan afin de les protéger est l'un des objectifs principaux de cette thèse. La compréhension des techniques de construction des ponts-arcades à Ispahan et ses changements au fil du temps est autre but de cette recherche qui montre l'intelligence et les talents des Iraniens dans la construction de ponts, non seulement en tant que lieu de passage, mais également en tant que lieu de réflexion, de divertissement et de rassemblement, ainsi qu'une structure technique telle que barrière permettant de contrôler l'écoulement d'eau.

Isfahan is one of the historic cities in the center of Iran. This city is the third most populated city of Iran which is also rich in history, art and architecture. The largest river of Iranian Plateau in central part Iran which name is Zayandeh-Rud also crosses Isfahan and from the past to the present day, this river played an important role in the formation of the civilization and development of the city of Isfahan. Therefore, due to the constant development of Isfahan throughout history, as well as the existence of a Zayandeh-Rud flow, numerous bridges were built with a various function in this city. These bridges were designed to connect water, wind, nature and the human being in a particular architectural concept. They were not just designed for passage of the individuals or just for connecting two banks of river, but their purpose was also to link spiritual advancement and human understanding. They have been designed in the way which makes the pedestrians to stay, watch the beauty of nature, listen to it and think. Since the Isfahan's bridges have different functions, they can be categorized into inhabited bridges.

**Les mot clés:** L'Iran, L'Isfahan, Les ponts habités, Les ponts Européens, pont Khaju.

**Keywords:** Iran, Isfahan, Inhabited bridge, European bridges, Khaju bridge.

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# Chapter I

## Résumé

À travers l'histoire humaine, la construction de ponts sur les rivières et les vallées relie différentes régions et parties, facilitant ainsi les relations entre les sociétés. Cette action de construction civile était si simple et fondamentale au début. Des matériaux et techniques élémentaires ont été utilisés pour leur construction, mais son processus de maturité des temps anciens jusqu'à présent a conduit à la construction de bâtiments immanents. La fonction principale d'un pont est de relier deux points différents pour franchir une barrière naturelle, le plus souvent une rivière. Les ponts habités sont une évolution de ce concept de base. Pour ces ponts, les constructeurs et les architectes remplissent d'autres fonctions afin de mieux répondre aux besoins de l'administration ou des citoyens de la ville. Ceci est fait en développant des environnements pour que les personnes habitent ou utilisent pour l'exercice de leurs professions en plus d'être juste un point de passage. Les ponts habités peuvent avoir diverses fonctions, notamment résidentielles, commerciales, industrielles, religieuses et militaires.

## Introduction

Through the human history, bridge construction on rivers and valleys connects different regions and parts and as a result they facilitate relation between societies. This civil building action was so simple and basic at the beginning. Elementary materials and techniques were used for their construction, but its maturity process from the old ages till now has led to construction of immanent buildings. The main function of a bridge is to connect two different points to cross a natural barrier, most often a river. Inhabited bridges are an evolution of that basic concept. For these bridges the builders and architects provide other functions so as to respond more and more to the necessities of a city's administration or citizenry. This is done by developing environments for people to inhabit or use for the execution of their professions in addition to just being a crossing point. The inhabited bridges can have various functions such as, residential, commercial, industrial, religious and military functions.

The concept of the inhabited bridge is defined in Living Bridges, The Inhabited Bridge, Past, Present and Future, as following:

*“An inhabited bridge in addition to its primary function of surmounting natural or man-made obstacles, be they rivers or canals railways or motorways-serves as an organic link between two urban areas by connecting them to each other with a development of buildings erected on the bridge deck to form permanent accommodation for various social and economic activities”.* (Cadman & Stevens & Murray, 1996)

It should be noted that the dominant function of old European inhabited bridges was a commercial function. Contrary to the European inhabited bridges, the Iranian inhabited bridges were not constructed mainly for commercial aims. They have other different functions like social and industrial functions and also they provided the temporary accommodations for the Caravans and travelers.

It should be mentioned that social functions are one of the main functions of Iranian inhabited bridges. The Iranian designers intended that the bridge create a new public space where people would gather as a community. There is no precise evidence of the first inhabited bridges in Iran, but the oldest bridges with several functions date back to the Sassanid era. These bridges were mostly considered as engineering structures which were used as dams for controlling the water flow.

Isfahan is one of the historic cities in the center of Iran. This city is the third most populated city of Iran which is also rich in history, art and architecture. According to the researchers, the city was built by the Aryans, who came around 2000 BC to the central part of Iran. The city grew considerably between 1050 and 1722, especially in the 16th century, because it was named the capital of Iran at the Safavid period. The city is famous for its beautiful Islamic architecture, its covered bridges, its unique mosques and its minarets that gave Isfahan the title of "half of the world" in Iranian culture.

The largest river of Iranian Plateau in central part Iran which name is Zayandeh-Rud also crosses Isfahan and from the past to the present day, this river played an important role in the formation of the civilization and development of the city of Isfahan. Therefore, due to the constant development of Isfahan throughout history, as well as the existence of a Zayandeh-Rud flow, numerous bridges were built with a various function in this city. These several bridges have been constructed to meet the needs of the people throughout the history of urbanization of Isfahan. Nowadays, there are five historic bridges on Zayandeh-Rud river in Isfahan which are masterpieces of Iranian architecture. These bridges were designed to connect water, wind, nature and the human being in a particular architectural concept. They were not just designed for passage of the individuals or just for connecting two banks of river, but their purpose was also to link spiritual advancement and human understanding. They have been designed in the way which makes the pedestrians to stay, watch the beauty of nature, listen to it and think. Since the Isfahan's bridges have different functions, they can be categorized into inhabited bridges. Among Isfahan inhabited bridges, Khaju bridge and Si-o-se pol ("pol" means bridge) have particular importance.

The bridges of Isfahan don't have a principal commercial role. According to historical documents, the only economical aspect of the bridges was paying the toll by the caravans which passed thorough the bridge. This issue has been mentioned in living bridge book as well:

*"Inhabited bridges seem to be rare in the Middle East and in Asia. To date, the most elaborate known example is the Iranian barrage bridge in Isfahan, which call Khaju bridge. This bridge has Constructed in the seventeenth century and it served a number of functions: a passage over the Zayandeh Rood a dam, and a place for guests to view aquatic and traditional*

*festivals. However, despite the fabulous of its architecture and engineering, it lacks the provision of commercial”.*

Unlike the European inhabited bridges, whose commercial aspect was the main purpose of creation of multifunctional bridges, Iranian ones didn't have a special commercial function. That constitutes a huge difference between European and Iranian inhabited bridges. Khaju bridge and Si-o-se pol, however, are the exception to this subject. These two bridges had a crucial role in economic growth of Isfahan in Safavid period. They were not only a place for crossing or leisure, but also they are protraction of main commercial axis of the city.

### **Literature review**

Iranian inhabited bridges have existed for a long time, but this issue has received negligible attention by architects and researchers as a result of which less research has been done and also much has not been published. The main issue of interest to the researchers has been the architectural part of the arch bridges in Iran, which has led to the neglect of their historical and functional aspects. As a result, the reasons of the formation of these bridges have remained hidden from view.

In the article which had been written by Doctor Afkhami (2010), the different functions of Iranian inhabited bridges have been pointed out, together with the reasons explaining why researchers have ignored the motivation behind their construction. This ignorance comes out as being especially strange as for what regards Isfahan, which has the best examples of inhabited bridges. Pournaderi (2013) has mentioned only architectural features and aspects of the Isfahan bridges in his book, vastly disregarding its historical motivations and value. The other sources in the field of historical bridge studies have focused more on architectural aspects and have overlooked other aspects.

This is not entirely these researchers' fault, as there is a lack of historical resources and information at the origin. In historical documents only the individuals and kings who ordered the bridges to be built had been recorded and unfortunately, no architects or builders had been named.

## **Research purposes**

The main purpose of this research is to understand the evolution of Isfahan's inhabited bridges and also studying the construction techniques of Isfahan's arch bridges and their changes over time. For this aim, the different things have been studied, such as the functions of arch bridges in Isfahan. This study encompasses their role as a place of passage, but also as a place of reflection, entertainment and gathering, as well as the technical structures such as the dams to control the flow of water. For an ampler understanding of their functionalities, two European inhabited bridges have been included in the study for comparative purposes.

## **Research questions**

The research questions for this study were:

1. What is the most important factor in the formation of inhabited bridges in Iran?
2. What are the different purposes of construction of inhabited bridges in Isfahan?
3. What are the differences between Iranian and European inhabited bridges?

## **Research methodology**

For the purposes of this research, many library resources such as books and articles have been studied. The existing documents in archives of Isfahan Cultural Heritage and Tourism Organization, such as images, historical documents and plans, have been reviewed as well.

The fieldwork research had been done by the author for better understanding of the subject. More information was obtained by site analysis. This part is done by photography, observing, field surveying and interviewing of locals. Studying of literature review and previous researches was one the most principal part of this study and made sure that the research proceeded in the right way and followed the former research courses.



## **Chapter II**

## Résumé

La traversée d'un point à un autre est la fonction principale des ponts, mais parfois, les conditions existantes et les besoins humains différents au fil du temps ont conduit à la formation de ponts remplissant diverses fonctions. La construction des premiers ponts en Iran remonte à l'ère antique et il convient de noter que l'émergence de ponts multifonctionnels s'est produite pendant la période sassanide. En Iran, l'eau a toujours été un élément très important de la formation des villes et de la vie collective. Depuis que l'eau, dans la plupart des régions de l'Iran, a été considérée comme un élément rare, elle a joué un rôle très important dans l'architecture iranienne. La formation de différentes fonctions dans le secteur de la construction de ponts au fil du temps est affectée de la même manière par ce problème.

## **2.1.Introduction**

Crossing from one point to another is the main function of the bridges, but sometimes the existing conditions and different human needs over time have led to the formation of bridges with various functions. The construction of the first bridges in Iran date back to the ancient era and it should be noted that the emergence of multi-functional bridges occurred during the Sassanid era. In Iran, water has always been a very important element in the formation of cities and collective life. Since water, in most parts of Iran, has been considered as a scarce element, it has played a very important role in Iranian architecture. The formation of different functions in the bridge construction industry over time, in like manner, is affected by this issue.

## **2.2.Iran introduction**

Iran's climate is diverse, mostly arid and semi-arid. Due to the climate condition of Iran, lack of water resources was always an important issue for the people. This ensured that water sustainability was the main element in the formation of Iranian architecture and urbanism. The lack of the water was always a limitation for them that also made them to create new structures to meet their needs such as traditional ice houses and large water reservoirs. This limitation also led the first settlements to be erected near the rivers, like Isfahan city. Watery rivers in different province cause a lot of bridges remains from Islamic period as memory.

In Safavid dynasty period, most attention was directed towards bridge building in Iran. In Isfahan the dimensions, design, resistance, architectural method and decoration of that times' bridges are noticeable and unique. Construction techniques and architectural features especially in Isfahan bridges indicate the big progress in bridge construction especially during the Safavid period.



Fig. 1: Iran's map, en.wikipedia.org

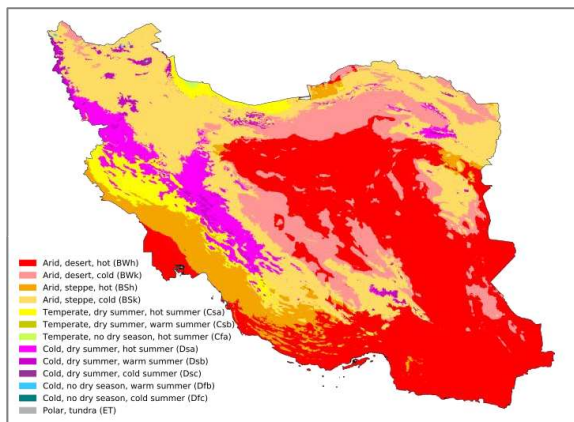


Fig. 2: Iran's climate map, 2016, en.wikipedia.org



Fig. 3: Iran's rivers, 2013, www.mapsofworld.com

### **2.3. History of arch bridge construction in Iran**

Masonry arch bridges have been used for at least 4000 years and Iran was one of the pioneers in building such structures. The first masonry arch bridges arise from Mesopotamia in Iran (Zahiri & Heydari Beni & Zargar, 2013). The first Iranian government was established more than 2500 years ago. Roads and bridges were laid in the Achaemenid's bid to develop contact between the remote regions of the far-flung empire. Nowadays, there have been found some traces of those bridges during archaeological excavations. Based on the remnants of the Achaemenid bridges, rock was used to construct bridge's piers and wood to build their surface (Kiani, 2014). The oldest bridges still surviving in Iran date back to Sassanid area. Some of them have been restored over time and still being used and some others had been demolished and new bridges rebuilt on their remains.

On the Achaemenid bridges, the interior spaces of the bridges are blocked among side walls such as the Kalhor bridge in Lorestan. Gradually and over time, the space created by bridges became more important and constructors considered some functions for empty spaces inside and outside the bridges, such as the bridge of Kashkan belonging to the Sassanid period (Pour Naderi & Torbati, 2013).

In the early Islamic period, due to the conflicts in Iran, there are no impressive example of bridges. In the following periods, bridge construction industry was most commonly done to connect two different cross points. In the Safavid period, because of the powerful government, the bridge construction industry made remarkable development.

Safavid dynasty has been one of the most influential period in the Iranian art and architecture. There are so many roads, buildings, bridges, caravanserais and mosques which were built in Safavid period. Bridges of this era are not only means to cross rivers but they are also places to stay. Many of them are still places for joy and holding ceremonies. The Safavid bridges have very strong foundations and most of them are still existing. Materials used in these bridges include stone, cobblestones, brick, grout, lime, clay and mud-brick (Hoseini, 2015). In Iran vernacular architecture, the use of vernacular materials is one of the main principles of architecture.

They are compatible with the surrounding environment of the region and are created by nature, and in case of a collapse, without any damage to nature, they can easily return to it and decompose in it. In the event of destruction and the need for restoration of the architecture monuments, the availability of these materials will lead to easy, feasible and lower cost operations. Thus in some parts of Iran, some of the materials which were used in bridges construction are different.

#### **2.4. Components of Iran's arch bridges**

Iran's bridges are consisting of different parts. Some of these components had changed over time and had led to the development of bridges construction and their functions. The different components of Iran's bridges include:

##### **2.4.1. Foundation**

During the low water level season, the bridges builders changed the direction of streamflow, by creating a diversion stream. Then they started to build the bridge foundation. In order to save time and money on bridge construction, the builders chose narrow sections of the river with stone beds (Mokhlesi, 2000). Construction on the remaining of old bridges was also in order to save on materials and construction costs.

##### **2.4.2. Bridge piers**

The piers of the bridge are one of the most important parts of it, because it is connected with the water streamflow and its forces. The bridges of the bridge were built in various shapes during different periods such as square, rectangular, ellipse and pointed-shape. Over time, architects have found that a pointed-shape pier is better than other forms and it is more resistant to water stream. For this reason, the piers of the latest arch bridges, such as the Khaju Bridge, were constructed in pointed-shape form.

For the construction of bridge piers, the wooden beams with sharp and pointed head were used. These beams were glued together and filled with mud or bitumen in order to drain the water inside them to prepare the conditions to make the piers (Dayuj Pooli, 2014).

### **2.4.3. Breakwaters**

On most bridges, there are triangular or semi-circular corbel structures that were used as breakwaters. In addition to reinforcing the bridge piers, these structures reduced water pressure on the bridge body (kiani, 2014).



Fig. 4: Breakwaters of Khaju bridge, Author



Fig. 5: Breakwaters of Joui bridge, Author



Fig. 6: Breakwaters of si-o-se pol, Author





Fig. 7: Spans of si-o-se pol, Author



Fig. 8: Spans of Marnan bridge, Author

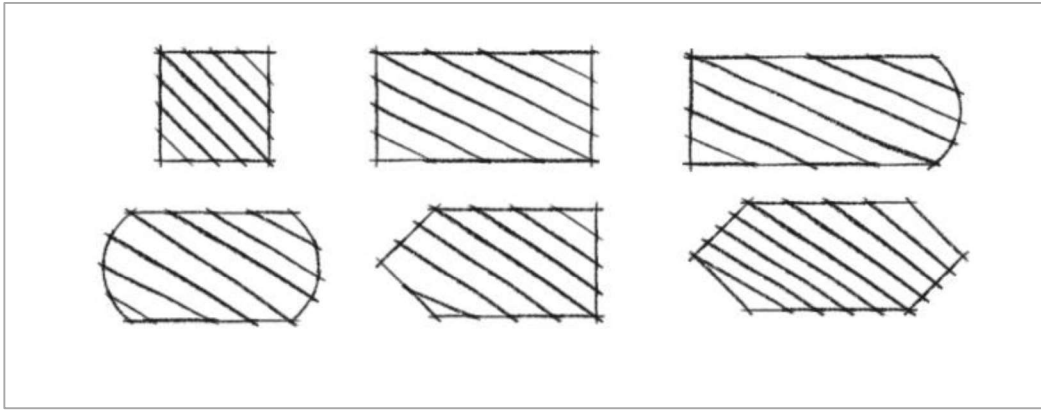


Fig. 9: Different type of Iranian bridge piers, Author

#### **2.4.4. Konoo**

There are the structural elements in arch bridges named "Konoo" and usually used in areas where the danger of earthquake is high. Konoo's are often located in between each two spans of the bridge to equilibrate the thrusts come from arches and support the stability of structure (Dayuj Pooli, 2014). Beside structural efficiencies, these openings have other advantages in bridges:

1. By reducing extra masonry, the bridge structure becomes lighter.
2. It helps to easier draining in flood conditions.
3. It helps dry the bridge after a flood by functioning as a ventilation channel (Zahiri & Heydari Beni & Haj Ebrahim, 2013).

#### **2.4.5. Parapet**

In order to protect the lives of pedestrians and caravans, 1.5m high walls were usually built around the passageways. These parapets made the users feel more comfortable to use and cross the edge of bridges.

#### **2.4.6. Covered corridors**

In some of the Iranian bridges we can see covered corridors on both sides of the bridges specially in upper floor of the bridges. These corridors have been constructed as safe shelters for pedestrians in both summer and winter to protect them specially from rain, sun and wind. The two covered corridors can be seen in both sides of plan of the second floor Si-o-se pol bridge.



Fig. 10: Konoos of shahrestan bridge, Author

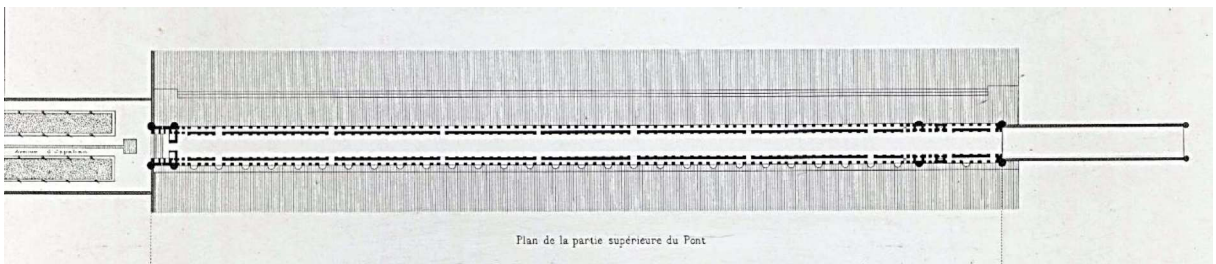


Fig. 11: Plan of the second floor of Si-o-se pol bridge, wikimedia.org, 1840

## **2.5. History of inhabited bridges in Iran**

Crossing, is the main function of the bridges, but there are also some bridges in Iran which are multi-functional. These multi-functional bridges were created under certain conditions to meet human needs. For example, the climatic conditions like lack of water in Iran have led to the formation of bridges with dam function, like Band-e-Amir in Shiraz which was used to spin the watermill wheel by the generated energy from water behind the dam.

The first examples of multi-function bridges come back to the Achaemenid and Sasanian periods. They made empty holes in the walls that missile troops could use to engage enemies, as can also be seen in some European bridges (Boostani, 2001). Over time, other functions were considered for these empty spaces; for example, using them to store food. Gradually, the spatial quality of these spaces increased, and as certain bridges had a strategic position, they provided special spaces for bridge guards (Emami Shooshtari, 1952). There are several factors for the formation of inhabited bridges in Iran which are discussed below:

### **2.5.1. Kashkan bridge**

The foundation of the Kashkan Bridge dates back to the Sassanid era, but the building was rebuilt in the 10th century. This bridge is located in Lorestan province, in western Iran in the Zagros mountains and it is quite well preserved and can show us the typical feature of the other bridges in that period. Rubble masonry and baked brick are the main materials which were used and there are hollow spaces (rooms) over piers and between the spans (Anisi, 2007).

The Kashkan bridge is 325-meter-long and connects two sides of the valley and it has different heights in different points. The height of the bridge is 26.5 in the tallest point and 4.80 meters in the lower part (Sajadi, 2003). The empty spaces in the bridge piers have made several rooms which were connected to each other. These rooms were used more for keeping animals (Farshidnik & Afhami, 2010).

The shape of the bridge pier is oval, which is the initial and primary form of the bridge piers in Iran. Over time, as the knowledge of the builders increased, they discovered that pointed-shape piers are more resistant to streamflow. Thus, the ellipsoidal form of the bridge piers changed to pointed-shape, which is also seen on the bridges built in later periods like Khaju Bridge in Isfahan.



Fig. 12: Kashkan bridge, commons.wikimedia.org, 2016



Fig. 13: Kashkan bridge, www.flickr.com, 2009

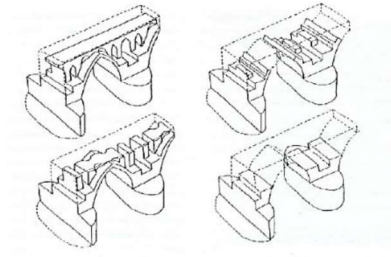


Fig. 14: Kashkan bridge piers, Anisi, 2007

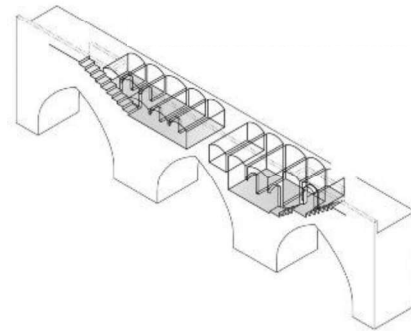


Fig. 15: Approximate reconstruction of residential space of Kashkan bridge, Farshidnik & Afhami, 2010

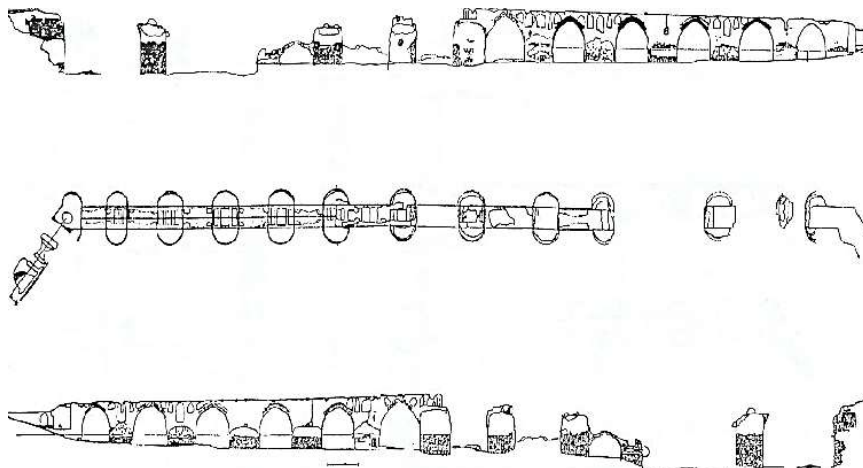


Fig. 16: Kashkân Bridge. Plan southern and northern elevation, Anisi, 2007

### **2.5.2. Aji-chay bridge**

According to historical texts, Aji-chay bridge was built during the Timurid era <sup>1</sup>. The bridge is located in the East Azarbaijan province, in the northeast of Iran. At that time, Tabriz was located on one of the main paths of the Silk road, so it had a great importance the past.

The bridge is 100 meters long and 5 meters wide. There were some rooms which were located in the piers of the bridge used to house resting caravans. These spaces were lost in the restoration carried out in subsequent periods (Farshidnik & Afhami, 2010).

### **2.5.3. Anbooh bridge**

The Anbooh bridge is one of the first bridges built during early Safavid period. This bridge is a beginning of the evolution and development of the construction of inhabited bridges in Iran which reached its peak in the Safavid period.

On this bridge there are two rooms on the southern and northern piers intended for the rest of the guards of the bridge and the passengers. In the construction of this bridge, we can see the combination of the enclosed space and semi-open spaces, Ivans<sup>2</sup> and the room for the first time. These spaces led to the lightening of the bridge structure and the Ivans that were embedded in them were intended to take advantage of landscapes (Boostani, 2001).

### **2.5.4. Manjil bridge**

This bridge was built in the early Safavid period in Manjil, in Gilan province. According to historic documents, the bridge has 9 piers, most of which had rooms for travelers to rest and stay. This bridge was a caravanserai with all facilities like a kitchen which was constructed in two floors (Olearius, 1984).

Thus, this bridge had a two different functions at the same time. Unfortunately, these spaces were destroyed by floods in 1943 and a new metal bridge was constructed on its foundations (Farahani, 1983). By studying the existing examples of inhabited bridges in Iran, the architectural and functional evolution of these bridges can be understood.

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<sup>1</sup> 16th century

<sup>2</sup> A space which is close on three sides and open on one, typical component of Iranian architecture.



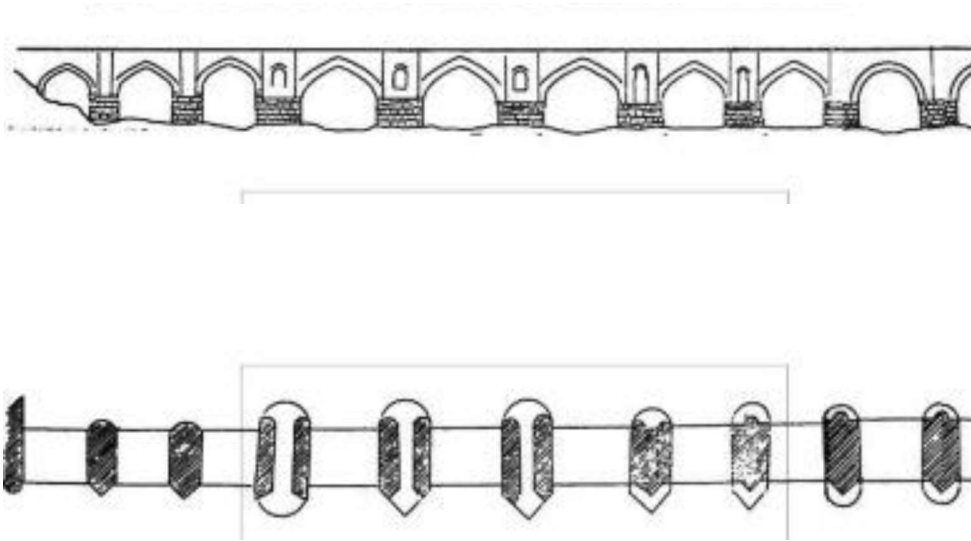


Fig. 17: Aji-chay bridge plan and facade, Farshidnik & Afhami, 2010



Fig. 18: Aji-chay bridge, [www.flickr.com](http://www.flickr.com), 2010

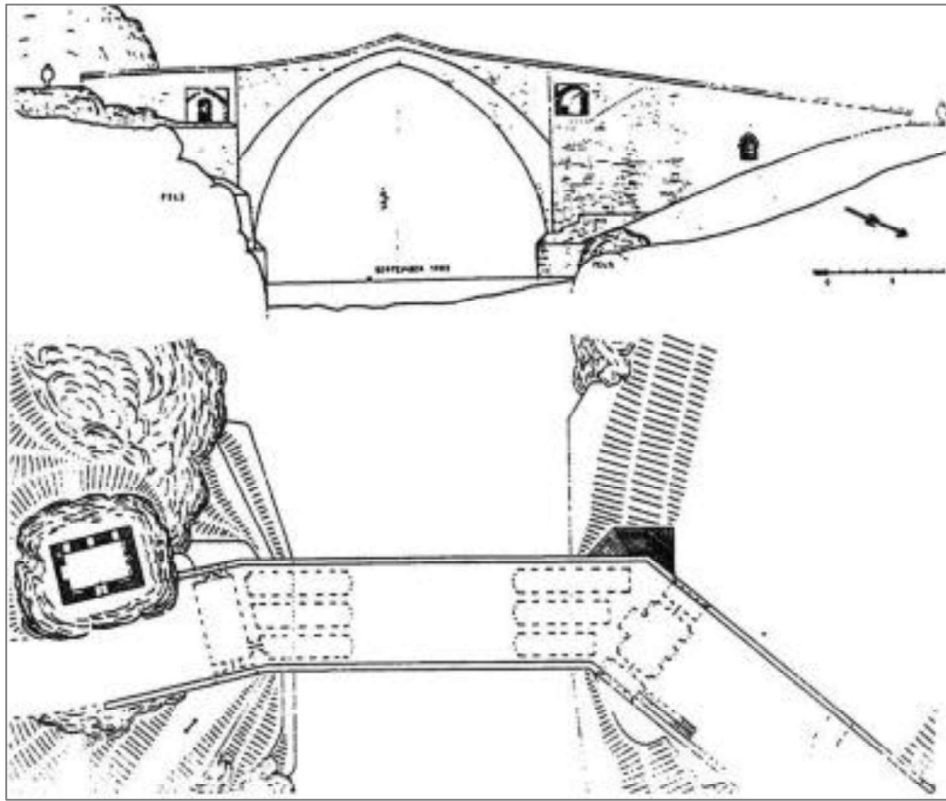


Fig .19: Anbooh bridge plan and facade, Farshidnik & Afhami, 2010



Fig. 20: Anbooh bridge, file.asanbegard.com, 2017

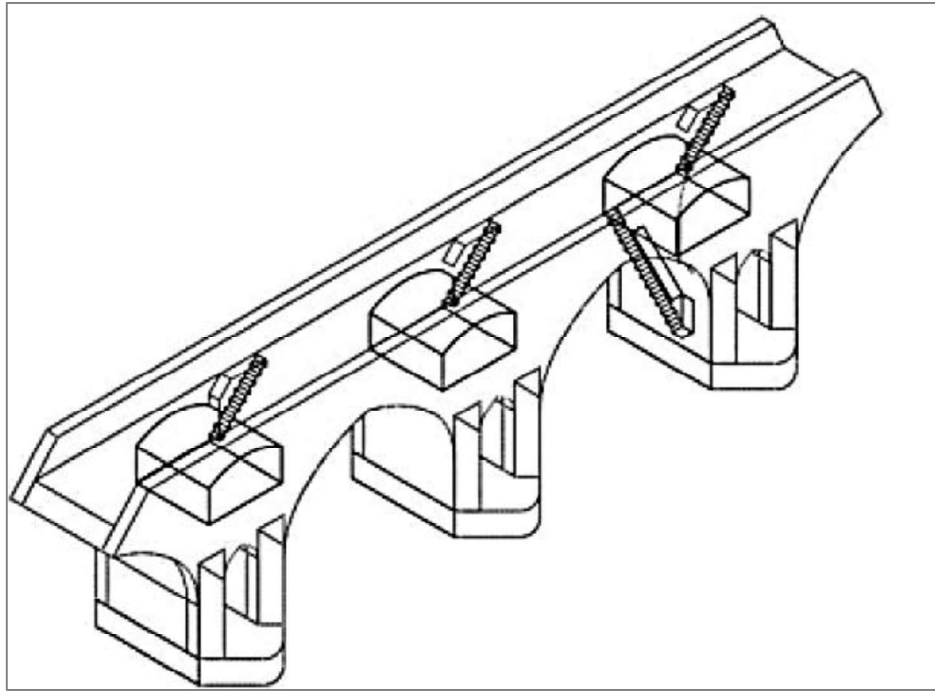


Fig. 21: Manjil bridge sketch, Farshidnik & Afhami, 2010

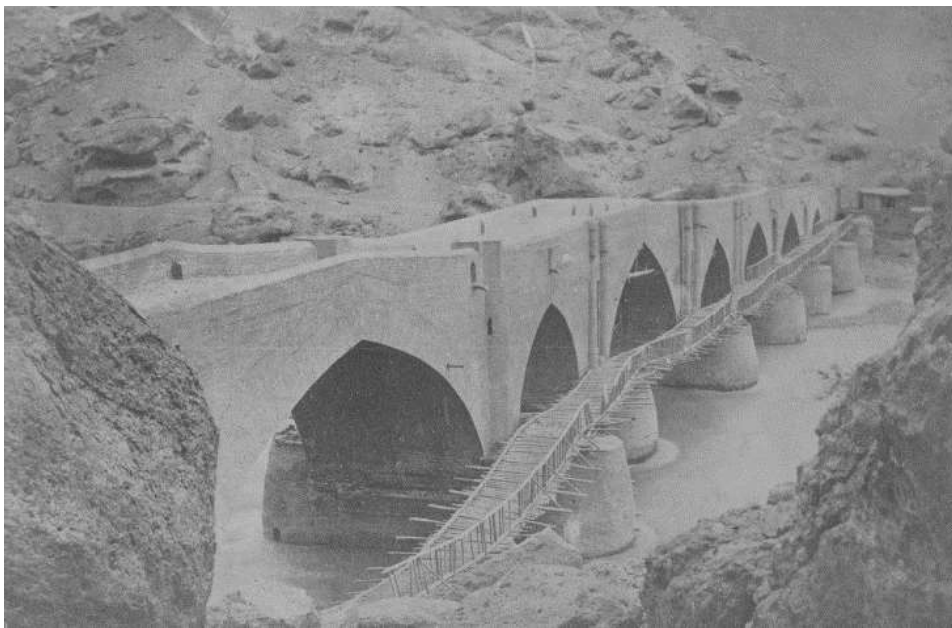


Fig. 22: Manjil bridge, [www.freersackler.si.edu](http://www.freersackler.si.edu), 19<sup>th</sup> century

## **2.6.Iranian arch construction method**

There is a huge difference between Iranian and European arch construction. In the book of "Iranian architecture" written by Gholam Hossein Memarian, this difference is well explained: In the Renaissance, in Europe, wooden molds were used to make the arches. The implementation of these wooden molds has been very complex and time consuming. In Iran, this method has not been used due to the arid climate and lack of accessibility to wood. After the molding was done, in Europe, they placed the bricks and ceramics on it and then poured the mortar on them. In this way, one smooth surface was obtained which was quite different from the Iranian arches.

Iran offered access to other viable options for the formation of arches. Iranian builders used plaster molds to construct the arches. At first, for making the plaster mold, they drew half-vaulted on the ground. The second profile of the vault was drawn about 10 to 20 cm apart from the other one. On the drawn lines, a row of bricks was arranged. The bottom of the mold was poured with a bit of sand to prevent the mold from adhering to the ground. Then, they put the straws into the mold and then poured the plaster mortar on them. The two plaster molds were left to be dry and then two plaster molds were prepared to use.

Plaster molds were located in the place which the arch should have been constructed. These molds were a structural support for the arch. they also used as a guide for builders to make a proper arch. These molds had little resistance to the weight of the brick rows. For this reason, the builders glued a row of bricks across the plaster molding body. This row of brick acted as a strong mold and tolerated the weight of subsequent bricks rows.

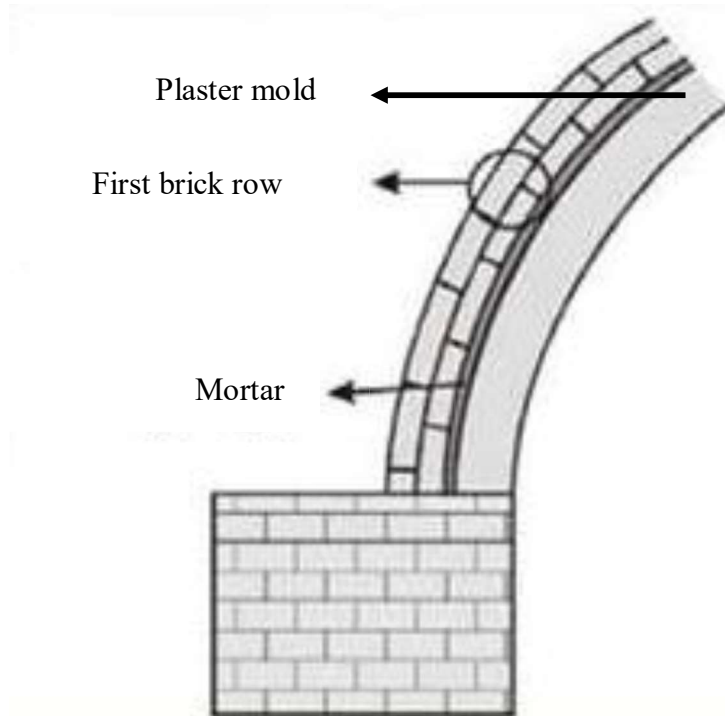


Fig. 23: Iranian arch Diagram, aoi.i.au-shoushtar.ac.ir

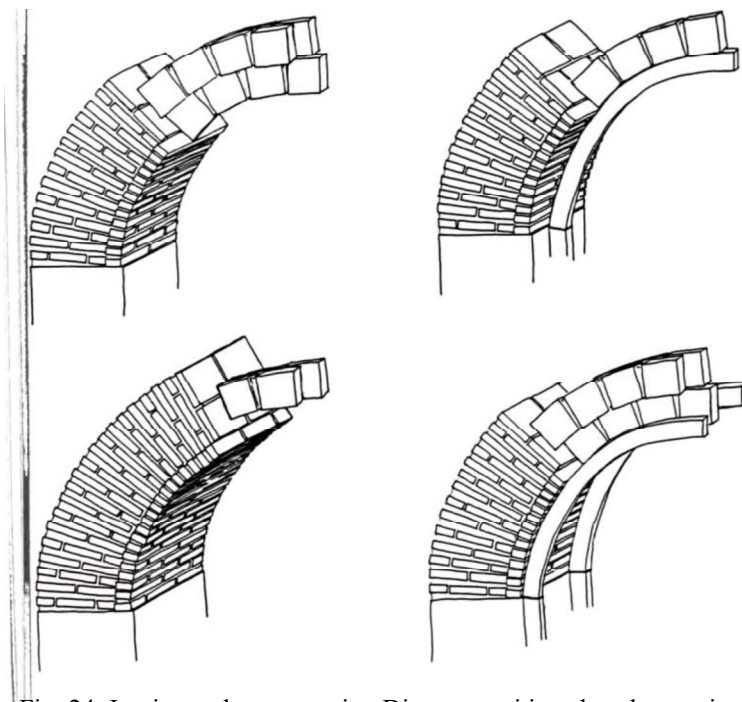


Fig. 24: Iranian arch construction Diagram, aoi.i.au-shoushtar.ac.ir

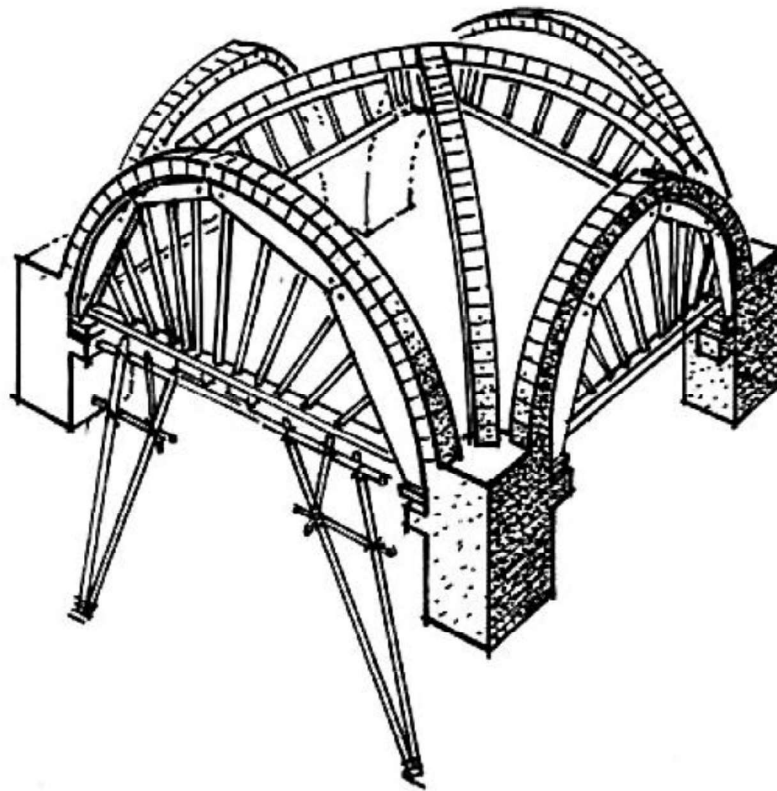


Fig. 25: European arch Diagram, [www.lanera.com](http://www.lanera.com)

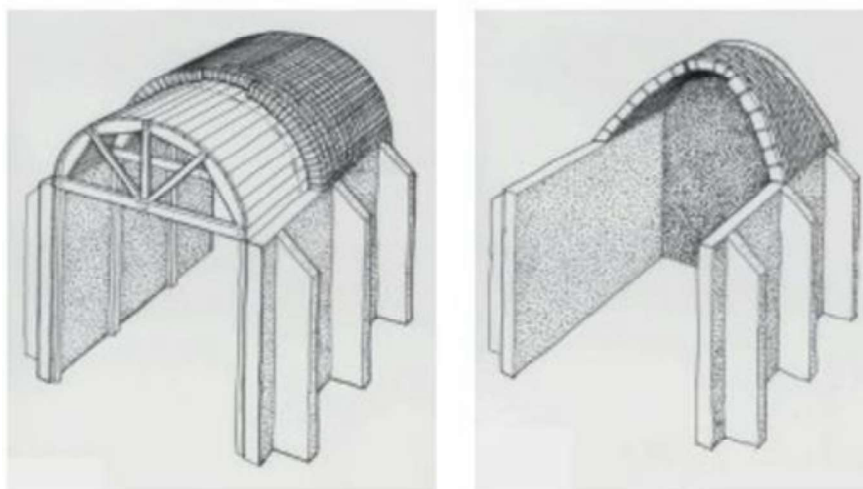


Fig. 26: European arch construction, <https://www.researchgate.net>

## 2.7. Conclusion

By studying the existing examples of Iranian inhabited bridges, it is possible to understand the effective factors in their construction evolution over time, which are so important in research process. bridge construction has a long history in Iran, and it started to get an inseparable relation with social dependency and architecture in Sassanid period. These methods continued even after Islam and in Safavid period, they culminated the peak point.

Iran is located in an arid and dry region in which lack of water resources was always a significant issue. It also affected the process of multi-functional bridge construction over time. This can be one of the main reasons for constructing a bridge and using it as a dam at the same time. The water stored behind the bridges was used for various purposes, such as turning the watermills wheels for milling, supplying water for caravansaries and passengers, irrigating farmlands and strengthening groundwater tables. Combining two or more functions in one structure in order to utilize the available facilities, is another important reason for arranging several functions in Iranian bridges. This issue had economic feasibility by the reduction of additional constructions.

In Iran's historic bridges, the architects began to create empty spaces in bridge bodies in order to lighten the structure and increase its resistance by reducing its heaviness. Due to the use of Iranian arches in bridges construction, these bridges are more resistant in comparison to European bridges. Thus, their architects were able to make empty spaces inside the bridges without using the buttresses for restraining forces. Gradually, the internal spaces of the bridges took into account other uses and changed them to multi-functional bridges.

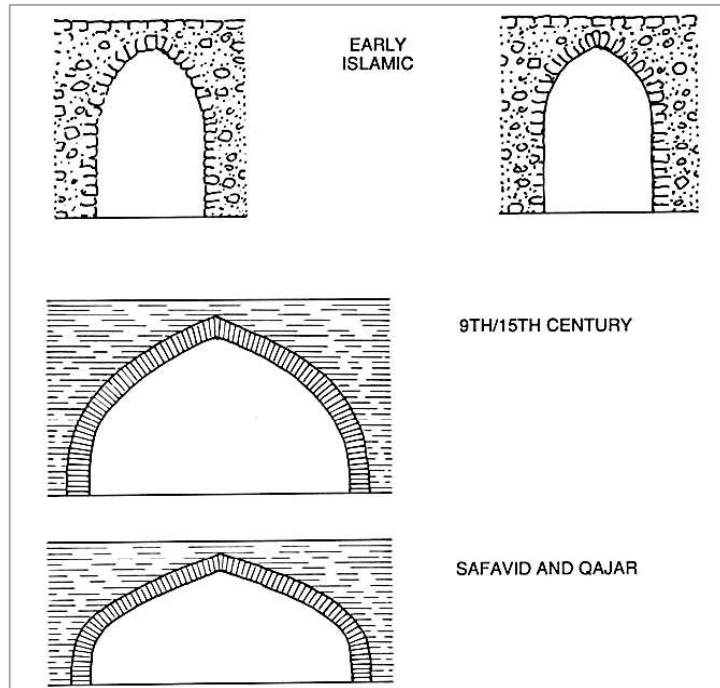


Fig. 27: Iranian arch diagram, [www.iranicaonline.org](http://www.iranicaonline.org)

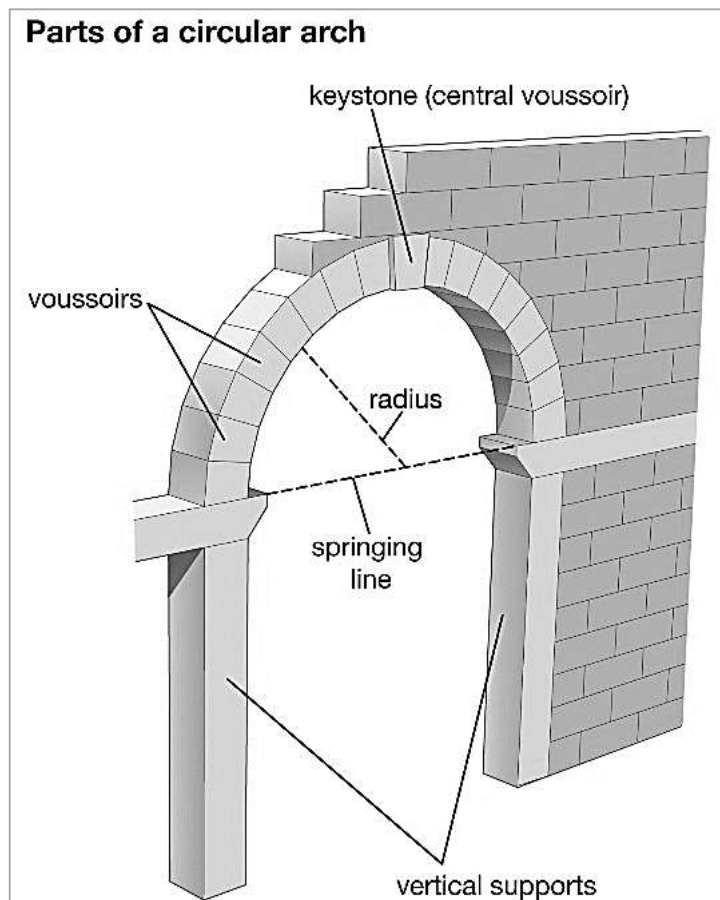


Fig. 28: European arch diagram, [www.britannica.com](http://www.britannica.com)



## **Chapter III**

## Résumé

La vie sociale dans le vieux contexte urbain d'Ispahan, située le long de la rivière Zayandehrood, dans la partie sud d'Ispahan, existait avant la période safavide, qui a une grande valeur à travers l'histoire. Zayandehrood a toujours été une rivière d'irrigation de fermes, un lieu de création d'un paysage urbain unique, de construction de palais et de célébrations autour de son lit au cours des premiers siècles de l'islam jusqu'à nos jours. En outre, il montre que l'affiliation de la vie sociale et urbaine des habitants d'Ispahan à Zayandehrood. L'existence des ponts historiques d'Ispahan a joué un rôle important dans la formation de la vie sociale, qu'il convient de mentionner ici. Il y a cinq ponts historiques sur la rivière Zayandehrood à Ispahan qui sont construits pendant la période safavide mais à des époques différentes.

### **3.1.Introduction**

The social life in old urban context of Isfahan which is located along the Zayandehrood River, in the southern part of Isphahan has been existed before the Safavid period, which has a great value throughout history. Zayandehrood has always been a river for irrigation of farms, a place for creating a unique urban landscape, construction of palaces and holding celebrations around its riverbed in the early centuries of Islam until today. In addition, it shows that the affiliation of the social and urban life of the people of Isfahan with Zayandehrood. The existence of the historic bridges of Isfahan played a significant role in the formation of social life, which should be mentioned here. There are five historical bridges on Zayandehrood river in Isfahan which are constructed in Safavid period but in different times.

### **3.2.Isfahan introduction**

Isfahan is one of the largest cities in Iran, and is located on the center of Iran. Isfahan is one the biggest cities of Iran which is located in the lush Zayandeh Rood plain between the foothills of the Zagros mountain range. This city has artifacts dating back to the Paleolithic period and the written history that goes back to ancient Aspadana. It has been the capital city of Persia during the Parthian Empire and the Safavid dynasty (Agha Ebrahimi & Samani & Bahrami & Salahesh, 2015).

In the 16th century, when it became the capital of the Iran during the Safavid period, the city became under developed by the idea of royal city which led it to its glory. There are many valuable Islamic architectures that make it so famous, especially the existence of many beautiful streets, boulevards, palaces, minarets, mosques and covered bridges. Isfahan has had many gardens which make it like a green spot in the heart of the desert like a miracle due to the Zayandeh-rood, the largest interior river in the Iranian plateau. Accessibility to the water resources had been of most importance to the history of civilization and formation of cities and have been always one of the most serious concerns of consumption and agriculture aspect in daily life. This matter is more significant and indisputable in the arid zones like Iran, where dependence of the people on water resources is so obvious.



Fig. 29: Location of Isfahan on Iran's map, [www.wikipedia.com](http://www.wikipedia.com)



Fig. 30: An old painting of Isfahan by Eugène Flandin, 1840, [www.wikipedia.com](http://www.wikipedia.com)

According to historians and geographers, the first central parts of the city belonged to the Sassanid period, which were close to the Zayandeh-rood. The two urban cores were located a short distance from each other, one east of recent Isfahan and in the north bank of Zayandeh-rood by the name of Jay and the other by a distance of 3 kilometers which had been called Judea (Eskandar).

In the Safavid period, we can see the formation of a new central core of the city close to Zayandeh-rood. What had been focused of Safavid architects was protecting and respecting the nature while they were using it in urban life. As a result, the importance of new infrastructures and new facilities such as the bridge on Zayandeh-rood for better transit had increased. Unlike previous kings, the Safavid kings did not want to live in the old core of the city. To this end, King Abbas established his own court on the southwestern edge of the city. At the center of the new section established by King Abbas was a square which was surrounded by all the administrative, commercial, religious, and other facilities. Shah Abbas I shifted the center of Isfahan to a new square, the Great Maydan, or Royal Square, which linked his palace, two mosques, and the Royal Bazaar. His successors continued to erect mosques, caravanserais, markets, palaces, gardens, and bridges.

The city structure was based on two natural and artificial functional axes. Functions which are formed by two major axes of the Chahar-bagh (artificial axis) and the Zayandeh-Rood (natural axis) and their connection, are entertainment, public, private and royal functions of the city. The artificial north-south axis passed over the river on one of the most noble city elements, the Si-o-se pol bridge. Chahar-bagh and Zayandeh-rood were two main elements in Safavid urbanization and they had a major impact on city development and expansion. The new complex which had been built by Shah Abbas were continued to chahar-bagh street and it was connected to other part of the river by Khaju and Si-o-se pol bridges.

The Zayandeh-rood is main element for creating natural axis in the city. This natural axe is the main element that has led the urban growth of Isfahan during its past four centuries. The main axis of Safavid dynasty consisted of Naqsh-e- Jahan, Chahar-Bagh Promenade, Si-o-se-pol Bridge over Zayande-rood which was ended by agricultural fields.

Chahar-bagh Street was the main element of Isfahan city during the Safavid era and around this street various neighborhoods of Isfahan and the palaces of princes, lords and nobles were located. The street in the south has ended to Zayandeh-rood. In the southern part of the river there were other neighborhoods that were inhabited by non-Muslims.

Jolfa neighborhood was located on the south bank of the Zayandeh-rood which was inhabited by Armenians. Prior to that, the Armenians of Isfahan lived in different parts of the city, but they were relocated to Jolfa by king Shah Abbas and the main reason for this matter was their high capacity in trades and business affairs. Gabrestan was the name of another neighborhood on the south side of the river that was inhabited by Zoroastrians. King Abbas II demolished that area and built its own royal monuments and gardens there and he named it Saadat Abad (Zareei Ebrahim, 1963).

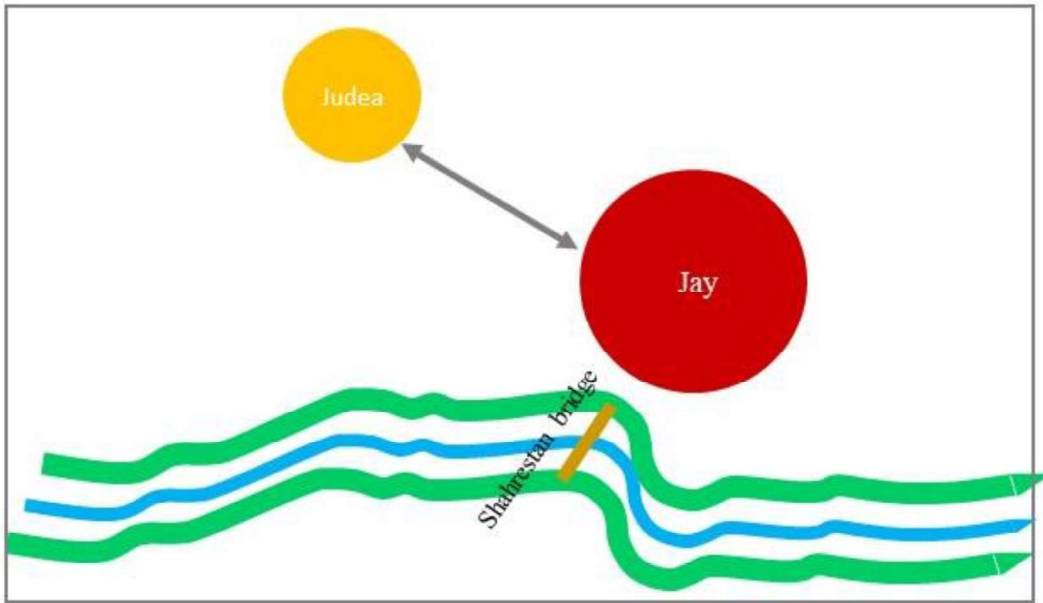


Fig. 31: The early cores of Isfahan during the Sassanid period, Author.

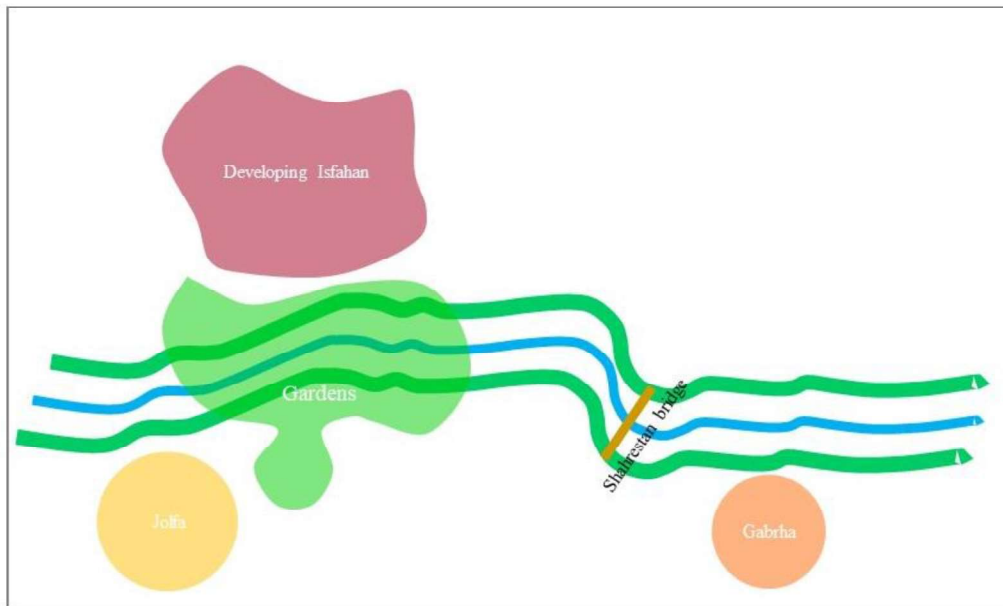


Fig. 32: The formation of new part of Isfahan in the Safavid period, Author.

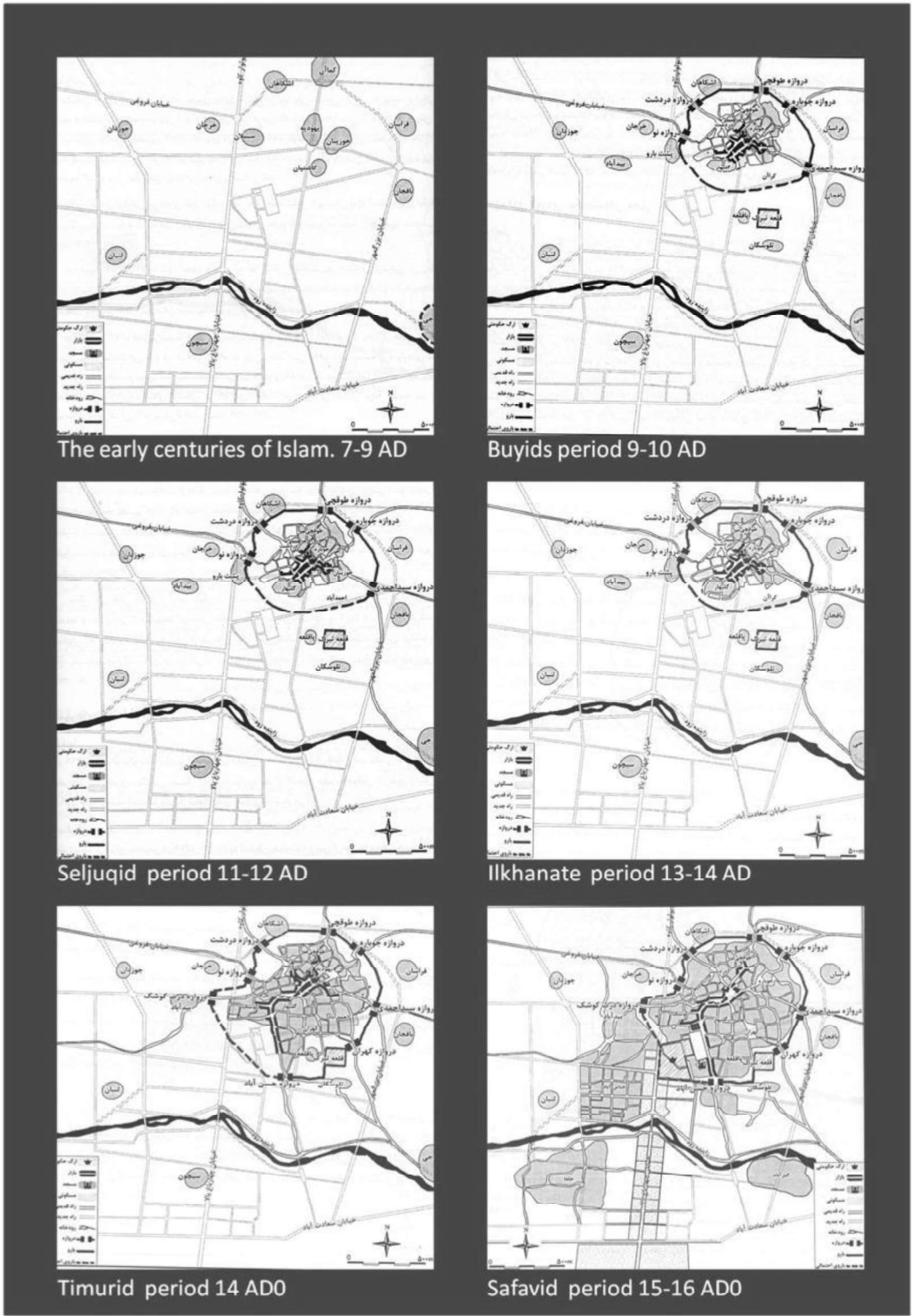


Fig. 33: Development of urban form in Isfahan during centuries Oliveira V, Pinho P, Batista L, 2014



### **3.3.Economy of Isfahan in Safavid era**

In the Safavid period, the economic growth of cities, especially Isfahan, as the capital of Iran, led to increased intercity traffic. The Safavid kings built many structures along cities for ease of travelers and merchants, such as Caravanserais, water reservoirs etc. During this period many bridges were built along the routes of these caravans and passengers which were also connected to the Caravanserais. For this reason, the Safavid period is a brilliant period in the history of bridge construction.

Maintenance and expansion of irrigation equipment, tax cuts, eradication of banditry, increased homeland security, construction of caravans and new roads for communication were some of the measures which had been done by him that not only increased domestic production but also increased national and international commerce.

One of the main reason which made shah Abbas to change Iran's capital from Qazvin to Isfahan was that this city -as one of the industrial cities- besides economic intermediary was an important passage in the cycle of foreign trade via the new trade road from North to South of Iran. During Shah Abbas's reign, Isfahan was converted to one of the leading cities in economy by changing the way of silk trade, which had been eastern-western, and affected on national and international changes in politic, economy and social life (Taghavi, Zoor & Farzin, 2013).

Due to the favorable weather conditions in Iran, especially in the north of the country, silk production in Iran had increased in Safavid period. The flourished silk commerce led to a booming period in the Iranian economy emerged. carpet weaving was promoted from a rural craft to a nationwide activity and led to open the first carpet weaving workshop in Isfahan. As a result, textiles and carpets, covered all of Iran and there was a huge trade in and out of the country (Floor & Herzig, 2012).

During the reign of Shah Abbas I, the construction of the caravan's road from Isfahan was began which was continued from there to the southern ports of Iran. Since Hormoz Island and Bandar Abbas port were main maritime trading centers of that time, this route was considered as one of the principle commercial path. It should be noted that the existence of many facilities such as bridges and inns along this route had a significant impact on King Abbas's recapture of Hormuz island from Portuguese army (Zareei Ebrahim, 1963). In addition, many bridges were

built in different Iranian cities, especially Isfahan. The purpose of these bridges was to provide links between different parts of the city, different districts and neighborhoods, and for the pleasure of the royal family.

### **3.4. Isfahan's agriculture in Safavid era**

As it's been mentioned, due to Zayandeh-rood many gardens and agricultural lands had been formed in Isfahan, especially close to the river. These gardens had various kind of functions and they were used as public, private or royal gardens. A special system called Madis was used to irrigate these gardens and agricultural lands. These Maddies were, in fact, small branches of the Zayandeh-rood that were directed to fields and gardens for irrigation.

The Maddies pattern was based on the topography of city so that water could flow inside the city and reach to far places from the river. These Maddies made an organic form inside the context of Isfahan city and gardens and greenways beside these Maddies were adapted to these organic form (Ansari & Rahbar, 2016).

According to Javaherkalam's book, "Isfahan and Julfa Historical Geography", this system was written in 21 big pages with names of the gardens and properties and they were divided into 365 days of year. Based on this system, during the first part of each year, which means first 75 days of year, water consumption had been free for all owners without any division. During the next 165 days, the river water was divided into 33 parts, each part Contained five 24 hours, which means 5 days and nights. Each land had a special portion, for example, 6 portions, which meant 30 full days. This system had been existed since Sassanid period and it was a genius way to divide river water.

Safavid government knew that for sustainability of each garden or landscape, water supply is necessary, so they used the Zayandeh-Rood water and land slope to create some streams branched out of the river, which were covering the whole city to solve the water supply problem. The most important effect of Medes has been stabilization of landscapes (gardens) surrounding streets and several gardens in the city.

In the field of economy, it should be mentioned that Isfahan's main economy in Safavid period after silk commerce was based on agricultural activities. Deriving water from Zayanderud thorough the Madies, made it possible to have more gardens and farming land in the city. This water usage planning made an exponential increase of agriculture products and subsequently an overall welfare for its citizens (Ansari & Rahbar, 2016).

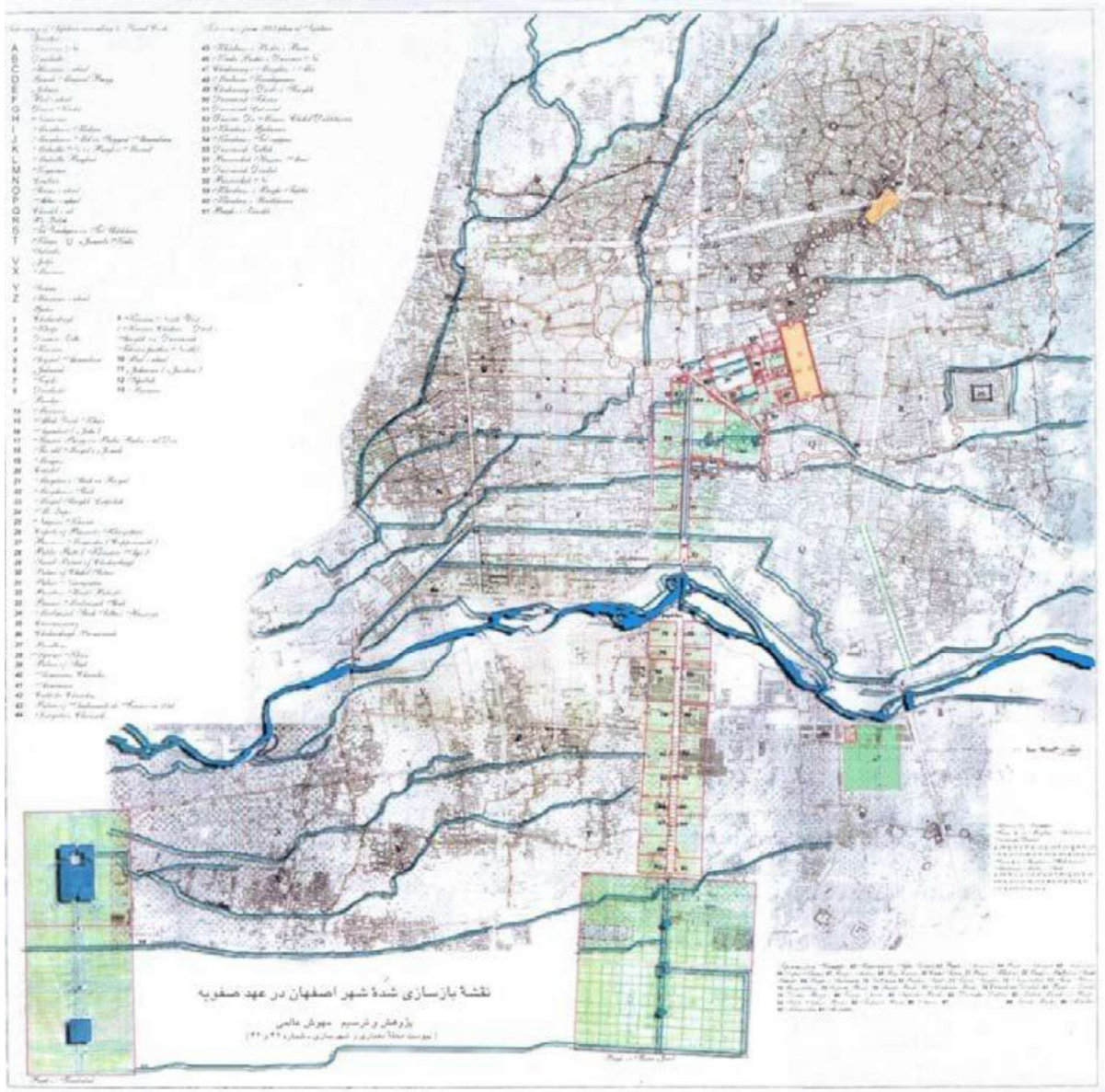


Fig. 34: Maddies in Isfahan (The main structure of Isfahan's Greenway Model), Ansari & Rahbar, 2016.

### **3.5.Zayandeh-rood**

Zayanderood, is a largest central river which starts in the Zagros Mountains and flows from west to east of Iran through the heart of Isfahan and it dries up in the Kavir desert (Taghi mahmoudi & Farhadi & Dokohaki, 2013). The river water from the west to the east of the river increases while its upstream dries in summer and as we approach downstream the water intensifies. Zayandeh-rood was only flooded during spring and in other seasons water was used to irrigate gardens and agricultural lands. In summer, river water levels reached to its lowest level. (Eskandar,2013).

Zayandeh-rood has had a significant impact on the process of Isfahan urbanization throughout the history. During the Safavid period, the city grew and expanded alongside the Zayandeh-rood, with many public, private, and royal gardens close to bank of the river. This river also led to the formation of many agricultural fields and orchards in the city which helped to the economic growth of the city of Isfahan.

In addition to economic and cultural benefits, Zayandeh-Rood River has developed a public domain for development of social interactions. In addition to being a local recreation and leisure spot, the river shows urban identity of citizens of Isfahan. Riverbank as a public sphere has a significant role in social interactions and elevates human exuberance and welfare. River dryness can decrease the social interactions between citizens and visitors of this location.

There are five historical bridges in Isfahan, since this city is divided in two parts by one of the biggest rivers in the middle part of Iran, Zayande-rood. All Safavid bridges by use of repetitive cellular units followed the common horizontal appearance. Si-o-se-Pol bridge is the longest bridge in Isfahan with 300m length intrepidly has been made totally horizontal by use of repetitive units. This horizontal calm layout exaggerates by reflection of bridge structure in the river. However, during the Safavids era the Zayandeh Rud River and its bridges played an important role for channeling commercial activities all over the city.



Fig. 35: Zayandehrood's location on Iran's map, [www.wikipedia.com](http://www.wikipedia.com).

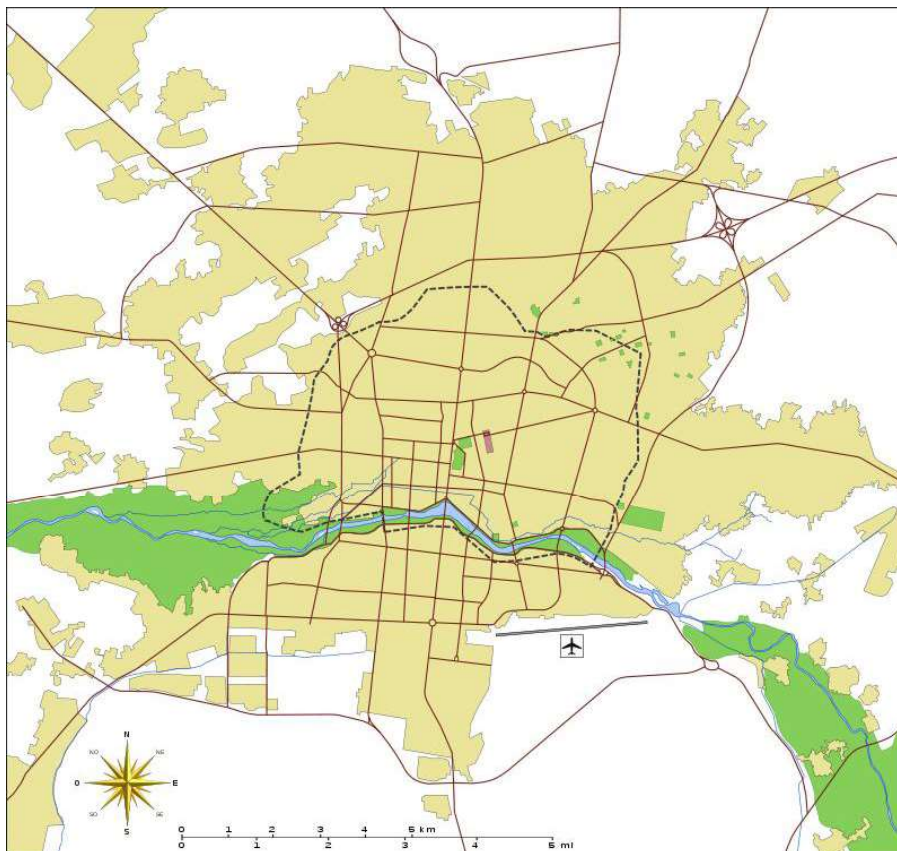


Fig. 36: Location of Zayandeh--rood in Isfahan, [www.wikipedia.com](http://www.wikipedia.com)

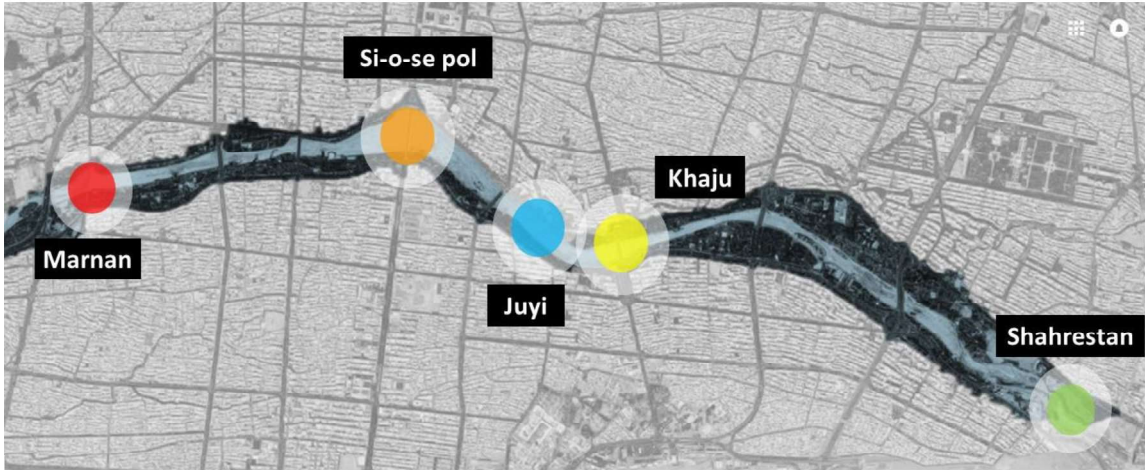


Fig. 37: Location of Isfahan bridges, Author.

### **3.6. Shahrestan bridge**

Shahrestan Bridge is the oldest bridge on Zayandeh -rood in central Iran which is located in east of Isfahan city. The foundations are from the 3rd to 7th century in Sasanid era, but the top was renovated in the 10th century by the Buyids and finally during the 11th century Seljuk period (Chahar Bagh Avenue, Isfahan: Genesis and Demise, 2016).

At the period of the Daylamites and Seljuk, Shahrestan bridge was the only bridge on the Zayanda-rood and it was located on the road that connected Isfahan to Shiraz, so it had a significant importance. In time, in the Safavid period, by constructing of multiple bridges on Zayandeh-rood, the bridge lost its notability (Mohammadi & Mollazadeh, 2000). As Madam Dieulafoy wrote in her itinerary that the bridge had lost its importance after the construction of the Khaju Bridge and Sio-o-she pol and people rarely pass through it (Damirchi, 1972).

The Zayandeh-rood bed is mainly composed of sand, but the foundation of this bridge is built on the stony and rocky part of the bed river, which has been led to its survival for 15 centuries from the Sassanian period to the present day (Qasemi & Shayesteh, 2004). On the other hand, within the boundaries of this bridge, the river bed has been diverted to the south and has led to the formation of a pond adjacent to the bridge with stagnant water, which also reduce the pressure of the water flow and its erosive effects on the bridge body.

At first glance, the visitors can notice the difference between Shahrestan bridge and other bridges in Isfahan. The Shahrestan bridge has a length of 107.8 meters and an average width of 5.2 meters. The lower level of the bridge has 13 spans and its upper level has 8 spans (Qasemi, 2006).

The bridge has parabolic form in the horizontal and vertical direction. Thus, the plan of the bridge has a curved shape and on the other hand, the bridge has the highest altitude in its (Pournaderi & Marvaje Torbati, 2013). The body of this bridge has a horizontal curve to the west; this curve in the opposite direction of the river, which is westward to the east. This curvature makes the bridge more resistant and leads to the strengthening of its midpoint, as the critical point of the bridge.





Fig. 38: Location of Shahrestan bridge in Isfahan, Google earth.



Fig. 39: The body of Shahrestan bridge, Author.



Fig. 40: A painting of Shahrestan bridge which shows the caravans close to it, 1982, [www.sardarabad.org](http://www.sardarabad.org)



Fig. 41: Shahrestan bridge, 1933, [www.archnet.net](http://www.archnet.net)

The bridge curvature in the vertical direction also prevents the overflow of the river from its edge during the flood. Surface water from the rain falls absorb through the shallow canal located in the middle of the bridge, which prevents the damages to the bridge's arches (Qasemi & Shayesteh, 2004).

The bridge has an organic structure in its plan and facade. The piers of the bridge are circular in both sides and they are in elliptical shape. The use of the top spans in this bridge, in addition to saving the materials, makes lighter weight and, on the other hand, during the flood of the river, reduce the pressure on the bridge body. This technique has been used to build bridges in subsequent periods.

The topographic condition of the earth has led to an increase in the water volume in the northern part of the bridge, thus, in that part, a structure has been made which increases the bridge more resistance to water pressure (Qasemi & Shayesteh, 2004).

At the northern side of the bridge, there is a structure built of brick and mud brick. It has a small room arches with a width of 16.1 m and a height of 93 cm (Nomination of Shushtar historical hydraulic system for Inclusion on The World Heritage List, 2008).

This three-store structure has large Ivans and also gorgeous windows. After a long period when it had been abandoned, it restored by Cultural heritage organization of Isfahan city. Shahrestan bridge is belong to the group of bridges who's their main function is crossing through, but in addition to increasing the stability and durability of the bridge, the pavilion has various functions in the past such as, receiving tolls, a tempting entrance, a place for passenger's accommodation (Qasemi & Shayesteh, 2004). Since this structure has a special architecture, which is not so modest, it gives the impression of being a specific place for governors too.

The materials used in the construction of Shahrestan bridge are stone, brick, Sarooj and plaster. The northern structure is made from adobe. (Nomination of Shushtar historical hydraulic system for Inclusion on The World Heritage List, 2008).

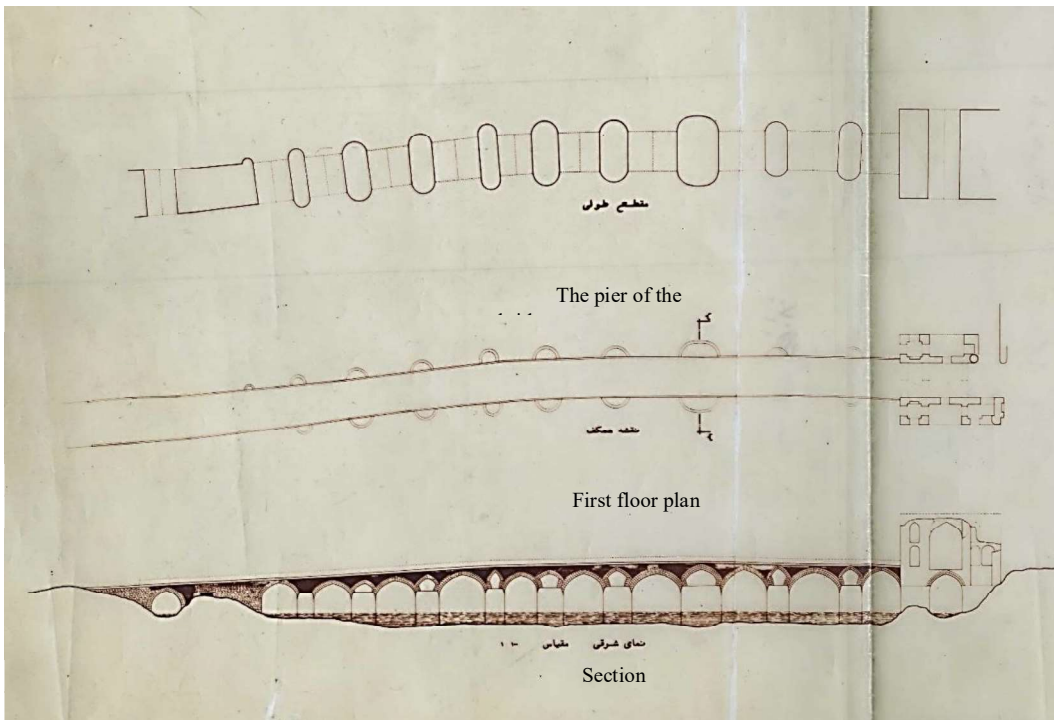


Fig. 42: Architectural document of bridge, Archive of cultural Heritage, handicrafts and tourism organization of Isfahan.



Fig. 43: The parabolic form of the body of bridge is visible in this picture, Author.



- The piers of the bridge are made by stone and have elliptical shape
- The body of the bridge is made by brick
- There are Konoo between the spans of the bridge

Fig. 44: Photo of the piers of the bridge, Author.



Fig. 45: The three-store structure of the bridge, Author.

### **3.7.Marnan bridge**

Marnan bridge was built in 1599, under order of Shah Safi, by one the wealthy Armenians to connect Armenian region to Isfahan city (Honarfar, 2010). According to some historical documents, it seems the foundations of the bridge belong to the Sassanid era and its first floor have been rebuilt during the Safavid period, but there is no exact evidence (Qasemi & Shayesteh, 2004).

Marnan bridge represents pedestrian path and this is the main function of this bridge. It has 17 main arches in between them 14 small arches based on stone. The form of its piers is like the Shahrestan bridge and has an oval plan. Marnan Bridge was constructed in one floor and is made of stone and brick. It has geometric and regular physical divisions in its plan and facade.

The foundations of Marnan bridge and Si-o-se pol have a similar construction; When the water was shallow the canal of water was dug to change the water path from where the bridge base was to be constructed.

After excavation for 4 to 5 meters from river floor, they supply suitable space for foundations. On this layer, big clay columns are set beside each other and the created holes by them were filled by clay puddle mortar, lime and lighting oil. After the lime was set, the foundation was constructed on clay columns (Shiraazi & OstadiAsl & Sheikhloie & Azami & Hassanimehr, 2012).



Fig. 46: Location of Marnan bridge in Isfahan, Google earth.

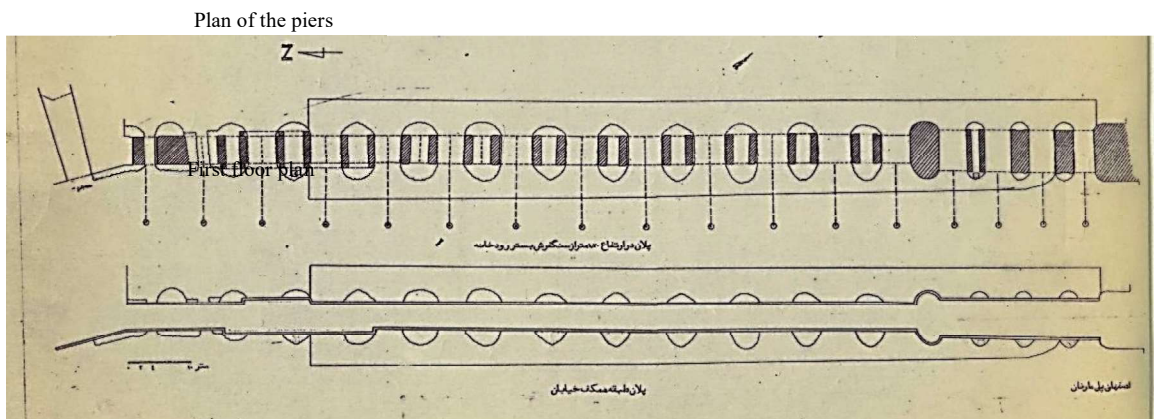


Fig. 47: Architectural document of Marnan bridge, Archive of cultural Heritage, handicrafts and tourism organization of Isfahan.





Fig. 48: Picture of the Marnan bridge, Author.

### 3.8. Juyi bridge

Jouei bridge was built in 1658 by King Abbas II. The bridge was one of the most important buildings of Sadat Abad Garden which was located west part of Khaju bridge and connected the women's section to the men's section in the Sadat Abad complex (Marnani, 2016). The bridge was used to irrigate the lands of the royal garden as well. The name of the bridge was taken of word "Joui"<sup>3</sup> and this name was given to bridge due to existence of a rock on the bridge during the Safavid period which made a flow of water on the bridge. Due to the location of the bridge in the Saadat Abad complex and the possibility of passing through the courtyards, it is also called as Sadat Abad Bridge (Rostami Najafabadi, 2011). This bridge was element to connect royal gardens in northern part of the river to Saadat Abad complex in southern part and it seems that it didn't have public function.

It is 147 meters long and 4 meters wide, with 21 arches. The bridge and the two pavilions within were for the exclusive use of the Shah and his courtiers (Gemaiey, 2014). The building of these royal pavilions has Stretched toward Khaju Bridge to provide better view for the people of the courtiers during the ceremonies (Qasemi & Shayesteh, 2004). Nowadays the pavilions are being used as tea houses and have a commercial function.

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<sup>3</sup> Joui means a small stream of water.

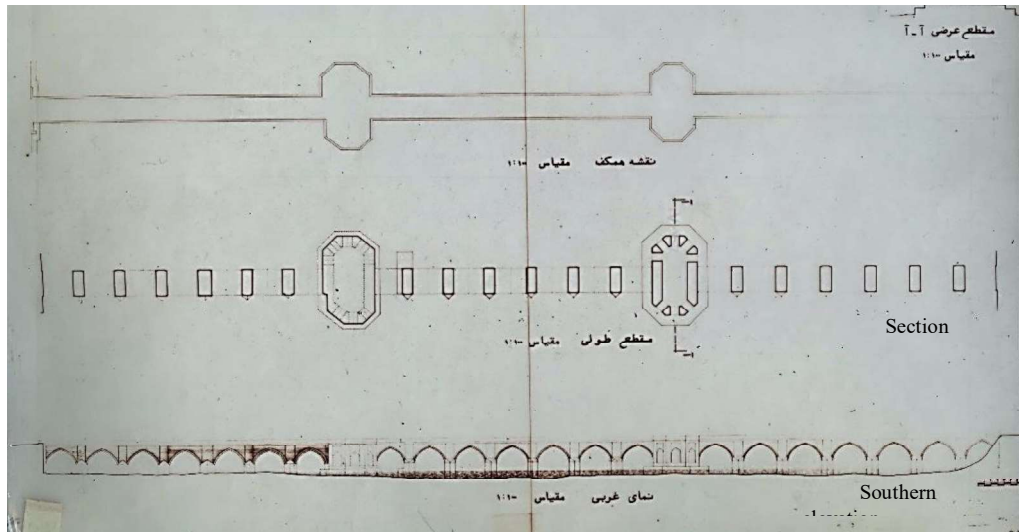


Fig. 49: Architectural document of Joui bridge, Archive of cultural Heritage, handicrafts and tourism organization of Isfahan.



Fig. 50: Location of Joui bridge in Isfahan, the trace of the old garden is visible, Google earth.



Fig. 51: The café of Joui bridge, Author.



Fig. 52: People who are relaxing close to bridge, Author.



Fig. 53: Dedicated route between Haft-Dast and Saadat Abad palace, Painting of Eugène Flandin 1851, [fa.wikipedia.org](http://fa.wikipedia.org).

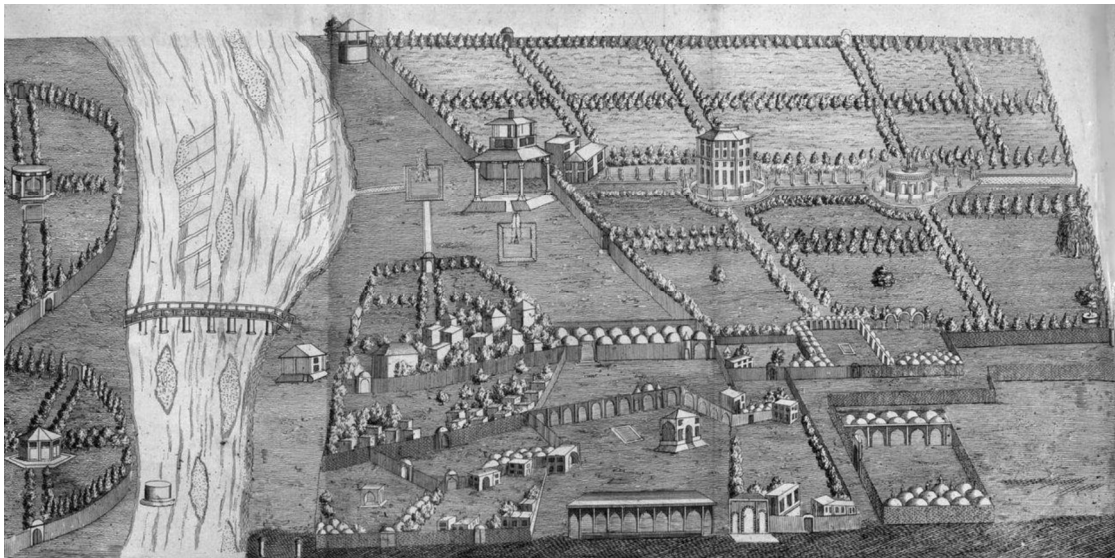


Fig. 54: Painting of Joui bridge between royal complex in Jean Chardin's book, 1670,

### **3.9.Si-o-se pol Bridge**

Si-o-se pol is one the most magnificent bridge of Isfahan which had been constructed in Safavid period. The bridge built under order of commander Allahverdi Khan, a notable governor and close associate of Shah Abbas. The bridge served as a symbol of Allahverdi Khan's devotion to his ruler, but also highlighted Shah Abbas' urban policies of resettlement and development (Mitchell & Melville, 2013). Accordingly, this bridge is called Allahverdi khan bridge as well. This bridge was a connection between main part of the city to south, indeed it was located on the main axis of Isfahan and it provided the possibility of connection between two principle parts of the city (Saber, 2003).

According to one the poems which had been written by one of the poets of Shah Abbas I in the Safavid period, Ostad Hossein Banna Esfahani was mentioned as the architect and builder of the si-o-se pol (Honarfar, 2009). He was one the famous master and architect of Safavid period, he also educated his son and he, Mohammad Reza Esfehni, became a great master after him and he built Sheykh-lotfollah mosque for women of the Safavid royal family. Si-o-se pol is the only Isfahan's bridge which its architect and builder had been mentioned in historical documents. The bridge was built in 1632 under the supervision of the commander with 300 meters long and 14 meters wide. Si-o-se pol was located at Chaharbagh street, in the north-south direction and it connected the old Chaharbagh street to the new one (Beg Munshi, 1971).



Fig. 55: Location of Si-o-se pol bridge in Isfahan, Google earth.



Fig. 56: Si-o-se pol bridge, Author.

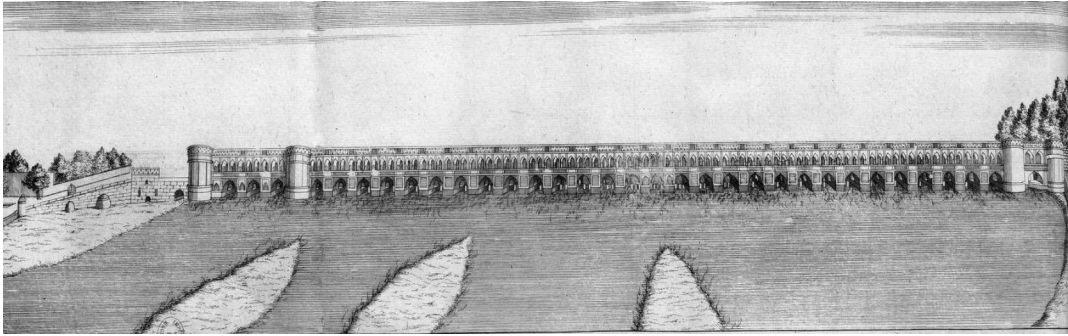


Fig. 57: Old painting of Chevalier Chardin, 1670, [www.wikipedia.com](http://www.wikipedia.com)

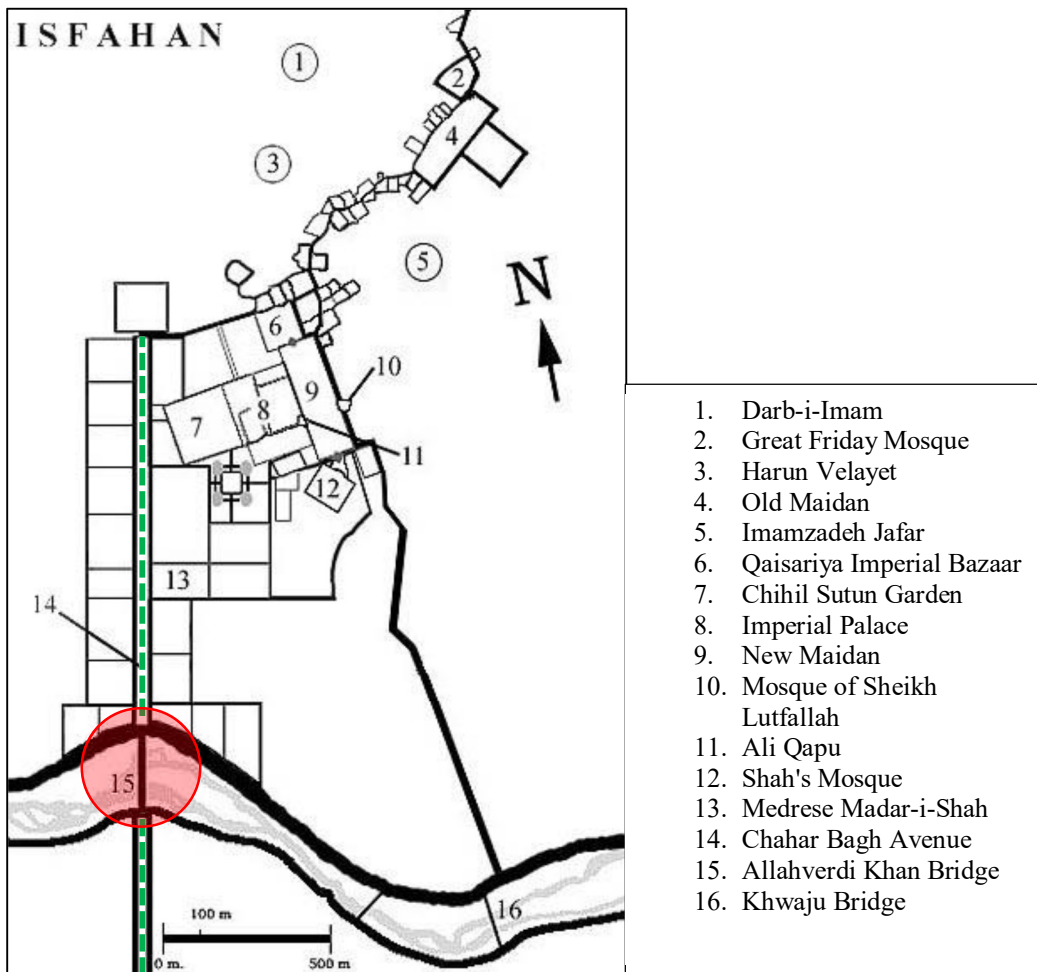


Fig. 58: Diagram of old Isfahan city, [depts.washington.edu](http://depts.washington.edu)



As it was mentioned earlier, the foundations of Marnan bridge and si-o-se pol have a similar construction. Since during Safavid period, the vernacular architecture was always considering, the used materials in bridge construction was provided from local materials. Thus, the walls of the bridge were made of brick and the pillars, for more resistance was made of stones. The bridge consisted of arcaded corridors for pedestrians which give them the possibility of enjoying the river's view in addition to providing passage for animals and goods transportation.

In the middle of the bridge there is two small rooms which cannot be considered as a pavilion. These spaces are not like the pavilion which is located in middle of Khaju bridge, actually they are smaller than what can be used as place to watch the ceremonies and traditional ritual events, and also none of the historical documents have mentions their usage for the royal family.

According to historical documents, during the ceremonies, the king with his attendants and his guests such as governors and commanders and foreign delegates, were sitting under the bridge's arches and watching the events (Si-o-se pol restoration report, 1970). However, it is not possible to find other kind of functions for these small room. It seems that these rooms were used for the royal family, especially for the women, to watch different ceremonies.

Therefore, in addition to that, apparently, these small spaces have structural values for the bridge and these rooms and their surrounding columns are intended to increase the resistance of the bridge, since the bridge length is too long and these columns are able to increase the resistance of the bridge to the forces which are imposed on it.

Before Khaju bridge construction, Si-o-se pol was the place for gathering and holding the traditional ceremonies, such as Nowrouz<sup>4</sup>. Khaju bridge had been constructed about 59 years after Si-o-se pol bridge. It is the most developed inhabited bridge of Isfahan and also whole country in which the builders tried to meet more and more needs of the users.

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<sup>4</sup> the Iranian new year, which is the most ancient traditional ceremony in Iran.

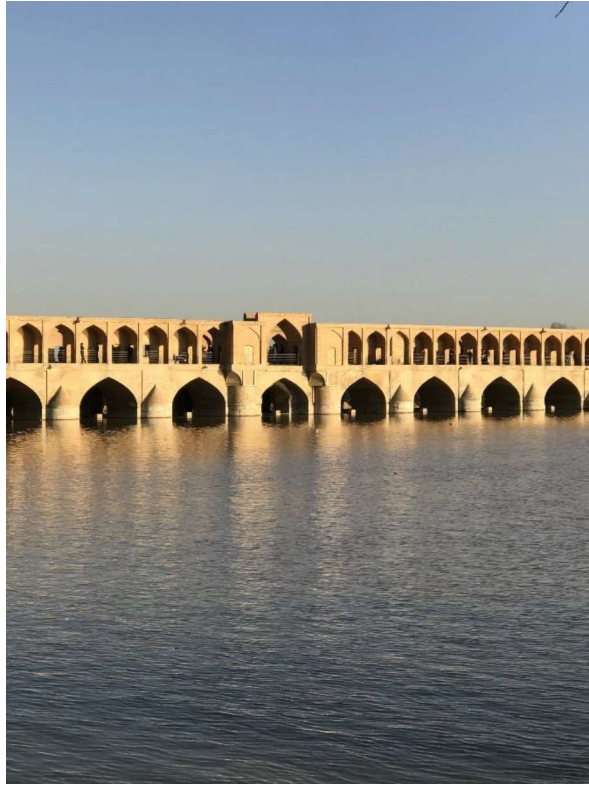


Fig. 59: Two small rooms of the bridge, Author.



Fig. 60: Entrance of the one room on bridge, Author.



Fig. 61: The columns of the bridge, Author.



Fig. 62: The arches under bridge, Author.

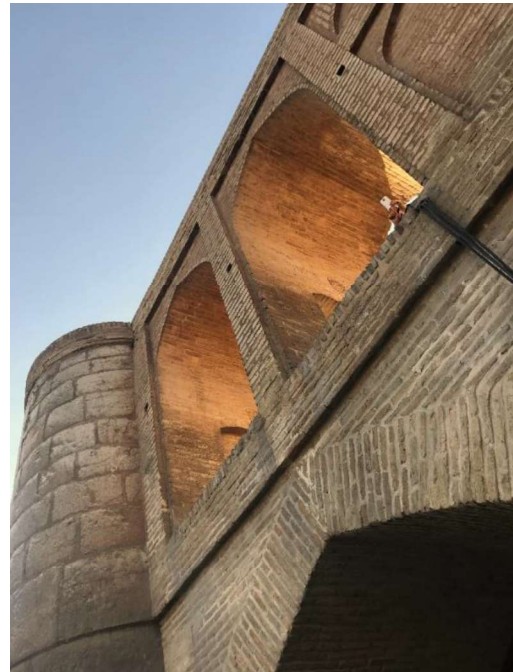


Fig. 63: Combination of brick and stone in bridge construction, Author.

According to the author, the lack of a special and comfortable place for the king and the royal family, made the builders and architects to find a solution for this problem. For this reason, they designed a pavilion for royal family presence. Si-o-se pol is the only bridge with religious function. Si-o-se pol consists one Sagha-khane which is located on its second floor. The Sagha-khaneh is a cubic-shaped chamber with different kind of decorations with tile, brick or mirror that provides beverage water for people and candles were lit around the it to inform passengers at night.

At the beginning, these places were used just for serving people and provide them water for free, but through time, they found new religious function and those who had an ex-voto lit candles in the Sagha-khaneh every Friday night. Generally, the Sagha-Khaneh are dedicated to people by their family member for bless their soul and their forgiveness. There is a Sagha-khaneh on second floor of the Si-o-se pol which is not been used nowadays, but it can be seen on the bridge. It's not been mentioned in historical documents that this Sagha-khaneh was dedicated to whom, but it is evident that it had been constructed by the bridge at the same time not sin following historical periods.



Fig. 64: Picture of the Sagha-khanch, Author.

### **3.9.1. Economy aspect of Si-ose pol**

In safavid period bazaar had been known as the symbol of Isfahan urban economy in Shah Abbas's reign. Shah Abbas new complex was consisted of a huge square, named naghsh-e-jahan square. This square in addition to the economic function, had importance role in different aspects of social and political functions too, many of foreign ambassadors and representatives are received to king here at Ali-Qapu palace. In other hand, this square was a place for celebrating national events such as Nourooz. In a general definition Naqsh-e-Jahan square, as the royal performance of Shah Abbas's political and economic power, is interpreted by an obvious form and architectural elements, mosque, bazaar and palace. After Shah Abbas, King's second main action on urban-planning in Isfahan was constructing and developing Chahar-Bagh Street. Uncommon size of street in length and utilizing four rows of green field and its connection with flow of water are the reasons to build Si-o-se pol over this street.

In safavid urbanization the Chaharbagh street must cross the river and for this reason the architects decided to construct Si-o-se Pol on the Zayandeh Rood River based on Chaharbagh route. Chahar-bagh Street was 60 m wide in which there had been planted 8 regular rows of poplar and sycamore trees. Between each tree, there were some flowers, including roses and jasmine and these trees had four streams. The widest had been located in the center and carved stones had adorned its surrounding (Dehghan Touran-Poshtil, Tayefi Nasrabadi & Naghizadeh, 2011). The products from the orchard gardens of Chaharbagh were open to the public and all people could use them. No income from these gardens was earned by the king.

This street was a recreational area for Isfahanian people, so Si-o-se pol also was engaged to this feature and it became a diversion place as well. While the bridges were constructed mainly on the less-width part of the river, since Si-o-se pol was constructed to connect two different sides of the street, it is excessively long in compare to the other bridges. This special feature of the bridge allows the pedestrians to enjoy the surrounding landscape and picturesque sight.

In the Shah's national economic policy and marketing strategy, however, Armenian merchants played a particularly crucial role of middlemen between Iranian manufacturers and foreign buyers. Social structure of urban quarters in Isfahan during this era indicated that the Safavid kings flourished urban life as well as national and international commerce by utilizing the skill of Jewish, Armenian and others and making use of it in economic sectors.

Armenians prior to their migration lived in the northwestern and northwestern parts of Iran, in their original and historical habitat. The main reason for their emigration, or in other words the forced migration of Armenians from their mainland, was the long wars and conflicts between and Ottoman empires. On the orders of Shah Abbas, these people were moved to Isfahan from various parts of the country, and in this way the risk of their loss and captivity by the Turks was eliminated because they were not near the borders of the Turks anymore (Soltanian, 2011). After the migration of them, they were located in south part of zayandeh-rood and they made their own quarter which was called Jolfa. Jolfa quarter is realized as an evident sample of this kind of thoughts in which economic activities were grown by centralization of forces and social shared duty –especially foreign trade- among them, and then king possessed their enormous profit.

The main economical purpose of construction of Si-ose pol bridge was to connect a part of the city to the south of part of the river. The bridge was intended to connect the neighborhood of the new residents to the city's economic axis. According to historical documents Chahar-bagh street has a special importance in Isfahan economic conditions, which can be say, as important as great Bazar. This street was the continuation of the Bazaar and there were different small and big shops, tents, stores to sell their products and stuff to people.

According to the author, Si-o-se pol bridge had a direct impact on commercial function of Isfahan in two different aspects, first of all, it was located on the axis of the Chahar-bagh street, to connect Jolfa quarter in south parts of the river to Chahar-bagh and bazaar, two main commercial axis of the city. In such circumstances, the Armanians as important merchants, could be able to frequante to main commercial parts of the city easily. In itther hands, the small shops and stores could be continued also on the bridge and small spaces on it which had been made by the bridge's arches. these small spaces could be used as small temporary shops and in such a way, the chahar-bagh street axis, as commercial axis, had not been broken off and it continued to other part of the city, on the other side of bank of river for other neighborhoods.

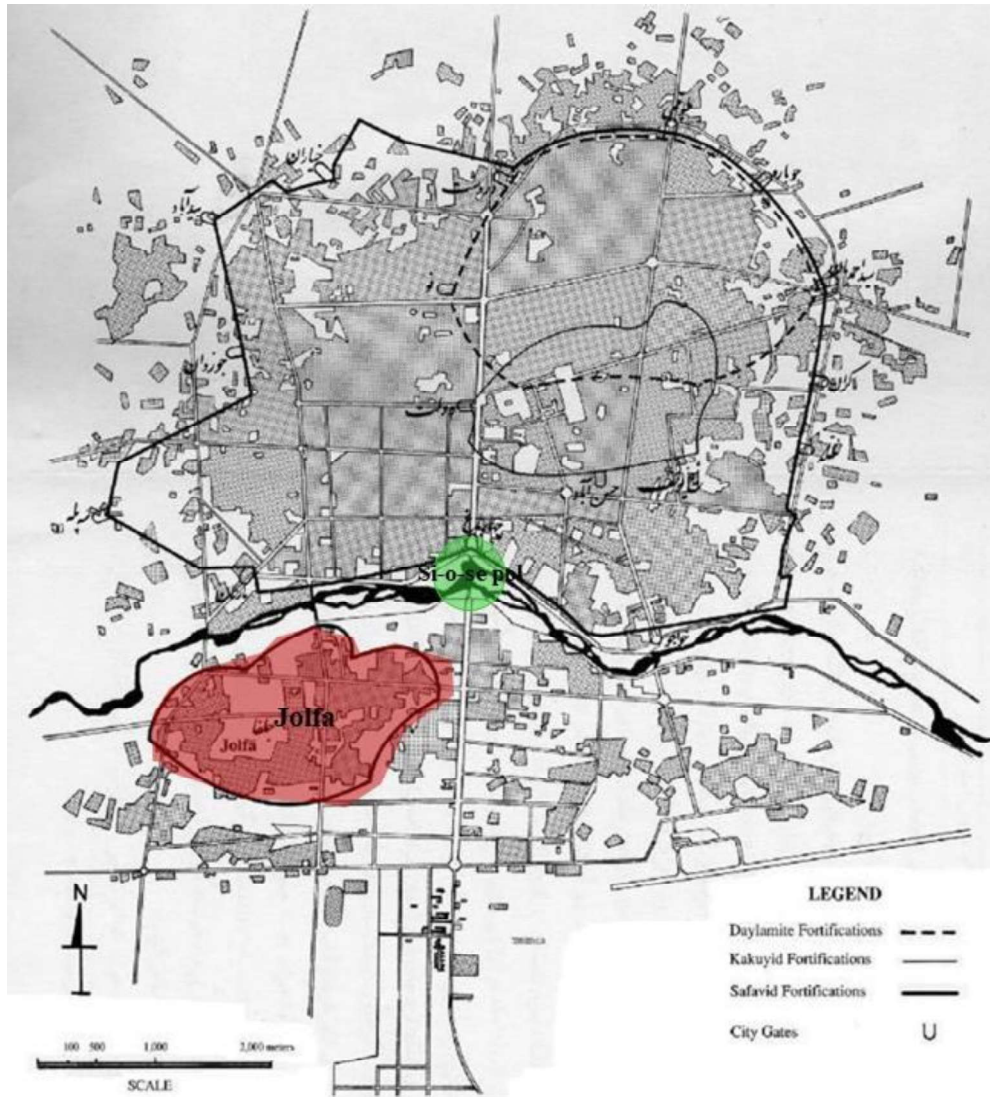


Fig. 65: Location of Armenians quarter, Author.



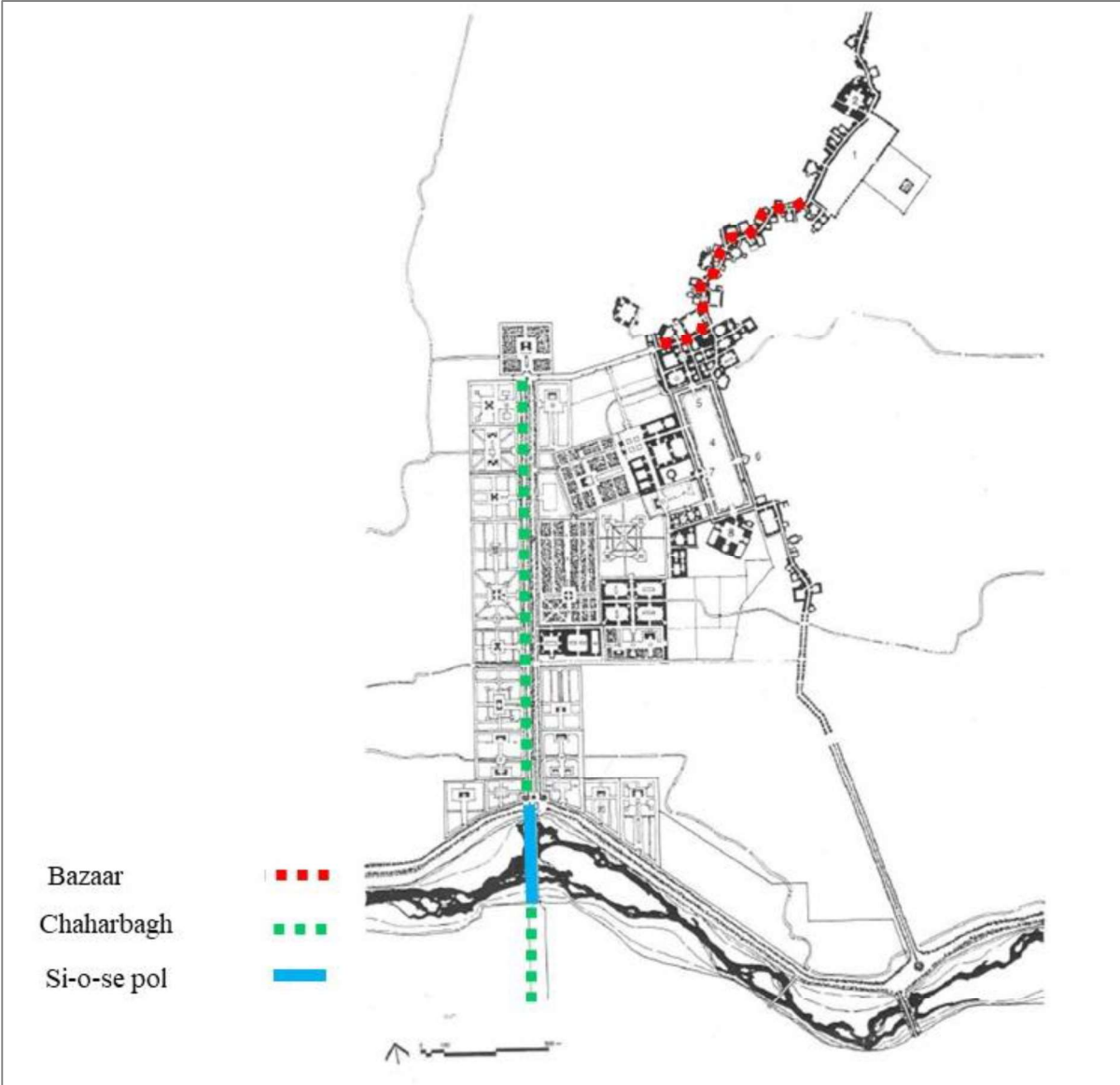


Fig. 66: Location of main commercial axis, Author.

### **3.10. Isfahan Bridge's architects**

In the Islamic era, the main attention was towards construction and design of the buildings. The architect's and constructor's name on the inscriptions was unnecessary and their name was not mentioned on any inscription. In most historical sources and documents written by poets and historians, they principally described the buildings and praised their design and architecture, and they didn't pay too much attention to architects and builders. Therefore, they are not too helpful to identify the architects and builders.

In some cases, after several restoration during different periods, the inscriptions were removed or demolished through subsequent restorations. Thus, occasionally, recognizing builders and architects of structures is complicated. The inscriptions were normally located out of the building, on the façade, and they were exposed to various atmospheric conditions such as wind, rain. As a result, they were more vulnerable to climate changes and they destructed and eroded easily.

Most importantly, based on the principle of humility in Islam, many architects and builders refused to mention themselves as architects and builders and they preferred to remain anonymous. On the other hand, after finishing their work, the architects and designers ceded the building to the ornamenters for its decorations, so they did not have the opportunity to mention their names on the building. Among the bridges of Isfahan which were built on Zayandeh-rood, the architect of Si-o-se pol is known, due to the inscription which was installed on the bridge. Unfortunately, according to the author's research, there is no valid information about other bridge architects. In other hand, this issue is less common in Islamic buildings such as mosque and Madrassah, because these buildings had particular importance, so more effort was made to record related information such as builders, architects, etc.

## **Chapter IV**

## Résumé

Le pont de Khaju est un exemple d'architecture civique complexe et multifonctionnelle qui a émergé dans le contexte de la convergence des connaissances et des compétences à Ispahan, la nouvelle capitale de l'ère safavide (Hensel, 2015). Construit sous Abbas II, le Khaju est également un barrage à vannes. L'originalité de la superstructure en brique réside dans les galeries latérales couvertes et dans les pavillons en saillie qui en font un palais plus qu'un pont. Le pont de Khaju est le dernier pont construit par la période safavide sur le Zayandeh Rood, témoin matériel de l'évolution de la construction du pont. C'est un exemple important de ponts d'arcade habités en Iran, l'un des plus avancés si on le compare aux précédents.

#### **4.1.Introduction**

The Khaju Bridge is an example of a complex multifunctional civic architecture that emerged in the context of the convergence of knowledge and skills in Isfahan the new capital of Safavid era (Hensel, 2015). Built under Abbas II, the Khaju is also a dam with sluice gates. The originality of the brick superstructure lies in the covered side galleries and in the projecting pavilions which make it more a palace than a bridge.

Khaju Bridge is the last bridge built by the Safavid period on Zayandeh Rood, material witness of the evolution of bridge construction. It's an important example of inhabited arcade bridges in Iran one of the most advanced if compared to the previous ones.

#### **4.2.History**

After the transfer of the capital of Iran to Isfahan during the Safavid period, many monuments and gardens were there built under order of the Safavid king. Unfortunately, plenty of these buildings were destroyed or abandoned in later periods, especially after the Afghan invasion. Saadat Abad Garden was one of those great Safavid gardens that was built during Shah Abbas II reign.

There is no evidence for what concerns the names of the builders or architects in related historical documents. In the Safavid period, the construction system for monuments was still tied to the practice of teaching and collaboration between master and apprentice, probably the architect was at the same time the master and the supervisor even if there was not specific architectural drawing which had been prepared previously for the buildings. And maybe that is why there are no historical plans and documents for the monuments from that era.

According to General Sir Albert Houtum-Schindler, British researcher, the bridge was built on the ruins of the old one, which was destroyed during the Afghan invasion (Mokhtarian, 2001). The name of this bridge is taken from one of the old neighborhoods of Isfahan. According to historical documents, the bridge was completed in 1060, coinciding with the eighth year of the reign of Shah Abbas II (Pournaderi & Marvaje Torbati, 2013).

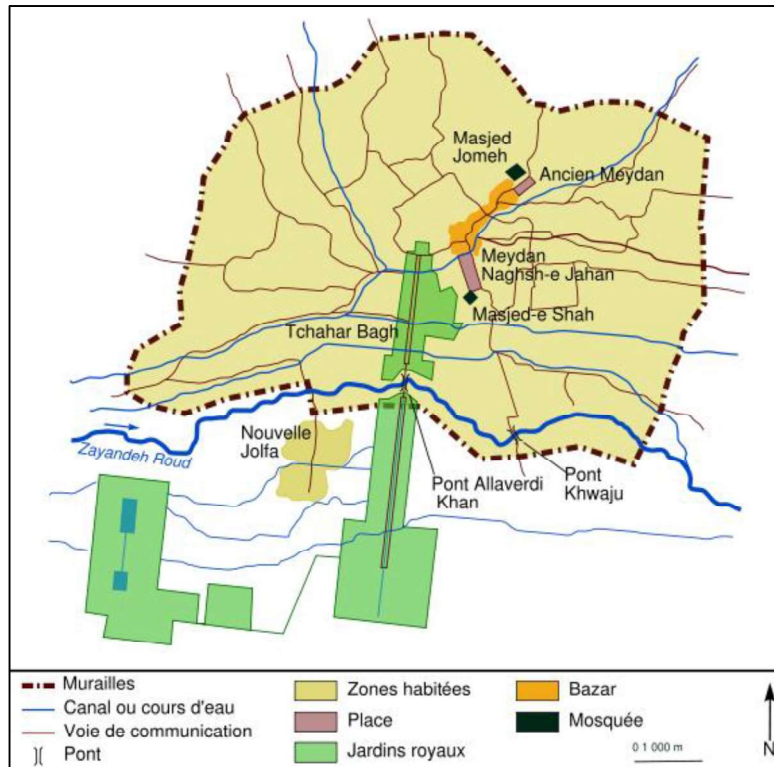


Fig. 67: Safavid Royal complex, commons.wikimedia.org

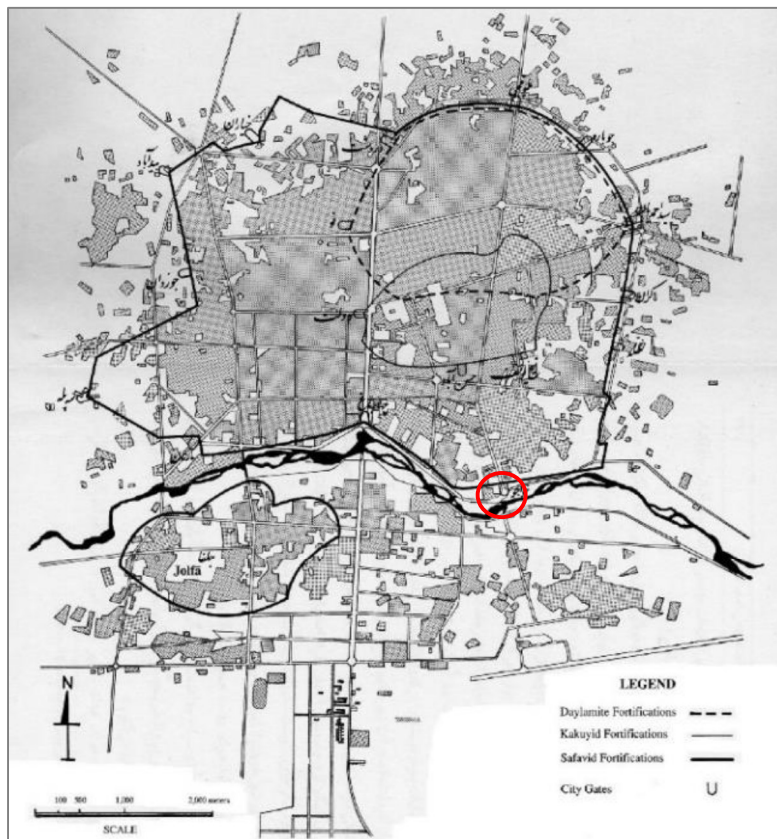


Fig. 68: Location of Khaju bridge in map of Isfahan city in Safavid era, www.iranica.org

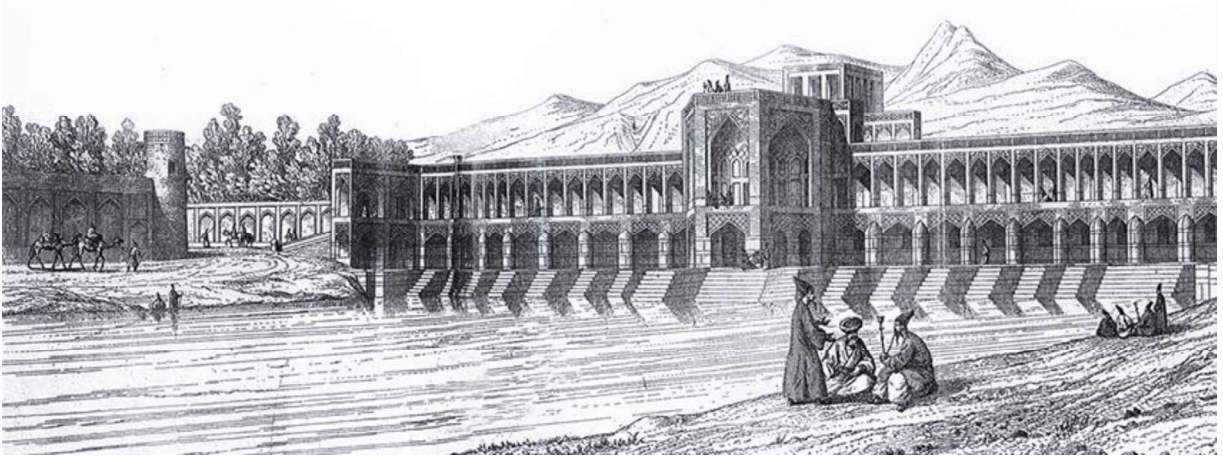


Fig. 69: Old painting of Khaju bridge, 1867, [www.islamic-arts.org](http://www.islamic-arts.org)

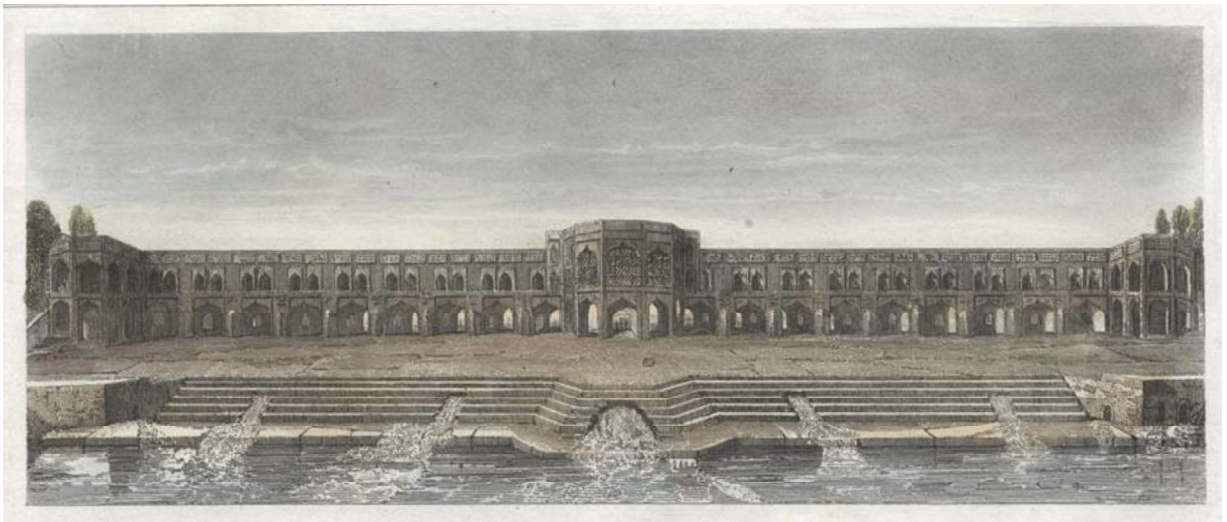


Fig. 70: Old painting of Khaju bridge, 1841, [www.ancestryimages.com](http://www.ancestryimages.com)

Jean-Baptiste Tavernier, 17th-century French traveler, has mentioned the Khaju bridge in his travel; the bridge is located on the most beautiful part of the river. There are two houses on both sides belonging to the king. This bridge is built to shorten the route of the neighborhood to Chabagh Street, according to Shah Abbas II order (Rostami Najafabadi, 2011). For this reason, Khaju Bridge is also referred to Pol-e-shahi (King's Bridge), because it had been located in the vicinity of the royal complex.

Saadat-Abad complex consisted in a gardens with buildings which were belonged to royal family and it was located on both sides of the river, where the river expands and takes the form of a lake. Thus, it was a good place for big royal celebrations with water and nature theme (Omrani Pour & Moradi & Faizi, 2012). Since the bridge was to be built near the Saadat Abad Garden, the architects tried to make it more beautiful, stronger and better than other Isfahan bridges.

#### **4.3. Architecture of bridge**

The idea of the Khaju bridge is based on the evolution of previous constructions and development of a suite of architectural ideas. This recognition of the Khaju Bridge has two important aspects: the continuation of the architectural experiences besides the advent of architectural creations and also attention to the presence of man as a recognition of his physical and mental needs (YazdaniRostam & Kia & Sadeghian & Khosravi, 2018).

Moreover, unlike its predecessor the Khaju bridge rests on a high stone platform which on the east shelves fall down to the river in a series of shallow steps broken by sluices, while to the west spear-shaped counterforts break the river's flow (Jackson, 1986). Khaju Bridge is 133 meters long and 12 meters wide. The pass way of the bridge is 7.5 meters wide (Çakmak & Khaleghimoghaddam, 2016). This bridge has two floors. Records from Safavid epoch show that the aim behind the designing of first and second levels of the bridge was to optimize water flow and forming an adorable landscape. The design of the bridge also takes advantage of wind and water flows to bring positive feelings to visitors especially in the summer (Torbaty & Hashemian, 2015).



The upper floor is for pedestrians who only want to cross the width of the river and go from one point to the next, and the lower floor is for the others who want to rest and stay near by the water (Qasemi & Shayesteh, 2004). The lowest section serves as a weir and its widest it reaches 26 meters. when the sluices were closed the level of the river rised by some two meters (Jackson,1986). In the lower floor there are 21 arc-shape openings.

This bridge has two different façades, the main one is toward the east where the sun rises (Eskandari & Toulaian, 2013). On the second floor, two covered sidewalks on both sides and a ride path in the middle are existed (Eskandari & Toulaian, 2013). The purpose of construction of ceiling on the sidewalks on both sides of bridge is to prevent rain and sunlight. It is lent a more imposing air by the massive octagonal pavilion which straddles it in mid-stream, and juts out on both sides like a prow (Jackson,1986).

#### **4.4.Construction techniques**

The form of frontal foundation has a sharp-point which absorb the dynamic force of water and reduce its damaging effects on the bridge structure (Shiraazi & OstadiAsl & Sheikhloie &Azami & Hassanimehr, 2012) In this case, the flow of water will increase as it passes through its span, because the piles of the bridge allow to decrease the size of the river.

The presence of stairs on the other side of the bridge reduces the speed of the water, so the level of the river's water before and after crossing the bridge has about three meters' difference. The stairs on the eastern side of the bridge are similar to the buttress, which support the bridge structurally. The sloping pyramid shapes of the stairs allow for the seating of about 500 people (Qasemi & Shayesteh, 2004).

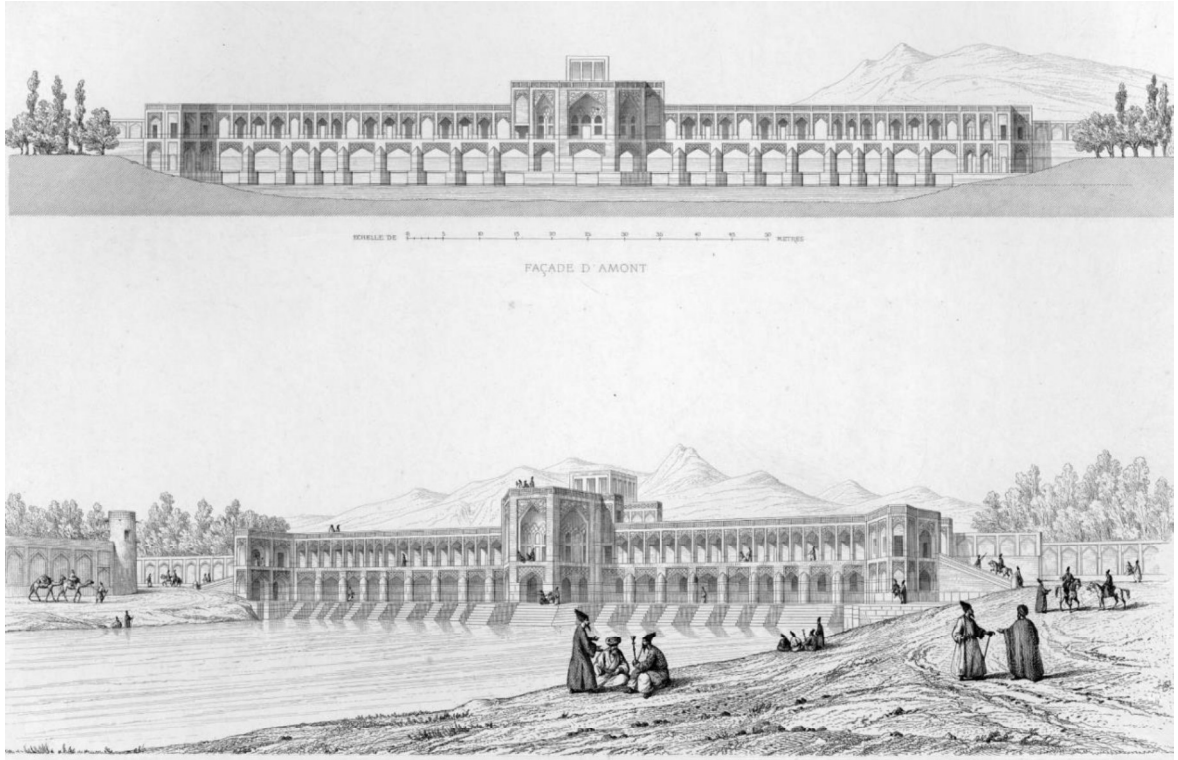


Fig. 71: Khaju bridge façade, Pascale Coste painting, 1840, upload.wikimedia.org

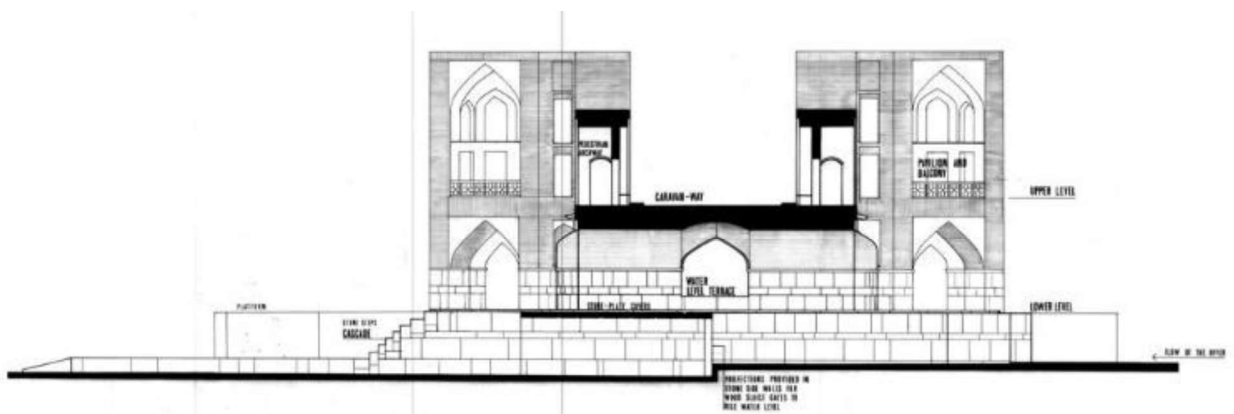


Fig. 72: Cross section of Khaju bridge, Isfahan cultural heritage organization archive

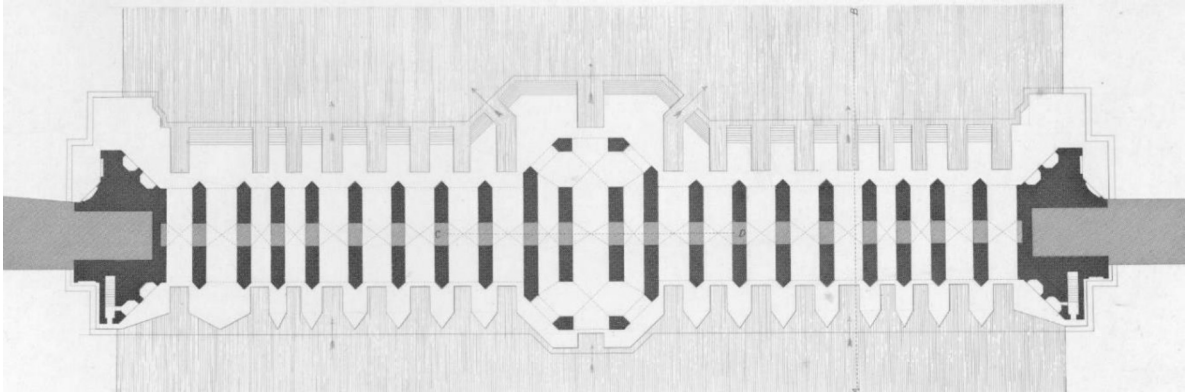


Fig. 73: First floor plan, [www.wikipedia.org](http://www.wikipedia.org)

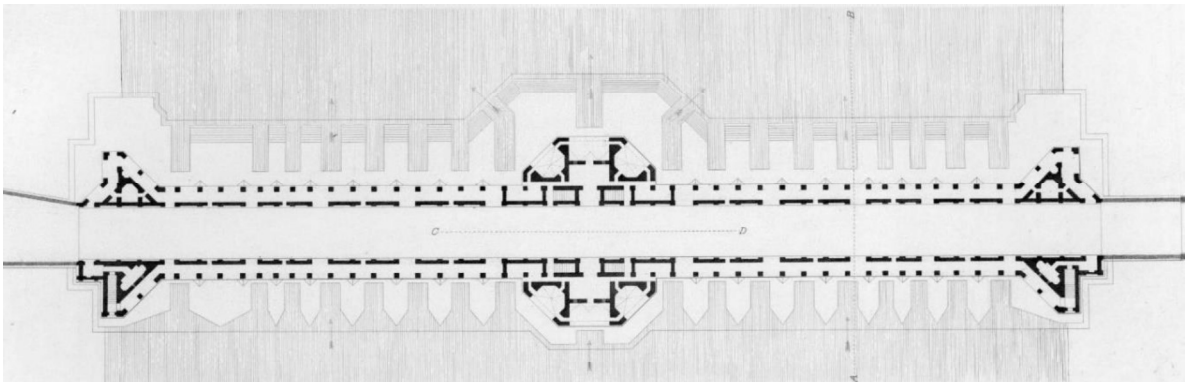
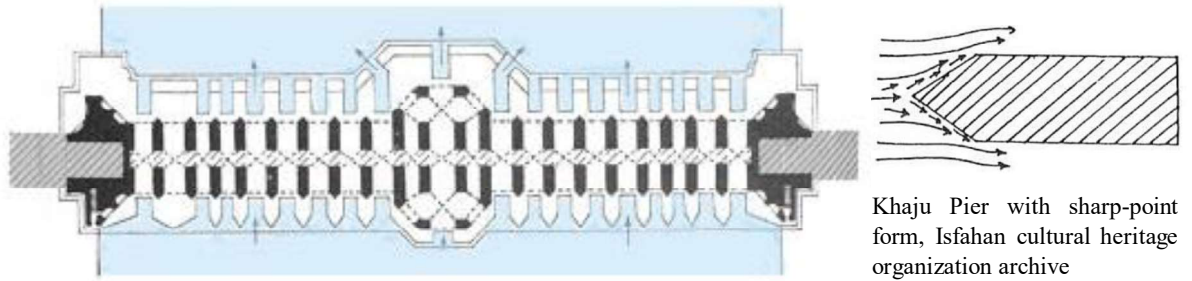


Fig. 74: Second floor plan, [www.wikipedia.org](http://www.wikipedia.org)



Khaju Pier with sharp-point form, Isfahan cultural heritage organization archive

Fig. 75: Bridge diagram, Isfahan cultural heritage organization archive



Fig. 76: Western side of bridge, Author

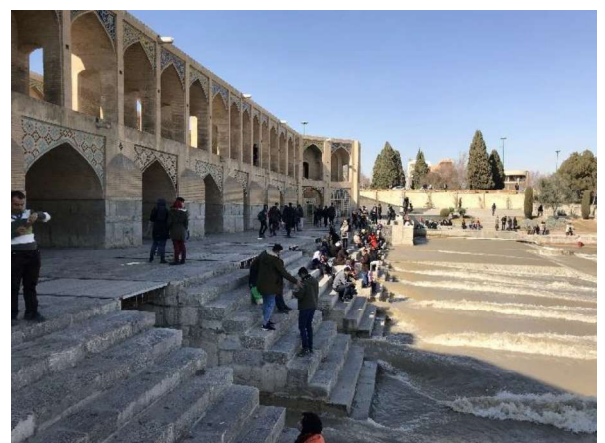


Fig. 77: Eastern side of bridge, Author

#### 4.5. Materials

The use of vernacular materials has always been one of the most important Iranian architectural issues, and Iranian architects have always paid attention to that. The materials as used in the construction of the Khaju bridge also reveal a vernacular inspiration.

Major materials used in the bridge construction include stone, brick and Sarooj<sup>5</sup>. In the foundation of the bridge, there are piled with a core of rocks and Sarooj that forms a coherent and resistant volume. The middle part is based on the combination of rock and lime mortar, which has a special resistance in wet environments. The upper part is made out of bricks with plaster and clay mortar (Amir shah karami, 2006). The stone which was used for construction of piers were imported from a mountain close to Isfahan, which called Soffeh. This mountain stretches from west to east and is located in the south of Isfahan, 6 km away from Isfahan.

Brick is one of the main components of Iranian traditional architecture. The history of using bricks in Iran goes back more than 6000 years ago. Brick is considered as a vernacular material in the central parts of Iran due to the arid and dry climate of those regions. Brick is one the most important material in Iranian architecture because of its special features, such as small dimensions, easy to carry and ease of application which provide the possibility of construction of large arch and dome. It is also highly resistant to climate change and has been able to endure for many years against erosion caused by climate changes.

In the Safavid era, bricks were made in the traditional way. To make the bricks in the traditional way, first they preparing the primary mud, then they were poured it into lubricated square wooden molds, which were hollow at top and down and later the smoothed them by hand. After this step, they exposed the molded bricks to the sun for three to fifteen days to let them dry. They then dug wells near the construction site on the ground for baking the bricks. The bricks were placed inside wells and allowed them to cook for 6 or 7 days. At the end, they turned off the fire of wells and led them to be cool and after that, they took out the bricks. In this way, the bricks were accessible to builders and their transportation was so easy for them. At the end of the construction, they filled the wells by stones and soil and they barred the wells.

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<sup>5</sup> Sarooj is a traditional water-resistant mortar which is made of lime and clay or sand.

#### **4.6.Ornaments**

Khaju bridge originally was ornate with artistic tile works and paintings. The gilded paintwork and moral saws which formerly graced these rooms have been replaced by modern tilework and stenciled carpet designs (Jackson,1986). This bridge is the only constructed one on Zayande-rood with tiling decoration which is simple as well and one of the main reason could be showing the glorious and power of the kingdom and make it different from the other bridges.

During the Safavid period, mosaic ornaments were often replaced by a haft rang (seven colors) technique. Pictures were painted on plain rectangle tiles, glazed and fired afterwards. Besides economic reasons, the seven colors method gave more freedom to artists and was less time-consuming. The seven colors of Haft Rang tiles were usually black, white, ultramarine, turquoise, red, yellow and fawn.

#### **4.7.Hidden geometry of the bridge**

There is a series of large rooms with domes under the Khaju Bridge and in the center, they both can be seen from below the bridge. The lower part of these arches is located on the columns of the bridge. In spatial composition of two adjacent rooms, the image of a candle is formed with its flame.

The flame of this candle is a result of the intersection of the north-south arc westward of the Hall A with the northern-southern arc of the eastern side of the hall B, and its body is formed by the intersection of the northern part of the pillar A with the southern part of the pillar B. These images are visible in four directions and the best angle for visiting them is a 39 degree to the horizon (Mokhtarian, 2001).



Fig. 78: Ornaments of the Pavilion of Khaju bridge,  
Author



Fig. 79: Ornaments of the Pavilion of Khaju bridge,  
Author

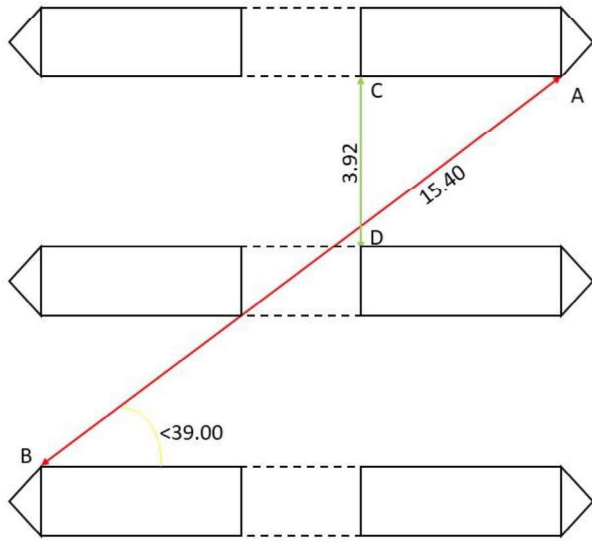


Fig. 80: Diagram of the hidden candles of Khaju bridge, Author



Fig. 81: Hidden candles of Khaju bridge, [www.raheeno.com](http://www.raheeno.com)



Fig. 82: The used materials (Brick and stone) are visible in this picture, Author



#### **4.8.Functions of the bridge**

The designers intended the bridge as a new public space where people would gather and enjoy social experience. The Khaju Bridge is an interesting exemplifies compound infrastructure. Its single structure combined transport functions with hydraulic regulation, while its steps, walkways, and interior spaces house civic activities (Brown, 2014).

The bridge serves as a dam by using arch brick sluices to control the flow of water in the river. In addition, the two-storied bridge provides walkways and meeting areas beneath pointed arches. The bridge widens both at each abutment and at the center of the river providing in this way a larger gathering place (Mansour, 2017).

##### **4.8.1. Dam-bridge**

Khoju is a dam-bridge which is the best of this type of arcade bridge construction in Iran. The bridge has 18 sluices. The amount of water collected behind the dam was adjusted by using wooden boards that were raised and lowered by the grooves on the body of the bridge. The performance of the dam-bridge can raise water up to a height of 6 meters behind the dam (Mokhtarian, 2001). The pieces of stone used in bridge are over 2 meters long and the distance between every channel and the ceiling base is 21 meters (Çakmak & Khaleghimoghaddam, 2016).

Khaju Bridge, with its function as a dam, provides water for the material and reinforces the underground water table and the small canals (Shahkarami, 2006). During summer droughts, sluice gates could regulate the river flow, impounding water to irrigate upstream agriculture and nearby ornamental gardens (Brown, 2014).

To store the river water behind the bridge, they first placed wooden boards between the sloping grooves of the lower canals to block them. The boards were pulled up and pulled down by ropes attached to the bridge arches for opening and closing the lower canals of the bridge. After closing the lower canals, it was time to close upper canals. To close the upper canals, two reliant timbers were located between grooves which were made on bridge piers, then between the horizontal timber and the lower cover, other wooden boards were laid and they used some wooden piles to make wooden boards more resistant against water pressure. They pulled up the lower boards to divide the water which was collected behind the bridge and measured the depth of the water flowing by using a graduated rod (Hami, 1971).

#### **4.8.2. A place for relaxation**

On the eastern side of the Khaju Bridge, the platform which the bridge's pillars are located, was made in a stepped manner, by pouring water on the stepped platform, a small waterfall was created which produced a pleasant sound. In this case, people who wanted to relax next to the river and nature were sitting in this part of the river and enjoying the sound of the waterfall. Those who had to hurry to cross the bridge, had to cross the upper level of the bridge to reach their destination as fast as possible.

#### **4.8.3. A place for social activities**

The interaction within the context of the city between architecture and nature in a case of Khaju Bridge is one of the main principle to its users which leads them to awareness of events and activities along the bridge and Zayandeh rood river (Shahedi & Inangda Manyam Keumala Hj. Daud & Mohd Yaacob, 2012). On the lower level, the design of the bridge provides a comfortable microclimate by utilizing airflow relating to evaporative cooling.

*“The laminar airflow along the river becomes turbulent and is slowed down in the arched and vaulted space of the lower level of the bridge and streams over the water surface of the river, thus benefitting from evaporative cooling. Effective self-shading of the masonry arches and vaults entails little thermal gain during the daytime. Airflow that streams along these surfaces also benefits from the cooling effect of the thermal mass of the bridge”* (Hensel, 2015).

Singing is one of the practiced tradition who has taken place from past up to now. People of Isfahan are used to sing and walk on the banks of the river. Nowadays, on the first floor, a series of linked arches still serve as popular social spaces and shops. In hot summer the vaults offer refreshment by shaded and cooled space through water's passage and on holidays, this space is filled with the singing of Isfahan people. Since Khaju bridge neighbors the Zayandeh-Rud, all the social activities are practiced even more regularly in the bridge especially by families who spend their spare time around the bridge at summer.

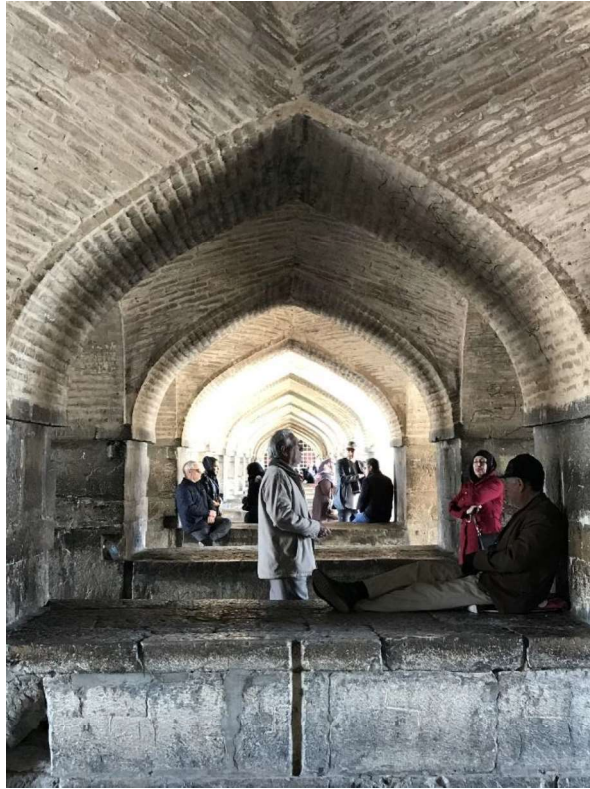


Fig. 83: People who are sitting under the arches of the bridge under the shadow, Author



Fig. 84: People who are sitting on the second floor of the bridge, Author

#### **4.8.4. Ceremonial place**

Khaju bridges is one of the favorite sites for celebrating the national ceremonies. As we know the special events can play an important role in emphasizing on the significance of places and also their shared memories. The attraction of the citizens to these bridges date back to their memories and also long time ago, since the construction of the bridge. The link between the bridge and the components of nature, such as the Zayandeh-Rud is another reason of attraction for people; as in the arid part of Iran, water is an important element to living. In Safavid period, there were some ceremonies which had been held close the river and the royal family participated in. As mentioned before, the royal family stayed in octagonal pavilion and watched the ceremonies.

Some of those ceremonies were so famous which had been mentioned in different historical documents, such as; Abrizan ceremony which had been held on 13<sup>th</sup> of July and people had been gathered close to the river and bridge and had poured water and rose water to each other. The most ancient ceremony Norouz, Iranian new year on 19<sup>th</sup> of March, also had been held on the bank of the river with presence of royal family. These traditions are still alive and every year Isfahanian people gather near the river and hold different traditional ceremonies there.

#### **4.8.5. Create temporary lake**

During the construction of the bridge, on the western bank of the river, royal citadels and palaces were already assembled. By closing the orifices of the bridge, beautiful lake would form and royal family could enjoy and entertain themselves. (Qasemi & Shayesteh, 2004). By closing the bridge sluices in the spring and summer, a temporary lake was formed to celebrate special national rituals and also for organizing water sports. The formation of the temporary lake has been forgotten due to inappropriate interventions on both the bridge and its surroundings.

#### **4.8.6. Royal pavilion**

In Khajou Bridge there are special stop points in the shape of half-octagon that is extending out of the bridge in three points in eastern and western parts of the bridge; and create a half open and half-roofed space for temporary stopover. In the middle of the bridge, a large space with an octagonal plan can be found as Royal pavilion which is constructed in two floors and

this pavilion is divided into two sections by the bridge path. In Persian language, this middle pavilion is called “Shahneshin”. The word “Shah” means king and Shahneshin means “place for king”.

There are also four smaller pavilions at the beginning and end of the bridge, similar to the central pavilion. The presence of Shahneshin in middle and pavilions at the beginning of the bridge, has also strengthened its structure. It should be noted that the pavilions at the beginning and the end of the bridge were used for caravans to pay the toll. (Qasemi & Shayesteh, 2004).

Madame Jane Dieulafoy <sup>6</sup> recalls the remarkable architecture of this bridge in her travelogue. In her writings, she mentioned the pleasant rooms in the upper floors of the bridge for accommodating travelers for free and also two royal residences in the middle of the eastern and western sides of the bridge, which were appropriated to royal family to attend the certain ceremonies.

The central pavilion is a typical Safavid pleasure palace which is a utilitarian structure. From this unique vantage point the king could watch different ceremonies like aquatic sports and traditional fetes. At the same time, the inner rooms gave king the opportunity to rest in private as he wished (Jackson,1986).

#### **4.8.7. Agricultural function**

Khaju bridge is one of the masterpieces of Iranian engineering which is not as well-known as it deserves, since it has not been studied by foreign Iranologists and in the other hand, there's not much left of Iranians writers. In addition to providing a path to cross the river and create an artificial lake on its upstream by closing the bridge's spans, this bridge was a facility to divide the water of river for agricultural purpose.

Khaju bridge has a special effect on underground water table augmentation. Amir Shah Karami had mentioned its role in his article and he explained that the formation of the lack at behind of the bridge had reinforced the Madis and underground water tables. There was a

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<sup>6</sup> A french traveler in 19th century.

system for irrigation of agricultural land in Isfahan which had been named Madis. The Madis are the small canals which steer the water flow to the agricultural lands.

Each of these channels branches off from the main stream of the Zayandeh Rood in its course before reaching the city and after running cross it join to the river again. The patterns of human settlement in Isfahan may had been considered, and influenced the planning and forming these channel network (Agha Ebrahimi & Samani & Bahrami & Salahesh, 2015).

Khaju bridge was used as a dam. Water canals of the bridge were closed during the spring and summer. Water is stored in a reservoir on the western side of the bridge, and then diverted to Maddies and distributed to different districts of the city, used for irrigation and agricultural purposes.

#### **4.8.8. Shops, tea rooms and restaurants**

Nowadays, the pavilions at the beginning and the end of the bridge do not have the former function and their function has changed. Today, they use as commercial place like cafes, teahouse and small shops and in this way they render service to visitors.



Fig. 85: Social activities like singing on the bridge, Author

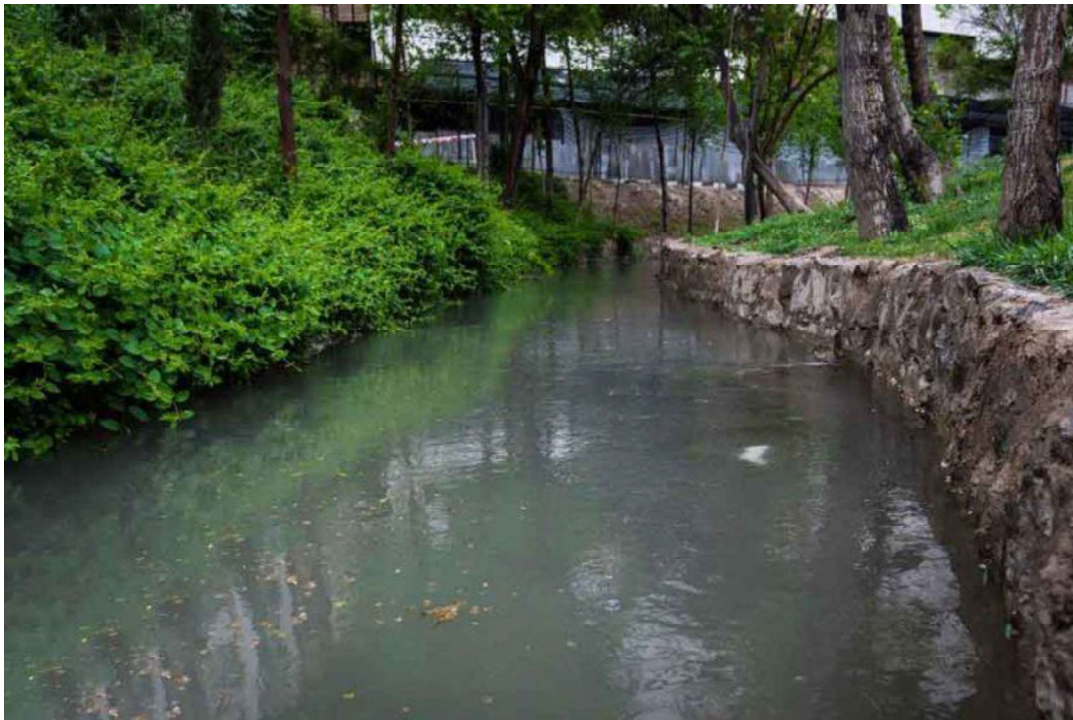


Fig. 86: One of the Isfahan's Madis, [www.jazebha.com](http://www.jazebha.com)

#### **4.9.Economical aspect**

According to historical documents Shah Abbas had two main reasons for constructing this bridge, first, he was interested in natural space and the unique scenery around the river and the other was creation a path close to Gabrha neighborhood. By creating this bridge, Shah Abbas wanted the Gabrha's inhabited to cross this bridge to get to the Isfahan city center instead of Chaharbagh Street, as it was a shorter route to downtown (Eskandar,2013).

This bridge was actually a connection between one of the main street which was branched from bazaar towards Zayandeh-rood. The importance of this street is not more than Chaharbagh street in commercial aspects, but it had been important as it was led from the Bazaar directly to the river and the Gabrha neighborhood. The bazaar of Isfahan as a strong movement under the shade that stretches from the Khaju Bridge on the southeast to the northern gateway, encompassing, in its course, the primary commercial, religious, and governmental activities of the city.

In addition to connect the northern part of the river to southern part, this bridge was one of the main route for Caravans to cross from Shiraz to Isfahan and vice versa (Saber, 2003). This bridge was a place to ask caravans to pay their toll, to provide them a temporary place to stay and a place to use local merchants' services and local trading. As it was mentioned, due to increased silk production, textile weaving was so common in Safavid era, in different rural or national levels.

According to historical records, many people in Isfahan washed their dyed and embroidered fabrics on the banks of the river and spread them out to dry in the sun (Eskandari,2013). According to the author, locals stayed close to Khaju bridge to sell these fabrics to Caravans which came to Isfahan from Shiraz, actually this bridge was a great temporary markets for them to sell their fabrics to Caravans which were crossing the bridge or stopped there to rest in rooms which had been provided for the passengers.





Fig. 87: The location of Gabrha quarter

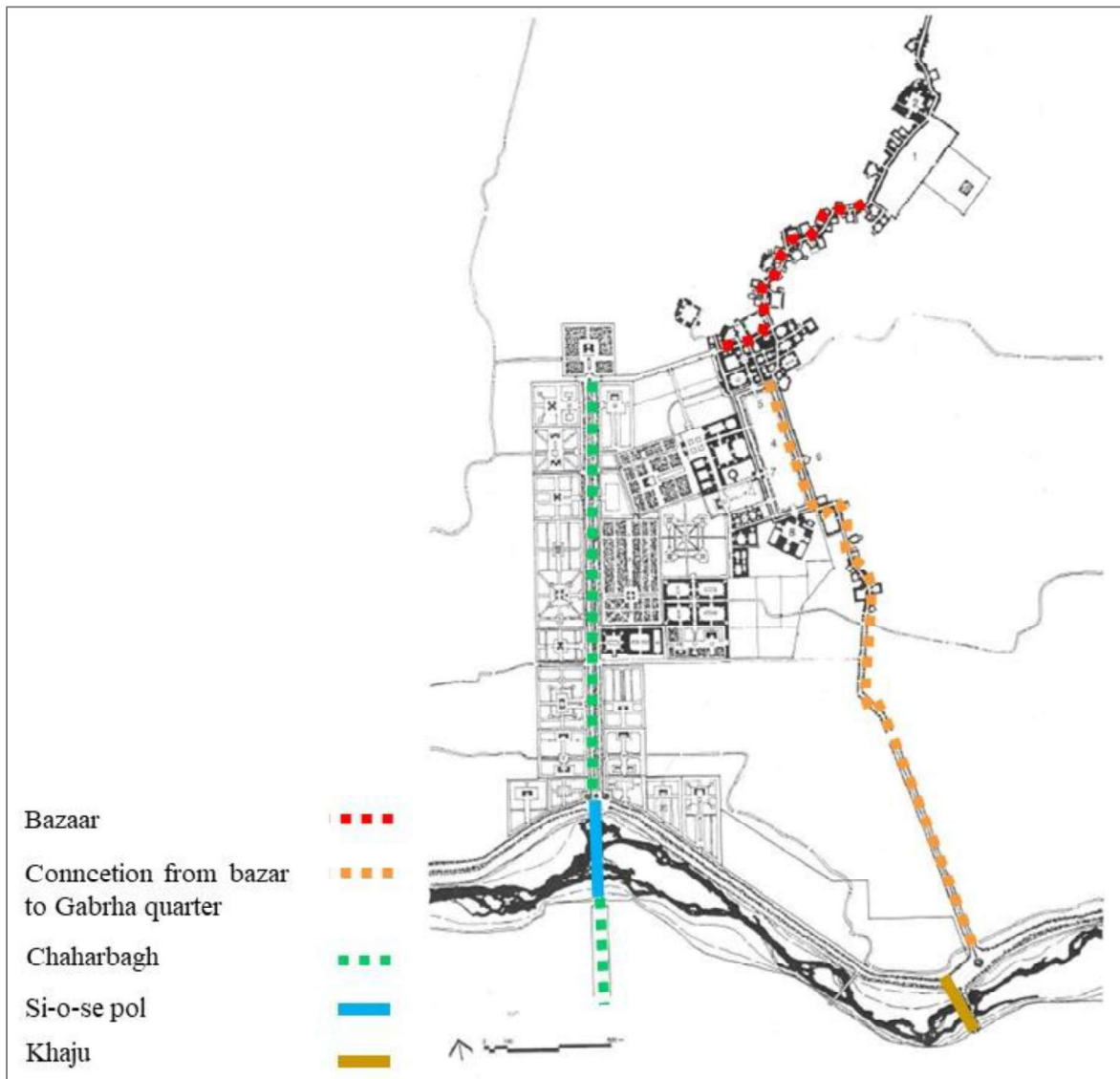


Fig. 88: The location of Khaju bridge and bazaar

#### 4.10. Khaju bridge values

N	CULTURAL_HISTORICAL VALUES	YN	DESCRIPTION
1	Artistic value	—	
2	Aesthetic value	↘	Khaju Bridge has creativity in design, innovation and efficiency, and has the ability to meet needs in different aspects.
3	Memorial value	↘	Khaju bridge is the most important part of collective memory of the city and the people.
4	Identity value	↘	Khaju bridge has a role in the identity of society, both global and regional.
5	Scientific value	—	
6	Rarity value	↘	Khaju Bridge is the most complete example of inhabited bridges in Iran, which is unique in its kind.
7	Emotional value	—	
8	Integrating value	—	
9	Symbolic value	↘	Khaju Bridge, like other Zayandeh Rood bridges in Isfahan, is a symbol of the Isfahan city and the glorious era of the Safavid period.
10	Creative value	↘	Khaju bridge has a creative design which makes it unique in architectural and structural aspects.

Chart 1: Khaju bridge values, Author

N	CONTEMPORARY SOCIO-ECONOMIC VALUES	Y/N	DESCRIPTION
11	Educational value	—	
12	Economic value	✓	Khaju bridge, as a cultural heritage, is a source of social well by attracting many tourists per year.
13	Functional value	✓	Although Khaju Bridge has lost some of its uses over time, but it is still a place for passing, staying, gathering and social activities.
14	Social value	✓	There are collective attachments to Khaju bridge which define its social value.
15	Political value	—	
16	Operational value	—	
17	Newness value	—	
18	Situational value	✓	Khaju bridge has influences on evaluations of tourism.
19	Financial value	—	
20	Potential value	✓	Khaju bridge has potential value for future exploitation and generation.

Chart 2: Khaju bridge values, Author

#### **4.11. Conclusion**

In ancient times, bridge construction techniques started to growing specially in Sassanid time in some way it reached to the peak of art and glory. After Islam, in Safavid time it reached to an exceptional glory and magnificence by constructing glorious bridges on Zayandeh Rood river in Isfahan. They tried to combine different styles and changeability into bridge, that made some of these bridges as masterpieces in bridge examples. Isfahan's bridges were constructed as sustainable structures, for different purpose as follows: connecting two sides of a river, storing water, controlling floods as a dam, making lanes of streams for farms' use, building recreational places for people and a place for gathering etc.

Applying the vernacular and durable materials is one the common point in Isfahan's bridge. Using lime mortar especially in bases and between the bases of bridges, is an effective element on durability of bridges in Iran which was prevalent in building construction at least from one thousand years before Christ. Using plaster, lime mortar, cement grout, dressed stones and finally brick helped the durability of bridges in first periods of bridge construction. Therefore, the bridges with high durability and long life got a significant insolubility against different factors of destruction.

Stabilizing bridge bases where the river water was less, was main effort of builders. Since digging river where water depth is high and constructing foundation under water was not possible, the foundation was constructed in less deep but massive spaces to avoid the displacement of foundation by running water.

The Iranian were expert in construct the arches without using framework, they also did not use frame work in constructing bridge arches. They constructed them with plaster mortar and brick using bonding method and between multiple arches of the bridge bonded to each other with brick partitions.

The structure of historical bridge piers indicates the fact that their sustainable design was based on both the architectural and structural methods. The shape of bridge pier which acts effectively in absorbing force. The shape of frontal pier and foundation are divided to different shape, with regard to the absorption amount of dynamic force of water. In general, the shape of the pier is in such a way that they are given a performance similar to breakwater. The form of breakwater causes a decrease in the dynamic force to the bridge preventing from water-flow turbulence. In general, the principles below were considered in Isfahan's construction bridges:

- a) Using simple shapes for the bridges shapes such as square, rectangle and octagon with particular traffic function.
- b) Making separate pathways for vehicles, pedestrians and stop points for those who want to stay.
- c) Using of parapet and high surrounding walls to create a safe enclosed space for traffic move.
- d) Making roofed pathways and spaces for stopover and resting places to protect people of atmospheric conditions.
- e) Using underneath part of the bridge as a place for accessing to water directly and connecting to the nature.
- f) Employing half-open or half-roofed spaces to creates different spaces with diverse spatial qualities for various functions.
- g) Bridges are designed to be used for diverse functions or a combination of different type of them.
- h) With structural schemes, the surrounding space can be changed in positive way and also be used differently, like Khaju bridge and its artificial lake.
- i) Use innovative designs for make the best of water flow especially its music.
- j) Make possible for passengers to enjoy of surrounding landscape green spaces.
- k) Integrating bridge design with urbanization plan and making maximum use of their location in the city to solve urban problems, such as Si-o-se pol bridge which connects Chahar bagh street.

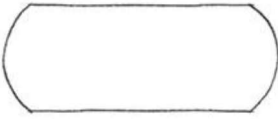
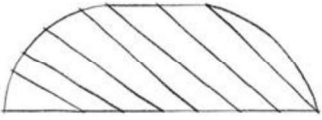
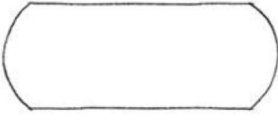
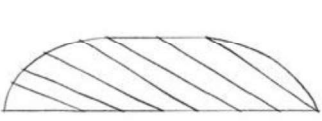

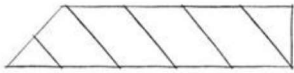

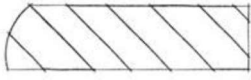
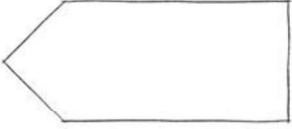
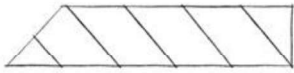
Bridge	Pier's form plan	Pier's form section
Shahrestan		
Marnan		
Joui		
Si-o-se pol		
Khaju		

Chart 3: Isfahan's bridge piers, Author

Physical form	Shahrestan	Maman	Joui	Si-o-se pol	Khaju
Floor	1	1	1	2	2
Foundation	Unknown	pile foundation	Unknown	pile foundation	pile foundation
Konoo	✓	✓	—	—	—
Breakwaters	—	—	—	✓	✓
Specific Entrance	✓	—	—	✓	✓
Specific Exit	—	—	—	✓	✓
Ornaments	—	—	—	—	✓

Chart 4: Isfahan's bridge comparison, Author



Physical form	Shahrestan	Marran	Joui	Si-o-se pol	Khaju
Floor	1	1	1	2	2
Foundation	Unknown	pile foundation	Unknown	pile foundation	pile foundation
Konoo	✓	✓	—	—	—
Breakwaters	—	—	—	✓	✓
Specific Entrance	✓	—	—	✓	✓
Specific Exit	—	—	—	✓	✓
Ornaments	—	—	—	—	✓

Chart 5: Isfahan's bridge comparison, Author



## **Chapter V**

## Résumé

Les ponts habités sont apparus au cours du Moyen Âge en Europe, selon les pays, au 11ème ou 12ème siècle. Au 17ème siècle, ils ont commencé à décliner et la plupart d'entre eux ont été démolis au 18ème siècle. De nos jours, malheureusement, une dizaine seulement survivent. Parmi tous les pays européens, seuls trois pays, l'Angleterre, la France et l'Italie, possédaient la grande majorité des ponts habités. Ceux-ci ont été construits sur une période de huit siècles. Avant l'apparition de ponts habités à la fin du Moyen Âge, ils étaient simplement des éléments de franchissement, servant à des fins logistiques pour des raisons militaires ou économiques, et étaient des symboles du progrès technologique. Avec l'émergence des ponts habités, le pont se voit attribuer de nouvelles fonctions commerciales, culturelles et résidentielles et devient une infrastructure multifonctionnelle.

### **5.1. Inhabited bridges in Europe**

The inhabited bridges appeared during Middle Ages in Europe, depending to the countries, in the 11th or 12th centuries. During 17th century, they went to decline and most of them were demolished during 18th century. Nowadays, only ten or so survive today unfortunately (Cadman & Stevens & Murray, 1996). Among all European countries, just three countries, England, France and Italy had the vast majority of inhabited bridges. These were constructed over a period of eight centuries.

Before the appearance of inhabited bridges in the late middle ages, bridges were mere crossing elements, serving logistics purposes for military or economic reasons, and were symbols of technological progress. With the emersion of inhabited bridges, the bridge was allocated with new commercial, cultural, and residential functions and became a multifunctional infrastructure (Youssef, 2017).

In the Middle Ages, when the walls surrounding the cities started to limit them for new developments, the inhabited bridges were built and adapted for residential purposes. They became one the best solutions for satisfying the needs of the citizenry and of the cities' administration (Marek & Klaudiusz, 2016). In addition to allowing passage across to the other side, these bridges could host various forms of other human activities.

By the end of Middle Ages, the inhabited bridges in Paris and London contained four or five levels of housing, quite differently from the ordinary streets. The tall and tight buildings didn't permit the people to see the river while they were crossing the bridge (Cadman & Stevens & Murray, 1996). This issue is in contrast to the two most important inhabited bridges in Italy. There is an opening in Ponte Vecchio in Florence, created for structural reasons, and also one in the central archway of the Rialto bridge in Venice. These openings provide for the crossing pedestrians ample and mesmerizing views of those respective cities which, in the author's view, produces an aesthetic solution to the necessity to create a sense of awe and loyalty to the city-state, so typical of that era's Italian polities.



Fig. 89: Oil painting of London bridge, 1632, [www.en.wikipedia.org](http://www.en.wikipedia.org)



Fig. 90: picture of London bridge recently, [www.en.wikipedia.org](http://www.en.wikipedia.org)

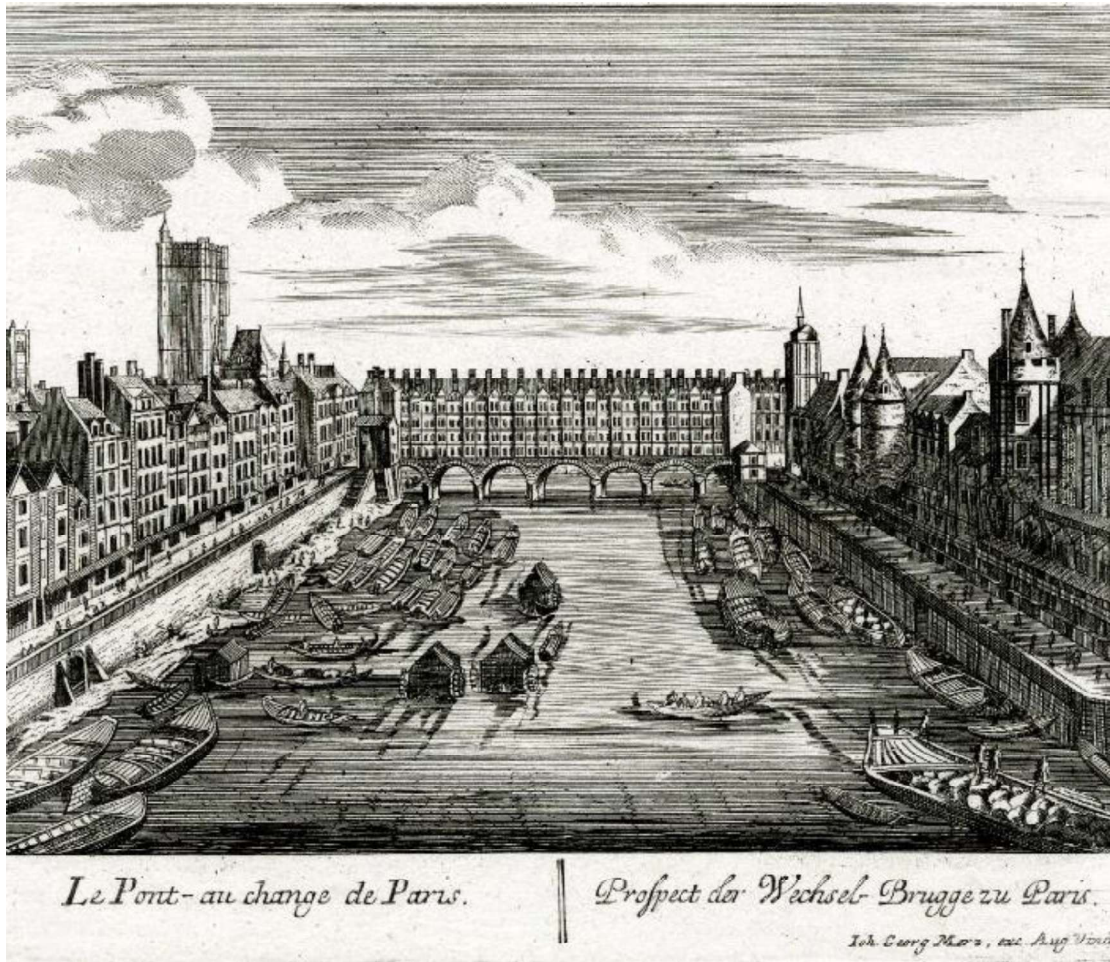


Fig. 91: Pont au change in Paris, 1750, [www.britishmuseum.org](http://www.britishmuseum.org)



Fig. 92: Pont au change recently, [www.en.wikipedia.org](http://www.en.wikipedia.org)

Still, the main function of most inhabited bridges in Europe was economic. A large number of European towns and cities were formed on the bank of a river. The main reason was the important role of water in different aspects like industry, agriculture, defense, navigation, commerce, etc. Thus, the settlements were both artificially limited in their expansion by the surrounding walls, and naturally limited by the presence of the river and its implied challenges (e.g. flood management). In this case, a new part of the city was usually constructed further from the urban center or on the other side of the river. These new districts couldn't immediately increase the commercial potential of their city.

Therefore the bridges, being the chokepoints of both human and mercantile traffic between the two parts of the city, and directly adjacent to the fluvial water-borne traffic, became prime commercial sites. This connected to the necessity to find more plots of buildable land, led by the constant increase in population, and ultimately translated into the urbanization of bridges. At the beginning, the ordinary shops were located on the inhabited bridges which later were replaced by other fancy and luxury shops due to increase the incomes and prestige of the bridges, which became in their cities small commercial and social centers of their own.

## **5.2. Inhabited bridges in Italy**

Italy contained a collection of inhabited bridges. In the fourteenth century in Italy began to use new techniques to build bridges, typical of the Renaissance. The existence of a large number of ancient Rome architectural monuments in the Italian cities led the architects to the creative use of techniques of ancient masters. Thus, bridges-markets have been built in Italian cities where trade flourished beside preserving the functions of medieval bridges (Kazhar, 2011). The most famous examples of this type of bridges are the Ponte Vecchio in Florence and the Rialto Bridge in Venice, which has a gallery with three passages.

### **5.2.1. The Ponte Vecchio in Florence**

The Ponte Vecchio is located on the Arno river and linking the city's former Roman to the Oltrarno. This bridge is the only one in Florence which maintain its mid-fourteenth-century vaulted substructure's plan. This bridge consists of a central square and is divided into two sections by a street in the middle and also it contains the bridge's famous shops (Flanigan, 2008).





Fig. 93: Province of Florence,  
[www.en.wikipedia.org](http://www.en.wikipedia.org)



Fig. 94: Map of Florence city, 1490, [www.en.wikipedia.org](http://www.en.wikipedia.org)

After six years of construction of Ponte Vecchio, on 4 November 1333, a large flood inundated Florence and destroyed Ponte Vecchio. In the Renaissance Period, due to the development of Florence and the obvious modification in land use and the increase in flood frequency led to many scientific observations by physicists and architects. (Caporali & Rinaldi & Casagli, 2005). After that incident, the Florence government decided to rebuild a masonry bridge. In 1345, the new Ponte Vecchio belonged to the Commune and the bridge with its 47 shops were constructed of stone in a single building campaign (Cadman & Stevens & Murray, 1996).

Taddeo Gaddi used the segmental arches for the Ponte Vecchio in Florence, because for economical and efficient reasons the arches of a bridge should be as long and as flat as possible (Hamill, 1999). The main guiding criteria for the design by Taddeo Gaddi were aesthetics, stability and commerce.

The Ponte Vecchio is a unique example of inhabited bridge which combines the habitation, the movement that has a strong impact on the place where it's located. The Ponte Vecchio carried out a central role within the urban layout of Florence after new town walls had been constructed in 1172 to encompass the bank on the far side of the Arno (Cadman & Stevens & Murray, 1996).

The bridge accommodated a church, dwellings, towers and a vegetable market and 43 shops. In 1442 the city authorities ordered butchers to move onto the bridge for hygienic reasons and also for getting round the problem of the unpleasant smells from the butcher's shop (Humar, 2014).

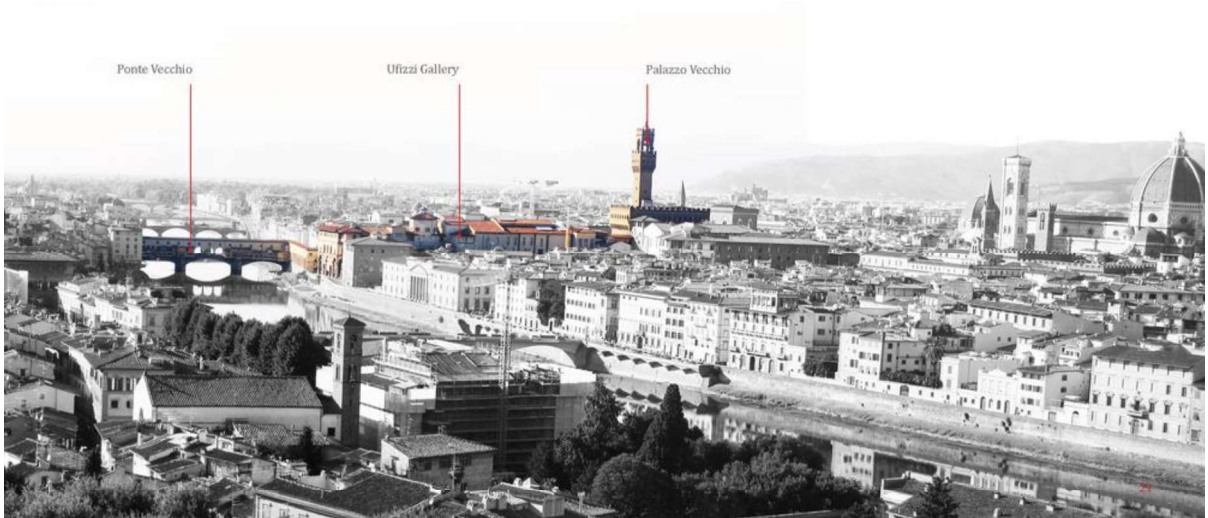


Fig. 95: Location of ponte vecchio, [www.squarespace.com](http://www.squarespace.com)



Fig. 96: Sketch of Ponte Vecchio, 1895, [www.nationalgalleries.org](http://www.nationalgalleries.org).



Fig. 97; View from east part of the bridge, [www.greatbuildings.com](http://www.greatbuildings.com)



Fig. 98: View from west part of the bridge, [www.wikipedia.com](http://www.wikipedia.com)

Thus, the shops were occupied by various tradesmen, such as butchers and grocers and blacksmiths (Cadman & Stevens & Murray, 1996). A new covered corridor was established in 1565 which was passing through the upper floor and serving as the prince's private passage under order of Grand Duke Cosimo I de' Medici, whose family ruled Florence (Youssef, 2017).

This secret passageway was almost 1.5 kilometres long and enabled Cosimo to pass unmolested and unseen from the Palazzo Vecchio, the seat of government and administration, to his residence in Palazzo Pitti (Humar, 2014).

The dominant function of old inhabited bridges in Europe was mainly commercial which is apparent in the Ponte Vecchio as well. As the economics changed, butcher shops were pushed out while more profitable businesses, like jewelers, moved in. In 1593, Duke Ferdinand suggested to replace luxury trades like jewelry and money-changing (Culbertson, 2014).

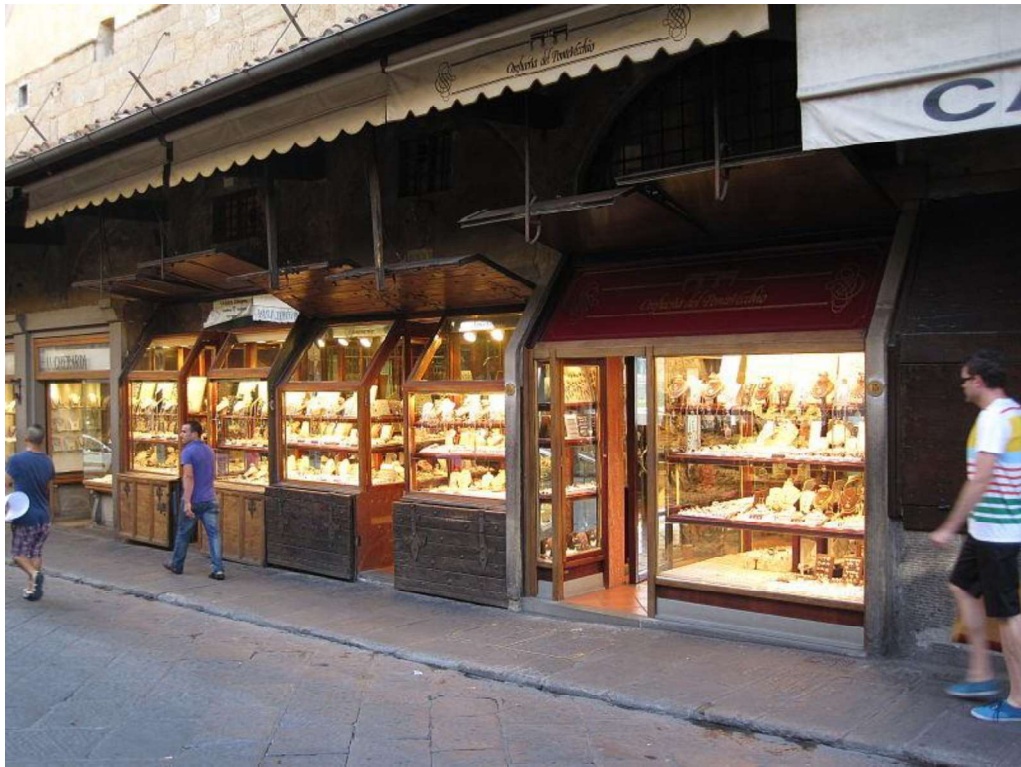


Fig. 99: Shops on the bridge, [www.wikipedia.com](http://www.wikipedia.com)

### **5.2.2. Rialto Bridge in Venice**

Before construction of bridges in Venice after the ninth century, goods and passengers were transported mainly by boat, or although piers and small wooden bridges existed because pedestrian traffic was still rather limited (Miranda & Barbisan & Pogacnik & Skansi, 2010). In the second half of the thirteenth, a growing need for mobility led to the development of a network of pedestrian ways led to construction of several bridges as an essential element.

The Ponte di Rialto was situated at that most significant geographical landmark which is the lowest bridging point, at which a bridge could easily be built. The original pontoon bridge was replaced at 1250 by a wooden structure (Howard, 1980). The bridge was burnt during the revolution in 1310. Later it also collapsed in 1444 under the weight of crowds of spectators during the visit of Emperor Frederick III of Austria. This bridge was rebuilt, once again in wood, in use and accommodated twelve small shops on either side of the bridge, like the Ponte Vecchio in Florence (Myburg, 2014).

These small shops were an attempt to control the unregulated presence of the squatters and salesmen, because of perfect location of the bridge as a unique link by foot to the eastern island. Thus, the magistracy in charge of Rialto bridge, approved the construction of two rows of shops in the first half of 15<sup>th</sup> century. The provided income of the shops was contributed to the maintenance expenses of the bridge (Miranda & Barbisan & Pogacnik & Skansi, 2010).

After the last collapse of the bridge in 1524, the city decided to rebuild the bridge with stone, and Antonio da Ponte won the contract. The Rialto Bridge was designed and built in 1588-1592, and remained the only way to cross the canal on foot until construction of the Ponte Academia in 1853 (Tolley, 2009).



Fig. 100: Province of Venice, Veneto, [www.en.wikipedia.org](http://www.en.wikipedia.org)



Fig. 101: Old map of Venice city, [maps-venice.com](http://maps-venice.com)





Fig. 102: Old map of Venice city with Ponte Rialto, 1729, [www.vintage-](http://www.vintage-)



Fig. 103: Painting of Ponte Rialto when it was made of wood, 1494, [commons.wikimedia.org](http://commons.wikimedia.org)



Fig. 104: Painting of Ponte Rialto, 1746, commons.wikimedia.org

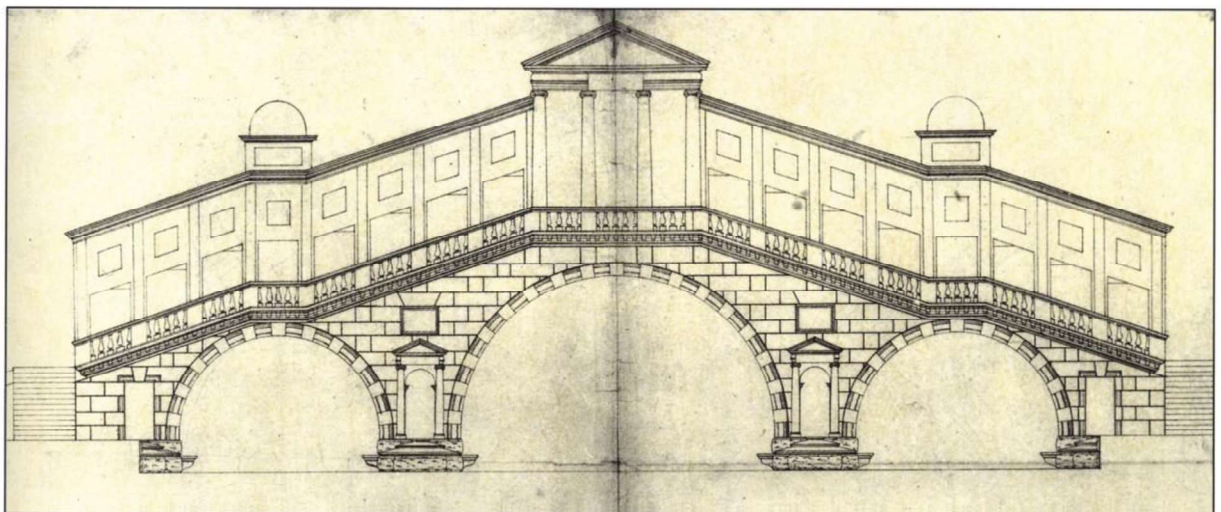


Fig. 105: The drawing of the Rialto bridge, 1588, <https://www.wga.hu>

The Rialto Bridge is undoubtedly one of the beautiful examples of Venice's bridges. It is 22.1 meters wide which makes it the widest of Venice's 431 bridges. It has the 24 little shops that line the bridge. Two rows of the shops rising up in steps on one side and descending on the other (Humar, 2014). Rialto bridge achieves excellence of design in several aspects. One of these is the strict quality of commercialization which is a truly vital aspect for an inhabited bridge. For the bridge to continue to be a success not only socially, but also financially, it must generate income (Culbertson, 2014). The bridge has an impressive 7.5-meter-high arch which allows the passage of the boats beneath it. The bridge can support a bustling tourist traffic and the shops on the same 12000 wooden pilings which were used since 400 years ago (Blakstad, 2002).

The Ponte Rialto's design considers different elements like commerce, architecture, and urban design at the same time. It provides the public three different paths of circulation which allows the bridge to have four facades instead of the typical two with a single main way of passage. The small gap at the apex of the arch let public to enjoy the privileged view of the city from the center of the Grand Canal.



Fig. 106: The shops locating on bridge, commons.wikimedia.org



Fig. 107: The corridor on side of the bridge, www.lares-restauri.it

### 5.3. Comparison of Iranian and European bridges

- Inhabited bridge in Iran has a long history. Bridge construction was common mostly in western and northern mountainous areas of Iran where there were many ephemeral stream or permanent rivers. The core of early Iranian civilization in these areas had led to continuation of bridge construction and their evolution. In the other hand, Iran as an arid and dry country have been always faced to lack of the water resources problem. Thus, the emergence of inhabited bridge was in Sassanid era, and dam-bridge was one the first functions which had appeared in Iran's Inhabited bridges.

Contrary to Iran, European inhabited bridges were emerged between 11th or 12th centuries and limitation for new developments of cities was the main reason of their nascence and the they were built and adapted for residential purposes.

- In Iran's historic bridges, the architects began to create empty spaces in bridge bodies in order to lighten the structure and increase its resistance by reducing its heaviness. Due to the use of Iranian arches in bridges construction, these bridges are more resistant in comparison to European bridges. These empty spaces which had been created for structural reasons, were used for different functions over time.

In European inhabited bridges, we can see that necessary rooms for various functions had been enhanced after bridge construction. Thus, contrary to Iranian inhabited bridges, these new areas were not integrated to bridge structure from the beginning and they had been added after. By the time passed the ordinary shops were located on the inhabited bridges were replaced by other fancy and luxury shops due to increase the incomes and prestige of the bridges.

- Iranian bridge builder tried to use special feature in bridge construction which allowed the pedestrians to enjoy the landscape and picturesque sight. They made different spaces for sitting in different levels of the bridges and indicated walking areas by the river side to connect the users to surrounding nature and let them to enjoy the natural environment. People who wanted to relax next to the river and nature were able to sit in different parts of the river and enjoying the ambiance, and sometimes they could enjoy the sound of the artificial waterfall which had been designed by the architects.

We can see the same feature in some of European inhabited bridges, especially in Italian ones. Defined spaces in Rialto and Ponte Vecchio bridges for this purpose are evidences of this

fact. Paying attention to nature and the surrounding landscapes and using them for passengers had been one of the goals of European bridge designers.

- In Safavid dynasty period, most attention directed towards bridge building in Iran also in Isfahan, that dimensions, design, resistance, architectural method and decoration of that time bridges are noticeable and unique. In that period, due to existence of the powerful government, the bridge construction industry made remarkable development. Economic growth in Safavid era, was one the main reason for development of the bridge construction. Wherefore, we can be witness of development of bridge construction and creation of masterpieces such as Si-o-se pol and Khaju bridge in that era. Thus, in compare to European inhabited bridges, which had main role in economic development of the cities, Isfahan's inhabited bridges had progressed in construction because of city's economic development. Strong economy in Safavid era, led to more construction with further quality.

In summary, we can consider that European inhabited bridges had an enormous influence on city's economic development, on the contrary, economic growth had affected the development of Isfahan's inhabited bridges.

- As it was mentioned, despite the European inhabited bridge, which the commercial aspect was the main purpose of creation of multifunctional bridges, Iranian ones didn't have a special commercial function that make a huge difference between European and Iranian inhabited bridges. Construction of different shops, stores on inhabited bridges which has a revenue for the city is a proof for this fact. According to historical documents, the most principle economical aspect of the bridge was paying the toll by the caravans which passed thorough the bridge. One of the main function of Iranian inhabited bridges, in addition to crossing from point to point, is ceremonial place. Since long time ago, Zayandeh-rood was always a promenade and a recreation place in Isfahan. Since Safavid period, Isfahan's bridges are place for social activities, gathering, holding traditional ceremonies etc. and these aspects define the main function of these bridges. In addition to crossing the river, social aspects are the main functions of the Iranian inhabited bridges.
- In Safavid era, Islam was adopted by the government as the country's official religion. The main purpose of this action was to unified the whole country and ethnic group. This issue had led to the strengthening of Islam and its laws in the culture and customs of the people.

Waqf, is one the most important Islamic laws which became one of the cultural aspect of Iranian culture. Waqf is an inalienable charitable endowment under Islamic law, which typically involves donating a building, plot of land or other assets for Muslim religious or charitable purposes with no intention of reclaiming the assets. According to these laws, wealthy people donated different buildings and constructions to serve people for free, such as mosques, schools, ice houses, bridges etc. and in this way, the commercial aspect lost its importance as far as according to historical documents, in Safavid period, even caravans could stay in bridge's room for free. This cultural aspect, made kings to provide citizens the necessary facilities for increasing the quality of life like the bridges which could be a place for crossing, amusing, recreation and holding different ceremonies.

## 5.4. Conclusion

The primary emergence of inhabited bridge was in Sassanid era, that we are witnessing the peak of creativity and development in the Safavid era as an inhabited dam-bridge. In order to lighten the structure and increase bridge's resistance Iran's historic bridges, empty spaces were created in bridge bodies were used for different functions over time. Iranian bridge builder tried to use special feature in bridge construction which allowed the pedestrians to enjoy the landscape and picturesque sight. They are different spaces for sitting or walking in different levels of the bridges to connect to nature. People who wanted to relax next to the river and nature were able to sit in different parts of the river and enjoying the ambiance, and sometimes they could enjoy the sound of the artificial waterfall.

Economic growth in Safavid era, was one the main reason for development of the bridge construction. Wherefore, we can be witness of development of bridge construction and creation of masterpieces such as Si-o-se pol and Khaju bridge in that era. These bridges had a major role in city growth and urbanization. They were main connections for main commercial axis of city and merchant's neighborhoods. There is an immense difference between European and Iranian bridges in their commercial functions. These two bridges were spots for temporary shops and stores for local trades, while in European inhabited bridges the bridges had a role of small bazaar for inhabitants. This distinction emerges due to two main commercial axis of Isfahan, Bazaar and Chahar-bagh street, which made the city needless to have other commercial axis, so these bridges were just a way to connect main commercial axis to other neighborhoods.

The main difference between Iranian and European bridges is their commercial performance. According to historical documents, the most important economical aspect of the bridge was paying the toll by the caravans which passed thorough the bridge. one the other hand, one of the main function of Iranian inhabited bridges, in addition to crossing from point to point, is ceremonial place, which is not true about European ones. Since long time ago, Zayandeh-rood was always a promenade and a recreation place in Isfahan. Since Safavid period, Isfahan's bridges are place for social activities, gathering, holding traditional ceremonies etc. and these aspects define the main function of these bridges. Si-o-se pol and Khaju bridges are the most important bridges on Zayandeh-rood which had an important role in Isfahan economy during Safavid period.



Si-ose pol bridge is one the most important bridges on Zayandeh-rood which had a major impact on Isfahan economy during Safavid era. It was used to connect a part of the city to the south of part of the river. The bridge was intended to connect the neighborhood of the new residents to the city's economic axis. According to historical documents Chahar-bagh street has a special importance in Isfahan economic conditions, which can be say, as important as great Bazar. This street was the continuation of the Bazaar and there were different small and big shops, tents, stores to sell their products and stuff to people. This bridge was located on the axis of the Chahar-bagh street, to connect Jolfa quarter in south parts of the river to Chahar-bagh and bazaar, two main commercial axis of the city. In such circumstances, the Armanians as important merchants, could be able to frequante to main commercial parts of the city easily. In other hands, the small shops and stores could be continued also on the bridge and small spaces on it which had been made by the bridge's arches. these small spaces could be used as small temporary shops and in such a way, the chahar-bagh street axis, as commercial axis, had not been broken off and it continued to other part of the city, on the other side of bank of river for other neighborhoods.

Khaju bridge was actually a connection between one of the main street which was branched from bazaar towards Zayandeh-rood. The importance of this street is not more than Chahar-bagh street in commercial aspects, but it had been important as it was led from the Bazaar directly to the river and the Gabrha neighborhood. The bazaar of Isfahan as a strong movement under the shade that stretches from the Khaju Bridge on the southeast to the northern gateway, encompassing, in its course, the primary commercial, religious, and governmental activities of the city. This bridge was a place to ask caravans to pat their toll, to provide them a temporary place to stay and a place to use local merchants' services and local trading. As it was mentioned, due to increased silk production, textile weaving was so common in Safavid era, in different rural or national levels. In addition to that, locals stayed close to Khaju bridge to sell their fabrics to Caravans which came to Isfahan from Shiraz, actually this bridge was a great temporary markets for them to sell their fabrics to Caravans which were crossing the bridge or stopped there to rest in rooms which had been provided for the passengers.

The construction of these bridges had been halted for a long time, and it was resumed again by the construction of the Nature Bridge in 2014 in Tehran, the current capital of Iran. this 270-metre bridge connects two public parks — Taleghani Park and Abo-Atash Park — by spanning Modarres highway, one of the main highways in northern Tehran. The structure comprises three levels that follow a curved path, and which are connected by various ramps and stairs. From the very beginning the concept was to have a spatial structure large enough to create an architectural space, while at the same time acting as the structure. Like other Iranian inhabited bridges, it is intended to be a place to linger rather than just one to pass through, and to act as an extension of the parks. This bridge is a place for relaxation, leisure, walk, cross with many commercial spaces such as cafes and restaurants. Despite of new technology and architecture of this bridge, it is more similar to European inhabited bridges in commercial aspects.

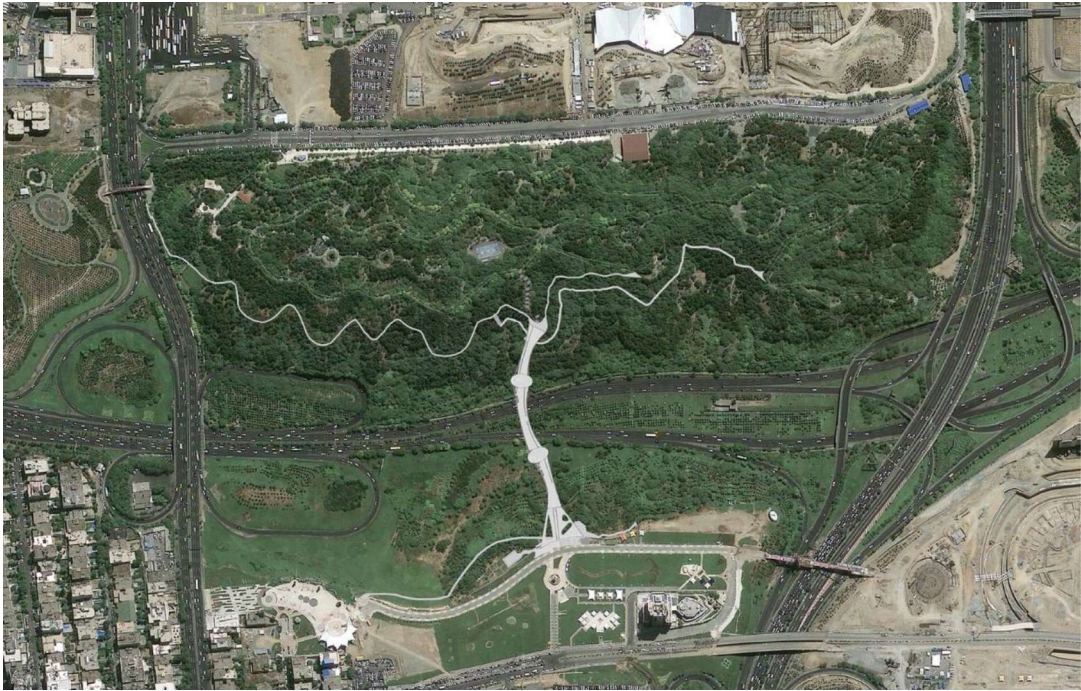


Fig. 108: Tabiat bridge from top, [www.archdaily.com](http://www.archdaily.com)



Fig. 109: Tabiat bridge front view, [www.archdaily.com](http://www.archdaily.com)

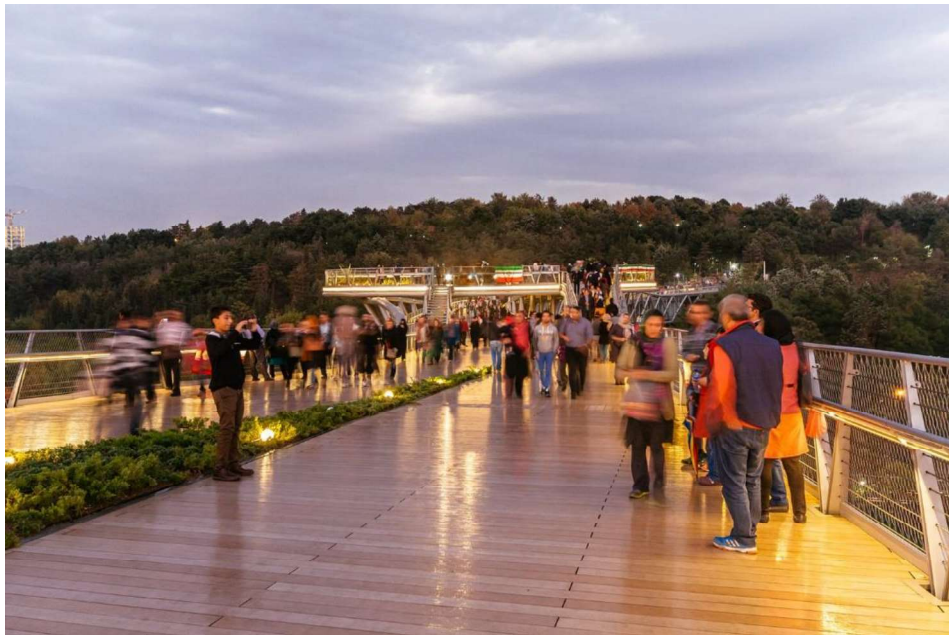


Fig. 110: Tabiat bridge, [www.wikimedia.com](http://www.wikimedia.com)



Fig. 111: Tabiat bridge and its users, [www.wikimedia.com](http://www.wikimedia.com)



## **Bibliography**

1. Mokhtarian Sasan, *The secrets of hidden geometry in the facade and architecture of Khaju Bridge*, Tehran, Yekta, 2001.
2. Goli farzad, *A bridge, thirty-three hesitations, from symbolism to ontology of imagination*, Tehran, Asim, 2009.
3. Ahari Zahra, *Isfahan doctrine in urban Planning*, Tehran, Honar university, 2001.
4. Rostami Najafabadi Mohammad, *Isfahan Architecture*, Tehran Negaresh, 2011.
5. Toolaian Farzin, Eskandari Jalal, *The Impact of Zayandehrood River on Isfahan Architecture and Urban Development*, Tehran, Navid, 2013.
6. Ghasemi Mansour, Shayesteh Mohammadreza, *Isfahan a small terrestrial paradise*, Isfahan, Kimia, 2004.
7. Pope Arthur, Ackerman Phyllis, Ayat-o-allah Shirazi Bagher (trans), *A survey of Persian art*, Tehran, Elmi-Farhangi, 2008.
8. Jackson Peter, Lockhart Laurence, *The Cambridge history of Iran, Timurid and Safavid periods*, vol.6, Cambridge, Cambridge University Press, 2008.
9. Mitchell Lynette, Melville Charles, *Every Inch a King Comparative Studies on Kings and Kingship in the Ancient and Medieval Worlds*, BOSTON, LEIDEN, 2013.
10. Munshi Iskandar beg, Iraj Afshar (trans), *Tarikh –e- alam Arai Abbasi*, vol 2, Tehran, 1971.
11. Ghasemi Mansour, *Isfahan is all this but there is not much*, Isfahan, Naghsh-e-khorshid, 2006.
12. Hossein Abri Hasan, *Zayandehrud River from the source to the marsh*, Isfahan, Golha, 2000.
13. Mohammadi Maryam, Mollazadeh Kazem, *Encyclopedia of Iranian monuments in the Islamic period*, Vol. 4, Tehran, Art of Islamic Advertising Organization, 2000.
14. Honarfar Lotfollah, *Isfahan*, Tehran, Scientific and Cultural Publications, 2010.

15. Makarchian Masoud, *OLD ARCH BRIDGES IN HAMADAN PROVINCE*, Barcelona, CIMNE, 2004.
16. Shooshtari Mohammad Ali, *Geographical History of Khuzestan*, Tehran, Amirkabir, 1957.
17. Farhani Mohammad Hasan, *Travelogue of Mirza Mohammad hossein Farahani*, Tehran, Farehvashi, 1983.
18. Olearius Adam, Behpour Ahmad (trans), *Travelogue of Adam Olearius*, Tehran, Innovative, 1984.
19. Kiani Yousef, *Iran architecture*, Tehran, Sonnat, 2014.
20. Mokhlesi Mohammad Ali, *Old bridges of Iran*, Tehran, National Heritage Organization, 2000.
21. *Footbridge, small beautifull*, European council of civil engineering, Slovenia, 2014.
22. Cadman David, Stevens, Mary Anne, Murray Peter, *Inhabited bridges, The inhabited bridge, past, present and future*, London, Royal Academy of Arts, 1996.
23. Blakstad Lucy, *Bridge: the architecture of connection*, Basel, Birkhauser, 2002.
24. Brown David j., *Bridges, Three thousand years of defying nature*, Mitchell Beazley, 1993.
25. Howard Deborah, *The Architectural History of Venice*, New Haven & London, Yale University Press, 1980.
26. Torbati Khaterreh, Poornader Hossein, “ Investigating the Continuation of the Traditions Affecting the Khaju Bridge Formation Based on a Comparative Study of the Historic Bridges in Isfahan” , *Bagh-e-Nazar*, n° 27, 2013, p. 61- 70.
27. Amir ShahKarami AbdolAzim, “Engineering Review of Khaju bridge”, *Golestan-e-Honar*, n° 6, 2006, p. 81-94.
28. Hensel Michael, “Architectural History from a Performance Perspective, The Latent Potential of Knowledge embedded in the Built Environment”, *Conference: Heritage and Technology – Mind, Knowledge, Experience*, n° 13, 2015, p. 794 – 802.

29. YazdaniRostam Faeze, Kia Anoosha, Sadeghian Azadeh, Khosravi Mahdieh, Zolfi Davod, “ The Concept of Privacy and Its Role in Creating, Original Persian Spaces”, *Journal of river engineering*, n° 4, 2019, p. 23-30.
30. Yılmaz Çakmak Bilgehan, Khaleghimoghaddam Navid, “Spatial Analysis of Khaju Bridge as an Urban Element, In The Context of Space Perception Through Senses”, *Journal Of Humanities And Social Science*, n° 21, 2016, P. 66-75.
31. Yarzadeh Sajjad Mohammad, Shamsollahi Behnoosh, “ Accompaniment of Natural and Artificial Urban Elements in the Creation of Urban Aesthetics (Case of Study: Isfahan City) “, *International Journal of Social Sciences*, n° 3, 2013, p. 61-70.
32. Tahouri nayer, “The Mythical Foundations of Architecture in Iran: A Bridge to Paradise”, *Honar-o-Khial*, n° 2, 2002, p. 18-49.
33. Hejazi Mehrdad, Hejazi Bina, Hejazi Saba, “ Evolution of Persian traditional architecture through the history”, *Journal of Architecture and Urbanism*, Volume 39(3), 2015, p. 188–207.
34. Shiraazi Karim, OstadiAsl Zargham, Sheikhloie Vahid, Azami Ahadollah, Hassanimehr Shahin, “ Traditionally Sustainability Analyses of Hydraulic-Architectural Bridge Construction in Iran”, *World Academy of Science, Engineering and Technology International Journal of Civil and Environmental Engineering*, n° 7 , 2012, p. 521-525.
35. Mansour Rami, “ The impact of ancient history, conflict and globalization on bridge aesthetics in Iran”, *New York City Bridge Conference*, n° 9, 2017.
36. Brown Hillary, “Compound Civil Infrastructure: Lessons from Engineering Precedents”, *Journal of Bridge Engineering*, n° 19, 2014.



37. Shahedi Bahram, Keumala Nila, Naziaty Yaacob, "Users' Perceptions of Aesthetic Design Approach of Safavid Architecture, Iran", *Journal of Design and Built Environment*, n° 10, 2012.
38. Shahidi Marnani Nazanin, "Isfahan's Saadat Abad Garden in Golzar Saadat Masnavi", *Iranian Architectural Studies*, n° 9, p. 67- 84, 2016.
39. Farshidi Farzaneh, Afkhami Reza, "The Evolution of the Continuity of Use of Crossing and Residence in Iranian Bridges", *Architecture journal of Fine arts*, n° 41, p. 55-66, 2010.
40. Torbaty Khate reh.Morvaej, TEFEh.S.Hashemian Atefeh, "Identifying Effective Factors in Transformation of Khajoo Bridge into a Successful Linear Public Space Based on Jan Gehl's Criteria", *Current World Environment*, n° 10, p. 157-167, 2015.
41. F. Agha Ebrahimi Samani, B. Bahrami, N. Salahesh, "LEARNING FROM THE PAST TO DEAL WITH FUTURE URBAN LANDSCAPE", *International Journal on "Technical and Physical Problems of Engineering"*, n° 7, p. 19-26, 2015.
42. El Gemaiey Gh, "THE ROLE OF WATER IN ISFAHAN: A STUDY OF SAMPLES OF BRIDGES AND DAMS ON ZÂYANDÉ-RÛD", *Egyptian Journal of Archaeological and Restoration Studies*, n° 4, p. 55-63, 2014.
43. Honarfar Lotfollah, "History of the Construction of Allah Verdi Khan bridge", *Honar-o-Mardom*, n° 81, p. 4-9, 2009.
44. Neyestani Javad, "A New Look to the Date and Architecture of Allah Verdi Khan Bridge", *The International Journal of Humanities*, n° 13, p. 125-132, 2006.
45. Taghi mahmoudi Mohammad, Farhadi Fatemeh, Dokohaki Samira, "Isfahan Waterfronts And Particular Places Management To Improve Relationships Between People ", *Global Journal Of Biodiversity Science And Management*, n° 3, p. 111-115, 2013.

46. Demirchi Azar, “A look towards the oldest bridge in Isfahan”, *Honar-o-Mardom*, n° 124, p. 42-46, 1972.
47. Radić Jure, Kušter Marija, “AESTHETICS AND SUSTAINABILITY OF ARCH BRIDGES”, *International conference on arch bridges*, n° 7, p.13-28, 2013.
48. Khajegir Ali reza, Afroogh Mohammad reza, Fahim Ali reza, “The Art of Islamic Architecture during the Safavid Period and the Introduction of the Teachings of Islam”, *Journal of Fine Arts*, n° 1, P. 37-42, 2018.
49. Hoseini Chiman, “ A Study on the Bridges of Safavid Era, Case study: Kurdistan and Azerbaijan district”, *JOURNAL OF APPLIED SCIENCES RESEARCH*, n° 11, P. 48-53, 2015.
50. Zahiri Zohreh, Heydari Beni Dariush, Haj Ebrahim Zargar Akbar, “ A survey on hidden openings in fill space of masonry arch bridges: A case study from Khan Bridge “, *International conference on Civil Engineering Architecture & Urban Sustainable Development*, 2013.  
[https://www.researchgate.net/publication/272089000\\_A\\_survey\\_on\\_hidden\\_openings\\_in\\_fill\\_space\\_of\\_masonry\\_arch\\_bridges\\_A\\_case\\_study\\_from\\_Khan\\_Bridge\\_Iran](https://www.researchgate.net/publication/272089000_A_survey_on_hidden_openings_in_fill_space_of_masonry_arch_bridges_A_case_study_from_Khan_Bridge_Iran).
51. Rafiemanzelat R., “ Influence of Place Identity on Walkability: A Comparative Study between Two Mixed Used Streets Chaharbagh St. Isfahan, Iran and Dereboyu St. Lefkosa, North Cyprus”, *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, n° 2, 2016.
52. Pooli Mona, “ The Role of Bridges in Safavid Architecture”, *National conference of native architecture and urbanism of Iran*, 2011.  
<https://www.sid.ir/fa/seminar/ViewPaper.aspx?FID=3711394H0163>.
53. Sajadi Ali, “ Kashkan bridge on historical roads of Lorestan”, *Asar Journal*, n° 35, 2003.

54. Salamaka Marek, Frossb Klaudiusz, “ Bridges in Urban Planning and Architectural Culture”, *World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium*, p. 207-212, 2016.
55. Caporali Enrica, Rinaldi Massimo, Casagli Nicola, “ The Arno River Floods”, *Giornale di Geologia Applicata*, n° 1, P. 177- 192, 2005.
56. Symeonidou Ioanna, “ THE HABITABLE BRIDGE: EXPLORING AN ARCHITECTURAL PARADIGM THAT COMBINES CONNECTIVITY WITH HABITATION PLACES AND TECHNOLOGIES “, *CONFERENCE PROCEEDINGS OF THE 5TH INTERNATIONAL*
57. *ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES*, n° 5, P. 421- 427, 2018.
58. Yousef Maged, “ PROBLEMS OF NEGLECTED PLACES UNDER BRIDGES: A CASE STUDY OF YEREVAN BRIDGE, BEIRUT, LEBANON”, *Sustainable Development and Planning*, n° 11, P. 739 - 750, 2017.
59. Flanigan Theresa, “ The ponte vecchio and the art of urban planning in late medieval Florence”, *The international center of medieval art*, n° 1, P. 1 -15, 2008.
60. DE MIRANDA Mario, BARBISAN Umberto, POGACNIK Marko, SKANSI Luka, “ Bridges in Venice - Architectural and Structural engineering aspects”, *INTERNATIONAL SYMPOSIUM ON BRIDGE AND STRUCTURAL ENGINEERING*, n° 34, P. 88 - 95, 2010.
61. Tolley N M E, “ ANALYSIS OF THE RIALTO BRIDGE, VENICE”, *Proceedings of Bridge Engineering 2 Conference*, 2009.  
<http://www.bath.ac.uk/ace/uploads/StudentProjects/Bridgeconference2009/Papers/TOLLEY.pdf>

62. Mokhtarshahi Sani Rafooneh, “An Inquiry into Iranian Architecture Manifestation of Identity, Symbolism, and Power in the Safavid’s Public Buildings”, Submitted to the Institute of Graduate Studies and Research in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Architecture, Eastern Mediterranean University, 2009.
63. Ahmadi Maryam, “ Chahar Bagh Avenue, Isfahan: Genesis and Demise, Pre-Islamic and Islamic Garden Influences in the Safavid Creation and History of its Subsequent Degeneration”, A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, Nottingham Trent University, 2016.
64. Houshangi Negar, “Monumental Architecture; National Identity; Conceptual Understanding of Iranian Monumental Architecture “, Monumental Architecture; National Identity; Conceptual Understanding of Iranian Monumental Architecture, Eastern Mediterranean University, 2013.
65. Boostan Arash, Kashkan bridge restoration, Master thesis of conservation of cultural heritage, Azad university of Tehran, 2001.
66. Anisi Ali Reza, “EARLY ISLAMIC ARCHITECTURE IN IRAN”, PHD Thesis of THE UNIVERSITY OF EDINBURG, 2007.
67. Smith Culbertson Benjamin, “Recapturing Urban Space: An Inhabited Bridge in Nashville, Tennessee”, A Thesis Presented for the Master of Architecture Degree, The University of Tennessee, Knoxville, August 2014.
68. Myburg John, “MESOPARASITEA Symbiotic Affair”, A Research Project submitted in partial fulfillment of the requirements for the degree of Masters of Architecture Professional, Unitech Institute of Technology, 2014.
69. Kazhar Nina, “ EVOLUTION OF STYLES IN ARCHITECTURE OF BRIDGES”, Construction 17 Science notebooks, Czestochowa University of Technology, 2011.

70. Hamill Les, “ Bridge Hydraulics”, School of Civil and Structural Engineering, University of Plymouth, 1999.
71. “Restoration report of Si-o-se pol bridge”, Isfahan Province Culture and Art Publications, 1970.
72. “SHUSHTAR HISTORICAL HYDRAULIC SYSTEM”, Nomination of Properties for Inclusion on The World Heritage List, Tehran, 2008.
73. Finn Paul, Ouellette Jesse, Hutchinson Katie, Muller Ryan, “ The Building Blocks of Venice Preserving knowledge of a city’s infrastructure and maintenance”, AN INTERACTIVE QUALIFYING PROJECT REPORT WORCESTER POLYTECHNIC INSTITUTE, 2011.
74. “Rialto Bridge in Venice”, PROJECTS ITALY RENOVATING MASONRY AND WATERPROOFING the RENOVATION focused on preserving the existing materials, removing the damaged elements and stopping any ongoing deterioration, 2018.
75. *Proceedings of Iran-Arg Bam Architecture and Urban History*, vol. 4, Tehran, National Heritage Organization, 1996.
76. Ghazvini Vahid, Taher Mohammad, Abbas-Nameh, Arak, Dadi, 1950.
77. Godard André, Sarv Moghadam Abolhassan (trans), *Athar-e Iran*, Mashhad, Astan-e-ghods, Vol. 4, 1989.
78. Alizadeh Abdolvahab, Najari Mohadeseh, *The architecture of Safavid period*, Tehran, Khatam, 2018.
79. Ebrahim Zareei Ebrahim, *Architecture of Iran*, Tehran, Samt, 1963.
80. Javaherkalam Ali, *Zendeh rood or Isfahan and Julfa Historical Geography*, Tehran, Ibn sina, 1969.
81. Saber Hamid, “The bridge thorough the time”, Master thesis of Architecture in Khorasgan university, 2003.

82. Saleh Joudat Barivan, "The Ornaments of Khaju bridge", Master thesis of Archeology in Theran university, 2003.
83. Hami Ahmad, Irrigation, "Water supply, Hydrometer in Ancient Iran", Sakhteman, n 3, pp. 10-19, 1971.
84. Taghavi Abed, Farzin Saman, Zoor Maryam, "Function of Iranian Cities in Safavid Erapolitical Cities or Commercial Cities", Journal of Anthropology & Archaeology, n 1, pp. 28-40, 2013.
85. Dehghan Touran-Poshti Atefeh, Tayefi Nasrabadi Abbas Ali, Naghizadeh Mohammad, "Sustainability and water transmission system in the Bagh-Shahr of Isfahan", Scientific Research and Essays, vol.7, pp. 834-838, 2012.
86. Floor Willem, Herzig Edmund, IRAN AND THE WORLD IN THE SAFAVID ERA, London, I.B. Tauris & Co. r-td, 2012.
87. Rahbar Morteza, Ansari Mojtaba, "Isfahan's Organic and Planned Form of Urban Greenways in Safavid Period", International Journal of Architecture and Urban Development, n 1, pp. 21-32, 2016.
88. Oliveira V, Pinho P, Batista L, Patatas T and Monteiro C (eds.), common future in Urban Morphology, Porto, FEUP, 2014.
89. Soltanian Abu Taleb, "The Function of Silk and the Role of Armenian Businessmen in Safavid Economics and Politics", Journal of Islamic Civilization History, n 2, pp. 79-101, 2011.









## **Tutored project**

The role of glass in Medieval architecture

Le rôle du verre dans l'architecture médiévale

## **Middle Ages**

The Middle Ages which called Dark Ages lasted from fifth to the fifteenth century, after the death of Byzantine Emperor. Medieval art was composed of three different styles: Byzantine, Romanesque and Gothic. Gothic architecture is a style that flourished in Europe during the Late Middle Ages. It evolved from Romanesque architecture and originated in 12th-century France, it was widely used, especially for cathedrals and churches, until the 16th century.

### **The art in middle Ages**

In The Middle Ages, people traveled for hundreds, sometimes thousands of miles to venerate their sacred objects, seeking cures, blessings, and atonement. The medieval Christian encounter with religious artifacts and sites like relying on aesthetics of stone, metal, glass, and light fueled their desires for blessings (Simson, 1956). The art of the Middle Ages, roughly the period between the late Roman era and the fifteenth century, set new standards of technical achievement in different aspects such as; architecture, mosaic, painting, sculpture, stained glass.

In medieval art, halos of light symbolized divinity and sainthood. Narratives of the Bible were illuminated through stained glass in thousands of churches. Candles were used to provide physical light, and symbolize the spiritual light in the darkness world. During The Middle Ages, illuminated stained glass served as a modern-day innovation which manifested a high level of aesthetic elaboration (Doyle & Mould, 2016).

Medieval art was composed of three various styles: Byzantine, Romanesque and Gothic. Two primary styles mostly characterize medieval architecture: The Romanesque and the Gothic. While there was overlap in style and technique making a clean division impossible, in general the Romanesque style emerged between the eleventh to the mid-twelfth century, and the Gothic style came to the forefront during the middle of the twelfth century ([www.saylor.org](http://www.saylor.org)).

## **The Architecture in middle Ages**

In early medieval Europe, stone went into the solid and powerful structures of Romanesque churches, in which their interiors had a mysterious darkness which were created by using the thick walls and pillars, small windows. Thereupon, in the twelfth and thirteenth centuries higher Gothic churches arose and the walls were transformed into networks of stained glass through the pointed arches. Medieval stained glass, used not just for the churches, but also, as the middle class grew in the later Middle Ages period in secular buildings such as important administrative places and private residences for wealthier class.

In architecture, little by little, the orientation toward the spiritual took the form of lighter, airier building. The mass and bulk of Roman architecture gave way to buildings which were reflecting the new ideal; modest on the outside while glowing with symbols of spirituality such as mosaics, frescoes, or stained glass inside (Simmons, 2007). Following are more explanations about different architectural style in The Middle Age:

- **Romanesque architecture**

As originally used the word “Romanesque” referred to the Romance languages. Thus when William Gunn in 1819 first applied the term “Romanesque” architecture to cover all the masonry buildings of Western Europe between the Roman period and the Gothic (Rudolph, 2006).

The Romanesque style took its inspiration from Roman basilicas. They were rectangular buildings with rounded, stone arches. Christians adopted the basilicas for their gatherings and transforming them into a holy space for their own purpose. By the late eleventh century the growth of Christianity necessitated larger spaces, and the wooden frames and flat roofs of basilicas had been changed and the builders began incorporating elements of the late imperial Roman edifices and make the larger spaces ([www.saylor.org](http://www.saylor.org)).

The medieval artisans began to roof churches with stone vaulting because the Roman buildings were timber-roofed and prone to fires. Thus, barrel and vaults resting on piers could span large openings with few internal supports or obstructions (Strickland & Boswell, 2007). There are two Romanic architectural periods: First; Pre-Roman architectural period, and second; Roman architectural period.

Romanic architecture or EARLY MEDIEVAL architecture, answered the needs of the Catholic religion and therefore appeared in Western and Central parts of Europe where the Catholic religion dominated between the 6th – 12th century such as France, England, Italy, Spain, Germany, Netherlands, Austria, Hungary, Poland and Transylvania (Ianca & Georgescu, 2nd year, first semester). Builders borrowed elements from Roman architecture, such as rounded arches and columns, giving rise to the term Romanesque for the art and architecture of the period (Strickland & Boswell, 2007). In that period, the churches built after the basilica type, the same as the independent buildings or part of large monastery were organized by functionally for religious Catholic ceremony.

- **Gothic architecture**

By the twelfth century, with the centralization of the one (Catholic) Church, came a new architecture for the cathedral to replace the older Romanesque architecture and thereby to manifest the Church's role in the community in a material way as well as in spiritual and political ways.

The word “Gothic” was a term which was used for the first time in the Italian Renaissance. It was a negative term for all art and architecture of The Middle Ages, which were suggesting the quality of the work of the barbarian Goths (Sankovitch, 2001). Unlike the Romanesque, the Gothic style has a special identifiable origin in a particular place and at a particular time, in the area around Paris in the 1130s and 1140s (Rudolph, 2006). The tendency of rising of the constructions through the sustaining elements such as piles and columns was increased and the builders emphasized on the verticality through the decorating style of the interior and the exterior of the buildings (Ianca & Georgescu, 2nd year, first semester).

The pointed arch allowed the church buildings to have flexibility in design. The walls between the columns can be punctured to provide large areas for windows because they are not critical to the structural integrity. The ribbed vault made it possible for Gothic architects to build churches with soaring interiors that were higher, more elegant, and more delicate than earlier Romanesque churches (Sankovitch, 2001). The use of the crossed arches, with panels that rest on ribs of the shape of broken arches called in general pointed arches.

The use of some rich exterior ornamentation is other important features of Gothic architecture. Different height towers, with sculptures representing religious and laic figures or

with representations of some bizarre fantastic beings, combinations of elements with human reasons, animalist and floral, anthropomorphous and zoomorphic (Ianca & Georgescu, 2nd year, first semester).

The Gothic style also incorporated cross ribs. This technique consisted of arches stretching diagonally among four columns, crossing at a bay in the center. Cross ribs significantly lightened the ceiling. Furthermore, if the remaining weight was buttressed externally, the walls could be opened up for more and larger windows. Flying buttresses were attached to exterior walls for this purpose. As a result of the number and size of windows now possible, Gothic churches were much brighter in design and construction than Romanesque churches (Rudolph, 2006). The taking over of the lateral pushing forces given by the arches through the use of the flying buttress arch, which transmits these forces to the exterior buttress. In Gothic architecture we are witness of the gradual reduction of the exterior walls in the favor of some large hollows for window surfaces, which closed with valuable multicolored strained-glass window.

### **Windows in Gothic Architecture**

Despite the connection made in medieval Catholicism between light and God, up until 12th century churches could only have very small windows. Thus, the Interiors of the churches were dark and somber. With the structural innovations of the 12th century, however, especially the invention of the flying buttress, a lot of the load could be transferred away from the wall-proper. this issue provided the builders possibility to have much larger expanses of glass.

Gothic windows are translucent screens of color that, together with the walls, enclose the interiors pace of a building. Like a carpet or an embroidery their appeal is first of all as pattern and only subsequently as narrative. There is no depth in a thirteenth-century windows: space is implied by the relationship of form and color (Hayward, 1971).

Gothic architecture brought large panels of colored glass, separated and supported by thin, molded tracery. As the light filtered through these panels into the otherwise dark interiors, it seemed as God himself was majestically entering the church, through the window. As light came in, all of its characteristics were used by the window to tell a particular message. Many of these windows told particular stories, drawn from sacred texts, but some, such as rose windows, told their stories simply through their geometry. Everything is static and in its place

in a rose window. The center is solid and it relates consistently to the boundary (Patterson, 2011).

There is an important difference between early Gothic period and later periods. With the Early Gothic period, the window was first designed in glazing, much like the pieces of a puzzle are put together, painting is used as a supplement to be added in the end if needed. In comparison, the late period, the glass-painter sketched the design first and then deciding on the glazing. The predominant form of window in the Late Gothic period was a canopy window. Unlike previous canopy windows, these forms of canopy were almost entirely white and restricted to a single light; the canopies themselves were meant to frame the picture, not be a part of it (Grieco, 2014).

### **Glass in The Middle Ages**

Glass Architecture which will let the sunlight and the light of the moon and stars shine into the room, not through a couple of windows but, as nearly as possible through whole walls, of colored glass.

Since the early middle ages, people have looked up into the diffused colored light filtering in from windows high in the church walls and felt inspired as much by the quality of the light as by the stories and moral lessons depicted in the images. The ever-changing sky brought new emphasis to different parts of a collection of image that never remained static. Glass was regarded as special in these times not only for its ability to transmit light, but also for the mysterious alchemy that transformed base elements into this new form (Simson, 1956).

The one particular feature which makes glass truly special is its ability to assume any color imaginable while at the same time remaining translucent. Hence, it is only logical...that because of its translucency, glass long has been used as an architectural element; it can both admit light into a building while at the same time protect the interior from the elements (Grieco, 2014).

Glass is a highly versatile medium. In its molten state, it can be spun, blown, rolled, cast in any shape, and given any color. Once cooled, it can be polished, beveled, chipped, etched, engraved, or painted. Of all the decorative effects possible with glass, however, none is more impressive than stained glass. Since the days of ancient Rome, stained glass in windows and

other building elements has shaped and colored light in infinite ways (Strickland & Boswell & Memel, 2007).

A fundamental text in the theology of the medieval image is Paul's pronouncement in 1 Corinthians 13: 12 that "For now we see through a glass, darkly; but then face to face." This prophecy of clear and divine vision after death, when the faithful will see their Lord directly and without mediation, is subject to much controversy in medieval theological discussion, culminating in a fourteenth-century papal constitution. In contrast to the confidence in vision of the late medieval period, in the early The Middle Ages, this same text is treated very differently. One might begin with art, but any vision of God was founded in prayer and the exercise of the "interior eyes." The corporeal eyes were lowered, even perhaps pressed into the dust of the earth in a symbolic abasement of the corporeal sense (Rudolph, 2006).

### **Stained glass**

The stained-glass window is one of the most spectacular art forms. This art is so directly affected by its environment and it owes its artistic existence to light. The windows of a Gothic cathedral from the outside are almost unnoticeable, scarcely different in texture from the stone itself and they are so encrusted with the dirt of centuries. But when we enter to the same cathedral, it lighted by tier upon tier of sparkling windows and it seems that we enter to another world.

Stained glass can mean colored, painted or enameled glass, or glass tinted with true glass stains. In this Brief the term refers to both colored and painted glass. It appears in windows, doors, ceilings, fanlights, sidelights, light fixtures, and other glazed features found in historic buildings. A number of notable churches, large mansions, civic buildings, and other prominent buildings boast windows or ceilings (Strickland & Boswell & Memel, 2007).

The exact time and place that stained glass was first used is not clear. Examples that may date from the eighth century have been found in France, colored glass beads were worn by ancient Egyptians, and the blowing technique was known to the Roman Empire. But we can mention that the cathedral window which is the ultimate achievement of the glazier's art, was Gothic. Ideas that resulted in walls of colored glass and windows that told the stories of the Bible and the saints were first conceived in the twelfth century. The Gothic skeletal system of



construction and the immense apertures that they provided allowed stained glass to reach its full potential as an art form (Hayward, 1971).

Stained glass from its birth to the Renaissance can be divided into three main periods, each having particular characteristics to itself. The First lasts from the earliest examples almost to the end of the thirteenth century, and might be subdivided again into twelfth and thirteenth century work, between which there is a distinct difference. The Second covers nearly the whole of the fourteenth century. The Third lasts down to the end of the fifteenth century, by which time the influence of the classic Renaissance began to be felt in glasswork, but lingers on in belated examples well into the sixteenth (Rudolph, 2006).

- Early Gothic (13th century until ~1280);
- Decorated Gothic (~1280-1380); and
- Perpendicular Gothic (~1380-1530).

Early Gothic windows are composed of white or colored glass, with a colored border around it. White windows of this period are silvery and cold due to the greenish-blue tint of the glass. This style of windows excludes more light than the other painted windows and gives an impressive yet solemn effect. The main goal of windows of this time was to create a mosaic effect; because most of the windows were so high up in churches and cathedrals, the details of the images were deemed less important than the overall effect.

The Middle Gothic period, also known as the Decorated Gothic period, began with a change in taste in stained glass, including the differently-shaped windows, desire for more light, more pictorial imagery, and increased resources of both the glazier and glass-painter. Windows were designed such that the most light was let in; therefore, a lot of white glass used, often surrounded by borders of colored glass. The figures themselves were still not perfect, but during this time they were improved by artists giving them a more graceful pose. Windows that were rich in color were laid out in bands of color with layers of white or yellow glass between tiers with figures. Another characteristic of windows of this period was an increase in window area. This allowed for more elaborate images of figures to be depicted effectively on a larger scale and successfully seen from a distance down below.

Picking up where the Middle period left off, the Late Gothic period, also known as the Perpendicular period, progressed further in both imagery and light. The 15th century also

brought the glass-painter into the most important role, surpassing the glazier for the first time (Grieco, 2014).

### **Stained glass and architecture**

The fall of the Roman Empire toward the end of the 5th century led to changes for flat glass in architecture. During this time and subsequent centuries, glass was used predominantly in church settings and in addition to the use of color already employed by the ancient Romans, images and symbols were now painted onto the glass.

Correspondences between glass and architecture originate in the fact that glaziers and masons worked hand-in-hand. This means that dating a building can help establish the glass chronology, and vice versa. Scholars have also noted more specific reciprocal influences. The progressive compositional changes in the clerestory figures are most logically explained by an accommodation between the window designs and the large interior space in which they would be viewed. In addition, the fashion in later thirteenth-century glazing programs for framing figures with architectural canopies united the window compositions to elements in architectural interiors, including choir screens and reliquaries (Rudolph, 2006).

A stained glass window is both an architectural building element and an individual work of art. Like architecture, a stained glass window is composed of a variety of materials, mainly glass, lead, and surface decoration. Stained glass is a fascinating field because it combines the worlds of art and architecture with a single object and the surface decoration plays an important role in this.

Stained glass windows are not only a practical element to a building but each one is also a unique work of art. Similar to architecture but unlike many works of art, they comprise several different components and materials. Stained glass is a fascinating field because while the windows themselves are viewed as works of art, they are meant to be placed within an architectural setting thereby combining the worlds of art and architecture with a single object (Grieco, 2014).

The gothic architecture is considered to be a true assembly of constructive methods and decorative means, having at its base the elements of romantic architecture from France and it is a continuation at a superior level of the schools and principles of architectural creation that were found in the catholic religion service. As a consequence, the spreading area of the gothic

architectural style was approximately the same as the one of the romantic architecture buildings (Ianca & Georgescu, 2nd year, first semester).

What made the Gothic cathedral possible were two engineering break-through: ribbed vaulting and external supports called flying buttresses. Applying such point supports where necessary allowed builders to forgo solid walls pierced by narrow windows for skeletal walls with huge stained glass window flooding the interior with light. Gothic cathedrals acknowledged no Dark Ages. Their evolution was a continuous expansion of light, until finally walls were so perforated as to be almost mullions framing immense fields of colored, story-telling glass (Nael, 2007).

### **Why churches?**

Thought to illuminate the church both physically and spiritually, stained-glass windows replaced so much of the walls that the buildings had to be supported by a system of pointed arches, ribbed vaults, and flying buttresses outside. The exterior of the churches also featured organized programs of narrative sculpture that together promoted a theme such as the Last Judgment or a saint's life. The principal catalyst for this surge of building was the growth of cities, where new wealth was concentrated. Church building primarily advanced primarily both styles. The same religious sentiment that caused groups of Christians to call for a purer form of Christian expression, reform of the Catholic Church, and put more and more pilgrims on the path to Christian shrines throughout Europe fueled a massive building campaign of new churches (Norris, 2005).

In examining the relationship between the cult of the relics and the architecture of medieval churches, Éric Palazzo concludes that church relics foster significant understanding of the symbolic meaning of the built environment of churches. He posits that liturgy and reliquary objects found within the church hold valuable clues to understanding the development of medieval church spaces, religious practices, and belief systems. Employing stained glass to tell the stories of the New Testament and specific accounts from Christ's life, the light that shone through the windows created an additional effect on the clergy and visitors alike (Lentz Wall, 2012).

As a result of the boom in church building, tools such as cranes and hoists improved, and workmanship also improved including that which applied to roads, walls of castles, towns, public buildings, and bridges. Moreover, it took the vision of patron and master builder to organize the design, funds, resources such as timber and stone, and, perhaps most importantly, labor. It took a whole force of masons, carpenters, metalworkers, sculptors, and with the Gothic style, glassmakers. A church in either style could take several decades to complete (Abbate, 2006).

All this constructive and architectural element presented before, offer to the gothic architecture the character of a bold architecture, logic and highly expressive and it places it in the architectural currents with one of the greatest influences in the universal architecture and with the greatest number of representative edifices kept in function mainly religious buildings (Ianca & Georgescu, 2nd year, first semester).

Gothic architecture is incomplete without stained glass; the two are practically synonymous. Not only did window subjects expand from figures to include complex iconography, but also heraldry in windows began to show the increased secularity of stained glass. This period was characterized by the erection of a large number of churches and cathedrals. The Gothic cathedrals were the driving force for the popularity and importance of stained glass windows. The cathedrals had much larger windows providing larger canvases for designs; however, they are often hard to see from the ground, usually being recessed in galleries or set within thick walls. These windows were filled with much more richly- colored glass than those of the Romanesque period and there was a great deal more of painted glass (Grieco, 2014).

# Reims Cathedral

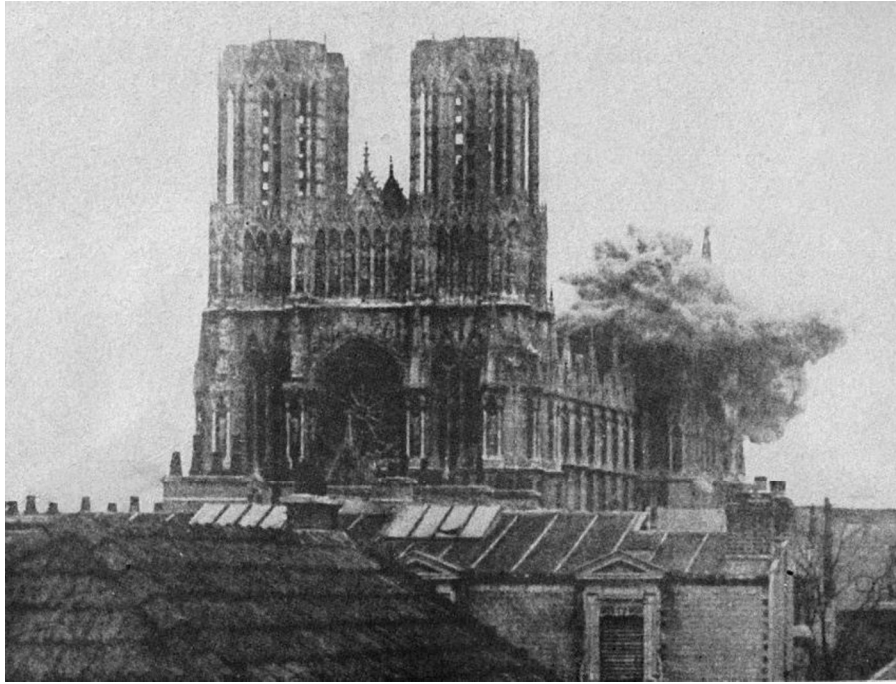
## **Introduction**

Cathedral of Notre-Dame in Reims is one of the most important place in France in terms of architecture. The cathedral originated in medieval France. The first religious structure to be built on the Cathedral site was in the very beginning of the 5th century. It was a modest edifice which was later rebuilt and enlarged, first during the Carolingian epoch (816-862), and then in the middle of 12th century, in early Gothic style. It was damaged by fire in 1210, and the structures were completely razed shortly after ([www.reims-cathedral.culture.fr](http://www.reims-cathedral.culture.fr)).

## **History**

The emergence of the church dates back to the 13<sup>th</sup> century. The cathedral stands on the site of the former Roman baths which became a Romanesque basilica after and then burned down in 1210. Construction of the cathedral began after burnout of the original church. Studying the style of the façade, allows us to estimate that the portal areas were finished about 1270, and the upper part of the rose window at the end of the 13th century. The central areas and those south of the Gallery of Kings were constructed above the rose window at the beginning of the 14th century. Overall, the cathedral was completed a century later. The Cathedral during its existence, has suffered a series of damages, especially after the 1st World War (Vondrackova & Nyvlt & Nemeč, 2016).

The rose-window zone was finished by 1260, but the north tower was not completed until 1460, as an inscription on it indicates. As a result of the slow progress of the work and the sea changes in design, the Reims facade is no longer High Gothic. The gables of the portals overlap the intermediate arcaded zone, and the central gable penetrates up into the rose window. This overlapping of elements in the facade represents a new kind of Gothic, quite different from the logical and classic balance of the facade of Amiens, the epitome of the High Gothic façade (Stoddard, 1972).



Reims cathedral 1914, Wikimedia.org



Reims cathedral 1787, Wikimedia.org

## **Architecture**

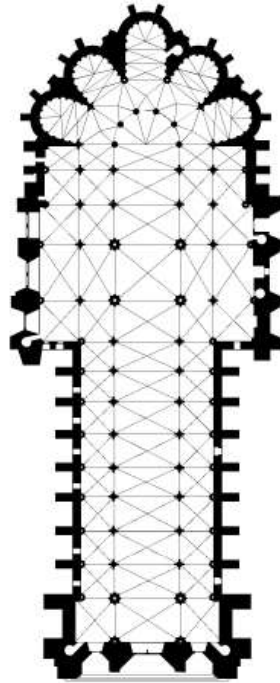
The Cathedral of Reims remains one of the most beautiful examples of Gothic art and represents ultimate medieval work in the Gothic style. It became the model for a series of later buildings across Europe. They were used window in tracery in the tympanum for the first time and also the window height reaches a height of arcades.

The interior elevation is remarkable for the impression of vertical tension created by the upward thrust and relative narrowness of its volumes. The division into three levels is typical of 13th century architecture: grand arcades on the ground floor, triforium (Gallery or open space at the second floor level of a church, often forming a rich interior arcade), and large, high windows. To the three galleries of circulation habitual in similar edifices with a passageway at the base of the high windows, a median, and the triforium; the Cathedral adds an interior passage at the base of the low windows: the "Passage Champions". Each of these passageways allows one to walk completely around the edifice ([www.reims-cathedral.culture.fr](http://www.reims-cathedral.culture.fr)).

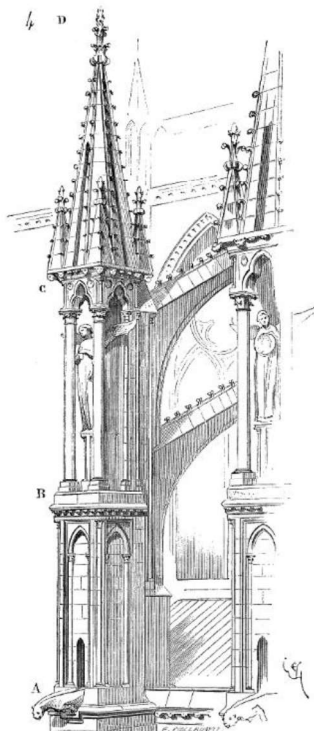
The most important difference, between the Reims and other cathedral like Chartres is clearly the new design of the windows. In general, the architects of Reims have animated the surfaces through the use of mullions and by the ornate pinnacles on top of the buttresses, and this animation has increased immeasurably the vertical nature of the exterior of the cathedral (Stoddard, 1972).

Because the entire large opening is filled with glass, the tracery creates more window shapes than were made in earlier structures—small medallions and triangular windows filling in the spaces around the lancet tops and roses. The overall effect is a reduction of structural stone members and a conversion of more of the wall to glass. The reduction of mass reached the point at Reims that the cathedral's west façade has the appearance of stone lace (Wilson, 2009).

At Reims the symbolism which so delighted the mediaeval mind was, perhaps, most clearly shown in the windows of the apse, where the architect placed those first window groups wherein the windows were separated one from the other by bars of stonework instead of by solid-flat expanses of wall (Burgess, 1919).



Plan of Reims cathedral, Wikimedia.org



Flying buttress with pinnacle, Wikimedia.org



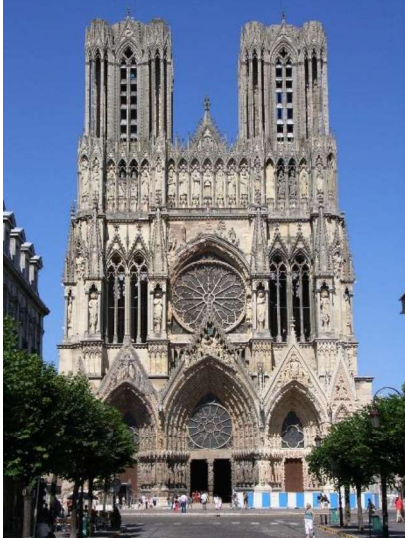
The aisle windows are completely related in design to the clerestory windows and are reflected on a smaller scale in the blind and open arcades of the pinnacles of the buttresses. The sense of planes in space moving from the aisle windows up through the buttresses to the clerestory windows is completely in harmony (Stoddard, 1972).

Despite of other architectural particularities like the exactness of the basepoints of the flying buttresses, the near-uniformity of the internal supports, as well as the wide use of the *tas-de-charge*, this is the Remois window that defines the Cathedral's architecture. This window consists of two lancet arches surmounted by a six-lobed rose window. It is independent of the architecture that surrounds it. In Reims, the so-called "window-chassis" became, for the first time in the history of architecture, a fundamental element of the edifice ([www.reims-cathedral.culture.fr](http://www.reims-cathedral.culture.fr)).

### **Stained glass**

Reims played important roles in medieval France. Along with being a seat of an archbishop it was also the location of the coronation of the French kings. Very many of the medieval stained glass windows of the Cathedral of Reims have disappeared because of vandalism and war. Their history reminds us just how fragile are the few that, through great care and effort, remain to us today. It has interesting stained glass ranging from the 13th to the 20th century. Originally, the great rose windows were the culmination of the rich stained glass ensemble of the Reims Cathedral.

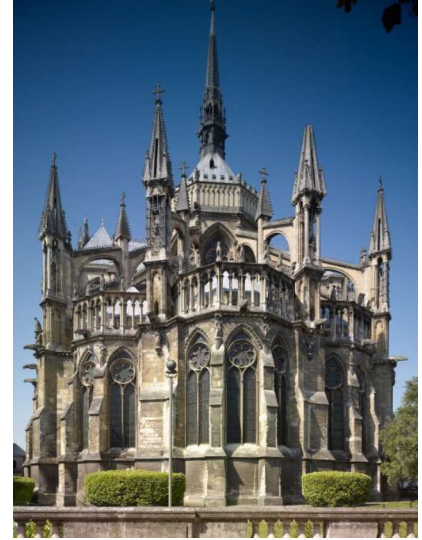
The Great Rose window of the Western facade of Reims Cathedral was counted the finest in France. Not only its great size--twelve by fifteen meters to the summit of the arch--but the beauty of the architecture of the Rose, complemented by the glorious color of the glass it contained, placed it in the highest rank of the stained-glass of the thirteenth century (Burgess, 1919).



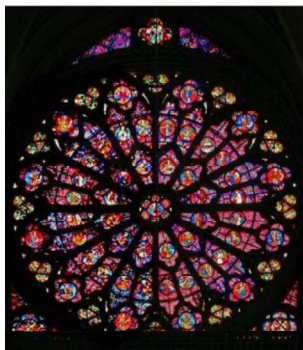
West view, Wikimedia.org



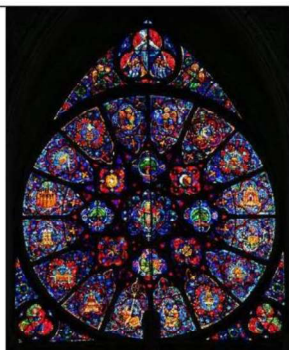
Nave, Wikimedia.org



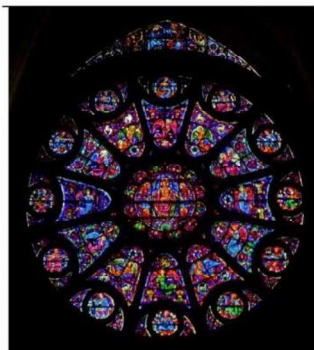
East view, mappinggothic.org



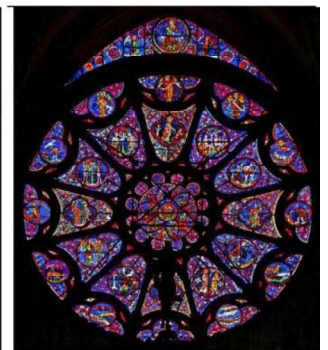
West rose upper



West rose lower



South rose

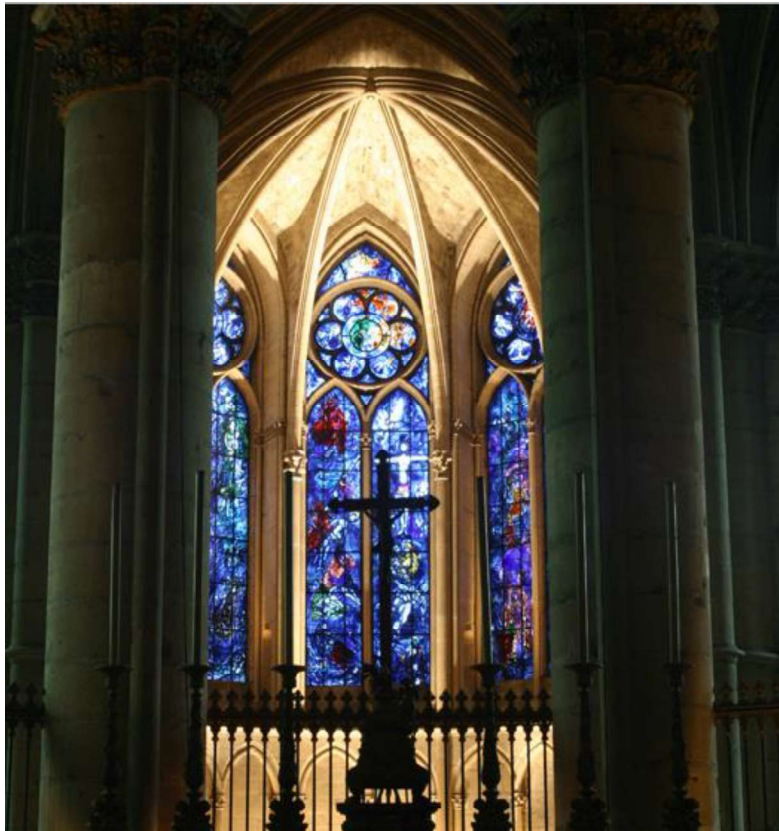


North rose

Rose windows of cathedral, [www.richardnilsendot.com](http://www.richardnilsendot.com)



Apse windows, [cathedrale.maisons-champagne.com](http://cathedrale.maisons-champagne.com)



North transept, [cathedrale.maisons-champagne.com](http://cathedrale.maisons-champagne.com)

## Milan Cathedral

### **Introduction**

The cathedral is white marble, over a brick core, and has a cruciform plan. It is one of the largest cathedrals in the world which was designed to accommodate 40,000 worshippers. It is closer to France cathedrals than most Italian cathedrals, it borrows more directly from the French "Rayonnant" style. This cathedral begun in the 1380's on a site where several churches had existed earlier, the building of this cathedral was fraught with difficulties. Over a number of years several different architects and consultants were asked to work on the design.

### **History**

The construction of Milan Cathedral was one of the most important episodes in the history of Italian and European architecture. This was, first, because of the uniqueness of the building itself, the largest Gothic church ever constructed in Italy. Secondly, because of the input of some of the most authoritative architects of the late fourteenth and fifteenth centuries in Europe (Lombard, French, German), who were invited from time to time to make architectural and structural proposals (SEBREGONDI & SCHOFIELD, 2016).

The plans for a new Cathedral was made by Archbishop Antonio da Saluzzo in 1385, to be built on the site of Basilica of Santa Maria Maggiore and dedicated to Santa Maria Nascente and formally completed only in 1965. The construction program was strictly regulated under the "Fabbrica del Duomo", which had 300 employees led by first chief engineer Simone da Orsenigo. Orsenigo initially planned to build the cathedral from brick in Lombard Gothic style ([www.duomomilano.it](http://www.duomomilano.it)).

Visconti had ambitions to follow the newest trends in European architecture. In 1389, a French chief engineer, Nicolas de Bonaventure, was appointed, adding to the church its Rayonnant Gothic, a French style not typical for Italy. He decided that the brick structure should be panelled with marble. Galeazzo gave the Fabbrica del Duomo exclusive use of the marble from the Candoglia quarry and exempted it from taxes. Ten years later another French architect, Jean Mignot, was called from Paris to judge and improve upon the work done, as the masons needed new technical aid to lift stones to an unprecedented height (Ackerman, 1949).

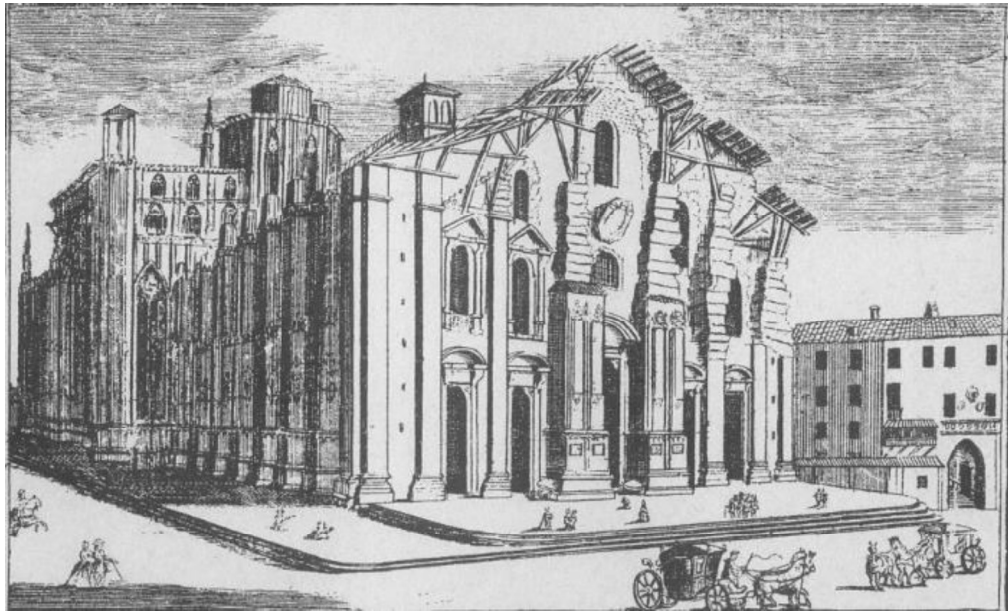
## **Architecture**

The cathedral of Milan, the city's iconic building, dedicated to Santa Maria Nascente is one of the most famous buildings and complexes in the world, a mixture of late Gothic French Gothic and Renaissance. In terms of Italian architecture, this means that the truly gigantic building projects of the declining 14th century-the Duomo (cathedral) in Milan and the church of San Petronio in Bologna-are written off as medieval resistance to more up-to-date trends toward the Classical. Their achievement as monumental resumes or summate of international building traditions and forerunners of the new aesthetic values remains largely overlooked (Toman, 2004).

The earliest part of the church and the most Gothic (French Gothic in particular) is this eastern and with the apse. The large apse windows have beautiful tracery in the Gothic style. Its primary style derives from the late French Gothic, with extensive use of statuary and flying buttresses. Construction of the new Cathedral Church of Milan began when Gothic cathedral architecture had already reached the height of its development (Sullivan, 2010).

When compared with other Gothic cathedrals, the Milan Cathedral exhibits a peculiar structural system, with metallic tie-rods being permanently installed under each vault and designed to exert an active part in resisting the lateral thrusts. The design was intended to comply with the elements of Lombard Gothic style, a more formal than substantial transcription of Lombard Romanesque style, from which it inherited the building experience, the structural decisions and the traditional material, brickwork ([www.duomomilano.it](http://www.duomomilano.it)).

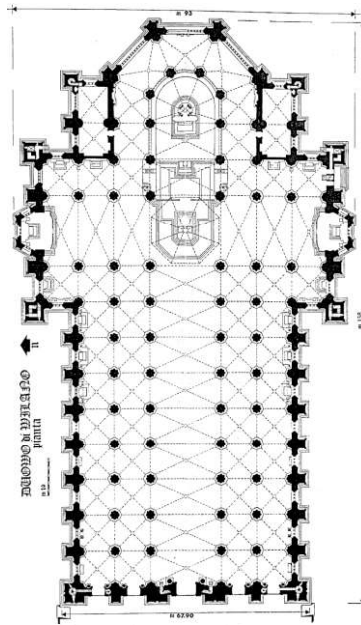
The cathedral's five broad naves, divided by 40 pillars, are reflected in the hierarchic openings of the façade. Even the transepts have aisles. The nave columns are 24.5 meters high, and the apsidal windows are 20.7 by 8.5 meters (Ackerman, 1949).



The cathedral in 1745, study.com



The cathedral in 1856, study.com



The plan of cathedral,  
[www.cambridge.org](http://www.cambridge.org)



The exterior of Milan cathedral, [www.italiangoodnews.com](http://www.italiangoodnews.com)

Historical documents, dating back to year 1400, testify that the tension bars in the Milan Cathedral were permanently installed on the top of the piers during the construction with the aim of reducing the horizontal thrust on the lateral buttresses, as those buttresses were judged too slender by the French architect Jean Mignot. A total of 122 metallic tie-rods is nowadays present in the Milan Cathedral and most of them are the original elements dating back to the age of construction (Gentile & Canali, 2018).

### **Stained glass**

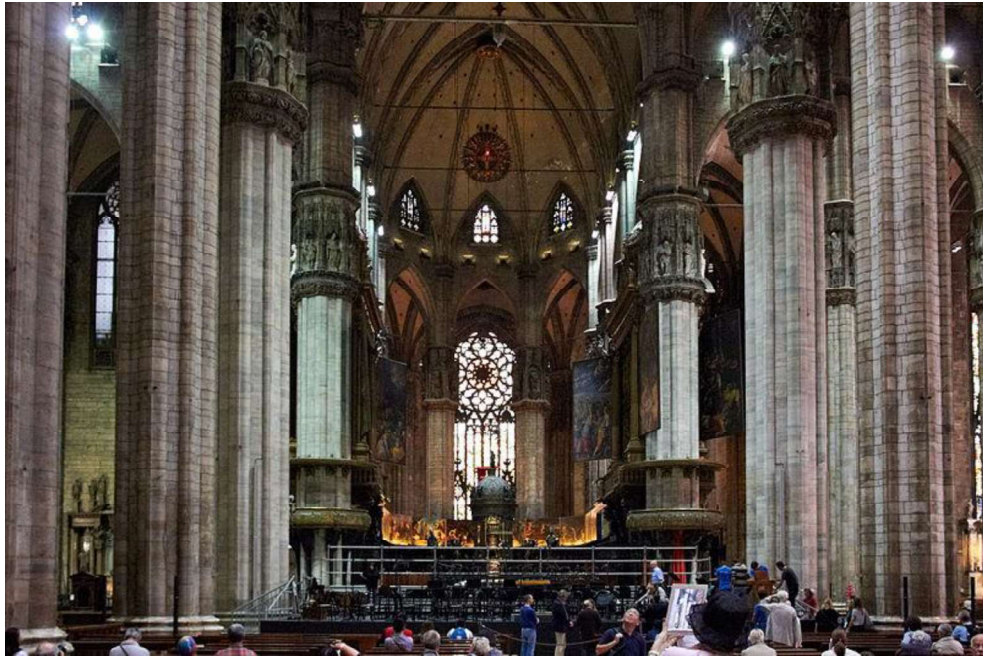
Glass making at the Duomo construction site went hand in hand with the other aspects of construction and the question of how to complete the windows with glass arose already with the completion of the first architectural structure, the 'aquilonare' or north sacristy. The first solution put forward (1397) was to insert colored glass, but in 1403 it was decided that historiated stained glass should be installed in the windows. The reason for this decision was the ease with which the stained glass could be understood, since the panes were decorated in such a way as to provide a visual account by which God shows himself to his people, the image of the “true light / that lighted every man”, that is Jesus Christ, son of the living God ([www.duomomilano.it](http://www.duomomilano.it)).

A very original style of stained glass windows was created in the Duomo in the second half of the 15th century. Its interior has a particular light. The rays of colored light that filters through the Gothic windows, true works of art, created a solemn and mystical atmosphere. On each of the doors we can see windows of the seventeenth century. The one on the main entrance, a balcony in 1790 is dominated in turn, as the two adjacent window of the other great nineteenth-century Gothic style ([en.wikiarquitectura.com](http://en.wikiarquitectura.com)).

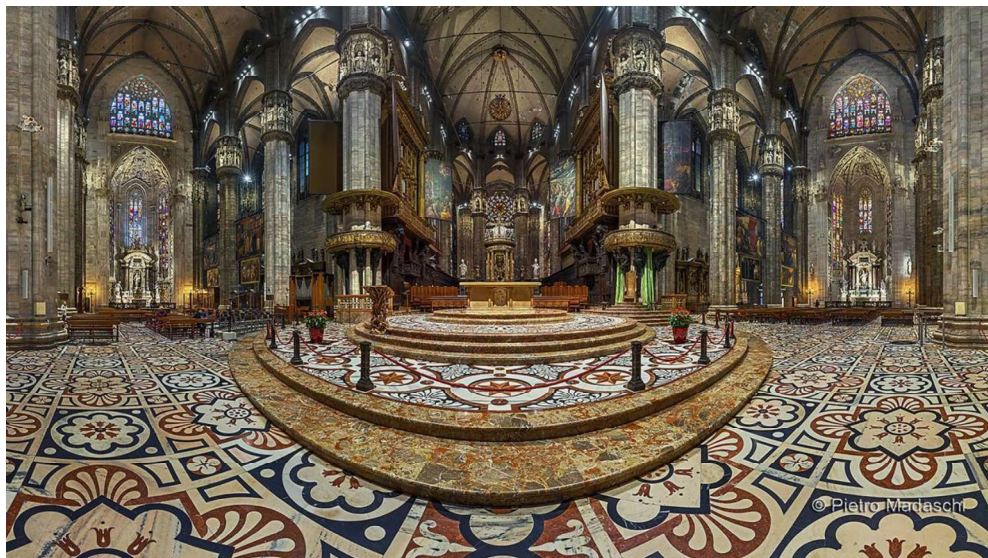
The famous tower (the Babel tower), who's top would have to touch the sky, is shown, and illustrating the biblical story, during the construction when the divine intervention led to the confusion of languages and at the dispersion of men all over the Earth. Against the backdrop of the city of Babel, whose horizon is closed by high barren hills with rounded and net contours against blue sky, the tower is imagined with circular plan with the lower part similar to that of a fortified tower whose solidity is described by the buttresses underlined by the lively tone of



the yellow silver, which also mark the openings, the doors and the first order of windows. After the string-course, the building rises upward in a spiral, again highlighted by the yellow silver, such as pilasters and arches under which there are small single-lancet windows ([museo.duomomilano.it](http://museo.duomomilano.it)).



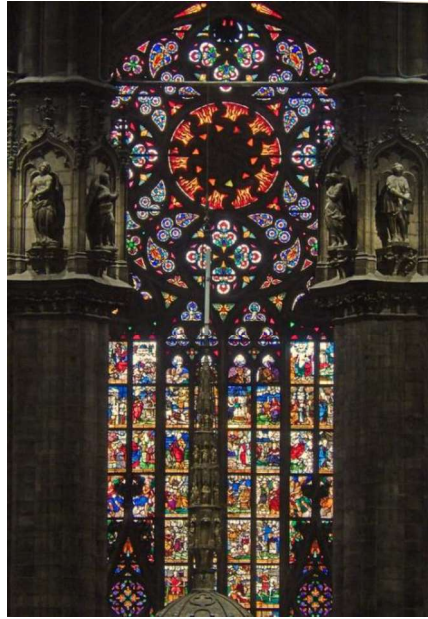
Central nave of Milan cathedral, [meta.wikimedia.org](https://meta.wikimedia.org)



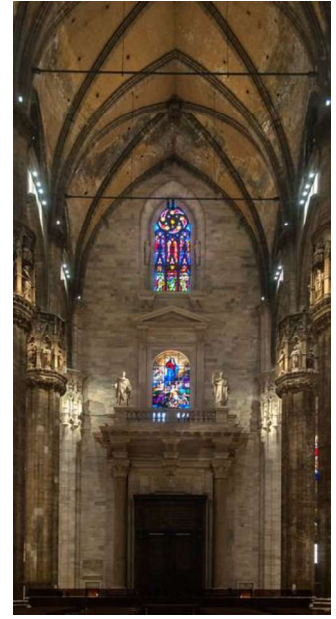
Interior of Milan cathedral, [www.duomomilano.it](http://www.duomomilano.it)



View of the apse  
awanderer.smugmug.com



The window behind the  
ciborium, awanderer.smugmug.com



West wall of main  
nave,

## **Batalha Monastery**

### **Introduction**

The monastery of Santa Maria da Vitória, Batalha is the main example of international Gothic architecture in Portugal; it has a unique stained-glass collection from the 15th century, the oldest in the country. Construction of the monastery began around 1388; from approximately 1430 to 1440 Luis Alemão, a stained-glass worker and creator of stained-glass panels from this period, worked for the monastery. The Monastery of Batalha was the Portuguese centre of stained glass production in the 15th and 16th centuries, being where most of its artists were based. From there they travelled across the country to carry out commissions. It is known that until the end of the 17th century, stained glass artists were constantly hired to maintain pieces produced in earlier centuries. In the course of the following century, the condition of the stained glass was to deteriorate substantially not only due to the lack of care but also the earthquake of 1755 (Machado & Vilarigues, 2011).

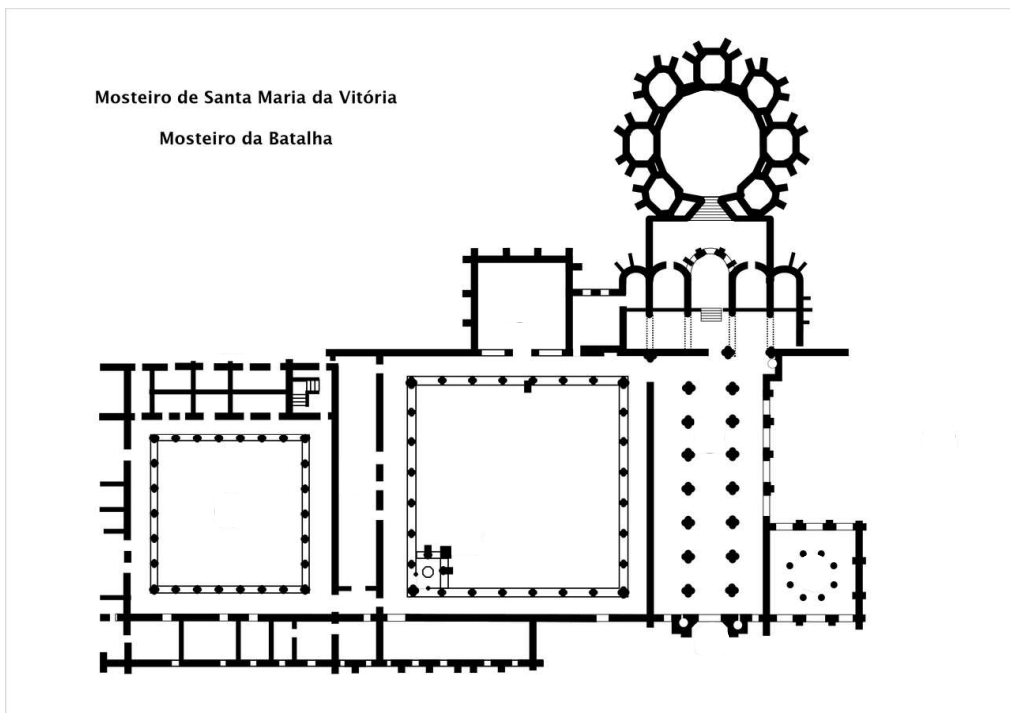
### **History**

The Monastery of Our Lady of Victory (also known as the Batalha Monastery) located in Batalha, Portugal, was built by King John I, as a thanksgiving to the Virgin Mary for the victory at the Battle. The first architect was Afonso Domingues, active from the beginning of the construction till 1402. He used the conception and the general outline of the monastic complex, constituted by the church with the sacristy, and the cloister with chapter house, dormitory, kitchen and refectory. After directing the construction for about fourteen years, a large part of the church, the sacristy and two wings of the cloister were built, while work on the chapter house had already begun ([mosteirobatalha.gov.pt](http://mosteirobatalha.gov.pt)).

Batalha is the conservatory of several privileged expressions of Portuguese art: the sober architectural style of the end of the 14th century, with the stupendous nave of the abbatial, of which the two-story elevation, with broad arcades and high windows, renders most impressive ([www.unesco.com](http://www.unesco.com)).



Monastery of Batalha, 1799, [mosteirobatalha.gov.pt](http://mosteirobatalha.gov.pt)



Plan of Monastery, [www.wikimedia.org](http://www.wikimedia.org)

## **Architecture**

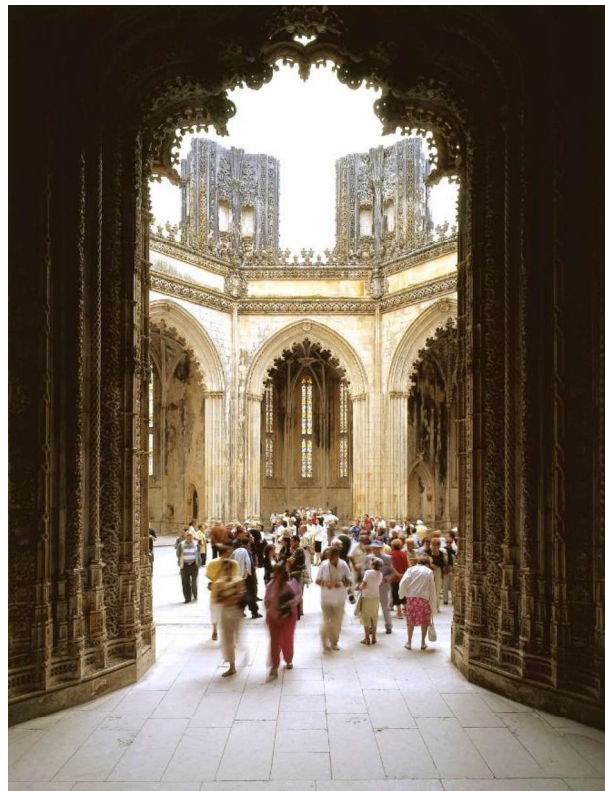
Since the end of the 14th century to the first years of the 16th, the Monastery of Batalha was the greatest and most advanced architectural project in Portugal. The Monastery is the most significant Gothic monument on Portuguese soil. To a certain extent, of equal importance is the sculpture, whether in terms of its decorative imagination. Often, great cavities are incorporated into the walls, atypical for Portuguese architecture, as well as certain elements which highlight the adoption of techniques learned abroad and adapted to the Portuguese style. The entire monastery is in fact very similar to the model, which allows us to consider its Cistercian Gothic architecture, here transcribed in white stone, as an example of “international style” of that time. In Portugal there is no such scale and quality (Xavier, 2002).

The main façade, which looks just like a church with three emphatic vertical naves, the main one taller than its flanking naves due to the height of its supporting buttresses on either side, essential as supports and decorative elements. The entire surface of the Monastery is finely worked in detail. This sacred ensemble is then embellished by stone gargoyles. On entering the Monument, we notice the vaulted surface decoration of mainly crisscross and starry patterns, and tall windows fitted with stained glass, mostly to be found in the Apse of the Church and the Founder’s Chapel (Visitor’s Guide to The Monastery of Batalha).

Batalha is inscribed in this tradition but its proportions and stoned vaulted spaces make it an exceptional example. It’s deeper and most of all it is higher. Here the Gothic verticality becomes a fact and, of course, we have all over the temple the light flowing in through large stained glass windows, now made possible by the accuracy of the constructive system. There is lighter inside, mainly in the presbytery and side chapels, which are the only vaulted spaces, where we see the characteristic ribbed structure of the Gothic with its narrow but high windows in between. The second architect whose name was Huguet possibly of English origin or at least with close English connections, took over the work and He increased the height of the nave and thereby the amount of light (Toman, 2004).



Royal Cloister; North gallery, [www.unesco.org](http://www.unesco.org)



Unfinished Chapels, [mosteiroatalha.gov.pt](http://mosteiroatalha.gov.pt)

The nave was raised to its present height by him, altering the proportions of the church and giving it its present aspect. The ribbed vaults, supported by compound piers, are closed by ornamented keystones. Light enters the church through ten stained-glass windows of the clerestory and the tall, traceries windows in the side walls and the transept and through the two rows of lenti-form windows in the choir. The choir extends into two-bay transepts and consists of five apsidal chapels, with the central one projecting (Monastery of Batalha: English guide, July 2005).

The church was organized into three naves, with two side naves that are narrower and lower than the central nave. The naves lead to the transept, where, in the centre of the crossing, one finds a modern high altar before the chancel proper. The chancel is made up of five polygonal chapels, whereby the central chapel is higher and deeper than the four side chapels. The elevation of the High Altar over two storeys, with tall lanciform windows filled with stained glass panels, the oldest of which date from the early 16th century, represents an innovation in Portuguese Gothic architecture. Together with the great height of the High Altar, which is equal to that of the central nave, this solution serves to project the latter, with the apse serving as a luminous and transparent finishing ([www.mosteirobatalha.gov.pt](http://www.mosteirobatalha.gov.pt)).

Each side of the apse has one tall narrow single-light window which, filled at some later date from top to bottom with elaborate stone tracery, has two thin shafts at each side and a rather bluntly-pointed head. The central apse has been much the same but with five sides, and two stories of similar windows one above the other. The elaborate many-sided canopies above are not so much so in form though they might well have been evolved from English detail. Above the gable comes another English feature, a very large three-light window running up to the very vault; at the top the mullions of each light are carried up so as to intersect, with cusped circles filling in each space, while the whole window to the top is filled with a veil of small reticulated tracery (WATSON, 1908).



### **Stained glass**

The introduction of the art of the stained glass in Portugal was due to a major architectural project from the Royal House: building the Monastery of Santa Maria da Vitória, best known as Monastery of Batalha. The architectonic quality of the Batalha Monastery is also seen in the stained glass windows, produced for the first time in Portugal, by German stained glass artists. In 1983, it was added to UNESCO's World Heritage List. The Monastery of Batalha was the first Portuguese building to be chosen for such an artistic solution, began to be implemented probably at the end of the 1430s or the beginning of the 1440s.

The first stained glass artist of Batalha of whom we have knowledge went by the name of Luís Alemão and came to work at the monastery at the end of the 1430s or the beginning of the 1440s.

The fragments of these works that have survived show prophets holding scrolls, some unrolled, some not, as well as patriarchs, saints and messenger angels. Others show scenes from the life of Christ or related to His death and resurrection ([mosteirobatalha.gov.pt](http://mosteirobatalha.gov.pt))

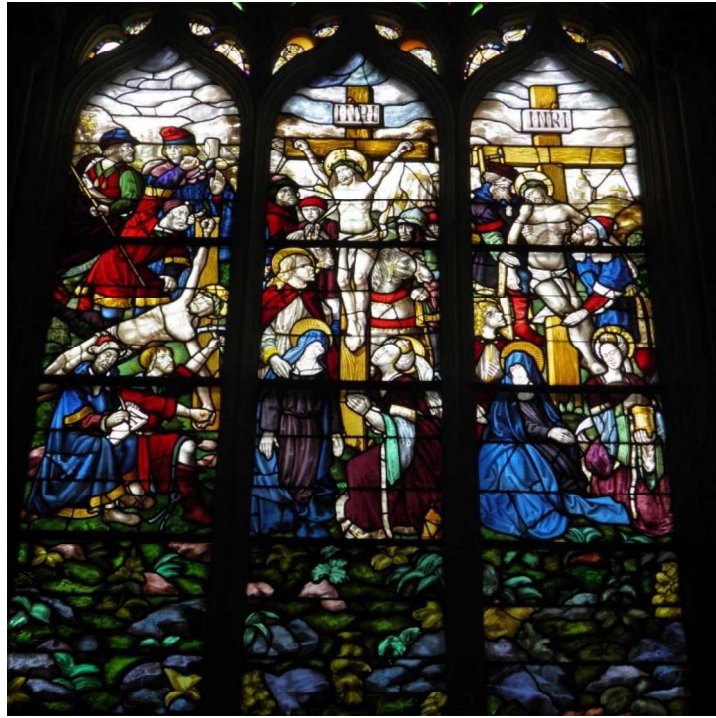
The nave's windows contain the oldest and most famous stained glass of the entire Monastery, also recognized as the oldest known in Portugal, dating from the 15th century. To these we can add the stained glass windows of the Main Chapel, which depict important scenes from the Bible and date from two different time periods, the second decade of the 16th century (Visitor's Guide to The Monastery of Batalha).



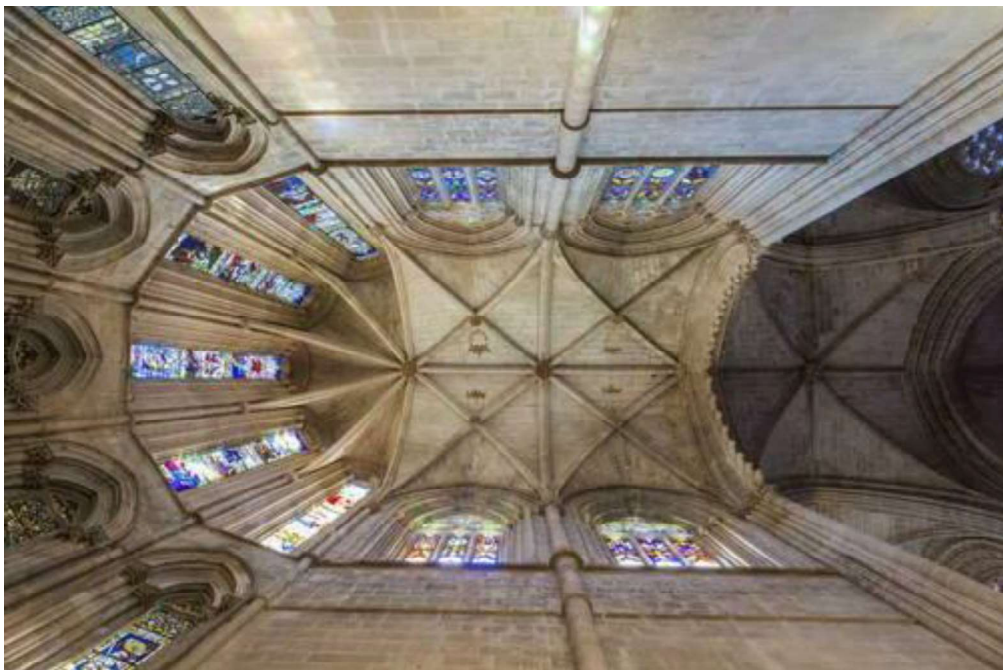
Entrance of monastery, [mosteirobatalha.gov.pt](http://mosteirobatalha.gov.pt)



Founder's Chapel's ceiling, [www.patrimoniocultural.gov.pt](http://www.patrimoniocultural.gov.pt)



chapter house stained glass, [essenciadalatitude.com](http://essenciadalatitude.com)



Stained glasses of choir, [www.unesco.org](http://www.unesco.org)

## Bibliography

1. ARNOLD HUGH, "Stained glass of the Middle Age in England and France", ADAM AND CHARLES BLACK SOHO SQUARE LONDON MCMXIII, 1913.
2. P. R. Patterson Duncan, "There's Glass between Us': A critical examination of 'the window' in art and architecture from Ancient Greece to the present day", *FORUM Journal*, n 10, pp. 1-21, 2011.
3. Vogel Neal A., Achilles Rolf, "The Preservation and Repair of Historic Stained and Leaded Glass", National Park Service U.S. Department of the Interior, October 2007.
4. Hayward Jane, "Painted Windows, Associate Curator of the Cloisters", Metropolitan Museum of Art Bulletin, 1971.
5. Doyle Lars, Mould David, "Painted Stained Glass, Carleton University", Ottawa, Canada, Euro graphics, EXPRESSIVE, 2016.
6. Sankovitch Anne-Marie, "The Myth of the "Myth of the Medieval": Gothic Architecture in Vasari's Rinascita and Panofsky's Renaissance", *Anthropology and Aesthetics*, n 40, pp. 29-50, 2001.
7. Lentz Wall Natalie, "RE-MYSTIFYING THE EXHIBITION OF MEDIEVAL SACRED OBJECTS", Greensboro, 2012.
8. Ianca Sevastian, Georgescu Mircea "ARCHITECTURE Notes, Politehnica University of Timisoara English Teaching Medium", Year: 2nd Semester: 1st/ [www.docplayer.net](http://www.docplayer.net)
9. Norris Michael, "MEDIEVAL ART A Resource for Educators", THE METROPOLITAN MUSEUM OF ART, 2005.
10. Abbate, Francesco, "The Planning and Building Instruments of Architects in the Late Middle Ages", *In Proceedings of the Second International Congress on Construction History, Queen's College*, pp. 111–25.2006.
11. Rudolph Conrad, "A Companion to Medieval Art: Romanesque and Gothic in Northern Europe", Blackwell Publishing, 2006.
12. Grieco Alyssa, "What's On the Surface Does Matter: The Conservation of Applied Surface Decoration of Historic Stained Glass Windows", Columbia University, 2014.
13. Strickland Carol, Boswell John, "The birth of art: prehistoric through Medieval, the annotated Mona Lisa, A Crash Course in Art History from Prehistoric to Post-Modern", Andrews Memel Publishing, 2007.
14. Simson Otto von, "THE GOTHIC CATHEDRAL", BOLLINGEN FOUNDATION, 1956.

15. Simmons Chris, “Let There Be Light: Stained Glass and, the Late Medieval Climate Transition”, Supervised by Dr. Lawrence Mysak, Centre for Climate and Global Change Research, McGill University, July 2007.
16. Machado Andreia Sofia, Vilarigues Marcia, “Ionic liquids for medieval stained glass cleaning: a new frontier”, September 2011.
17. S. Valadas · A. Candeias · C. Dias · N. Schiavon, M. Cotovio · J. Pestana · M. Gil · J. Mirão, “A multi-analytical study of the fifteenth century mural paintings of the Batalha Monastery (Portugal) in view of their conservation”, 29 May 2013.
18. Visitor’s Guide to The Monastery of Batalha, 2018.
19. Xavier João Pedro, “Post-Conference Excursion: The Monasteries of Alcobaça and Batalha”, *NEXUS NETWORK JOURNAL*, VOL. 4, n. 2, 2002.
20. WATSON WALTER CRUM, “PORTUGUESE ARCHITECTURE”, LONDON, ARCHIBALD CONSTABLE AND COMPANY, 1908.
21. Toman Rolf, “The Art of Gothic: Architecture• Sculpture• Painting”, KONEMANN, 2004.
22. Sullivan Mary Ann, Index of Art Historical Sites: Milan, Italy: Milan Cathedral”, 2006.
23. SEBREGONDI GIULIA CERIANI, SCHOFIELD RICHARD, “First Principles: Gabriele Stornaloco and Milan Cathedral” *Architectural History the Society of Architectural Historians of Great Britain*, 59, 2016.
24. Gentile Carmelo, and Canali Francesco, “Continuous Monitoring the Cathedral of Milan: Design, Installation and Preliminary Results” MPDI, June 2018.
25. Ackerman, James (June 1949). ""Ars Sine Scientia Nihil Est" Gothic Theory of Architecture at the Cathedral of Milan". *The Art Bulletin*. 31 (2): 96. JSTOR 3047224.
26. "Milan Cathedral lighting design is executed with ERCO LED spotlights". *LEDs Magazine*. PennWell Corporation. 9 June 2015. Retrieved 2 October 2015.
27. Vondrackova Terezie, Nyvlt Vladimir, Nemeč Frantisek, “Characteristics of Gothic Cathedrals in France and their structural elements”, *World multidisciplinary civil engineering-architecture-urban planning symposium*, 2016.
28. Wilson Mary E., “Gothic cathedral as theology and literature”, University of South Florida, 2009.
29. Stoddard Whitney S., “Art and architecture in medieval France”, originally published under the title *Monastery and Cathedral in France*, Wesleyan University Press, First ICON edition published 1972.
30. Ida J. Burgess, “The Shattered Glass of Reims”, Source: *Art & Life*, Vol. 10, No. 6, pp. 298-302, 1919.

31. [www.saylor.org/courses/hist302/#5.3.1](http://www.saylor.org/courses/hist302/#5.3.1)
32. [www.howlingpixel.com](http://www.howlingpixel.com)
33. [www.mosteirobatalha.gov.pt](http://www.mosteirobatalha.gov.pt)
34. [www.mosteirobatalha.pt](http://www.mosteirobatalha.pt)
35. [www.mosteirobatalha.gov.pt](http://www.mosteirobatalha.gov.pt)
36. [www.unesco.com](http://www.unesco.com)
37. [www.duomomilano.it](http://www.duomomilano.it)
38. [www.museo.duomomilano.it](http://www.museo.duomomilano.it)