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Reviewing the Bricks Used in The Traditional Architecture with The Shape Grammar Method

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ABSTRACT

The tradition started off as exposing the brick surfaces in the facades later lead to a technique that use the bricks on the facades as ornamental elements by glazing the surfaces of the material. In traditional Turkish architecture, the first examples of this technique can most potentially be found in buildings of early periods of Anatolian Principalities and Anatolian Seljuks. There are mainly two methods of application of exposed bricks: the first is the earlier period examples where surfaces were built in the form of brickworks; and the second is the later period examples where surfaces were built in the form of brick claddings. These different brick facing methods lead to the formation of varying ornamental arrangements. Particularly, the brick facing orders using the concepts of proportion, symmetry and replacement that are derived from the disciplines of mathematics and geometry, are significantly used on facade arrangements and decorations in later periods. One of the methods to determine the rule strings and decipher the design terminology of this brick facing arrangements that are themselves are formed according to a certain ordering system is the shape grammar method. As an order-based method, shape grammar allows to form new design strategies by determining the rules of the existing design terminology. In this study, it is aimed to analyze the brick facing arrangements defining the facade formations via shape grammar method. For that matter, the primary aim is to designate the facade arrangements indigenous to Anatolia.

Keywords: Terracotta, Brick, Brick Facing-Pattern, Shape Grammar.

1. INTRODUCTION

In terms of type, production methods, quality, dimensions and application techniques, construction materials are used within the bounds of possibility of their period [1]. Accordingly, it is known that traditional buildings predominantly benefit from natural and local materials that are used as they are or formed with the least production effort [2]. As a determining factor forming a region's local design terminology, the material choice emerges according to geological structure, flora, topography and climate of a certain region. Predominantly, the materials are distinguished as are found in immediate environment, thus are easier to supply. Terra-cotta and its derivatives as clay-based materials known to be one of the most common construction material used in examples around the globe including most of the pioneer cases of construction history were used in varying cases that are different in their primitive, simple or advanced identities [3]. In this respect, terracotta materials were evaluated as the first construction materials, the form and dimensions of which were determined and produced according to the needs of individuals and regions [4].

When the cases in and close to Anatolia built since the first ages of firstly mud brick, then the brick obtained via baking the mud brick are analyzed, a two-way evolution can be traced: earlier examples using the material as structural, and later examples using it both structural and

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decorative [5]. The pure structural use of brick is observed to emerge and used since in the first settlements where Turks started a settled life in pre-Islamic period including Central Asia, Turkestan and Khorasan. [6], [5]. Aside from its structural use, as its potential to be a visual component when left exposed or glazed was realized, to use the brick as a decorative element on facade ornamentation was brought to the agenda. Bakırer (1981) states that, Ismail Samani Tomb in Bukhara (Figure.1) that was built in 907 according to the gregorian calendar formed the first example of such use. This structure indicates a significant pursuit of an alternative use of bricks by exposing and orderly piling the material.[5].

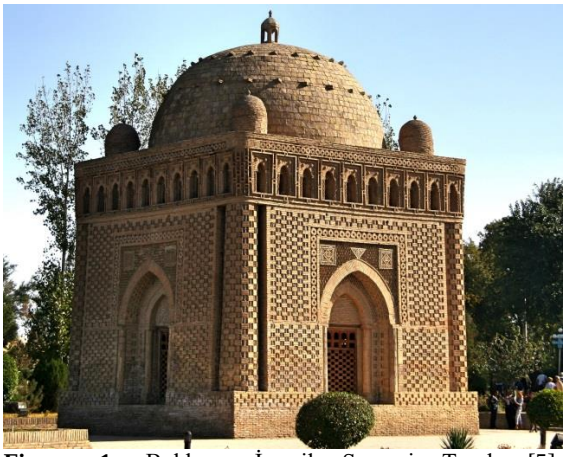


Figure 1. Bukhara İsmail Samani Tomb [5]. (https://gokbenutkun.wordpress.com/tag/ismail-samani-turbesi/)

When the tradition of bare brick structures improving in Turkestan, Khorasan, Gaza and Central Iran in the periods of Karakhanids, Ghaznevids and Great Seljuks completed its evolution, it was transferred to Anatolia as the main material component of Seljuks. [5]. Within this period, the exposed bricks are used as brick facings formed of different alignment orders in some occasions, while in others, the bricks are used as facade ornamentations by glazing the material. The alternative uses of these arrangement techniques caused the emergence of several significant brick pattern orders on the facades. Within the framework of this study, the multiple facade patterns consisted by the changing brick facing arrangements are aimed to be analyzed. These brick facings here claimed to be organized in a specific mathematical and geometrical order are decided to be handled within the boundaries of shape grammar methodology. Thus, this methodology would decipher the design terminology of brick orders that had been formed according to a significant arrangement code in the geography of Anatolia for hundreds of years and would allow creating re-enactment strategies of brick facings as re-appropriated design strategies.

2. THE USE OF BRICK AS AN ORNAMENTAL ELEMENT AND BRICK FACINGS

The brick used as a common construction material in the second half of 12th century in Anatolia, is mentioned to be applied as a structural component in some cases, and as a decorative component in the others. Kuban (2010), while analyzing the examples of brick application, states that in certain cases brick facings are used as structural components on the external surface of a building, while in the exterior, on roof cover and minaret it becomes both a structural and ornamental component [4]. On the other hand, Bakırer (1981) indicates that the brick component used in varying building types as mosques, madrasas, prayer halls, caravanserais, hakinahs, zawiyahs, hospitals and minarets in Anatolia is used as a structural component on walls, windows and door openings, as a load-bearing component on column bases and arches, as a transitional component on trimmers, triquetras and pendentives, as an upper structure component on domes, vaults and squinches, as a minaret component on pedestals, transitional surfaces and minaret bodies, and states that these applications combined shows that the material is used both as a structural and decorative element, and adds furthermore that the brick use as a sole structural component in this period is rarely encountered. Bakırer also states that brick facings are commonly observed to be used as claddings over building's structural components, and there existed a strong relationship between the structural element and brick to be worth-noticing [5].

Brick surfaces are compositionally used in two ways as facings and paddings. Facing methods forms unglazed units shaping geometric brick arrangements on the surfaces, while padding methods forms units arranging the joint spaces between brick units acts as binders [5]. Unglazed brick units used in facing methods is divided into two categories form-wise: module bricks and trimmed bricks. In module bricks, the unit is constant as it can vary as plenary, half, square and minaret units. Padding units, on the other hand, are produced in different sizes and forms according to the geometrical order preferred [7]. Bakırer (1981) classifies structural and decorative application methods of bricks used in Anatolia starting from mid-12th century regarding specifically to the units, shapes and facing methods mentioned above in two types as brick facing and trimmed brick cladding. Within this study, the brick facing arrangements that are identical in the form, but different in facing orders are aimed to be analyzed. The trimmed brick units varying in form as per order are excluded from the framework of study.

2.1. Brick Facings

There exist five parameters defining brick facing orders used in Anatolia, extracted from different sources and determined here by examining those classifications, respectively as brick piling method, brick facing style, shifting ratio, material and joint space ratio.

The main components used in brick facings unit-wise and form-wise form four divisions as plenary, half, small squares and minaret bricks. Brick facings are formed of varying compositions of these four elements lining together in an order, and this order composes the core of facade decorations. These varying brick units lining together is called piling or aligning. In Anatolian Seljukid architecture, the piling methods consists three types as horizontal, horizontal/vertical and oblique [5]. Each piling method consists of an idiosyncratic brick facing order. The horizontal piling is identified with plain facing, while the horizontal/vertical is with v-wave

facing, and the oblique piling with spica facing [5]. Each of these piling methods contains subdivisions regarding the shifting ratio of the bricks, exceptional joint space arrangements and the use of alternative materials [8].

Within this study, the facade arrangements generated by different brick facing sequences regarding the piling method used in these sequences are aimed to be analyzed via shape grammar methodology.

3. SHAPE GRAMMAR

Shape grammar, which is a rule based design method, is the grammar of the forms. With the help of shape grammar; it is possible to figure out a design language, understand it and derive new designs with the same language. The structures of several architects or traditional structuring process of a community were studied with the frame of shape grammars. Such as Palladian villas [9], Frank Lloyd Wright's country houses [10], Queen Anne houses [11], Alvaro Siza's Malagueira Houses [12], Traditional Turkish Houses [13], Sinan Mosques [14]. As the formal analysis of architectural structures might be formulated in shape grammar method, to discover the geometrical patterns, the codes of door/window configurations as well as a recreational settlement would also be possible. [15].

Particularly in the recent years, there emerged a wide range of studies focusing on geometrical patterns in Islamic architecture. Kaplan's Islamic patterns study based on 17 types of symmetry [16], Grunbaum and Shephard's (1992) Interlace patterns in Islamic and Moorish Art articles [17], where they study the symmetry and repetition rules, Shape Grammar studies of Cenani and Çağdaş (2007) where they conducted on the rule sets allowing two- and three-dimensional derivations of Islamic geometries [18] and Birgül Çolakoğlu&et.al. (2008), software proposal in the field of computational design focusing on Islamic geometries and the derivation of star patterns [19] are significant examples of these studies. [15].

Shape grammar is a rule-based designing method producing shape compositions. In shape grammar the starting point is the shape, which, then, allows the methodology to determine the rules of formal transition codes around that starter unit. By applying the rules of these formal transition codes in varying instances, a shape group is consisted. (Figure.2) The idea here is to obtain different patterns derived from the same application rule and from the same formal unit.

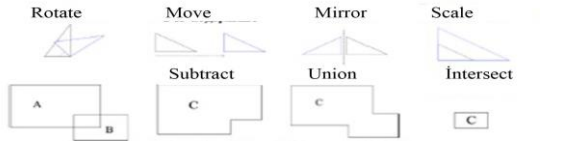


Figure 2. The formal transition codes used in shape Grammar [20].

4. CASE STUDY: ANALYSIS OF BRICK FACINGS WITH SHAPE GRAMMAR

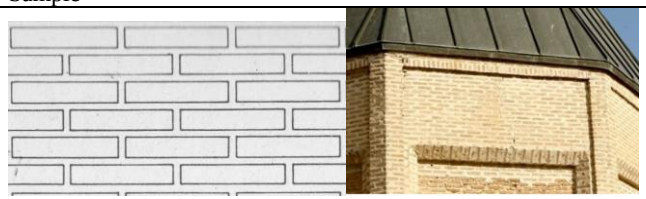
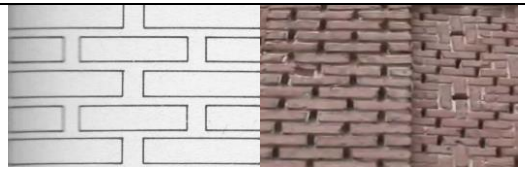
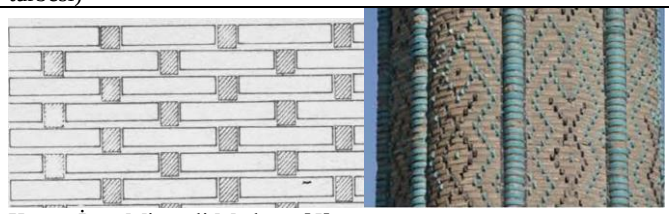
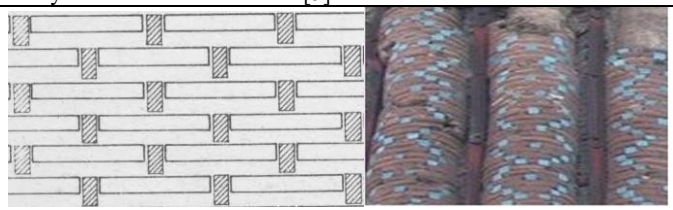
Brick facings are formed by lining brick units during the process of construction. Within this process, it is possible to achieve varying compositions by lining the units in methods of piling, shifting and material changes. In this study, it is aimed to analyze different brick facing arrangements used as a decorative component on the facades in Anatolian Seljuks period via shape grammar method, and eventually to determine the rules of different facing patterns which are extracted from shape grammar analysis. In this respect, firstly a classification of brick facings and general facing orders referring to Bakırer's study of types of brick facings (1981) were made and a general knowledge on the issue was aimed to be developed. All of the facing methods mentioned diversifies in terms of differences in shapes and dimensions, shifting ratios, joint spaces and materials of brick units.

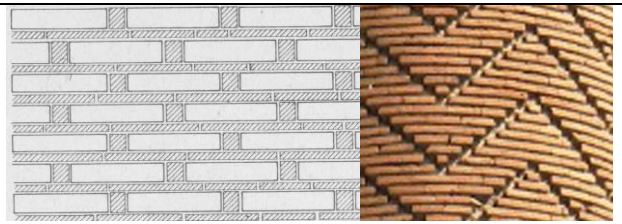
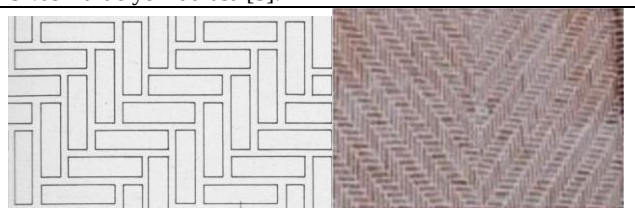
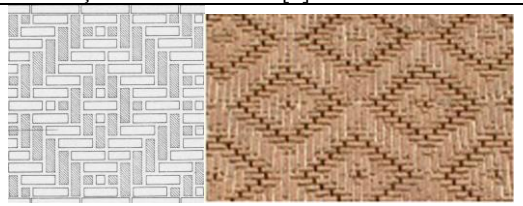
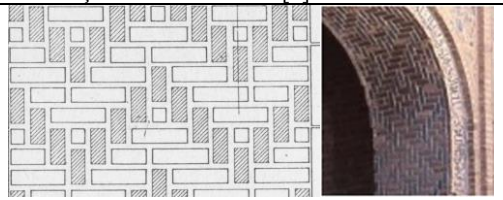
- Horizontal Piling/ Plain Facing: formed of conjoint linings of brick units in horizontal manner and sequential piling in the vertical manner. [5]. In the horizontal piling mostly the unglazed materials are used, while ceramic tiles would also be preferred. The shifting ratio being half the dimension of length of the unit, the shifting method is arranged by shifting 1/4 of the long side at the rate of 1/5 of the unit. The search of a formal diversity can be observed in this method as the varieties between joint spaces as well as in materials are recognized (Table 1).

- Horizontal-Vertical Piling/ V-Wave Facing: formed by piling of brick units both in horizontal and vertical directions [5]. In this facing method, the patterns material-wise are formed by the use of either the unglazed bricks alone, or the conjointly composed unglazed bricks with ceramic tiles; piling-wise half-sized or full-sized bricks are used as both vertical and horizontal units. The shifting ratio between units are constant while the shifts change directions in certain lines and small joint spaces are commonly preferred. The search of a formal diversity can also be observed in this method as the brick units creates a dynamic surface both by shifting and rotating on the surface (Table 1).

- Oblique Piling/ Spica Facing: formed by arranging brick units with an angle of 45 degrees both in horizontal and vertical directions. [5]. In this facing method, generally the plenary units are used. By using glazed brick units with unglazed ones material variety are aimed to be achieved. There are no existing shifts in the pattern, no joint space varieties. The formal variety is only achieved through the use of different materials together (Table 1).

Table 1. Types of Brick Facings [5].

Stack type	Weave type	Weave type	Sliding ratio	Grout gaps	Materials	Sample
Horizontal	Plain	Plain	1/2	thin	unglazed brick	 [5]. Tomb [5]. (http://www.erzincan.gov.tr)
Horizontal	Plain	Plain	1/2	thick	unglazed brick	 Pınarbaşı Melik Gazi Tomb [5]. (http://www.kayseri.gov.tr/melikgazi-turbesi)
Horizontal	Plain	Plain	1/2	thin	unglazed brick and ceramic tiles	 Konya İnce Minareli Madrasa [5].
Horizontal	Plain	Plain	1/4- 1/5	thin	unglazed brick and ceramic tiles	 Erzurun çifte minareli Madrasa [5].

Horizontal	Plain	Plain	1/4- 1/5	different materials used in joint spaces	unglazed brick and ceramic tiles	 Sivas Buruciye madrasa [5].
Horizontal-vertical	v-wave	half bull nose	1/2	thin	unglazed brick	 Pınarbaşı Melik Gazi Tomb [5].
Horizontal-vertical	v-wave	half bull nose	1/2	thin	unglazed brick and brick units in different color	 Pınarbaşı Melik Gazi Tomb [5].
Horizontal-vertical	v-wave	half bull nose	1/2	thin	unglazed brick	 Malatya Great Mosque [5].
Oblique	spica	Herringbone	1/2	thin	unglazed brick	 Pınarbaşı Melik Gazi Tomb [5].

The second stage of analysis aims to examine the evolution of different brick facing methods through shape grammar. Through examples specifically formed according to different brick facing methods, the evolution of the patterns will be analyzed. According to this;

• Horizontal Piling/ Plain Facing method is determined to have three individual evolution processes. The first consists of patterns formed by shifting and repetition of brick units identical in size, however compositionally vary in joint space differences. The second consists of patterns formed of half- and whole-square brick units composed together. In this process, the patterns can be formed by changing the shifting ratio or using the symmetry, unlike the first group. The last group consists of patterns where whole-, half- and square-bricks, or square-bricks and ceramic tiles are used together and by shifting each unit on each other it uses the materials much like joint space components (Table 2)

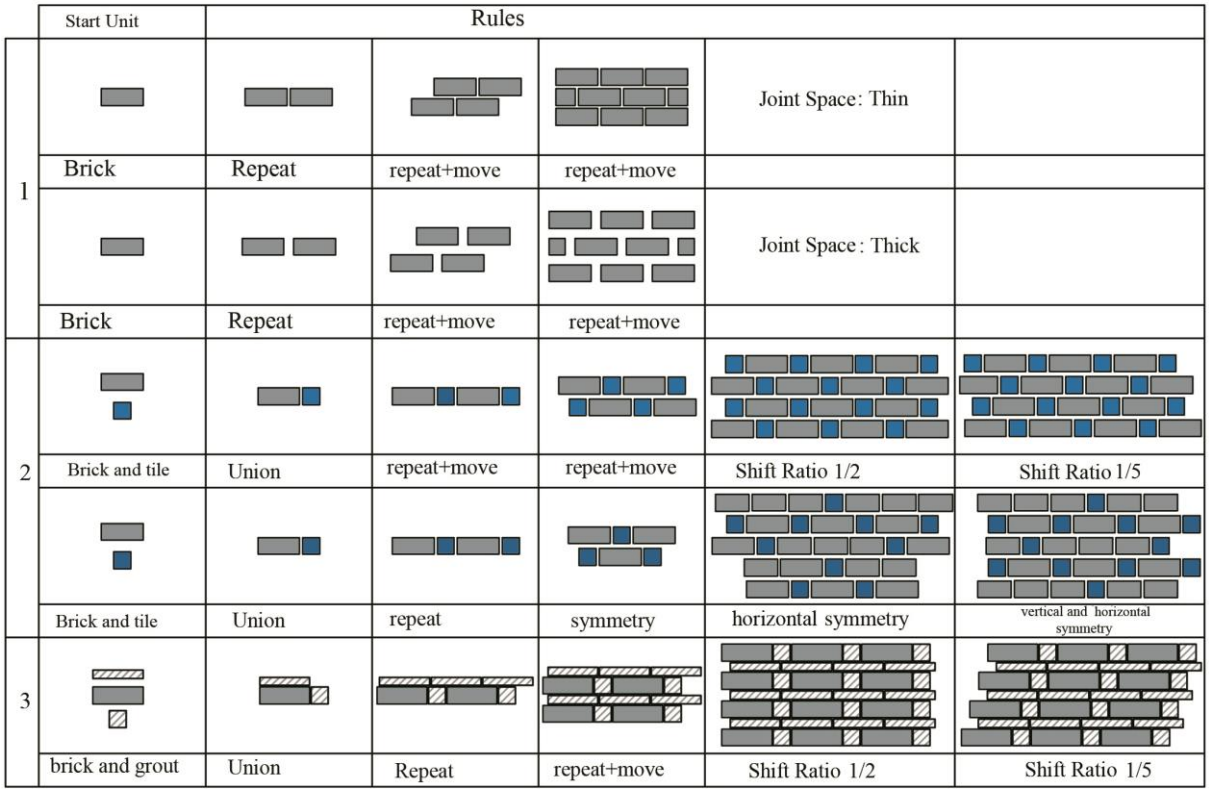


Table 2. The Shape Grammar Analysis of Horizontal Piling / Plain Facing Arrangement

• In Horizontal-Vertical Piling/ V-Wave Facing method, on the other hand, two alternative evolution process can be observed. The first process consists of patterns formed by the use of whole- or whole and half brick units together. In this alternative, there exist three different orders. The first order is formed by lining the identical units in horizontal and vertical directions, so that they compose rotation and repetition; and the second order is formed by piling whole- or whole and half brick units in v-wave method, so that they compose plenary repetition and proportional changes; and the third order is formed by using brick units different in size, so that they compose proportional changes as well as symmetry.

The examples of the second process, on the other hand, consist of whole-and-square or square brick-and-square ceramic tiles used together. In this alternative, there also exist three different orders. The first order is formed by diagonal lining of whole- and square-brick units so that they compose diagonal symmetry and repetition; the second order is formed by piling of whole- and square-brick units in v-wave method so that they compose rotation, shifting and vertical repetition; and third order is formed by piling of whole- and square-brick units in v-wave method so that they compose rotation, shifting and both horizontal and vertical repetition. (Table 3)

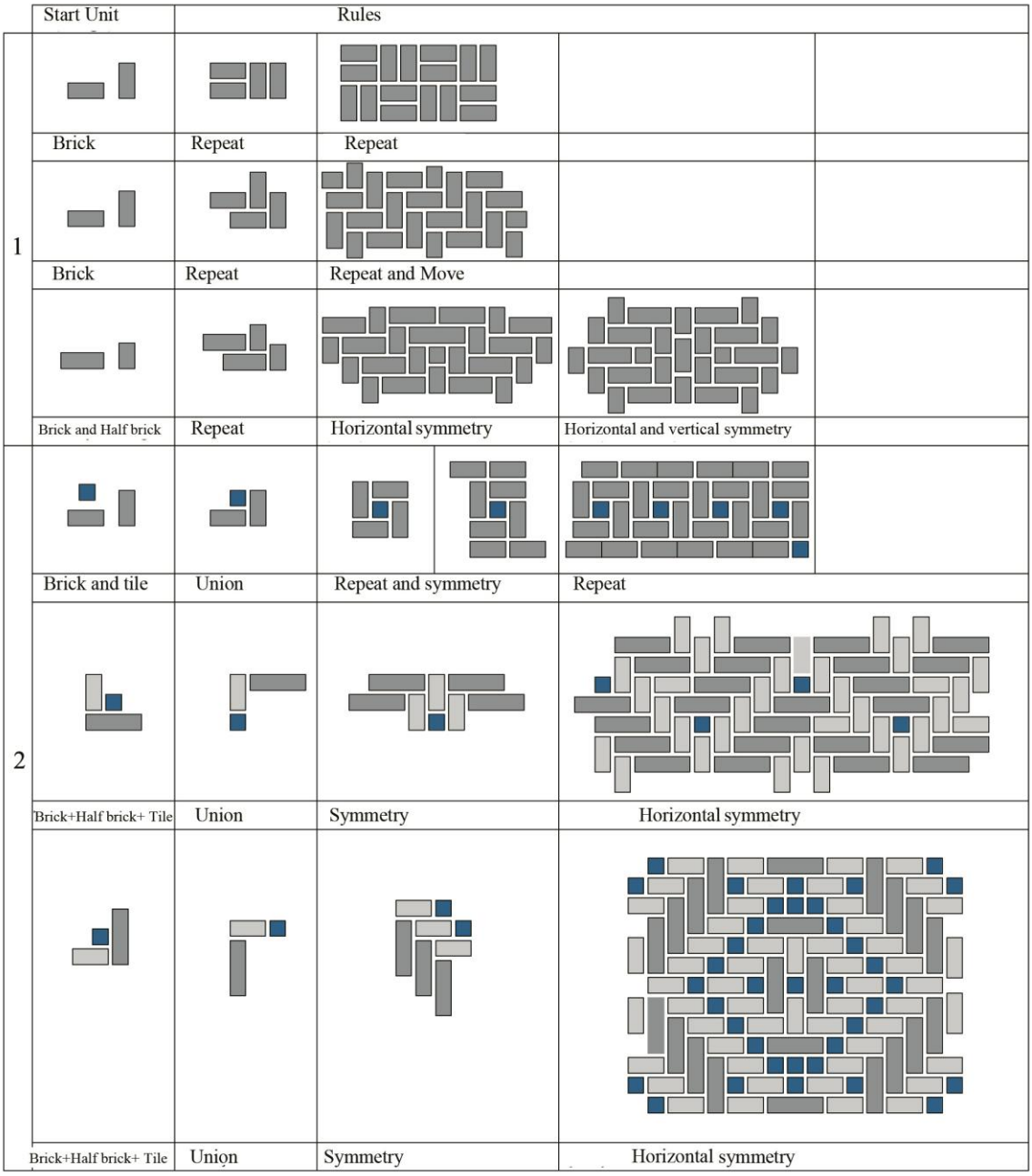


Table 3. The Shape Grammar Analysis of Horizontal-Vertical Piling/ V-Wave Facing Arrangement

• Oblique Piling/ Spica Facing method do not follow any rules besides that brick units arranged in an angle of 45 degrees. (Table 4).

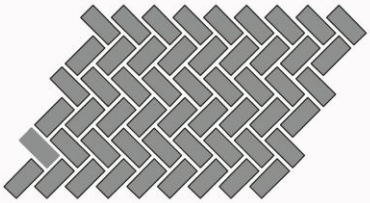
	Start Unit	Rules		
1				
	Brick	Repeat	Rotate	Repeat

Table 4. The Shape Grammar Analysis of Oblique Piling/ Spica Facing: Arrangement

5. EVALUATION AND CONCLUSION

Although the brick facing arrangements achieved through different piling applications of brick facings were used to solidify architectural structures in earlier stages, they then used as decorative elements as design perceptions have changed to leave the material exposed on facades. Through the material's evolution process, the search for different formal arrangements reflecting as alternative proportions, aspects and directions design orders on facades had emerged.

When the cases included in this study which are traditionally suitable for their brick facing methods are analyzed, it can be indicated that in horizontal piling cases one can more potentially encounter to repetition, varying shifting ratios, differences in joint space dimensions and symmetry; while in horizontal-vertical piling cases it is more likely to encounter rotation, shifting, joint space differences due to the use of different materials together and especially symmetry. In oblique piling, on the other hand, the evolution process is barely noticed. Other than this fact, the potential of the method lies in its search for alternative forms by using varying materials like ceramic tiles are used together with brick units.

As a result; the rules of the Islamic geometry used in facade ornamentation in Islamic architecture, also apply for the brick facing arrangements. The rules of rational variation, symmetry and the tradition of producing designs with non-orthogonal angles are also applied in brick facing patterns. As a result of the analysis conducted; a wide range of end results are obtained via the use of brick units of identical design terminology and shape, and with the permutation rules based on a similar algorithms. This result is an indicator for the fact that the existing rules of composition may form guidelines for new design strategies.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

[1] Aydın, D., "Bina Bezeme Malzemelerinin Uygulamadaki Konumu ve Yitirilen Görsel Kalite", 2. Ulusal Yapı Malzemesi Kongresi ve Sergisi Bildiriler kitabı, YapKat, İstanbul, 5, (2004).

[2] Lloyd, S., Building in Brick and Stone, History Of Tecnology, Oxford, 456, (1956).

[3] İzgi, U., Mimarlıkta Süreç, Kavramlar, İlişkiler, YEM Yayınları, İstanbul, 104,105, 182, (1999).

[4] Kuban, D., Mimarlık Kavramları, YEM Yayınları, İstanbul, 36, (2010).

[5] Bakırer, Ö., Selçuklu Öncesi ve Selçuklu Dönemi Anadolu Mimarisinde Tuğla Kullanımı (Cilt 1-2), ODTÜ yayınları, Ankara, 1, 3,5, 9, 21, 24, 35, 36, 53, 63, 117, 148, 159, (1981).

[6] Cezar, M., Anadolu Öncesi Türklerde Şehir ve Mimarlık, Türkiye İş Bankası Kültür Yayınları, İstanbul, 16, 1977

[7] Tayla, H., Geleneksel Türk Mimarisinde Yapı Sistem Ve Elemanları (Cilt1-2), Türkiye Anıt Çevre Turizm Değerlerini Koruma Vakfı Yayınları, İstanbul, 507, (2007).

[8] Bakırer, Ö., "A Study on The Use of Brickbonds in Anatolian Seljuk Architectyure", M.E.T.U. Journal of the Faculty of Architecture, Fall 1980, 20(2), 148, (1980).

[9] Stiny G., Mitchell W. J., "The Palladian Grammar", Environment and Planning B, 5(1), 5 – 18, (1978).

[10] Köning H., Eizenberg J., "The Language of the Prairie: Frank Lloyd Wright's Prairie Houses", Environment and Planning B, 8(3), 295-323, (1981).

[11] Flemming, U., "More Than The Sum of Its Parts: The Grammar of Queen Anne Houses", Environment and Planning B, 14, 323-350, (1987).

[12] Duarte, J. P., "Towards the Mass Customization of Housing: The Grammar of Siza's Houses at Malagueira", Environment and Planning B, 32, 347 – 380, (2005).

[13] Çağdaş, G., "A Shape Grammar: The Language of Traditional Turkish Houses", Environment and Planning B, 5, 443-464, (1996).

[14] Şener, S. M., "A Shape Grammar Algorithm and Educational Software to Analize Classic Ottoman Mosques", A|Z Journal of Faculty of Architecture, Spring 5(1), 12-30, (2009).

[15] Ulu, E., "İslami Geometrik Örüntü Türetimi Amaçlı Bir Biçim Grameri Modeli", Ms.C. Thesis, İTÜ, Instute of Natural and Applied Science, İstanbul, 5-10, (2009).

[16] Kaplan, C. S., "Computer Generated Islamic Star Patterns", Bridges 2000 Proceedings, (2000). (http://www.cgl.uwaterloo.ca/~csk/)

[17] Grünbaum, B., Shephard G. C., "Interlace patterns in Islamic and Moorish Art", Leonardo, 25, 331–339, (1992).

[18] Cenani, Ş. ve Çağdaş, G., "A Shape Grammar Study: Form Generation with Geometric Islamic Patterns", 10th Generative Art Conference GA, (2007).

[19] Çolakoğlu, B., Yazar T., Uysal, S., "Educational Experiment on Generative Tool Development In Architecture PatGen: Islamic Star Pattern Generator", Architecture in Computro 26th eCAADe Conference Proceedings, 685-691, (2008).

[20] Özen Yavuz, A., "Çağdaş Konut Örneklerinin Morfolojik Analizi ve İşlemsel Tasarım Ortamında Üretimine Yönelik Kavramsal ve Deneysel Bir Model Önerisi", Ph. D. Thesis, Gazi University, Instute of Natural and Applied Science, Ankara, (2011)