

Structural Identification of Bridges (Case Study: Mazandaran, Iran)

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ABSTRACT: Throughout more thousand years of human civilization, bridge and bridge architecture had indicated the creativity, initiative and ingenuity of human and his understanding and feeling about architect, resistance, beauty, symmetry, harmony and other values were always under the judgment of next generations. Across history, bridge was not just a tool to connect two areas but it was a sample of ability, ingenuity, creativity and the skill of human. The connection between two parts was a source of inspiration, a new idea was formed, new methods were created and new bridges were constructed. 363 historical bridges indicate the importance of this structure among different Iranian historical architecture works. Bridge building was flourished simultaneously by creating more connection between cities and commercial centers. Iranian architecture history quoted the building of several bridges which nowadays there is no any sign of them. The bridges were always exposed to rivers overflowing and natural erosion. Probably there is no such dependency between structure and architecture in other kind of constructions. In fact, the bridge architecture is a combination of structures which are influenced by river bed, ground strength and amount of water across it.

Keywords: Bridge Architecture, Design Method, Material Type, Constructing Technique, Natural Factors.

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INTRODUCTION

Before appearing and developing the bridges building, natural limitations especially big rivers on different cultural, commercial, political and economic communications and also water shortage, seasonal violent torrents and floods in most part of the earth, were the big and basis problem of human life and obstacle in progressing and developing of human civilization till through building the bridges these problems were resolved in a large extent. From very beginning of bridge construction they faced with great fortunate because of their importance role in creating, maintaining and developing of communication. Through historical aspects, first bridges were simple beams of stone or wood which placed on river over stony piles. In larger spans, using fiber and creating suspended forms were replaced with beams in some lands.

Watery rivers and fertile lands in Mazandaran province cause a lot of bridges remains from Islamic period as memory. In Islamic term (especially Safavid dynasty period) after Sassanid, most attention directed towards bridge building in Iran specifically in Mazandaran so that dimensions, design, resistance, architectural method and decoration of that time bridges are noticeable and unique. Regarding to construction techniques and architectural features especially in Mazandaran bridges in Safavid dynasty and Qajar dynasty period, this time indicates the big progress in bridge

building in this region. Thus the most attention of this paper is focused on investigating and structural identifying of Mazandaran bridges in Islamic term specially Safavid dynasty and Qajar dynasty period.

Through arrival of Arabs to Iran and overthrowing the Sassanid empire, architecture progressing specially bridge building mostly became slower and had a downward movement for one or two centuries; this depended on three factors:

- Arabs arrived from a territory which didn't have big rivers and consequently important ridges. Therefore it can be said that through this explanations, they did not have enough scientific knowledge about architecture especially bridge building.
- Lake of facilities and knowledge about local conditions
- Involving of Arabs in military, political and cultural affairs did not remain any time for them to build the bridge.

So they had to still use the former periods bridge during their campaigns and other essential cases and these bridges properly were repaired slightly by native architects and if there was bridge building, it were performed by propertied and charitable people.

Generally, bridge building operations was performed through two ways in Islamic periods:

- Bridge building which had high progress after fourth century.
- Repairing and restructuring the old bridges

MATERIAL AND METHODS

Bridge building in Safavid dynasty era

The confusion created after the death of Abu Saeed King across Iran, was moderated through arriving of Shah Ismail Safavid and quelling of rebellious and insurgents and a peace came on force. This provided a basis for reformations in Shah Abbasi period.

Through arrival of Shah Abbas and when Esfahan selected as capital, this town developed as the most brightness city in the East and again concentrated all country ' art forces. Therefore Esfahan became a full sample of Safavid period architecture. Majestic mosques and squares, several palaces and streets were constructed in this town. Huge bridges were built to cross Zayanderud River; some of these were directly constructed by controlling of Safavid kings and the government and more creativity was applied on them. Siosepol, Khaju Bridge and Joui Bridges were considered as a promenade for king, courtiers and sometime for foreign ambassadors at that time along with providing traffic. At this time, bridge building was not limited just to outside of cities and road but to the inside of cities.

Through investigating different periods of Islamic terms till Safavid dynasty period, road construction and its related building means bridge and inn was not developed in any period of Iranian history as Safavid time and most of bridges which nowadays can be observed across this wide country are the valuable works of this era. North Road is one of the roads constructed at that time.

Bridge building in Qajar dynasty period

Terrible events occurred in Iran during the governance of Qajar kings which led to country weakness and decomposing some parts of it and undermining independence basis of Iran. Several wars, ineptitude of kings, chaos, betray and hypocrisy of rulers and officials of courts caused that the time of despots and wanton kings spent for wars, courtier's dissipation and creating their harem. Thus an important activity was not performed about country reformations and most of roads were those which were constructed before Safavid period. Two roads which connected Tehran to Mazandaran through Alborz Mountains were constructed at the time of Amirkabir and in Qajar period.

Roads constructed in Qajar period include:

- Tehran-Chalus Road which was ordered to construct by Nasser Al Din Shah
- Haraz Road was constructed on Shah Abbasi Road direction which was gradually destroyed.

After Amirkabir died most of roads and bridges which were frequented and had the signs of Amirkabir reformations, were gradually destroying due to the negligence of current officials. Thus the government was not able to directly build proper roads and constructing these roads was assigned to different domestic and foreign institutes and companies.

History of bridge building in Mazandaran

Mazandaran and Gilan region was always regarded by Safavid kings; among them Shah Abbas travelled several times to Mazandaran and stayed a long time. Thus he was going to restore the blocked roads existed from the

past specifically swamps and a lot of floods overflowed during storm and even forests which were considered as big barriers in front of caravans' traffic. As ordered by Shah Abbas, Firozkoh road to Gorgan and a wide paved road from Jajarm to Mugan Plain were constructed which passed from all province of Iran in southern coast of Caspian Sea.

This road was expanded as a wide road in east of Astarabad (Now is Gorgan) and passed through Ashraf, Sari, Aliabad (Shahi-Qaemshahr) and Amol and expanded to the boundary between Gilan and Mazandaran. The appearance of some Mazandaran cities were changed through this road known as Shah Abbasi Road such as Amol, Babol and Sari which were placed on commercial and trade path; they became the center of transactions and trades. Also, Shah Abbas was trying to connect capital to northern regions through creating several roads and connected Esfahan to the north through some chains of road. Roads which were ended to the north include:

- A road which led from Esfahan to Firozkoh and by two bridges, after passing Telar River was led to Shirgah and Sari and then Farahabad where was the location of Safavid palaces and on its direction passed through Farahabad famous bridge (will be mentioned later).
- A road which led from Esfahan to Varamin and then was connected to Amole after passing Emamzadeh Hashim and through Haraz and Polour road. A lot of bridges were constructed on this road which Shah Abbasi Bridge was the most important of them over Lar River nearing to Polour.
- Shah Abbasi Road which led from Qazvin to north. The most important bridge on this path is the huge Bulour Deccan Bridge which attracted the attentions as half-destroying bridge on Amlash River.

Also in Qajar period, location favorable climatic and natural attractions of this province drew further attention of current rulers and governors. Palaces and court resorts were created in good climate and fertile regions of Mazandaran. In this period, reconstruction and development process of Mazandaran was not considered as other part of Iran and natural properties of region was not employed in social and economic progress and development. Despite the constructing of some buildings included restoration of Amol Davazda Cheshme (twelve springs) Bridge and also constructing the beautiful bridge of Mohammad Hassan Khan Qajar on old road of Amol to Babol, no works are observed from that period.

RESULTS AND DISCUSSION

Assessment of some most important bridge in Mazandaran

• **Davazda Cheshme (Twelve Springs) bridge of Amol:** Davazda Cheshme Bridge is constructed over Haraz River in downtown and traffic is still continued on it after passing lots of years and is a place for pass of vehicles, cars and pedestrians (Figure 1).

This bridge currently has twelve springs (river mouth) which the water is flowing under three springs of it. There is an open space under bridge which changes to park and green space in recent years; there is a paved road for cars under two spans in west of the bridge. Unfortunately municipality colors the contour of bridge

with white for beauty which destroys the soffits among springs of bridge. Today, this bridge is known as Davazda Pele (12 steps) in Amol.

Different names of bridge across history

In addition to the name of ["Davazda Pele"(12 step)] is attributed by Amole citizens, this bridge is also known as "Haraz" and "Imam Hassan".

Bridge history

The exact construction time of this bridge is not clear. The dead Etemad Al Saltane expressed the construction of this bridge related to the post of Islam. Some researches attributed it among the works of first Shah Abbas Safavid. At the south, next to Davazda Cheshme Bridge, there is a new bridge which constructed in Reza Shah Pahlavi time and is called Suspension Bridge (Pole Moalagh) (Figure 2) (Sotode, 1987).

History of repairs performed on this bridge

This bridge was destroyed several times through natural factors such as earthquake or overflowing of Haraz River and then was repaired. Because its construction time is not distinguishable so its first repair is not clear but it is probable the first repair of this bridge occurred in period of Shah Abbas Safavid; because of structure method and its tightness, the building is attributed to past time of Safavid by some individuals and then was repaired in Shah Abbas period (Shayan, 1985).



Figure 1. Today' bridge view

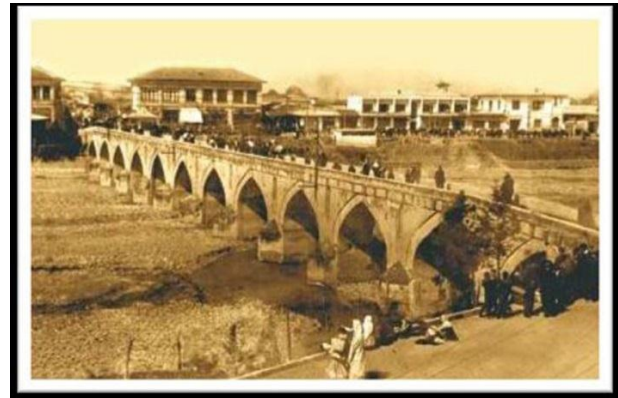


Figure 2. General view of bridge in the past

Table 1. Table of existed bridges in Mazandaran

Row	Name of Bridge	Location	Antiquity
1	Band boride Bridge	Old road of Haraz, Strait of Band boride	Sassanid
2	Qalabon Bridge	Between Bajjan village and Astrabko Hot Water Springs	Sassanid
3	Pol Dokhtar Bridge	The north of Shirgah	Before Safavid
4	Davazda Cheshme Bridge	Amol	Safavid
5	Brick Bridge	Between the village of Pain rostam and village Astarabad Mahale	Safavid
6	Shah Abbasi Bridge	Shirgah, Savadkuh-Qaem Shahr	Safavid
7	Vache Kile Bridge	On the road of Nesiye mahale to Faghih mahale and the village of Beramsar, 8 kilometer in west of Tonekabon	Safavid
8	Polfesfid (White Bridge)	Polfesfid station of Savadkooch	Safavid
9	Shah Abbasi Bridge	Farah abad (khazar Shahr), Sari	Safavid
10	Sikapel	Behshahr, Qanbarabad neighborhood	Safavid
11	Bezpel	Behshahr, Qanbarabad neighborhood	Safavid
12	Balou bridge	On the road of Zirab to Shirgah, Inside of Balou forest	Safavid
13	Javarom Bridge	Savadkuh, Javarom village	Safavid
14	Lepasar Bridge	On the road of Ramj mahale and Kechanak Goleijan of Tonekabon	Qajar
15	Valem rood Bridge	Khoramabad of Tonekabon, over Valamrood river	Qajar
16	Velashe Bridge	Velashe village, the viron of Miyanrood of Noor	Qajar
17	Adobe Bridge	Noor, next to martyrs	Qajar
18	Moun Bridge	Haraz road, on the road of Niyak village	Qajar
19	Mohammad Hassan khan Bridge	Babol	Qajar
20	Serajkola Bridge	Serajkola Village, the environs of Gilkharan of Juybar	Qajar
21	Shapur Bridge	Along the way of Shirgah to Qaem Shahr	Qajar
22	Metal bridge	Amol	Pahlavi

Analyzing the structure of bridge

Davazda Cheshme Bridge is constructed as a direct plan which connected two sides of city known as "Pol be Yur" (this side of bridge) and "Pol be Yer"(other side of bridge). The bridge has length of 130 meter, pass width of 3 meter and the height from water level of 6 meter. This

bridge is located in 120 meter distance of north of suspension bridge (Reza Shah). The bridge which has 12 spans or springs with gable arch has 12 piers which are without bump and straight at the north and triangle-shaped at the south, i.e. opposite direction of water flow had triangle-shaped breakwaters (Figure 3).

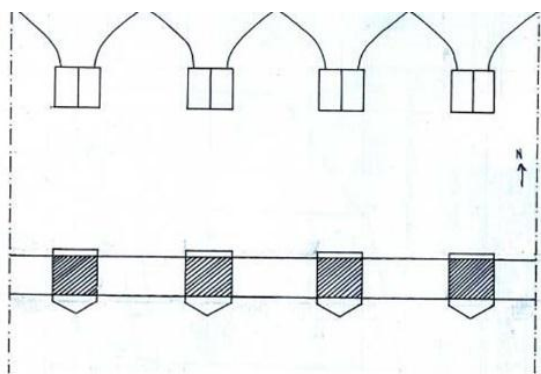


Figure 3. Mode and plan of bridge

All spans are almost constructed in same size and so the pass of the bridge is straight and flat. According to documents, over the piers and between arches, there were nested and low width extrados which are used just for decoration and nowadays, there is no any sign of them. The piers were wider than width in north and south and there was an arch (curve) with very low slope or very low bump over upper piers (South) which through careless of specialists and negligence the municipality straightened the surface of piers and passed the urban water pipe over it.

As mentioned, arches and spring arches of Davazda Cheshme Bridge are 12 which some travelers and historians called it as 10 springs bridge and it is not clear they meant this bridge or not; as an example, Sani-ol Douleh in Merat-ol Baldan and Jobeir sent ambassador of Napoleon Bonaparte to the court of Fath-Ali Shah mentioned 10 springs for bridge arches springs (Azari Mirchi, 1973).

Regarding to high width of river, bridge constructing process performed in several stages; at first it was needed to dry the bed of river performed in several stages and in low water seasons of river and bridge piers which were probably as rubble in foundation should be laid at river bed respectively. Before constructing the piers, the most important issue is selection a reliable place to construct the bridge; to achieve this it is necessary to evaluate the water speed, meander and the water which passed through river; thus the most proper and accurate place was selected for Twelve Springs Bridge. In terms of technique and structure this bridge was comparable with Farahabad Bridge which its piers and two springs are remained. Since Farahabad bridge was built in Safavid dynasty period, constructing and repairing of Amol twelve Springs Bridge can be attributed to Safavid dynasty period.

Material of bridge

The main materials of this structure are brick and mortar of plaster and lime. Some determined the bricks as only material used in this structure.

• Mohammad Hassan Khan bridge of Babol:

This bridge is located on old road of Babol to Amol over Babel River. After passing a lot of years of its construction, it is yet using by people and the vehicles are traveling on it (Figure 4). This bridge has 8 springs which its 6 main springs are larger and two initial and final

springs are smaller than others (Figure 5) (Mahjori, 1966). Until 1343 (1994) this bridge was used as a communication path from Babol to Bandpey, Amol, Tehran, villages in south and southwest of Babol which through operating the new road, the pressure on the bridge is reduced. Through increasing of population and raising the vehicles, this bridge did not meet the needs of region and the destroying and destructing danger threatened this bridge so that in recent years, a concrete bridge was constructed in west part of it and the traffic is passing through the new bridge.



Figure 4. Today view of bridge

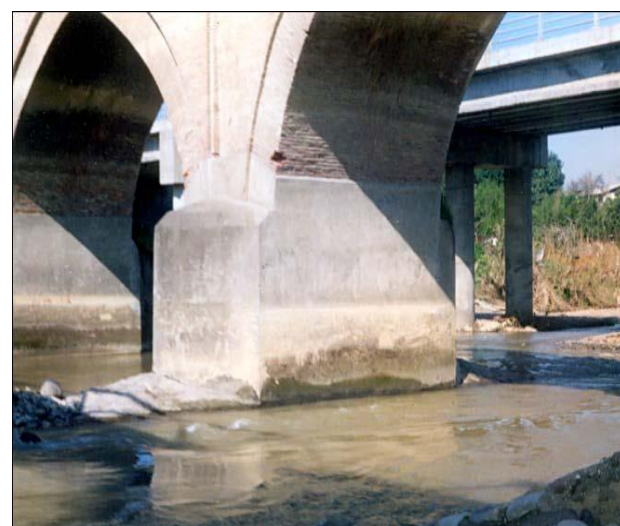


Figure 5. A closed view of bridge piers

History of bridge

Mohammad Hassan Khan Bridge was likely known from the beginning by this name and it did not have another name. This bridge was constructed by Mohammad Hassan Khan Qajar the ancestor of Agha Mohammad Khan Qajar over Babel River in 1168 of Islamic calendar (1755) (Husseinzade, 1964).

History of repairs performed on this bridge

This bridge historically suffered a lot of damages through earthquake and natural factors which caused some repairs performed on it (Etemad Al Saltane et al., 1994). In 1324 of Islamic calendar (1906), two piers of 9, were flooded and broke; one of Barforush merchants who did not have any child, spent most of his properties to repair this bridge. Two arches of bridges were destroyed in earthquake of 1820 which were repaired shortly after (Rubino, 1957).

Analyzing the structure of bridge

Mohammad Hassan Khan Bridge is straight with a glacis and very low slope from center to bridge sides. Now, this bridge has the length of 14 meter and the sidewalk width of bridge is about 6 meter which has parapet in either sides. The bridge has 8 spans which its 6 main spans are larger with 7.55 meter in each. Two springs are placed in two sides of these smaller springs with length of 4.10 meter for each. The piers of bridge are concrete and are paving on the river bottom. Triangular-shaped breakwaters are placed in the front of piers and smaller extrados were constructed over piers. Breakwaters are repeated in two sides of piers. These piers are placed on a stony bed which was constructed by large rocks and rubble. Lower part of parapets outer surface has brick decorations. The curve of arch is herringbone and has a relatively sharp deflection. Three springs in center of bridge are larger than others and the spring in the middle of bridge is larger than all; there are brick circular piers in two parts of north and south side, two in north and two in south (Figure 6).

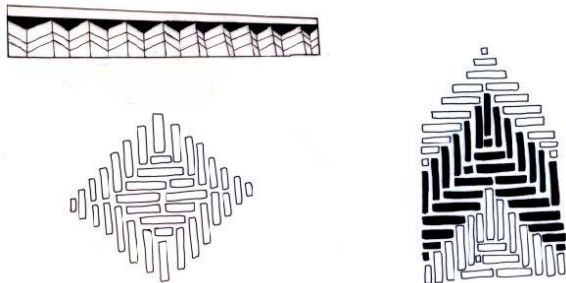


Figure 6. Decorations applied in bridge

Malgonov determined the length of bridge about 100 meters with seven spans and the width of 6 meter, from one parapet to other parapet (Malgonov, 334, 1997). Also, Etemad-ol Saltaneh, determined 10 springs for bridge (Etemad Al Saltane et al., 1994) and Daracy, E, Todd (Taheri, 1968) said that it has eight springs. This disagreement on springs number of bridge-some determine 8 springs and some other 10 ones- is because of that someone who believed on eight springs don't calculate two ball-shaped piers at the first part of bridge in north and the other in south and those who believed on ten springs calculated these two springs.

In upper part of bridge, there are two rows of netted parapets in the length of bridge. These parapets are probably added in repairs of first Pahlavi. Outer part of bridge has parapets and its lower part has brick decoration. Brickwork can be divided into several categories; these decorations include zigzag decoration, steppe brickwork and decorations known as mouse tooth. Mouse tooth decorations are located under parapets in upper part of bridge and are expanded in form of straight line comprehensively either sides of bridge. There are long and rectangular extrados in both sides of springs and zigzag and stepped decoration exists in inside of them. Some extrados decorations can be observed at the beginning of bridge in north and in east side with some decorations at the top which their number is variable – in west of the bridge there are extradoses, one of them like a door which is closed now- these decorations are placed in

two sides of the bridge and next to the pier. Rhombic brickwork decorations in the middle of long extrados are other bridge decoration which is placed in center of springs. There are a lot of small extrados at the top of decoration and under mouse tooth decorations which are variable in two sides of bridge. This difference may be because of performed repairs. The number of extrados is 111 in west part and 113 in east side. There are other and beautiful decorations under springs. These are big rhombuses in two part of bridge floor (under springs). But these decorations are not repeated in all springs and are only observed in five one. From north, despite one spring, other five springs directed to south have rhombic decorations.

A spring in south of bridge as a small room is one of the most important and obvious characteristic of Mohammad Hassan Khan Bridge. Breakwater is placed about 500 centimeter in two sides of this small room. This small room is square from inside and was probably the sitting and rest place of passengers and travelers. This room was not observed in other bridges constructed in Mazandaran at mentioned time.

Material of bridge

Brick and mortar of plaster and lime are the main materials of this bridge which later stone and concrete were added during repairs (Husseinzade, 1964).

• **FarahAbad bridge of Sari:** This bridge is placed over Tajan River in Farahabad of Sari and was constructed by First Shah Abbas along with other Safavid structures in this region. Nowadays this bridge changes to a ruin and all its arches instead two ones are collapsed (Figure 7). From west, bridge is connected to an old bathroom. Bridge piers are so huge and the pathway is also flat and without slope. This bridge was known as (Farahabad Bridge), (Shah Abbasi Bridge), (Farahabad Tijenerood Bridge) across history and now is known as (Farahabad Bridge) and Tijenerood Bridge (Mahjori, 1966).



Figure 7. Today view of bridge

Bridge history

This bridge is one of the structures which Shah Abbas Safavid constructed in Farahabad and as a collection along with other buildings. In Mazandaran History, Esmaeil Mahjori specified 1019 of Islamic calendar (1610) as construction date of this bridge (Mahjori, 1966).

Analyzing the structure of bridge

Nowadays, Shah Abbas Bridge of Farahabad is a ruin and most of its arches are collapsed (it was about 100 meter in length, had width of 60 meters and almost 9 springs) (Sotode, 1987). The arches of bridge were herringbone in same size and form and the width of each was 4.80 meter. The piers with dimension of 6×3 meter had circular breakwater in opposite direction of river flow; this piers stretched from the bottom of the bridge to its surface and were as dome from the upper of breakwater. Piers more strength against the pressure and flood of water was the reason which they were made semicircular (Figure 8).

Manouchehr Sotode expressed destruction reasons of bridge as following:" apparently, Tajan River diverted from main direction and flowed in just one side of bridge and caused collapsing of its three piers, other four piers are remained but upper part of one of them is broken"(Sotode, 1987). There are two brick pitches on the surface of bridge in west part which are now in place and the bases of other pitch can be observed on the bridge. These pitches are more likely used to guide travelers and caravans who passed through this region. It is also probable that these pitches were placed as a parallel row on the surface of bridge which their bases signs can be seen on the bridge. Manouchehr Sotode determined 9 arches or springs for this bridge when it was constant (Sotode, 1987). This is probably he took this from a poem about the history of bridge. Shah Abbasi Bridge of Farahabad is structurally similar to Twelve Spring Bridges of Amol; mentioned bridge belongs to Safavid dynasty period as Farahabad Bridge.

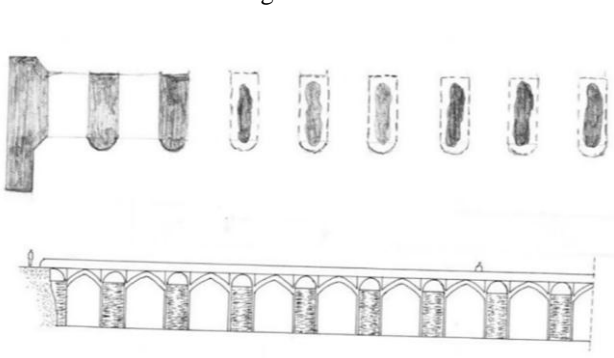


Figure 8. Mode and plan of bridge

Material of bridge

Brick and mortar of gypsum are the materials of bridge.

CONCLUSION

Regarding to special location of region and watery rivers and land fertility, Mazandaran province needs a special architecture type where all construction, stability and decoration characteristics should be considered.

Because of watery rivers in province, existence of bridges is a crucial issue in both economic and transportation. Intensity and water flow in determining the bridge place is another point which is very important in bridge building. It was trying to construct the bridges in places with lower intensity and water flow. As the performance of bridge was different based on social, economic, political and strategic conditions, its form also depends on environmental and climatic conditions such as roughness of ground surface, depth, width and intensity of water flow, raining amount, seasonal floods, type of available materials and resistance of river bed. Arches with high deflection and wide span are obvious characteristics of Mazandaran bridges.

Through assessment of bridges in Mazandaran, this can be achieved that most of bridges have slope from center to sides which indicate a local architecture of this region. Slope in Bridges is one of the obvious characteristics of this type of architecture which is related to climatic and weather type of this region.

Overall characteristics of Mazandaran bridges should be found in their materials which most bridges in region have piers of stone and a contour of brick and mortar of gypsum and lime which can be mostly observed in all bridges of region.

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