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Typology and Developments in buttresses from the beginning to the historical era in Iranian architecture

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Abstract

As a masonry structure, buttresses have the role of controlling the sliding force of the main wall. This architectural element has been used in residential and non-residential buildings in various methods and ways from distant years. In this regard, archaeological evidences are the only valid indices by referring to which we can tacitly learn about the record of buttresses. Where and how it has first been used is not known, and nowhere has it been explicitly referred to. Even archaeologists have tacitly and briefly referred to it in their excavation reports. However, based on accessible limited reports, expansive application of this structure can be dated to post-Neolithic era when architects became aware of structural performance of this element and gradually with their part experiences; they used it in a different way with better structural performance. In this research, studied about Buttress types in terms of position, form and shape, used material, execution technique, ornament and technical function. By studying buttresses built during pre-historic and historical period, it will be seen that there were no structural scientific frameworks based on findings related to the strength of materials and mechanical rules. Little by little and through time, architects began to understand structural performance and structural perception of buttresses, owing to the experience and deep attitude towards the nature and behavior of masonry buildings. They emphasized not only the balance in forces, but also their appearance and esthetics. Lack of comprehensive research in this regard necessitated this research, and this issue was dealt with through library studies and descriptive and analytical research method.

Keywords

Iranian architecture, Pre-historic era, Historical period, Typology of Buttress structure.

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Introduction

Buttress is an architectural element which has been used with a structural approach in historical land marks abundantly. The architecture of buttresses and their performance which have been effective on brace of thrust force of different structures of building such as wall, dome, porch, etc. indicates the genius and deep understanding of the architects on their structural behaviors. Many references, even, have recognized land as a buttress. According to Pirnia (2008:32), “architects used the removed soil of courtyard once again in the same building. Dishing of the building contributed to the stativity of vaults because the land was as a buttress against the thrust”.

Significance of the study

The significance of this research lies in identification of probable time and place of emergence of buttress and its evolution in different historical periods in a way that based on Mrs. Dieulafoy “professor Dieulafoy traveled to East and the ancient world to shed light on the relationship between Eastern architecture and Gothic architecture which was created in the Middle Ages” (Negahban, 1996: 88). In a castle which was constructed by Bahram V in the fifth century in Sarvestan, more complete progress and developed techniques were witnessed, in way that the squinch was used to reinforce the circular domes, although in addition to this, usage of column as ceiling protector is observed in the adjoining room (Pope, 2003: 59). Long walls and buttresses are obvious features of Gothic architecture. Given the fact that no clear point is made to the aforementioned impact by Mrs. Dieulafoy and her husband and also the others, is it possible to claim that this structural element in tall buildings of the Iranian monuments has affected the above European style? Where Burton found construction remains with the height of fourteen meters (Negahban, 1996:99) in Shush (Sūsa) at layers B and C, and remained silent about its stability and strengthening, is it possible to know it an indication of existence of a buttress? Buttress is one of the most important architecture elements

for stabilization of buildings against thrust and it has been widely used in much Iranian classical architecture. Examination of its types, background, and change and evolution trend is important in a way that types are tools for analysis and identification. As typology is a common way of organizing the mind, the scientific typology of buttress is of significance with the aim of enjoying the mental promotion and intellectual integrity on the structure of historical land marks which has been left unnoticed in scientific researches and needs to be studied aptly.

Research questions

The present study aims at providing answers to the following question:

- The first buttresses dates back to which period?
- What are the first buttresses designed for?
- What were the first types of buttresses?
- How were first buttresses used in buildings and what were their positions to servicing structures?
- How is the evolution trend of structural shape and function of buttresses in the prehistory to the late historic period and what are the driving factors?

Research methodology

After Carrying out many studies on archeology and architecture focusing on buttresses, the researchers embarked on the investigation of the first buttresses in terms of form, material, servicing structure, and performance technique. Therefore, this research has been focused on library studies. All attempts have been made in this study to provide a better introduction, analysis, and identification of the primary buttresses and their features using images and suitable maps. This is a qualitative research and a descriptive-analytical study that has treated the evolutionary trend of the studied structures in prehistoric (Neolithic, Eneolithic Age and Bronze) and historic (Elamite, Median, Achaemenid, Ashkanids and Sassanid) periods.

Literature review

As a structural element, buttress has played a

functional role in construction. Archaeological and excavations reports have only implied the matter without any precise elaboration. Archaeologists have described and investigated the buttresses in their reports, in the studied sites. Professor Negahban (2008:364) in his reports of TepeZagheh introduced these walls as dwarf walls to support and maintain the walls and their strength, and following describing their shapes and dimensions, divided them into three categories. In exploration reports of Nush- e Jan Tepe, Stronach (1978: 1-28 & 1968: 77-88) investigated the precise dimensions of the buttresses in terms of the used material and ornaments using images and manual drawings. Many archaeologists have noted only on the existence of buttress in the respective site and have not elaborated on the exact study of this structural element and its difference with other concurrent or past sites. Also, the evolutionary trend of buttress and its types have not been investigated in the aforementioned period. This trend has not been studied aptly and that is why there is not any comprehensive information available on the primary buttresses and their types and evolution trends.

Definitions of buttress

This architectural element is defined in general dictionaries as “a short wall behind a long wall to protect it against falling; a structure behind the wall to help it stand” (Dehkhoda Dictionary, 1998: 5638); “what placed behind something or to support it (Anvari, 2002: 1388); “what placed behind a broken wall to protect it from falling (Moein Dictionary, 2010:791); the concept is referred in Borhan- e Ghate (1651) encyclopedia as “buttress is a support or a wood which connects the wall with the ground to strengthen it (quoted by KhalafTabrizi). This word is sometimes referred to as back prop in architecture. The word of buttress is called Huyeh by classical craftsmen in Isfahan (Rezayat, 2014). According to Fereshteh Nejad (2010: 395), in certain architecture dictionaries, buttress is called a support to prevent any hade and falling. In architecture and masonry, it is called Huyeh which is a wall, arch, or

semi-arch that, as a support, protects the structure from any drive or demolition and makes the whole architectural sat integrated. Accordingly, any damage to this part leads to a similar condition in the whole structure and would continue.

Buttress

components of old buildings mostly act with pressure, and all thrust forces are made neutralized by pressure forces and conducted to the ground. so when a force is applied to a structure in different directions irrespective of its balance, the equilibrium of the structure is lost, resulting in cracks and displacements. Therefore, buttress was used as a strengthening structure. There are various types of buttress that are classified in terms of shape and initial form in face and section, and are represented in figure 1. The first example that is called Flying buttress and is widely used in Western architecture; according to Longman dictionary, it is defined as “a curved line of stones or bricks that are joined to the outside wall of a large building such as a church, and help to support it”.

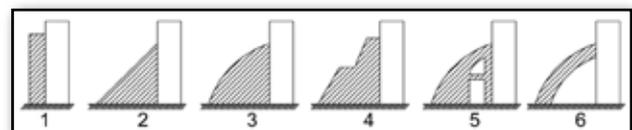


Fig. 1. Types of buttress. Source: authors.

Development trend of buttresses

In this study, the prehistory and historical periods were considered as the time span of investigation of buttresses development trend. The total of 50 archaeological sites were chosen for the study which reduced to 32 later due to exclusion of buttress-free sites, as to no buttress trace or relevant report were found in these areas. The final sites which were studied are Sang- e Chakhmaq, BozmordeTepe, TepeZagheh, Chogha Mish, YanikTepe, Tal- e Eblis, TepeYahya, TepeHissar, Godin Tepe, Shahr- e Sukhteh, Baba Jan Tepe, SegzabadTepe, Pasargadae Palace, ChogaZanbil, Tipi Ahar Tomb, GunsyanTepe, Sialk, AltinTepe, Tal-Hasanlu,

Bastam, TappeOzbaki, Nush- e Jan Tepe, Mithridates Fort, MasjedSoleyman, BardeNeshandeh, Takht- e Soleyman, QalehYazdiGird, QalehDokhtar Palace, Sarvestan, Ardeshir Palace, Ctesiphon palace ruin, Khosrou Palace.

The investigation of evolution of buttress in the aforementioned sites indicates that buttresses in prehistoric period were created from clay wall and handmade Adobe. They were made as relatively small rectangular cubes to the height of the wall or slightly shorter which suggests little experience of the architect in designing this type of structure. Emergence of monumental architecture such as temples and larger structures made architects more experienced and resulted in prevalence of using larger buttresses with different shapes, like caisson buttresses in the painted temple of TepeZagheh. With more knowledge of architects in transition from prehistory to historical periods, the scientific and endurance principles in buttress were used. Among signs of this progress are simultaneous construction of both buttress and building, number of buttresses, and evolution of form, shape and more regular intervals of buttresses. For example, in confining walls, buttresses appear in the form of Papil. This form even with stratified structure became prevalent to save materials and increase the beauty of facade, as what occurred in Nush- e Jan Tepe. Sassanid architecture, as the brilliant architectural art era, used this structure as well via employing of arcade buttresses to control thrust forces of portico, dome that indicates the evolutionary trend of buttress in this era compared to the former periods.

The aforementioned evolutionary trend is illustrated in detail in tables 1 to 5. The features of buttresses were investigated giving the function, site and area (North, Northeast, Northwest, East, West, South, Southeast, Southwest and Central), position of structure and its time period. The investigation is made considering certain indicators including the serviced structure (i.e. the structure which is supported by the buttress), shape and form of the buttress, position of the buttress to the building and to the serviced structure,

the used material and mortar in the buttress, size of buttress in plan, execution technique and technology of the buttress, and its function and ornaments. To elaborate the issue and desired objectives, the images of buildings are presented in which the positions of buttresses are highlighted and determined, and the last column of tables includes the relevant references.

Description of the buttress tables in the reviewed sites

Natural sources are always available in different ways for higher efficiency and evolution of human beings. Man has used the above sources over the eras consistent with his intellectual growth which has been demonstrated with different representations. Given this and the other collected data as shown in tables 1 and 2, the researchers in this study made attempts to elaborate the matter the development of buttress in different periods, places, and with different equipment, and proximity with mother or source structures within the above sites. What is covered here includes:

- a. Buttress types in terms of position;
- b. Buttress types in terms of form and shape;
- c. Buttress types in terms of used material;
- d. Buttress types in terms of executive technique;
- e. Buttress types in terms of ornament;
- f. Buttress types in terms of technical function.

Buttress types in terms of position

Researchers have considered position of the buttress depended upon the type of building, projected site and performance method as below:

1. Outside the building, discontinuous along the wall
In this connection, prominent profiles such as Nush- e Jan Tepe could be noted in which, according to Mollazadeh (2014: 108) in his book titled Median archeology, the position of buttresses in external walls of the central temple could be considered in two points in the southern facade of the building and near the northeast corner of the building. Also, in the old west building in Nush- e Jan Tepe, a number of buttresses in the external face of the building are

Table 1. The Buttress of prehistoric age. Source: authors.

pre-historic/Neolithic, Bronze and Iron periods									
9	8	7	6	5	4	3	2	1	Column number
<p>Type Yulysa</p> <p>Central</p> <p>Chalcolithic</p> <p>Kerman</p> <p>Dwelling House</p> <p>4000 B.C.</p> <p>Walls of rooms</p> <p>Rectangular Wall</p> <p>Inside the building</p>	<p>Tal-e Eshk</p> <p>Central</p> <p>Chalcolithic</p> <p>Kerman</p> <p>Dwelling House</p> <p>4000 B.C.</p> <p>Walls of rooms</p> <p>Rectangular Wall</p> <p>Outside and inside the building</p> <p>Center of Walls and Discontinuity along the Wall</p>	<p>Chogha Mish</p> <p>Southwest</p> <p>Chalcolithic</p> <p>Dizful</p> <p>Dwelling House</p> <p>4000 B.C.</p> <p>Walls of rooms</p> <p>Rectangular Wall</p> <p>Inside the building</p> <p>Center of Walls</p>	<p>Yazki Type</p> <p>Northwest</p> <p>Neolithic</p> <p>Taloz</p> <p>Char Dakh</p> <p>5600 B.C.</p> <p>Wall of building</p> <p>Caisson Walls</p> <p>Outside the building</p> <p>Discontinuous along the Wall</p>	<p>Type Zagroh</p> <p>Central</p> <p>Neolithic</p> <p>Qerzin</p> <p>Painted Temple</p> <p>6000 B.C.</p> <p>Walls of rooms</p> <p>Rectangular Wall</p> <p>Inside the building</p> <p>Center of Walls</p>	<p>Chogha Mish</p> <p>Southwest</p> <p>Neolithic</p> <p>Dizful</p> <p>Dwelling House</p> <p>6500 B.C.</p> <p>Walls of rooms</p> <p>Rectangular Wall</p> <p>Outside the building</p> <p>Center of Walls</p>	<p>Type Zagroh</p> <p>Central</p> <p>Neolithic</p> <p>Qerzin</p> <p>Dwelling House</p> <p>7000 B.C.</p> <p>Walls of rooms</p> <p>Rectangular Wall</p> <p>Outside the building</p> <p>Discontinuous along the Wall</p>	<p>Bomanda Type</p> <p>Southwest</p> <p>Neolithic</p> <p>Khorasan</p> <p>Dwelling House</p> <p>7000-7500 B.C.</p> <p>Walls of rooms</p> <p>Rectangular Wall</p> <p>Outside the building</p> <p>Discontinuous along the Wall</p>	<p>Sang-e Chakhmaq</p> <p>Northwest</p> <p>Neolithic</p> <p>Shahrood</p> <p>Religious Building</p> <p>8000-7000 B.C.</p> <p>Walls of rooms</p> <p>Rectangular Wall</p> <p>Outside the building</p> <p>Middle of Wall</p>	<p>Site</p> <p>Area</p> <p>Period</p> <p>Location</p> <p>Type of Building</p> <p>Age</p> <p>Structural Structure</p> <p>Form of Buttress</p> <p>Position of the Buttress in building</p> <p>Position of the Buttress in Structural Structure</p> <p>Material and Mortar</p> <p>Size in plan (CM²)</p> <p>Technology</p> <p>Ornaments</p> <p>Function</p> <p>Photos</p> <p>Source</p>
									
<p>(Lambert and Karlovsky1970: 134, 135) and (Bede1986: 81)</p>	<p>(Caldwell 1967: 239)</p>	<p>(Aflouzi et al. 2005: 11-34)</p>	<p>(Sagban2006: 358, 359) and (Malk Spalitradi 1992: 2-12)</p>	<p>(Sagban2006: 358, 359) and (Malk Spalitradi 1992: 2-12)</p>	<p>(Aflouzi et al. 2005: 11-34)</p>	<p>(Sagban2006: 358, 359) and (Malk Spalitradi 1992: 2-12)</p>	<p>(Malk Spalitradi 1999: 349)</p>	<p>(Aflouzi et al. 2005: 10) and (Malk Spalitradi 1999: 349)</p>	<p>Source</p>

Table2. The Buttress of prehistoric age. Source: authors.

pre-Historic/Neolithic, Bronze and Iron periods									
18	17	16	15	14	13	12	11	10	Column number
Stair + Salkhsh Southwest Bronze Zabdan palace 1900 B.C.	Sagahat Type Central Bronze Qarvin Dwelling House 2500-3000 B.C.	Baba Jan Type West Bronze Lorstan cave 2400 B.C.	Stair + Salkhsh Southwest Bronze Zabdan Dwelling House 2600 B.C.	Tepe Hissar Northeast Bronze Eranjan Hurd building 2600 B.C.	Tepe Yahya Central Bronze Kerman Dwelling House 3300 B.C.	Tepe Hissar Southwest Neolithic and Recent Dwelling House 3300 B.C.	Godin Type West Neolithic and Recent Dwelling House 3500-2900 B.C.	Tepe Hissar Northeast Neolithic Dwelling House 3900 B.C.	Shims Area Period Location Type of Building Age Serviced Structure Form of Buttress Position of the Buttress in building Position of the Buttress in Serviced Structure Material and Mortar Size in place (CM ²) Technology Ornaments Function
Confining Walls of building Caisson Walls Outside the building Behind of the wall with the different distance Adobe completely separate and without facing Without ornaments Structural Function	Outside the building Discontinuous along the Wall Adobe Concurrent with construction of the building Painted with red and white color Structural Function	Inside the building At the Distance of 20 Cm Adobe 150 × 50 the building Structural Function	Inside the building Middle and Corner of Walls Adobe 40 × 10 × 10 Without ornaments Structural Function	Inside and corner of the building Inside and corner of the building Adobe 75 × 65 completely separate and without facing Structural Function	Inside the building Corner of Walls Adobe 30 × 13 × 15 Without ornaments Structural Function	Corner of Walls Corner of Walls Adobe 170 × 76 Without ornaments Structural Function	Outside the building Behind of the wall with the different distance Adobe 260 × 90 Without ornaments Structural Function	Outside the building Different Adobe completely separate and without facing Without ornaments Structural Function	Picture Source
(Tucci(1977, 80) and (Sajadi)2005, 66:68)	(Tajiri)2009, 136	(Gaff)1976, 1-10 (Gaff)1976, 19-43	(Tucci)1977, 80 (Boughra)1977, 211	(Dyson)1972, 243	(Aghajadid et al., 2005, 123)	(Dyson)1972, 18)	(Aghajadid et al., 2005, 75-96)	(Dyson)1972, 38) and (Schmidt)2008, 20,22)	

Table3. The Buttress of historic age. Source: authors.

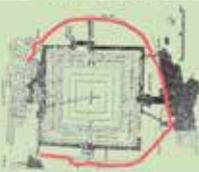
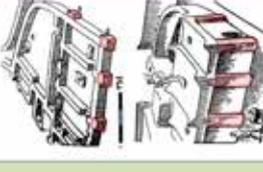
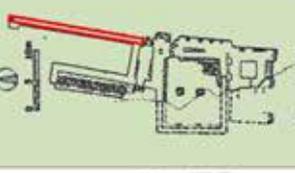
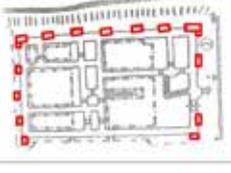
Historic Age (Iran, Media, Seljuqid, Achaemenid, Sassanid)									
Column number	1	2	3	4	5	6	7	8	9
Site	Chap-e Zohab	Chap-e Zohab	Chap-e Zohab	Chap-e Zohab	Chap-e Zohab	Chap-e Zohab	Chap-e Zohab	Chap-e Zohab	Chap-e Zohab
Area	Southwest	Southwest	Southwest	West	central	Northwest	North	Northwest	Northwest
Period	Historic (Elam)	Historic (Elam)	Historic (Elam)	Historic (Elam)	Historic (Elam)	Historic (Elam)	Historic (Elam)	Historic (Elam)	Historic (Elam)
Location	Khuzestan	Subh, Khuzestan	Subh, Khuzestan	Malayir	Kashan	Orumiyeh	Bandar Turkman	Orumiyeh	Orumiyeh
Type of Building	Tomb	Temple	Temple	Dwelling House	Dwelling House	Dwelling House	Dwelling House	Walls of houses	Walls of houses
Age	1375 B.C.	1265 B.C.	1263 B.C.	1390 - 1000 B.C.	1100 B.C.	1100 B.C.	800 B.C.	790 B.C.	790 B.C.
Service Structure	Wall	Wall around the building	Ziggurat	Walls of building	Walls of rooms	Wall around the building	Wall around the building	Walls of houses	Walls of houses
Form of Buttress	Rectangular Wall	Rectangular Wall	Prop	Stratified wall	Rectangular Wall	Papil	Papil	Papil	Papil
Position of the Buttress in building	On Both Sides of the Vault	Outside and inside the building	Inside the building	Outside the building	Inside the building	Outside the building	Outside the building	Outside the building	Outside the building
Position of the Buttress in Service Structure	On Both Sides of the Vault	On Both Sides of the Wall	between first floor and middle floor	At the Distance of two meters	Center of Walls	At the Distance of 125 cm	Behind of wall	Behind of wall	Behind of wall
Material and Mosaic	Brick	Adobe	Brick and Adobe	Adobe	Adobe	Adobe	Adobe	Adobe	Adobe
Size in (Plan/CM ²)	38 × 38 × 8	188 × 62	-	42 × 28 × 12	190 × 75	125 × 40	-	77 × 36	77 × 36
Technology	completely separate and without fastening	completely separate and without fastening	completely separate and without fastening	completely separate and without fastening	completely separate and without fastening	completely separate and without fastening			
Ornaments	Without ornaments	Red color	Without ornaments	Without ornaments	Red and white plastering	Incident of the Wall	Incident of the Wall	Incident of the Wall	Incident of the Wall
Function	Structural Function	Structural and ornamental Function	Structural Function	Structural and ornamental Function	Structural Function	Structural and ornamental Function	Structural and ornamental Function	Structural and ornamental Function	Structural and ornamental Function
Picture									
Source	(Nogubhan 1993, 79, 80)	(Ghoshman 1994, 23, 40) and (Zare 2009, 58 - 60)	(Shahman 1984, 32-33)	(Mabrouk 2014, 250)	(Ghoshman 1993, 41-52)	(Young 2013, 5)	(Seyd 2005, 479)	(Dyoon 1972, 48-60)	(Adlzadeh et al. 2005, 285-300)

Table4. The Buttress of historic age. Source: authors.

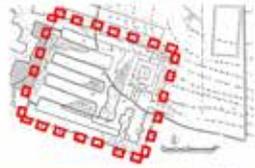
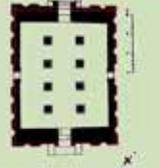
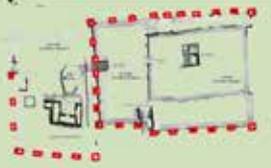
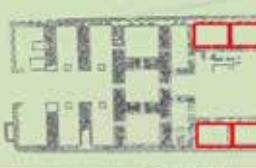
Historic: Agha Elm, Madia, Agha Mahmud, Agha Karim and Susani									
Column number	10	11	12	13	14	15	16	17	18
Sites	Baba Jan Type	Tappe Oskohi	Nau-e Jan Type	Nau-e Jan Type	Tal-Hazeh	Puragad	Mithradatkert Castle	Buro'e Nizozda	Safe Soleyman
Area	West	Central	West	West	Southwest	southwest		southwest	southwest
Period	Historic(Media)	Historic(Media)	Historic(Media)	Historic(Media)	Historic(Achaemenid)	Historic(Achaemenid)	Historic(Ashkan)	Historic(Ashkan)	Historic(Ashkan)
Location	Lecanian	Nauar Abad	Malayer	Malayer	Orumyeh	Shiraz	Nusa	Majd-e Soleyman	Majd-e Soleyman
Type of Building	Kitchens of Servers	Castle	Castle	Temple	Castle	palace	Castle	Temple	Temple
Age	700 B.C.	600 B.C.	600 B.C.	600 B.C.	500 B.C.	500-330 B.C.	173- 163 B.C.	224-250 A.D.	224-250 A.D.
Service Structures	Wall	Wall around the building	Wall around the building	Wall around the building	Wall around the building	Main walls	Wall around the Castle	Wall around the building	Wall around the building
Form of Buttress	Rectangular Wall	Rectangular Wall	Papil	Papil	Papil	Strengthened walls	Papil	Papil	Papil
Position of the Buttress in building	Outside the building	Outside the building	Outside the building	Outside the building	Outside the building	Outside the building	Outside the building	Outside the building	Outside the building
Position of the Buttress to Service Structure	Behind of the Wall	Behind of the Wall	At the Distance of 125 Cm	At the Distance of 160 Cm	At the Distance of 120 Cm	At the Distance of methodical	Behind of the Wall	Behind of the Wall	Behind of the Wall
Material and Mortar	Adobe	Adobe	Adobe	Adobe	Adobe	Stone	Brick	Stone without mortar	Stone without mortar
Size in plan(Cm ²)	400 × 60	42 × 42 × 10	156 × 78	150 × 60	100 × 50			Different size	Different size
Technology	completely separate and without fastening	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building
Ornaments	Without ornaments		Islet of the Wall and rood ornamental	Islet of the Wall and rood ornamental	Without ornaments	Islet of the Wall	Islet of the Wall	Islet of the Wall	Islet of the Wall
Function	Structural Function	Structural and ornamental Function	Structural and ornamental Function	Structural and ornamental Function	Structural and ornamental Function	Structural and ornamental Function	Structural and ornamental Function	Structural and ornamental Function	Structural and ornamental Function
Picture									
Source	(Goff 1976, 1-18) 3 (Goff 1976, 19-41)	(Mollabadi2014, 280) and (Aljafarid2016, 79)	(Stromach 1978, 1-28) and (Stromach 1968, 77-86) and (Mollabadi2014, 110-125)	(Stromach 1978, 1-28) and (Stromach 1968, 77-86) and (Mollabadi2014, 110-125)	(Dyson1968, 39-58) and (Dyson1972, 48-60)	(Zare2009, 85)	(MohammadiFar2009, 136) and (Piriz2008, 100)	(Salari2014, 55-60) and (MohammadiFar2009, 133)	(Salari2014, 69-77) and (MohammadiFar2009, 136)

Table5. The Buttress of historic age. Source: authors.

Historic Age(Iran, Media, Achenmenad, Achahead and Sassani)									
Column number	27	26	25	24	23	22	31	20	19
Historic Age(Iran, Media, Achenmenad, Achahead and Sassani)	Northwest	Northwest	West	West	South	South	South	South	West
Area									
Period	Historic(Sassani)	Historic(Sassani)	Historic(Sassani)	Historic(Sassani)	Historic(Sassani)	Historic(Sassani)	Historic(Sassani)	Historic(Sassani)	Historic(Sassani)
Location	Takht-e Soleyman	Takht-e Soleyman	Khorsro Palace	Khorsro Palace	Sarvestan	Qaleh Dokhtar Palace	Caspian palace	Arashdar Palace	Qaleh Yazd/Gard
Type of building	Palace	Palace	Palace	Palace	Palace	Palace	Palace	Palace	Quar e Shirin
Age	600 A.D.	600 A.D.	600 A.D.	600 A.D.	300-500 A.D.	350-600 A.D.	300-500 A.D.	224-241 A.D.	100-200 A.D.
Structural structure	Wall around the building	Wall around the building	Dome	porch	Dome	porch	porch	porch	Wall around the building
Form of Buttress	tower	tower	vault	vault	vault	vault	Walls	vault	tower
Position of the Buttress in building	Outside the building	Outside the building	On Both Sides of the Dome	On Both Sides of the Porch	On Both Sides of the Dome	On Both Sides of the Porch	On Both Sides of the Porch	On Both Sides of the Porch	Outside the building
Position of the Buttress in Serviced Structure	At the Distance of 10-70 Meters	At the Distance of 10-70 Meters	On Both Sides of the Dome	On Both Sides of the Porch	On Both Sides of the Dome	On Both Sides of the Porch	On Both Sides of the Porch	On Both Sides of the Porch	At the Distance of 15 to 25 Meter
Material and Mortar	Stone and Brick	Rubble and stone	Rubble	Rubble	Rubble	Rubble	Rubble and Brick	Rubble	Rubble
Star in plan (m ²)		tower with diagonal 7.37 meter						1783 * 928	tower with diagonal 4 to 8 meter
Technology	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building	Concurrent with construction of the building				
Ornaments	Without ornaments	Without ornaments					plastering	Without ornaments	Without ornaments
Function	Structural Function	Structural and ornamental Function	Structural Function	Structural Function	Structural Function	Structural Function	Structural Function	Structural Function	Structural Function
Picture									
Source	(Der Oshin and Naiman 1959, 82)	(Der Oshin and Naiman 1959, 70)	(Pezza2008, 129)	(Pezza2008, 129)	(Popo2007, 99)	(Zandi Rob Kermani2001, 22-30)	(Prima2008, 121)	(Abdusadeh et al. 2005, 401-418)	(Abdusadeh et al. 2005, 371-388) And (Kazali1996, 132-133)

observable (Ibid: 121); or in Godin Tepe, the face of external walls of hall, store houses and other parts of the building are completed with towers and buttresses (Ibid: 186); also, according to professor Negahban in his exploration attempts, the external supports in TepeZagheh are placed behind the walls as adjunct; for example, in the painted building of the site, some of these supports are built in a very large size especially along with western and southern walls which lack any other types of support. Except for the rest of the walls, 4, 2, and 4 of these independent supports have been built along with southern, western and northern walls respectively with no clear relevant situation for eastern walls. The largest of the aforementioned supports are seen in the western walls with about 89 cm long and 46 cm diameter (Negahban, 2006:364). The similar cases in this connection are witnessed, based on tables 1 and 2, in the sites of Sang- e Chakhmaq (column 1), BozordeTepe (column 2), TepeZagheh (column 3), Chogha Mish (column 4), TepeZagheh(column 5), YanikTepe(column 6), Tal- e Eblis(column 8), TepeHissar(column 10), Godin Tepe(column 11), SegzabadTepe(column 17), Shahr- e Sukhteh(column 18), and according to tables 3-5 in TipiAhar Tomb (column 1), ChogaZanbil(column 2), GunsyanTepe(column4), Tal-Hasanlu(columns 6, 8,&14), ItinTepe (column 7), Bastam(column 9), Baba Jan Tepe(column10), TappeOzbaki(column 11), Nush- e Jan Tepe (columns 12&13), Pasargadae Palace (column 15), Mithridates Fort (column16), BardeNeshandeh(column 17), MasjedSoleyman(column18), QalehYazdiGird(column19), Ardeshir Palace (column 20), tesiphon palace ruin (column 21), QalehDokhtar Palace column 22), Sarvestan (column 23), Khosrou Palace (columns24&25), Takht- e Soleyman (columns26&27) of which the diagram is shown in figure 2.

2. Outside the building, at the joint of two walls (walls' corner)

A sample of this type is demonstrated in table 1 related to the sites of TepeZagheh (column 5) of which the diagram is shown in figure 2. According to Negahban (2006: 364), the external supports in

TepeZagheh were built as dwarf walls behind the main walls adjunct at the joint of two walls of a room and protected the wall against falling. The length of these buttresses differs in terms of height of the wall and their functions.

3. Inside the building, discontinuous along the wall
In this connection, prominent profiles such as Baba Jan Tepe can be noted in which, according to Mollazadeh (2014: 211) in his book titled Median archeology, they can be observed obviously in the side rooms of the hall (western and eastern rooms); decorative buttress in interior face is among the architectural features of these two rooms. This is while this type of buttress has been used in this era only in exterior face of buildings. The similar cases in this connection based on tables 1 and 2 could be seen in TepeZagheh (column 5), Tal- e Eblis (column 8), TepeYahya (column 9), Shahr- e Sukhteh (column 15), Baba Jan Tepe (column 16). The sites under study lack this type of buttress in historical periods. Figure 2 demonstrates the diagram of the aforementioned type.

4. Inside the building, at the joint of two walls (walls' corner)

The prominent example of this type could be seen in TepeZagheh; according to Negahban (2006: 364), in the painted temple in TepeZagheh, these types of support are designed to strengthen more the "joint of walls" at the interior corner and joint of walls. Within the temple building, there are five interior supports of which the largest ones are observed at northeastern corner. Although this support is built close to the wall, it is built in a way to have distance from one another and is not built as a masonry bond. The length of this support is 130 in the north-south direction and its width is 67cm in the east-west direction. There are two interior supports in the southern adjunct room including one in northeastern corner with the size of 28×95 cm and another in western corner with the size of 30×67 cm. in the southwestern site of the temple, there are two supports at the south interior corners of which the largest is of 59×61cm size and another with the size of 31×43 cm. other relevant

examples are seen, based on tables 1 and 2, in Chogha Mish (column 7), Tal- e Eblis (column 8), TepeYahya (column 13), TepeHissar (columns 12&14), Shahr- e Sukhteh (column 15), and given table 3, the sites of Sialk (column 5) of which the diagram is illustrated in figure 2.

According to the investigations, the executive position of buttress which is used most dependent to its position is associated with the first situation, i.e. outside the building, discontinuous along the wall. Approximately 70% of the aforementioned buildings were acquired the same state for using buttress; this indicates that over the time, architects have been more informed of the high thrust force in confining walls of buildings, so that Papil shapes were used commonly during the historic period.

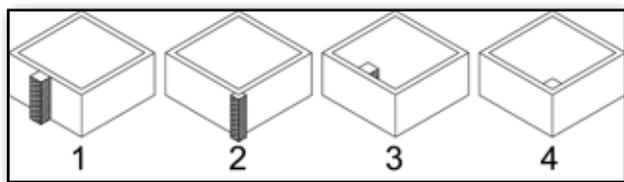


Fig. 2. Types of buttress in terms of position. Source: authors.

Types of buttress in terms of form and shape

A number of classes could be considered for buttresses in terms of form and shape in different periods, including:

1. Walls of rectangular cubes volume with square or rectangular plan elongated parallel to the main wall directly from the ground to the height of the wall or less than it; they are such as columns or half-columns attached to the wall, receiving forces from the wall and conducting it to the ground. A number of examples of this type, as shown in tables 1 and 2, are observed in Sang- e Chakhmaq (column 1), Chogha Mish (column 7), Tal- e Eblis (column 8), TepeYahya (columns 9 &13), TepeHissar (column 12), Shahr- e Sukhteh (column 15), Baba Jan Tepe (column 16), and in tables 3-5, in the sites of ChogaZanbil (column 2), Sialk (column 5), Tal-Hasanlu (columns 6, 8 &14), Bastam (column 9), Baba Jan Tepe (column 10), Nush- e Jan Tepe (columns 12 & 13), Pasargadae Palace (column 15), Mithridates Fort (column 16),

BardeNeshandeh (column 17), MasjedSoleyman (column 18), and QalehDokhtar Palace (column 22). The relevant diagram of these types of buttress is demonstrated in figure 3.

2. Walls with rectangular plans in different volumes which are elongated perpendicular to the main wall. According to tables 1 and 2, these kind of walls are observable, in TepeZagheh (column 5), YanikTepe (column 6), Godin Tepe (column 11), and TepeHissar (column 12) of which the diagram is illustrated in figure 3.

3. Walls which are built with the same height of the main wall and parallel to it (as additional wall), such as the dwelling house in TepeZagheh. According to MalekShahmirzadi (1992: 7), “in this house, there is an additional wall adjacent to the main wall which most probably plays the role of a support”. Another example of this type could be seen in Sialk area (table 3, column 5). Figure 3 shows the diagram of this type of buttress.

4. Walls of stratified structure which are built with combination of square, rectangular and circular plans such as the Papil shapes in GunsyanTepe. According to Mollazadeh (2014: 248), “west room with the size of 60/3×60/21 m, has buttresses in its west wall which are put with a distance of 2 m from each other”. The type of these buttresses is different from that of Nush- e Jan Tepe and Godin Tepe, and is comparable to the type of Pasargadae Palace. Another example of this type is seen as a stratified structure with the combined form of rectangular and circle which could be observed in elephant's foot shapes of Ardeshir Palace.

5. Cylindrical or cone-shaped towers such as the sites presented in table 5 including Takht- e Soleyman (column 26) and QalehYazdiGird (column 19), as is shown in figure 3.

6. Caisson arrangement, such as the painted temple in TepeZagheh. According to Negahban (2006:365), “one of the most important buttresses of the painted temple is the type of caisson. In order to build this support, a wall is constructed outside the building parallel to the north wall of the temple. From this

wall, with one meter distance from the main wall, a number of supports are connected to the back of the north wall, creating a caisson-like space". Other examples of this type are seen within the sites mentioned in tables 1 and 2 in YanikTepe (column 6) and Shahr- e Sukhteh (column 18). The relevant diagram is demonstrated in figure 3.

7. Broad wall on the both sides of vault of the height higher than vault, such as TipiAhar Tomb in table 3, column 1, as is shown in figure 3.

8. Nave walls, as the most advanced types of buttress of the period. Building very broad walls like the simple shape of 7. This is costly and uneconomical, and takes up a lot of land around the arch. This problem was salvaged via its optimization and creation of an arch and an open space within massive walls of which the diagram is shown in figure 3. This type could be found in the works associated with historical and Sassanid periods. The examples of this type could be observed in table 5 in Ardeshir Palace (column 20), Sarvestan (column 23), Khosrou Palace (columns 24&25), Takht- e Soleyman (column 27), and Ctesiphon palace ruin (column 21). According to Pirnia (2008: 121), corridors are built on the both sides of Ctesiphon palace ruin.

On the form and shape of buttresses, 70% of the buttresses discussed in this study included in the state 1 which are used in the form of Papil shapes. This shows usage of this element with regular layout along the wall which had won attention of architects since the Median period and has been used as a structure or ornament. Circular and elliptical plans are seen as well as square and rectangular which indicates the importance of aesthetic principles in buildings. The examples of 4 and 5 are included in this type. The singular or compound usage of these plans has been prevalent as discussed earlier as stratified structures. The example 5 shows the strength wall with an elliptical shape in lower parts of which the volume decreases in upper parts, such as Takht- e Soleyman and QalehYazdiGird towers. This suggests that architects were informed that "the strength wall may have more strength and durability

if it is headed to the wall it must rely on. Since the masonry mass was not useful in lower part of the buttress, it is moved to the upper part of the cone to increase the strength" (Shuwazi, 2007: 341). The advanced example of buttress is nave walls form which, holding the main vault, conducts the forces to the ground and preserves the balance of the building. According to Huerta (2001: 47), it is the geometry that has provided this balance and safety and made building of safe masonry structures (balanced buildings) possible. We can claim that classical principles for designing of buttress and masonry arches are geometric; since they define certain ratios among structural elements (e.g. the thickness of the buttress is a fraction of vault's mouth).

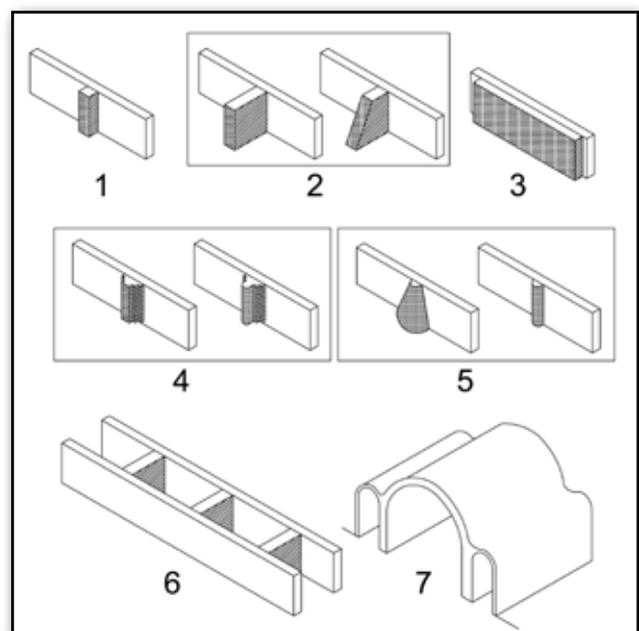


Fig. 3. Types of buttress in terms of form and shape. Source: authors.

Types of buttress in terms of employed material

The material employed in buttress in the studying sites is consistent with that of the main building, since homogeneity of buttress and the main pier contributes highly to stability of load bearing components of the structure. Due to shortage of wood and stone materials in Iran, usage of soil in different forms such as clay wall, adobe and brick have been widely common for building of buttresses. However, stone materials are used more during

historical periods, especially from Achaemenid onwards, and in monumental architecture such as using of rotten stone in the architecture of Pasargadae Palace. During Sassanid period in which nave walls buttresses became prevalent and given that the mold plays key role in execution of vault and has limited load bearing strength, and the importance of rapid hardening of the mortar, plaster was used widely as the mortar. Some used materials are shown in figure 4.

Types of buttress in terms of executive technique

Architects have acquired different execution techniques via analysis of the needs of residents and the environment, during their trainings and experiences, and employed them in construction. Understanding buttress execution technique is important since it sheds light on the repairing role of buttress in structures of the studying periods. The aforementioned technique is categorized in two groups of “completely separate and without fastening”, and “concurrent with construction of the building”. The first technique is observed

in prehistoric cases as indicated in tables 1 and 2, including Sang- e Chakhmaq (column 1), BozmordeTepe(column 2), TepeZagheh(columns 3&5), YanikTepe(column 6), and Chogha Mish (column 7), , while the latter method is seen in historical sites, as shown in tables 3-5, including ChogaZanbil (columns 2&3), GunsyanTepe(column 4), Sialk(column 5), Bastam (column 9), Nush- e Jan Tepe (columns 12&13), Khosrou Palace (columns 24&25), Takht- e Soleyman (columns 26&27).

Types of buttress in terms of ornament

With advancement of architecture and higher awareness of execution techniques of buildings, especially with development of monumental architecture, the aesthetics of structures became significant gradually for human beings. Usage of paint was a common ornament in buildings; colors such as ocher, yellow, black, red, plaster, clay lime plaster. These types of ornaments could be considered in some buttresses, especially those executed in elephant's foot shape. In this connection,

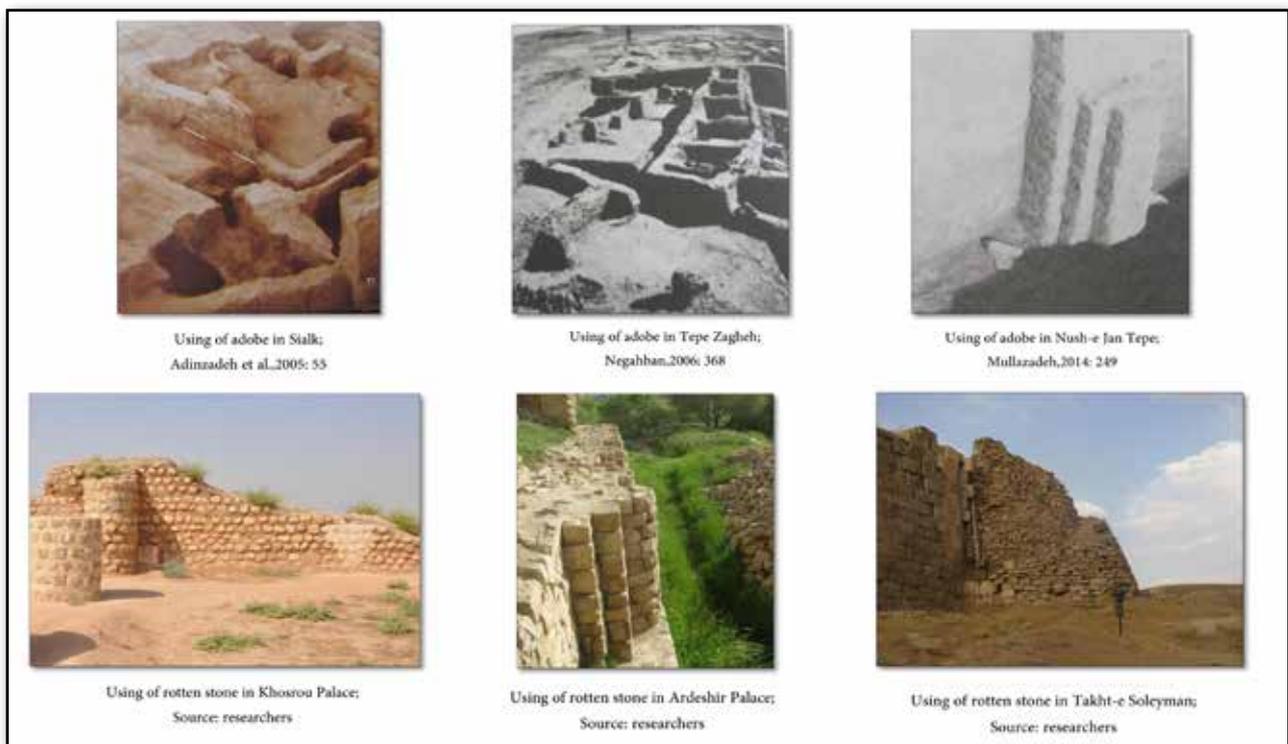


Fig. 4. Used materials in buttress. Source: authors.

other ornament cases could be noted as examples, as Stronach (1978: 110) states on Nush- e Jan Tepe that “the exterior fence of buildings in Nush- e Jan Tepe is completed with buttresses of carved upward arrow like designs” (Fig. 5); or the buttresses of Takht- e Soleyman (towers of the exterior fence), as is illustrated in figure 5, have cornice ornaments with stone material as stretching header.

Types of buttress in terms of technical function

Given the available evidences and information, two functions are identified for buttress within the designated time span; structural function and structural-ornamental function. In the early stages of the emergence of buttresses, the structural work has been dominant while decorative function is added in the later development and evolution trend. Tables 1-5 illustrate the relevant examples.

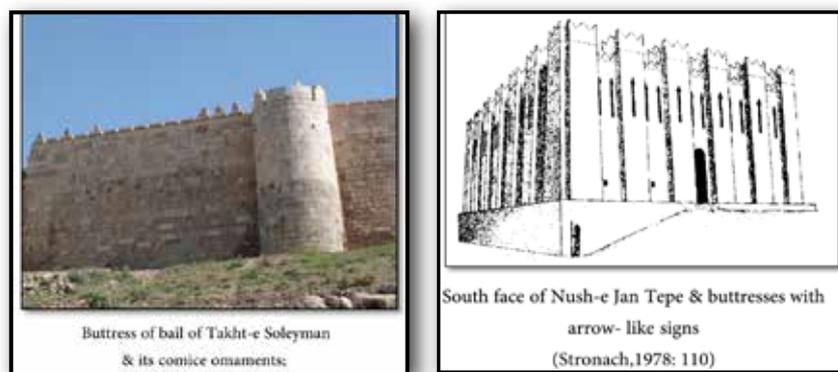


Fig. 5. Example of buttress ornaments. Source: authors.

Conclusion

Considering the features of Neolithic era, buttress could be considered as an element of this period that is likely to enter in the field of architecture with repairing role (case study: table 1). Since buttress has been created separately without any masonry bond with the main wall of the structure, it could be identified as an adjunct structure to the main building following the damages resulted from the thrust force (tables 1-5, rows of execution technique and usage). The primary types of buttress could be identified in categories of position, form and shape, used material, execution technique, ornaments and technical function. Based on the carried out research, the first buttresses were employed in prehistoric dwelling houses (Neolithic, Eneolithic Age, and Iron Age), mostly at the wall’s corner or center, outside of the building ornament-free in historical period, and outside of the building with regular intervals as Papil (tables 1-5, position rows, buttresses positions, and images). The used material in buttresses in this period was similar to the main material of the building which includes clay wall and adobe in prehistory, and brick and rottenstone and rustic stone in historical periods. With increase of knowledge and information of architects in transition from prehistory to historical periods, the scientific and endurance principles in buttress were used. Among signs of this progress are simultaneous construction of both buttress and building, number of buttresses, and evolution of form, shape and more regular intervals of buttresses (tables 3-5). Arch-like buttresses on the both sides of high porches in Persian and Parthian architectures indicate the architect’s awareness of principles of retrofitting buildings and harness portico’s thrust forces. Construction of thick walls on both sides of the portico is probably a way to control forces, but it is uneconomical and Non-functional. Benefitting from supporting vaults, the architecture has used optimally of the existing space and made effective use of material. Sassanid architecture represented the

most prominent type of buttress in building domes in a way that according to Oscar Reuther, “this was the first interim step taken towards masonry principles of which Gothic architecture could be known as its final realization”.

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