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Development and Typology of the Roman and Turkish Bridge Architecture in and Around the Vicinity of the Greater Menderes Basin*

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Abstract

The Anatolian civilizations have generated various structures for transportation purposes and in the meantime, constructed bridges to overpass the large aquatic obstructions on the roads. The bridges, each of which is deemed to be reflection of the level of development of the civilizations, should be assessed to be the determinants of the architectural identity of the societies. In this study, efforts have been made to define the comparative periodical styles of the Roman and Turkish bridges in Great Meander Basin and its vicinity in the Western Anatolia in the manner to ascertain and find out the architectural design, materials, construction technique, morphological properties, utilization type and the properties of the ornamentations, if any, and put forward the inter-periodical interactions observed on such bridges as well as typological assessments. It is thought that both this study and the thesis that this study is based on can form a basis for future applied studies, though to some extent.

1. INTRODUCTION

The construction and developmental history of the bridges date back to centuries ago by which time challenges have been made to make the life habitable for the people, enhance the economic and social welfare of the societies, meet the militaristic requirements and overpass the natural obstacles, using the tools and equipment they had. Within the historical process, two types of obstructions have been observed to exist along the centuries long lines on the roads. These are the mountains and rivers. The mountains have been over- passed through sharp bend, ramps and tunnels while bridges have been constructed to overpass the rivers. The bridges which were initially supposed to be serving for over-passing the natural obstructions on the transportation corridor have turned out to be the complementary elements of the cultural history as time pass by, in line with the militaristic, commercial, economic, social and cultural developments. Design and construction systems used in the course of the construction of the bridges display the synthesis of the architectural trends at the time they were built. When the-still surviving bridges are examined in their entirety, they cover up a large time scale. It dates back to the antique period and middle age with extension to the 19th century, namely, the period when the static structures and strength laws had been introduced in the bridge construction. Each period has its own architectural and social patterns and carries the socio - cultural characteristics of the respective period. The bridges, as part of the historical materialism modelled in conformity with the synthesis of the whole objects of the past and the socially acceptable norms, are divided into specific periods.

These are as follows:

Bridges before the Roman Period: The subgroups of such bridges include : Egyptian, Mesopotamian, Hittite and Candian - Mycenaean bridges, ancient Greek bridges (Archaic Period); Bridges of Roman Period and subgroups: Roman Bridges dating back to Republican and Emperorship Eras, Byzantine

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Bridges, bridges of Turkish period: Bridges of Anatolian Seljuk period, Bridges of the Period of Principalities, Ottoman Bridges and Bridges of Republican Period.

Substantial civilizations have been established in the course of history of settlement in the Western Anatolia and numerous bridges and transportation infrastructure have been constructed. The arterial roads which provide connection between the Aegean coasts, ports and the Western Anatolia with the Central and Eastern Anatolia and even to the furthermost (From the time of royal roads to the present time) passed through this particular region. However, it has been observed that the bridges along the transportation network constructed during Roman, Byzantine, Seljuks, Principalities and Ottoman periods, all of which established sovereignty relatively for a longer time and attained some level of welfare within the region, have not been studied exactly and these have not been assessed properly in architectural and structural aspects. In fact, some of the researchers who conducted studies in the area stated in their works that there existed several bridges at some locations. For instance, Texier who made studies in the region around 1840's pointed out in his book that there was an old bridge next to the Emir Baths within the Şehitoğlu village some 15 km northeast to Kula [1]. It was specified therein that "there existed a bridge on the river to the north of the wall which was partly ruined dating back to Byzantine period". Ramsey who did researches in the region between 1880 through 1884 expressed in his book [2]that "the passage between Satala (Sandal) and Temenothyai (somewhere around Güre) was quite rigorous but they witnessed two Roman bridges hereabout in 1881 with Sir C. Wilson, one of the bridges was completely ruined just to the upwards where the recently constructed road intersected with the Maionia after leaving Kula with the second bridge to the furthermost which was still in use but even the subsequent additions and restorations made to the bridge failed to occult the fact that it was originally a Roman bridge". The said bridge is considered to be the bridge which, now, is known to be the Yenişehir Çataltepe Bridge on the previous alignment between Güre and Kula.

The geographical conditions have always been the primary determinants for the construction of the roads and bridges in the Western Anatolia. The construction of the roads and bridges in such a region where the mountains and valleys intermingled with each other require not only mastership but also experience. The region which has always been assumed to be the substantial alignment for transportation purposes almost in all periods, is remained to be the region connecting the eastern and central Anatolian regions with the ports in the Western Anatolia following the Meander and Maionia valleys In addition, there exist aisle ways linking the arterial roads with each other at some points. The region with densely planted natural roads where the physical conditions substantially govern is the important passageway to provide uninterruptable access almost in all seasons.

In this study, efforts have been made to define the comparative periodical styles of the Roman and Turkish bridges in Great Meander Basin and its vicinity. It is aimed to ascertain and find out the architectural design, materials, construction technique, morphological properties, utilization type and the properties of the ornamentations, if any, and put forward the inter-periodical interactions observed on such bridges as well as typological assessments. Despite depictable breakdown of the bridge structures, it is aimed to put forward the periodical characteristics of such bridges showing the distinctions and similarities, if any together with the reflections in view of the morphology and materials used. The study also aims at finding out the specific architectural characteristics of the bridge structures dating back to Roman, Seljuk, Principalities and Early Ottoman Periods as well as the influences of the materials used (stone and grout) and architectural styles of the other periods with interpretations on the stylistic requirements.

2. MATERIAL AND METHOD

In this study, it is aimed to define the comparative periodical styles of the Roman and Turkish bridges in Great Meander Basin to the Western Anatolia and its vicinity in the manner to ascertain and find out the architectural design, materials, construction technique, morphological properties, utilization type and the properties of the ornamentations, if any, and put forward the inter-periodical interactions observed on such bridges as well as typological assessments. The research is based on the quantitative methods. The study includes literature and resource searches, efforts for certification and determination purposes, and

comparative typological reviews. During surveys, an approximate number of 76 bridge structures dating back to Roman, Seljuk, Principalities and Early Ottoman periods has been accessed in Great Meander basin and its vicinity in the Western Anatolia. To find out the typological characteristics of the bridges dating back to Roman and Turkish periods and the interactions among such bridges, the archived projects and material analysis have been used in addition to the measurements made on the ascertained bridges. Measured drawings have been drawn up for the bridges with archived projects approved by the regional conservation board and the bridges with no project at all and all such drawings have been digitalized in order to provide compliance with the scope and objectives of this study. In addition, The material analysis reports conducted by the competent laboratories and kept at the archives were used for a total of 20 bridges dating back to different periods which fall within the scope of this study. As a consequence of the researches;

Comprehensive assessment has been made within the frame of *"Frontal and plan typology", *"Typology of the Bearing Elements", *Typology of the Non-Bearing Elements", to find out the periodical styles of the bridges such as Roman style, Seljuk style, Principalities style and Early Ottoman Style. and the interactions, similarities and distinctive characteristics have been put forward.

3. MILITARISTIC AND COMMERCIAL ROAD NETWORKS IN ANATOLIA

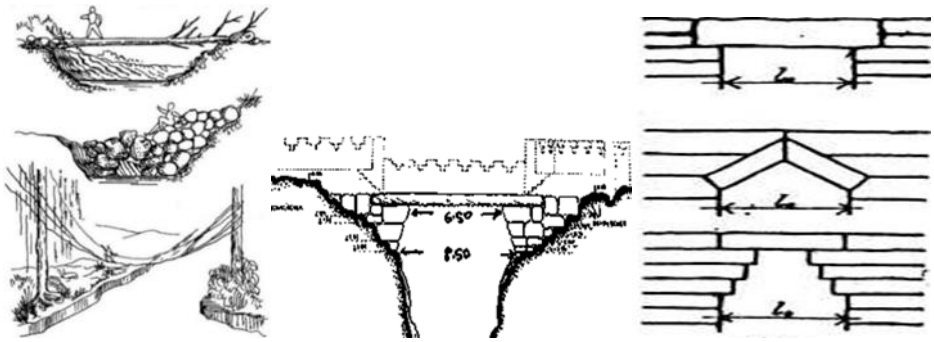
Assyrian and Babylon civilizations in Mesopotamia and Syria which is known to be the first regular road in the history, commences in Cizre in our country and moves inwards to Anatolia. In around 2000 B.C, the Assyrians and Babylonians adopted the road passing along the left bank of the River Euphrates. The road connecting Thapsacus to Babylon was partially on the terrain and partially on the waters. The roads from the south of Thapsacus and Asia Minor and the roads from Aleppo to the south intersected in Thapsacus. One of the major alignments was that of the road to Syria through Thapsacus, Epiphania (Hama), Damascus and Aleppo . The other route was the one starting from Mawsil (Mosul) arriving at Edessa (Urfa) through Nisibis (Nusaybin) which ends up in Central Anatolia by over-passing Euphrates in Biradjik (Birecik) (Umar, 1951). This road alignment was used by the Hittites, Persians, Helens, , Romans and East Romans while the Seljuks and Ottomans followed the same route thereafter[3]. The arterial roads of historical nature ranged generally towards the east - west direction in parallel to the mountains based on the geographical conditions. One of such routes was the one extending to the straits along the mountains passing through the Halys River to the north of Euphrates and the other one was the route starting somewhere around Lake of Van which ended up in Central Anatolia by getting over the northern slopes of the Taurus Mountains. The road to the south reaches to Syria through Cilicia and Amanos Mountains to establish the linkage between Syria and the Straits in the manner to end up in the straits by prescinding the Anatolian plateau from the south-east to northwest direction [4].

The road alignment to the south was reaching to Panonium, Miletos and Balat which replaced the latter in the middle ages, on the skirts of the Mount Mykale. The Ephesus - Magnesia road with no southern access proceeded towards Çamlık and ended up in Caeserea (Kayseri) to the furthermost through Tralles, Nysa, Mastaura and Laodikeia by turning left at this point[6]. Such roads were in use during Ottoman period with minor changes and occasionally survived its functions with the introduction of the new roads[7]. The historic commercial roads and the cities from the very points in the Central Anatolia lying on the route to Port of İzmir continued to be the centre of production and trade. In the second half of the12th century, the Oriental Commercial Road (Silk Road) which starts from İzmir turned to the east overspassing the Mountains of Tralles (Aydın) somewhere around the Bay of Kuşadası and reached to Sarayköy following the Great Meander Valley where it curled up to the North to Dinar. One of the junctions found its route to the central plateau to the northeast, namely, Çay while the other ended up in a mountainous blind alley at Yalvaç Plain. To the north of Dinar, Çivril, one of the stopover centres was linked to Great Meander Valley through a complicated caravan route [8].

Figure 3.1.*Historical road network of the great meander basin [9].*

4. DEVELOPMENTS IN BRIDGE ARCHITECTURE

The first examples of the bridges may be the simple timber beam with self-formed arched structures which were not made by the humans. As time passed by, the classical simple beamed systems have gradually been replaced by the structural "cantilever system" with the increase in the number of spans, that is, the overlapping cantilever system along the midst of the span. The cantilever system for such an arched pattern, is distinct from the smooth arches constructed through simple beam system. Meanwhile, this structural system has been assumed to be an important step in the construction of the arched bridges (Figure 4.1).



a b c

Figure 4.1. *Primitive bridge examples a)Simple wooden beam[13], b)Wooden cantilever[10], c)Overlap cantilever[10]*

The ideal form of structural arches were introduced by the Etruscans in 7th century B.C. Initially, the Etruscans used the primitive form of such arches while they made it much smoother over time. With progressive developments experienced in the first arched structures, the bearing elements were thus introduced for use in the bridge construction. The vertical loads within the arches were directed on both of the ends at the initial stage and onto the piers thereafter. In addition, the use of the arches allowed to cover up the larger spaces in a smoother manner (Figure 4.2).

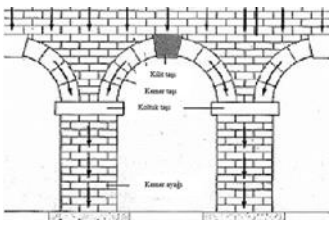


Figure 4.2. *Ideal arch application[15]*

During Roman period, the first bridges were built on the timber piles or the timbered material on the stone piers (Figure 4.3) . The first stone arched bridge was introduced after 4th century B.C., while the

ideal form and structural characteristics were attained through the applications during Roman Period [10].

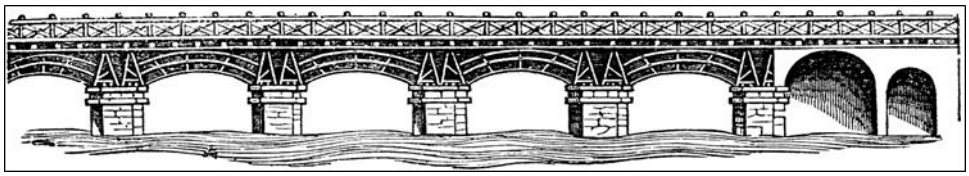


Figure 4.3. *Trajan Bridge built on the Danube River in 2th century B.C. [11].*

In addition, it will not be inaccurate to specify that the bridge architecture dating back to the Roman period forms the basis of the stone bridges which were subsequently constructed in Europe and the Middle East. Therefore, there is a never-ending challenge against the waters along with the other external factors. The effects of such challenges may be observed in the major applications in the bridge construction. In designing and building up the bridge, the water flow regime and characteristics of such flows should be taken into consideration together with the topography and the construction technique applicable in the waters should be carefully planned. If the construction of bridges is outlined in general terms, cofferdam which makes it possible to work in the waters should be first constructed on the location where the foundations are to be established. After formation of relatively dry working space and discharge of the water, the stone blocks should be placed on the foundations and piers. Further to construction of such blocks clamped with the grout and iron cramps, the internal piers are filled with grout and stone. For the construction of the arches, coarse stone blocks and evenly fired bricks were used. The connection between the stone blocks were enabled through the metal clamps and mortises [11]. As one of the substantial developments observed in the Roman Architecture, a quality grouting material was obtained by mixing pozzolana (pozzolana : volcanic tuff) and powdered brick with the slaked and reclaimed lime. "Roman Concrete" or in literal terms, Opus caementicium' is the lime mix r enriched with the sand, gravel and pozzolana [12].This specific mix keeps hardened even under water and it is featured to be non solvent. Thus, it was used on the bridge foundations and piers.

Two major groups exist in the bridge architecture in Anatolia;
a) Inclined or flat bridges rising enormously on both ends towards the larger or higher main vault in the midst of the span over the rivers with deep and narrow bed.

b) For the rivers with larger beds, the bridge levelling was either in the inclined or flat form with no substantial difference in view of width and height of the arches where there exist two or more arches [13].

Figure 4.4. *Single and more arches bridges a)Olukköprü (Antalya), b)Cendere (Adıyaman), c)Taşköprü (Adana), d)Uzunköprü (Edirne) [14].*

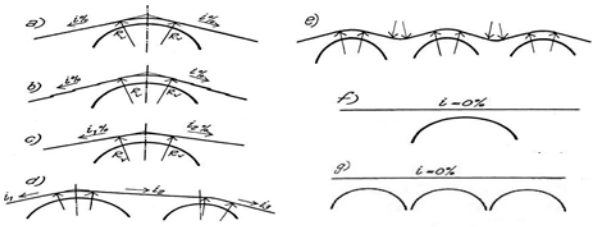


Figure 4.5. *Some bridge levelling forms [14].*

The form wise harmony between the arches and the levelling lines constitute the bases of the visual concept of the bridge forms. Levelling in bridges rises to the centre of the bridge, that is to say that it rises on top of the arch crown. Although it is not assumed to be a rule, the breakpoint of the levelling is round in shape (Fig 4.5).

The arches with similar width may pass over the waters without necessitating large and high spans over a large bed. In this aspect, the length of the bridge and the number of arches increase and the levelling of bridge remains to be flat. The bridge abutments are erected in the manner to detect sound supportive points within the river bed, if this is proven to be impossible, artificial supportive points are to be established to construct the bridge. As far as the rivers with deep beds are concerned, the space between the abutments on the shallow ends of the foundation level are passed through a large and high arch due to the technical difficulties encountered in settling the piers on the sheer slopes (Fig 4.5).

5. REVIEW OF ROMAN AND TURKISH BRIDGES IN AND AROUND GREAT MEANDER BASIN IN WESTERN ANATOLIA IN VIEW OF MATERIAL, CONSTRUCTION TECHNIQUE AND STRUCTURAL ELEMENTS

When the geographical conditions and the status of the historical bridges on the road network in and around Great Meander Basin to the Western Anatolia are taken into consideration, such roads and bridges are located within the boundaries of 10 districts namely, Afyon, Aydın, Burdur, Denizli, Isparta, İzmir, Kütahya, Manisa, Muğla and Uşak. The bridges located in the afore listed cities and the distribution of the same according to the periods are as follows;

Roman Period (together with East Rome, prior to 11th century): 41
Seljuk (11th through 13th centuries) : 14
The principalities (13th through 14th centuries) : 12
Early Ottoman Period (14th through 15th centuries) : 9

totalling to 76 bridges. The list of the bridges is given below (Table 5.1).

Table 5.1. *Distribution of the Bridges According to Periods*

NO	CITY	BRIDGE NAME	PERIOD	NO	CITY	BRIDGE NAME	PERIOD
1	AFYON	DÖRTGÖZ	ROMAN	2	AFYON	İSCEHİSAR	ROMAN
3	AFYON	KIRKGÖZ	ROMAN	4	AYDIN	ESKİHİSAR I	ROMAN
5	AYDIN	ESKİHİSAR II	ROMAN	6	AYDIN	ESKİHİSAR III	ROMAN
7	AYDIN	ADIGÜZEL	ROMAN	8	AYDIN	İKİZDERE	ROMAN
9	AYDIN	ANTİK GÜRLEN	ROMAN	10	AYDIN	SARIKEMER	ROMAN
11	AYDIN	DANİŞMENT	ROMAN	12	BURDUR	KAYAALTI	ROMAN
13	BURDUR	DAĞARCIK	ROMAN	14	DENİZLİ	AHMETLİ	ROMAN
15	DENİZLİ	HANÇALAR	ROMAN	16	DENİZLİ	BEDİRBEY	ROMAN
17	DENİZLİ	CİNDERE	ROMAN	18	DENİZLİ	BAYIRALAN	ROMAN
19	DENİZLİ	TOZLUKARA	ROMAN	20	DENİZLİ	TABAE	ROMAN
21	DENİZLİ	KANLIKEMER	ROMAN	22	DENİZLİ	EBECİK	ROMAN
23	DENİZLİ	ÇİFTLİKKÖY	ROMAN	24	DENİZLİ	ZEYVE	ROMAN
25	ISPARTA	KÖPÜRLÜ	ROMAN	26	ISPARTA	ÇANDIR	ROMAN
27	ISPARTA	ZİNDAN MAĞARASI	ROMAN	28	ISPARTA	BARLA	ROMAN
29	İZMİR	ZEYTİNKÖY	ROMAN	30	İZMİR	PEŞREFLİ	ROMAN
31	İZMİR	KARAOSMANOĞLU	ROMAN	32	İZMİR	YAKAKÖY	ROMAN
33	İZMİR	KİLİSE	ROMAN	34	KÜTAHYA	ÇAVDARHİSAR	ROMAN
35	KÜTAHYA	KOCAKÖPRÜ	ROMAN	36	KÜTAHYA	PINARCIK	ROMAN
37	MANİSA	KIRMIZI	ROMAN	38	MUĞLA	KEMERDERE	ROMAN
39	MUĞLA	SINDI	ROMAN	40	MUĞLA	DEMİRLER	ROMAN
41	UŞAK	CILANDRAS	ROMAN	42	AFYON	ALTIGÖZ	SELJUK
43	AFYON	KADINANA	SELJUK	44	BURDUR	ÇENDİK	SELJUK
45	BURDUR	ONAÇ ÇAYI	SELJUK	46	BURDUR	BOĞAZİÇİ	SELJUK
47	DENİZLİ	TEMURTAŞ	SELJUK	48	DENİZLİ	AKHAN	SELJUK
49	ISPARTA	AFŞAR	SELJUK	50	ISPARTA	HÖYÜKLÜ	SELJUK
51	ISPARTA	YAYCILAR	SELJUK	52	ISPARTA	KÜÇÜK KÖPRÜ	SELJUK
53	MUĞLA	URLUCA	SELJUK	54	UŞAK	ÇANLI	SELJUK
55	UŞAK	YENİŞEHİR	SELJUK	56	AYDIN	MERMER	PRINCIPATIES
57	AYDIN	İKİZDERE	PRINCIPATIES	58	AYDIN	KARACASU	PRINCIPATIES
59	AYDIN	GÖLBENT	PRINCIPATIES	60	AYDIN	TAHİR PAŞA	PRINCIPATIES
61	AYDIN	ALTINTAŞ	PRINCIPATIES	62	İZMİR	İÇMELER	PRINCIPATIES
63	İZMİR	KONA	PRINCIPATIES	64	İZMİR	ILICA ERGENLİ	PRINCIPATIES
65	MUĞLA	SARIÇAY	PRINCIPATIES	66	UŞAK	BEYLERHAN	PRINCIPATIES
67	UŞAK	İNAY KÖYÜ	PRINCIPATIES	68	AYDIN	DANDALAS	E. OTTOMAN
69	İZMİR	MENDERES	E. OTTOMAN	70	İZMİR	TATAR	E. OTTOMAN
71	KÜTAHYA	DUMLUPINAR	E. OTTOMAN	72	KÜTAHYA	YIPRAK EZEN	E. OTTOMAN
73	MANİSA	KISMALI	E. OTTOMAN	74	MANİSA	KIZ	E. OTTOMAN
75	MANİSA	GEDİZ BAHAS	E. OTTOMAN	76	UŞAK	HASKÖY	E. OTTOMAN

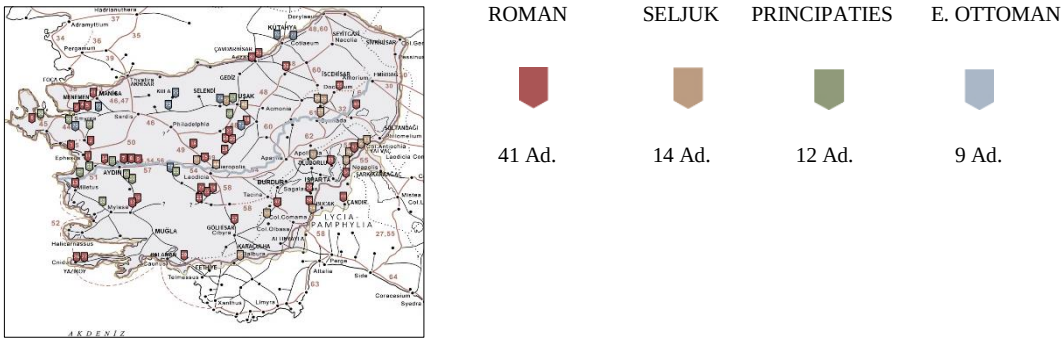


Figure 5.2. *Locations of the bridges*

6. COMPARATIVE STUDY AND TYPOLOGICAL ANALYSIS

Comparison and scrutinization of the Roman and Turkish Bridges in Western Anatolia are made under three captions. These include;

1.Frontal and plan typology
2.Typology of the structural elements (foundations, piers, arches and spandrels)
3.Typology of the non-structural elements (cornices, parapets and pavements)

Table 6.1. *Classification of bridges according to the frontal and plan types*

FRONTAL AND PLAN TYPOLOGY			FRONTAL						PLAN	
			A.SINGLE SPACE		B.TWO SPACE		C.POLY SPACE		FLAT	BROKEN
			1.FLAT	2.SLOPE	1.FLAT	2.SLOPE	1.FLAT	2.SLOPE		
ROMAN	1	DÖRTGÖZ						✓	✓	
	2	İSCEHİSAR		✓					✓	
	3	KIRKGÖZ					✓		✓	
	4	ESKİHİSAR I			✓				✓	
	5	ESKİHİSAR II	✓							✓
	6	ESKİHİSAR III	✓						✓	
	7	ADIGÜZEL					✓		✓	
	8	ROMA İKİZDERE				✓			✓	
	9	ANTİK GÜRLEN					✓		✓	
	10	SARIKEMER						✓	✓	
	11	DANİŞMENT	✓						✓	
	12	KAYAALTI	✓						✓	
	13	DAĞARCIK				✓			✓	
	14	AHMETLİ						✓	✓	
	15	HANÇALAR						✓	✓	
	16	BEDİRBEY					✓		✓	
	17	CİNDERE						✓	✓	
	18	BAYIRALAN	✓						✓	
	19	TOZLUKARA				✓			✓	
	20	TABAE	✓						✓	
ROMAN	21	KANLIKEMER						✓	✓	
	22	EBECİK	✓						✓	
	23	ÇİFTLİKKÖYÜ			✓				✓	
	24	ZEYVE						✓	✓	
	25	KÖPÜRLÜ					✓			✓
	26	ÇANDIR		✓					✓	
	27	ZİNDAN MAĞARASI	✓						✓	
	28	BARLA		✓						✓
	29	ZEYTİNKÖY						✓	✓	
	30	PEŞREFLİ	✓						✓	
	31	KARAOSMANOĞLU						✓		✓
	32	YAKAKÖY		✓						✓
	33	KİLİSE	✓						✓	
	34	ÇAVDARHİSAR						✓	✓	
	35	KOCAKÖPRÜ						✓	✓	
	36	PINARCIK						✓	✓	
	37	KIRMIZI	✓						✓	
	38	KEMERDERE	✓						✓	
	39	SINDI			✓				✓	
	40	DEMİRLER				✓			✓	
	41	CILANDRAS	✓						✓	
SELJUK	42	ALTIGÖZ					✓		✓	
	43	ARK KADINANA	✓						✓	
	44	ÇENDİK								
	45	ONAÇ ÇAYI						✓	✓	
	46	BOĞAZİÇİ						✓	✓	
	47	TEMURTAŞ								
	48	AKHAN						✓	✓	
	49	AFŞAR				✓			✓	
	50	HÖYÜKLÜ						✓	✓	
	51	YAYCILAR		✓					✓	
	52	KÜÇÜKKÖPRÜ	✓						✓	
	53	URLUCA				✓				✓
	54	ÇANLI		✓					✓	
	55	YENİŞEHİR						✓	✓	

FRONTAL AND PLAN TYPOLOGY			FRONTAL						PLAN	
			A. SINGLE SPACE		B. TWO SPACE		C. POLY SPACE		FLAT	BROKEN
			1. FLAT	2. SLOPE	1. FLAT	2. SLOPE	1. FLAT	2. SLOPE		
PRINCIPATIES	56	MERMER		✓					✓	
	57	İKİZDERE						✓	✓	
	58	KARACASU	✓						✓	
	59	GÖLBENT						✓	✓	
	60	TAHİR PAŞA	✓						✓	
	61	ALTINTAŞ		✓					✓	
	62	İÇMELER						✓	✓	
	63	SARIÇAY KONA		✓					✓	
	64	ILICA ERGENLİ				✓			✓	
	65	SARIÇAY DEĞİRMENÇAYI						✓	✓	
	66	BEYLERHAN						✓		✓
	67	İNAY KÖYÜ		✓					✓	
E. OTTOMAN	68	DANDALAS	✓						✓	
	69	MENDERES		✓					✓	
	70	TATAR					✓		✓	
	71	DUMLUPINAR			✓				✓	
	72	YIPRAK EZEN						✓	✓	
	73	KISMALI					✓			✓
	74	KIZ						✓	✓	
	75	GEDİZ BAHAS			✓				✓	
	76	HAMAM HASKÖY						✓	✓	

***Table 6.2**. Typology of arches*

ARCH TYPOLOGY DAİ: Circular arch B-D: Flattened circular arch SİV: Lancet arch B-S: Flattened lancet arch			Number of arch	MAİN ARCH											SUBSİDİARY ARCH		
				FORM					MATERIAL AND TECHNICAL						FORM		
									Front of arch			Bottom of arch					
				DAİ	B-D	SİV	B-S	DİĞ	Massive stone	Rubble slate	Brick	Massive stone	Rubble slate	Brick	DAİ	B-D	SİV
ROMAN	1	DÖRTGÖZ	4	✓					✓			✓			✓		
	2	İSCEHİSAR	1				✓		✓			✓					
	3	KIRKGÖZ	57	✓					✓			✓			✓		
	4	ESKİHİSAR I	2	✓						✓			✓				
	5	ESKİHİSAR II	1	✓						✓			✓				
	6	ESKİHİSAR III	1	✓						✓			✓				
	7	ADIGÜZEL	3	✓					✓			✓			✓		
	8	ROMA İKİZDERE	2	✓					✓			✓			✓		
	9	ANTİK GÜRLEN	6	✓						✓			✓		✓		
	10	SARIKEMER	7	✓					✓			✓			✓		
	11	DANİŞMENT	1							✓							
	12	KAYAALTI	1	✓					✓			✓					
	13	DAĞARCIK	2	✓					✓			✓			✓		
	14	AHMETLİ	7	✓					✓			✓			✓		
	15	HANÇALAR	3	✓					✓			✓			✓		
	16	BEDİRBEY	5	✓					✓			✓			✓		
	17	CİNDERE	6	✓					✓			✓			✓		
	18	BAYIRALAN	1	✓					✓			✓					
	19	TOZLUKARA	2	✓					✓			✓			✓		
	20	TABAE	1	✓					✓			✓					
	21	KANLIKEMER	2	✓					✓			✓			✓		
	22	EBECİK	1	✓					✓			✓					
	23	ÇİFTLİKKÖYÜ	2	✓					✓			✓			✓		
	24	ZEYVE	3	✓						✓		✓			✓		
	25	KÖPÜRLÜ	3	✓					✓			✓			✓		
	26	ÇANDIR	1	✓					✓			✓					
	27	ZİNDAN MAĞARASI	1		✓				✓			✓					
	28	BARLA	1				✓		✓			✓					
	29	ZEYTİNKÖY	4	✓					✓			✓			✓		
	30	PEŞREFLİ	1	✓						✓			✓				
	31	KARAOSMANOĞLU	7			✓			✓			✓			✓		
	32	YAKAKÖY	1	✓					✓			✓					
	33	KİLİSE	1	✓					✓			✓					
	34	ÇAVDARHİSAR	5	✓					✓			✓			✓		
	35	KOCAKÖPRÜ	4	✓					✓			✓			✓		
	36	PINARCIK	9	✓					✓			✓			✓		
	37	KIRMIZI	1	✓							✓			✓			
	38	KEMERDERE	1					✓	✓			✓					
	39	SINDI	2		✓					✓			✓			✓	
	40	DEMİRLER	2			✓					✓			✓	✓		
	41	CILANDRAS	1	✓					✓			✓					

ARCH TYPOLOGY DAI: Circular arch B-D: Flattened circular arch SİV: Lancet arch B-S: Flattened lancet arch			Number of arch	MAIN ARCH										SUBSİDİAR		
				FORM					MATERIAL AND TECHNICAL					FORM		
									Front of arch			Bottom of arch				
				DAİ	B-D	SİV	B-S	DİĞ	Massive stone	Rubble slate	Brick	Massive stone	Rubble slate	Brick	DAİ	B-D	SİV
SELJUK	42	ALTIGÖZ	6			✓			✓			✓					✓
	43	ARK KADINANA	3			✓			✓			✓			✓		
	44	ÇENDİK															
	45	ONAÇ ÇAYI	3			✓			✓				✓		✓		
	46	BOĞAZİÇİ	3			✓			✓			✓					✓
	47	TEMURTAŞ															
	48	AKHAN	3														
	49	AFŞAR	2			✓			✓				✓				✓
	50	HÖYÜKLÜ	3			✓			✓				✓		✓		
	51	YAYCILAR	1			✓			✓			✓					
	52	KÜÇÜKKÖPRÜ	1			✓			✓				✓				
	53	URLUCA	2			✓			✓				✓	✓	✓		
	54	ÇANLI	1			✓			✓			✓					
	55	YENİŞEHİR	3	✓					✓				✓		✓		
PRİNCİPATİES	56	MERMER	1	✓						✓			✓				
	57	İKİZDERE	5			✓			✓			✓			✓		✓
	58	KARACASU	1	✓					✓			✓					
	59	GÖLBENT	3			✓			✓				✓				✓
	60	TAHİR PAŞA	1	✓					✓				✓				
	61	ALTINTAŞ	1	✓						✓			✓				
	62	İÇMELER	3	✓					✓			✓			✓		
	63	SARIÇAY KONA	1		✓				✓			✓					
	64	ILICA ERGENLİ	2	✓						✓			✓				✓
	65	SARIÇAY DEĞİRMENÇAYI	9	✓					✓				✓		✓		✓
	66	BEYLERHAN	6	✓					✓			✓			✓		✓
	67	İNAY KÖYÜ	1	✓					✓			✓					
E. OTTOMAN	68	DANDALAS	1	✓					✓			✓					
	69	MENDERES	1			✓			✓			✓					
	70	TATAR	3		✓				✓			✓			✓		
	71	DUMLUPINAR	2	✓					✓			✓			✓		
	72	YIPRAK EZEN	25			✓			✓			✓			✓		
	73	KISMALI	19			✓			✓				✓		✓		
	74	KIZ	6	✓					✓				✓		✓		
	75	GEDİZ BAHAS	2	✓					✓			✓			✓		
	76	HAMAM HASKÖY	4		✓				✓			✓			✓		

Table 6.3. *Pier and spandrel typology*

PIER AND SPANDREL TYPOLOGY			Number of pier	PIER				SPANDREL				
				Flat		Floodsplitter		Massive stone		Rough stone	Rubble slate	Brick
				Massive stone	Rubble slate	Massive stone	Rubble slate	regular	irregular			
ROMAN	1	DÖRTGÖZ	5	✓				✓				
	2	İSCEHİSAR	2	✓				✓	✓			
	3	KIRKGÖZ	58	✓				✓				
	4	ESKİHİSAR I	3	✓							✓	
	5	ESKİHİSAR II	2	✓							✓	
	6	ESKİHİSAR III	2	✓							✓	
	7	ADIGÜZEL	4	✓						✓	✓	
	8	ROMA İKİZDERE	3			✓		✓				
	9	ANTİK GÜRLEN	7	✓	✓					✓	✓	
	10	SARIKEMER	8			✓				✓	✓	
	11	DANİŞMENT	2	✓						✓	✓	
	12	KAYAALTI	2	✓				✓				
	13	DAĞARCIK	3	✓				✓		✓	✓	
	14	AHMETLİ	8			✓		✓				
	15	HANÇALAR	4			✓				✓	✓	✓
	16	BEDİRBEY	6	✓						✓	✓	
	17	CİNDERE	7			✓		✓		✓		
	18	BAYIRALAN	2	✓					✓	✓		
	19	TOZLUKARA	3			✓				✓		✓
	20	TABAE	2	✓						✓	✓	
	21	KANLIKEMER	4	✓						✓	✓	
	22	EBECİK	2	✓						✓		
	23	ÇİFTLİKKÖYÜ	3	✓						✓	✓	
	24	ZEYVE	4	✓							✓	
	25	KÖPÜRLÜ	4	✓					✓	✓		
	26	ÇANDIR	2	✓							✓	
	27	ZİNDAN MAĞARASI	2	✓				✓				

PIER AND SPANDREL TYPOLOGY			Number of pier	PIER				SPANDREL				
				Flat		Floodsplitter		Massive stone		Rough stone	Rubble slate	Brick
				Massive stone	Rubble slate	Massive stone	Rubble slate	regular	irregular			
ROMAN	28	BARLA	2	✓				✓				
	29	ZEYTİNKÖY	5	✓						✓		
	30	PEŞREFLİ	2		✓						✓	
	31	KARAOSMANOĞLU	10			✓				✓		
	32	YAKAKÖY	2	✓						✓	✓	
	33	KİLİSE	2	✓						✓		
	34	ÇAVDARHİSAR	6			✓		✓				
	35	KOCAKÖPRÜ	5			✓		✓				
	36	PINARCIK	10			✓		✓		✓		
	37	KIRMIZI	2	✓				✓				✓
	38	KEMERDERE	2	✓				✓				
	39	SINDI	3	✓							✓	
	40	DEMİRLER	3			✓				✓		✓
	41	CILANDRAS	2	✓						✓		
SELJUK	42	ALTIGÖZ	7			✓		✓	✓			
	43	ARK KADINANA	4	✓				✓		✓	✓	
	44	ÇENDİK	4	✓						✓	✓	
	45	ONAÇ ÇAYI	4				✓				✓	
	46	BOĞAZİÇİ	4			✓		✓		✓		
	47	TEMURTAŞ									✓	
	48	AKHAN	4			✓		✓				
	49	AFŞAR	3	✓				✓				
	50	HÖYÜKLÜ	4	✓				✓			✓	
	51	YAYCILAR	2	✓						✓	✓	
	52	KÜÇÜKKÖPRÜ	2	✓						✓	✓	
	53	URLUCA	3	✓							✓	✓
	54	ÇANLI	2	✓				✓		✓		
	55	YENİŞEHİR	4			✓					✓	
PRINCIPATIE	56	MERMER	2	✓							✓	
	57	İKİZDERE	6			✓		✓			✓	✓
	58	KARACASU	2	✓						✓	✓	
	59	GÖLBENT	4	✓							✓	
	60	TAHİR PAŞA	2	✓						✓	✓	
	61	ALTINTAŞ	2	✓	✓						✓	
	62	İÇMELER	4	✓				✓				
	63	SARIÇAY KONA	2	✓					✓	✓		
	64	ILICA ERGENLİ	3	✓							✓	
	65	SARIÇAY DEĞİRMENÇAYI	10			✓				✓	✓	✓
	66	BEYLERHAN	7			✓				✓	✓	
	67	İNAY KÖYÜ	2	✓							✓	
E. OTTOMAN	68	DANDALAS	2	✓						✓	✓	
	69	MENDERES	2	✓							✓	
	70	TATAR	4	✓							✓	
	71	DUMLUPINAR	3	✓				✓				
	72	YIPRAK EZEN	26	✓				✓	✓			
	73	KISMALI	20			✓	✓			✓	✓	✓
	74	KIZ	7			✓	✓			✓	✓	
	75	GEDİZ BAHAS	3			✓				✓	✓	
	76	HAMAM HASKÖY	5			✓					✓	

Table 6.4. *Parapet, cornice and pavement typology*

PARAPET, CORNICE, PAVEMENT TYPOLOGY			PARAPET						CORNICE			PAVEMENT			
			Massive		Build			Non-parapet	Protruding		Non-protruding	Massived stone		Rubble geometric shape	River stone
			Flat	Profiled	Massived	Rubble	Protruding		Flat	Profiled		regular	irregular		
ROMAN	1	DÖRTGÖZ	✓								✓	✓			
	2	İSCEHİSAR		✓						✓		✓			
	3	KIRKGÖZ	✓						✓			✓			
	4	ESKİHİSAR I				✓					✓		✓		
	5	ESKİHİSAR II				✓					✓		✓		
	6	ESKİHİSAR III				✓					✓		✓		
	7	ADIGÜZEL						✓			✓		✓		
	8	ROMA İKİZDERE	✓								✓		✓		
	9	ANTİK GÜRLEN				✓					✓			✓	
	10	SARIKEMER				✓					✓			✓	
	11	DANİŞMENT													
	12	KAYAALTI						✓			✓	✓			
	13	DAĞARCIK	✓								✓	✓			
	14	AHMETLİ	✓							✓		✓			
	15	HANÇALAR	✓								✓			✓	
	16	BEDİRBEY						✓			✓		✓		
	17	CİNDERE	✓								✓		✓		
	18	BAYIRALAN	✓								✓			✓	
	19	TOZLUKARA	✓								✓			✓	
	20	TABAE	✓								✓			✓	
ROMAN	21	KANLIKEMER						✓			✓		✓		
	22	EBECİK						✓			✓		✓		
	23	ÇİFTLİKKÖYÜ				✓					✓			✓	
	24	ZEYVE				✓					✓			✓	
	25	KÖPÜRLÜ						✓			✓		✓		
	26	ÇANDIR				✓					✓			✓	
	27	ZİNDAN MAĞARASI						✓		✓			✓		
	28	BARLA	✓								✓			✓	
	29	ZEYTİNKÖY	✓								✓			✓	
	30	PEŞREFLİ				✓					✓		✓		
	31	KARAOSMANOĞLU	✓								✓			✓	
	32	YAKAKÖY	✓								✓			✓	
	33	KİLİSE	✓								✓			✓	
	34	ÇAVDARHİSAR		✓						✓		✓			
	35	KOCAKÖPRÜ		✓						✓		✓			
	36	PINARCIK						✓			✓	✓			
	37	KIRMIZI						✓			✓			✓	
	38	KEMERDERE						✓			✓	✓			
	39	SINDI				✓					✓			✓	
	40	DEMİRLER				✓					✓			✓	
	41	CILANDRAS			✓						✓	✓			
SELJUK	42	ALTIGÖZ	✓								✓	✓			
	43	ARK KADINANA				✓			✓					✓	
	44	ÇENDİK													
	45	ONAÇ ÇAYI						✓			✓			✓	
	46	BOĞAZİÇİ	✓								✓	✓			
	47	TEMURTAŞ													✓
	48	AKHAN													
	49	AFŞAR	✓								✓	✓			
	50	HÖYÜKLÜ			✓		✓				✓	✓			
	51	YAYCILAR			✓						✓		✓		
	52	KÜÇÜKKÖPRÜ			✓						✓		✓		
	53	URLUCA			✓						✓			✓	
	54	ÇANLI	✓								✓	✓			
	55	YENİŞEHİR				✓					✓			✓	
PRINCIPATIE	56	MERMER				✓					✓			✓	
	57	İKİZDERE				✓					✓			✓	
	58	KARACASU				✓					✓			✓	
	59	GÖLBENT				✓					✓			✓	
	60	TAHİR PAŞA				✓					✓			✓	
	61	ALTINTAŞ				✓					✓			✓	
	62	İÇMELER						✓	✓						✓
	63	SARIÇAY KONA						✓			✓			✓	
	64	ILICA ERGENLİ				✓					✓			✓	
	65	SARIÇAY DEĞİRMENÇAYI				✓					✓			✓	
	66	BEYLERHAN				✓					✓			✓	
	67	İNAY KÖYÜ	✓								✓			✓	
E. OTTOMAN	68	DANDALAS			✓				✓					✓	
	69	MENDERES	✓								✓			✓	
	70	TATAR	✓						✓					✓	
	71	DUMLUPINAR	✓						✓			✓			
	72	YIPRAK EZEN	✓							✓		✓			
	73	KISMALI	✓						✓					✓	
	74	KIZ				✓					✓				✓
	75	GEDİZ BAHAS	✓								✓			✓	
	76	HAMAM HASKÖY	✓						✓					✓	

7. RESULTS AND DISCUSSION

The bridges which are utterly functional in the provision of the transportation between two banks, may, in general terms, be plain structures in view of architectural elements but the design and construction systems reveal the synthesis of the architectural trends within the period they are constructed. Each period has its own architectural and social patterns and carries the socio-cultural features of the period. In addition, as a consequence of the determination and analysis of the structural elements of the plain bridge structure and its typology, it is possible to have an access to the synthesis that show the design and technical characteristics of the period in which they were constructed. The roman road networks in Anatolia were first designed to provide connection between the military headquarters and the capitals of the states starting from early 2nd century. Some of the roads were of particular importance in view of military, commercial and religious purposes on one, while the others lost their previously attached significance. The roads which were topographically available to the extent allowed by the topographical conditions within the settlement areas, survived in the manner to protect their main arterial feature. Starting from 330 A.C., the routes to the west and the south which were of particular importance replaced by the routes to the north due to its proximity with Istanbul. The bridges which fall within the scope of this study, have been focused on certain periods. These are the Roman Bridges dating back to 2nd through 4th centuries by the time of which Emperor Hadrian and Constantine reigned, 6th and 7th centuries by the time of which Justinian reigned, Late Byzantine bridges dating back to 11th and 12th centuries, Seljuk period dating back to the years 1200 through 1260 and the era of Principalities, in particular the Principality of the Aydinids, Germiyanids and Menteshids. When the materials and technique used in the construction of the bridges , it has been observed that a single construction technique was occasionally in use while at other times, different construction techniques were used all together. For example, the Bridge of Ahmetli constructed on the arterial road linking Laodicia with the cities of Thyaria (Akhisar) and Magnesia in 3rd and 4th centuries during Roman Period had undergone substantial repairs in Late Byzantine Period by the time of the Lascaris. The facade linings of the bridge were repaired in the manner to apply the walling technique with frames filled with pitch-faced stone and crushed brick. Similarly, when the architectural and material wise characteristics of Yenişehir Bridge dating back to the Seljuk period, on the caravan route between Uşak and İzmir is reviewed, it is noted that it was reconstructed on the abutments of the bridge at the same location, the arches of which were previously demolished.

Use of stone with grout in relatively smaller dimensions but through different construction technique was introduced by the Romans. Technically Roman period can be regarded as the transition period [15]. The construction of the walls using grout has led to the development of the structural system distinct from the previous periods. The walls of the structure was constructed through the grout injected on the outer shell with coarse and regularly stacked stones. Use of rubble stone within the grout raises attention. During Turkish period, it is observed that the natural stones are selected in the manner to fit its purpose of use and increasingly used in the structures in an ingenious manner due to the traditional effects. The calcareous sinter and marble type stones are generally used as the structural stone in the bridges studied. Out of the bridges dating back to the Seljuk Period, the smoothly cut stones observed in the bridges of Altıgöz, Akhan and Çanlı proves that the workmanship is quite well (Figure 7.1). The used of black and white stones in Altıgöz bridge, a harmonious and diligent manner is of importance to reveal the level of stonemasonry. It is observed that the stones are used dexterously in the bridges during Early Ottoman period. The other material used in the Roman bridges is the hearth brick. The wall pattern with large and rectangular bricks named opus latericium or testaceum are used both on the walls and the lining of the walls.

Figure 7.1. *Seljuk bridges a)Altıgöz, b)Akhan, c)Çanlı [14]*

It has been found out during the surveys that the groutis with different ratios were used in the bridges in Western Anatolia. The bonding content of the grouts used in Roman and Turkish Bridges is slaked lime at a rate ranging between 25 % to 35 % with various amount of aggregate. Crushed or powdered carbonated stone at a rate ranging from 5 % to 20 % usually made up of lime stone, is amongst the materials found in the contents of the grout (Table 7.1).

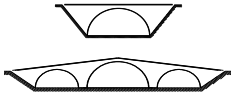
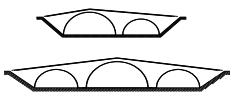
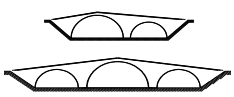
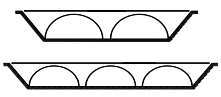
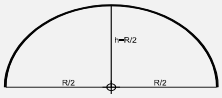
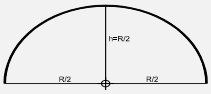
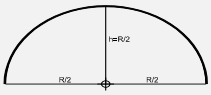
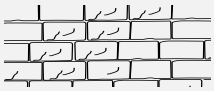
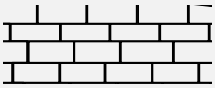
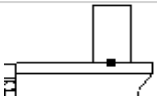
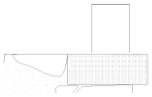
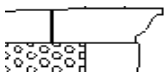
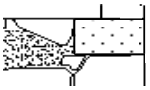
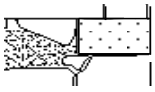
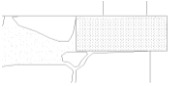
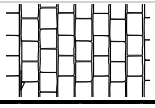
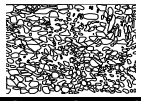
The grout used in Roman bridges is featured to be much more pozzolanic (Table 7.1). The natural puzzolana and volcanic tuff are mostly used at a rate of 5 % to 10 % while crushes of bricks are observed in some of the bridges as artificial puzzolana. The use of tow and fine fibre at a rate of 4 % to 7 % raises attention in the bridges dating back to Seljuk and Principalities period. Such materials are added into the grout for bonding purposes. It has also been observed in the Seljuk and Principalities bridges that there added natural and artificial pozzolanic materials within the grout. As for the Early Ottoman period, efforts have been made to enhance the hydraulic characteristics of the clayed and other silicate materials of puzzolanic nature by adding them in the grouts as so observed in Kaısmalı Bridge. The material used in the hydraulic grout is hardened upon chemical reaction with water. Therefore, the resistance of such grout against water is quite higher.

Table 7.1. *Content and proportions of the mortars used in bridges[14]*

Period	Bridge	Puzzolan volcanic tuff	Slaked lime	Carbonated stone fracture/pow	Volcanic rock aggregate	Quartz aggregate	Tow Little fibre	Broken brick
Roman	4.Eskihisar-I	10%	25%	5%	50%	10%		
	20.Tabae	12,50%	12,50%	20%	30%	25%		
	31.Karaosmanoğlu	5%	30%	15%		50%		
	32.Yakaköy		35%	5%	45%	10%		5%
	33.Kilise		35%	10%		50%	5%	
	34.Çavdarhisar	5%	25%	15%		50%		5%
	35.Kocaköprü	5%	30%	15%		50%		
	41.Cılandras	10%	15%	7,50%	17,50%	50%		
Seljuk	48.Akhan		28%	23%	43%		6%	
	54.Çanlı		30%	17,50%	28%	17,50%	7%	
	55.Yenişehir		30%	15%		55%		
Principaties	57.İkizdere		40%	32%		4%	4%	
	61.Altıntaş		30%	15%		55%		
	62.İçmeler	5%	30%	20%		45%		
	65.Sarıçay		25%	7,50%	60%			7,50%
	66.Beylerhan		30%	17,50%	17,50%	35%		
Early Ottoman	68.Dandalas		35%	15%		50%		
	69.Menderes		30%	30%		40%		
	73.Kısmalı	5%	25%	25%		45%		
	76.Hamam		30%	20%		50%		

The Roman and Turkish bridges in Western Anatolia have been observed to have specific periodical characteristics by making use of the several synthesis (Table 7.2).

Table 7.2. *Architectural features of Roman and Turkish bridges*

Architectural Features		Roman Period	Seljuk Period	Principaties Period	E. Ottoman Period
Frontal Type		Single space flat type / Poly space slope type	Two space slope type / Poly space slope type	Two space slope type / Poly space slope type	Two space flat type / Poly space flat type
	Pier				
Strukturel Elements	Pier	Floodsplitter 	Floodsplitter 	Flat type 	Flat type 
	Arch	Circular arch 	Lancet arch 	Circular arch 	Circular arch 
	Spandrel	Massive regular stone 	Massive regular stone 	Rubble slate stone 	Rough regular stone 
Non Structurel Elements	Parapet Cornice	Massived parapet 	Massived build parapet 	Rubble build parapet 	Massived parapet 
	Cornice	Protruding profiled cornice 	Non-protruding cornice 	Non-protruding cornice 	Flat protruding cornice 
	Pavement Pavement	Massived stone- irregular 	Massived stone -regular 	Rubble stone oversized 	Rubble stone smallsized 

With respect to the relationship between the form of arches and levelling as a significant element in the formation of the bridges, the circular form introduced by the Romans with flat levelling have turned out to be pointed in form with inclined levelling during Seljuk period . The inclined levelling continued to be in use during the period of Principalities with the re - utilization of the circular arches (Table 7.2). Transition period has been experienced in this context during Early Ottoman period with the use of the circular and pointed forms of the arches together as well as the flat and inclined levelling. the archivolt tradition introduced by the Seljuks on the arches was suspended during the age of principalities, however, the Ottomans continued to make use of it. Regarding the use of the materials, the large and smoothly shaped freestone was in use by the Romans together with occasionally used brick and lime grout with natural pozzolana base as bonding agent whereas this was partially changed during the periods of Seljuks and Principalities. The Seljuks made use of the smoothly cut freestone but the dimensions of the stones were relatively smaller. By the age of the Principalities, the use of rubble stone increased as well as the picked up stones. Tow and fine fibre were used in lieu of natural pozzolana in the mortar content. Although it has been observed that smoothly cut relatively small freestones were in use in the Ottoman Bridges similar to the Seljuks, natural pozolana has been observed to be incorporated in the grout. The large and thick arch forms in the Roman Bridges have been turned out to be gradually subtilized arched structures.

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