Sinan's Screens: Networks of Intersecting Polygons in Ottoman Architecture

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Abstract

An often overlooked characteristic of Sinan's architectural production of the 16th century is the use of low screening walls and windows carved of marble with pierced openwork or tracery to let in light and allow for air circulation. Typically these screens display polygonal networks often with intersecting polygons. This paper explores aspects of these carved patterns, which have antecedents in earlier Islamic architecture, attributing particular significance to this architectural feature in the works of Sinan and three successors whom he had trained. These slabs (and their counterparts in forged iron) may be considered *études*, serving as opportunities for the training of the royal corps of architects in what was then called the "science of geometry," documenting a sustained concern with polygonal networks half a century before publication of Kepler's *Harmonices Mundi* in 1619.

Figure 1 *(left) Süleymaniye Mosque, Istanbul. Side entry with pierced marble screens. © D. Kuban, 2010.*
Figure 2 *(right) Süleymaniye, detail of screens showing intersecting dodecagons. © C. Bier, 2011.*

Sinan (1489-1588) and His Works

The architect Sinan (1489-1588) worked successively for three Ottoman sultans; his work as chief architect of the Ottoman Empire spanned nearly five decades and included imperial commissions as well as public works and buildings built for viziers [11, 12, 14]. He is best known for his genius combining architecture and engineering to open up interior space by creatively utilizing piers, columns and arches to support a succession of domes and half-domes [9]. As chief architect, he was responsible not only for design and oversight of construction throughout the Ottoman Empire, but also for the training of the corps of royal architects in the science of geometry. Great building complexes ((*külliye*), such as the imperial Süleymaniye mosque complex in Istanbul (figs. 1-2), and the Selimiye in Edirne (figs. 3-4), were conceived in their entirety and designed down to every last detail. Such complexes comprise a mosque with minarets, school (*medrese*), courtyards with porticos and a central fountain, and might include a soup kitchen (*imaret*), bath house (*hamam*) and medical facility (*dar al-shifa'*); the entire complex usually has an enclosure wall with monumental portals, gates and gardens, and tombs. Palaces and pavilions, hospitals, and public works such as bridges and aqueducts were also the domain of the chief architect and his team. Sinan credits himself with the design of more than 400 monuments [5], most of which were built in the capital, Istanbul, transforming the landscape of the Byzantine capital, Constantinople, the conquest of which in 1453 brought an end to the Byzantine Empire.

Born near Kayseri in central Anatolia, Sinan was the son of a stonemason. He was accepted into the Janissary corps at a young age and began his training as an apprentice in carpentry. He progressed to engineering, accompanied the sultan on numerous military campaigns, and was accepted into the corps of royal architects where he excelled in many endeavors. He well understood and expressed geometry in his three-dimensional compositions that were contemporary with the height of the European Renaissance [14]. The seriousness of his scientific endeavor may be gleaned towards the end of his career from an imperial decree of 1578 that required the donation of the library on science and geometry, which was housed in a mosque Sinan had endowed, to the new astronomical observatory in Galata, directed by Takiyyüddin and located across the Golden Horn from the imperial palace at Topkapi [14, p.150].

Sinan's Screens

Architectural Function. Present as a feature in nearly all of Sinan's buildings, except his public works (e.g bridges and aqueducts), are a series of architectural panels with pierced openwork, which serve a variety of screening functions. Because of their extraordinary use of intersecting polygons and polygonal networks, they may be considered *études* for the study of plane geometry and would have been eminently suitable for training young architects. The use of such screens persists in the work of three of Sinan's successors (Davud Agha, Mehmed Agha Sedefkār, Dalgiç Ahmed Agha), whom he trained in the science of geometry. They served in the Corps of Royal Architects and received their training in mother-of-pearl inlay in the imperial gardens of Topkapi palace [4, p.28]. Several of their monuments, including Yeni Cami in Eminönü and the Blue Mosque frame the landscape of Istanbul today, the original pierced screens of marble and iron grillwork contributing to an overall unified aesthetic based on pattern.

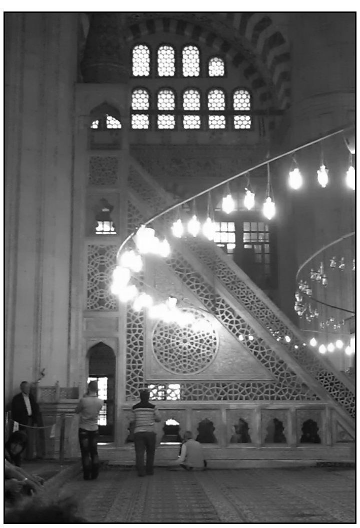

Figure 3 *(left) Edirne. Selimiye Mosque (1568-74), interior view with minbar. © C. Bier, 2013.*
Figure 4 *(right) Minbar, detail of hexagonal grid with intersecting nonagons. © C. Bier, 2013.*

Modest in scale, but exceptional in the formal elegant simplicity of design in relation to historical antecedents of the patterns, "Sinan's screens" are flat panels, usually rectangular, made of carved and pierced marble or forged of iron. As low enclosing walls for porticos, second-storey galleries, and balconies, or as windows in architectural monuments including fountains, these screens delineate space while preserving a sense of privacy, and they allow the passage of light and the flow of air. Aesthetically, these panels play with solid and void, and light and shade. The effects of sunlight, constantly changing throughout the day and in different seasons, create projections of shadows that contribute visual interest to the articulated ambiguities of interior and exterior space that is mediated by the openwork. Rectangular pierced panels are used to frame and contain the platform of mosque furniture such as the *maqṣura* and *mahfil* for screening of the ruler, imam or *müezzin*; similarly pierced panels in carved wood are used for *kursi* (Qur'an stands). Panels that frame the stairs of the *minbar* in mosques are triangular in format. These screens explicitly articulate aspects of geometry in the plane with particular relevance to relationships among intersecting polygons, star polygons, and polygonal networks.

The Ottoman Turkish word for these works is *aḥcār-i müşebbeke,* which translates literally to "stone networks," or "reticulated stones." Sinan himself was credited with having constructed a primary school having "a walled enclosure surrounded by a most beautifully constructed *aḥcār-i müşebbeke*" [14, p.149]. And this form of stone screen was selected by him for use as windows in the enclosure wall surrounding his own burial ground, located at the edge of the imperial mosque complex of Süleymaniye [14, p.150].

Figure 5 *(left and right) Süleymaniye, Istanbul. Interior view of windows of* şadırvan *(fountain) in main courtyard, showing iron grillwork with intersecting regular dodecagons (left) and dual tessellation of regular hexagons and equilateral triangles (right). Analyses by the author. © C. Bier, 2013.*

Many walks through Istanbul and Edirne and a culling of images published in the literature on Ottoman architectural history [7, 9, 11, 12, 14] have yielded more than one hundred examples in mosques and tomb structures. Broug [2] and Majewski [13] have analyzed several of the geometric constructions. Many more examples can be located throughout the Empire [9]; Sinan with his cadre of trained architects worked to refurbish the historical holy sites of Mecca and Madina, and the Dome of the Rock in Jerusalem, for all of which the Ottomans assumed oversight in 1517 after conquest of Mamluk domains.

Designs. In the screens examined, all of the tessellations of regular polygons (triangles, squares, hexagons) have been identified. The screens may be classified according to their compositions in relation to these grids, suggesting several distinct categories of intersecting polygons and polygon networks:

a. intersecting dodecagons without any articulated grid (figs. 1-2)
b. dual tessellation of hexagons and equilateral triangles, yielding a tessellation of kites [9, p. 94]
c. intersecting dodecagons with a dual tessellation of hexagons and equilateral triangles (fig. 5)
d. intersecting nonagons with a hexagonal grid (fig. 4)

e. network of adjacent dodecagons in a square grid [13, fig. 53]
f. circular compositions with radial symmetry of pentagons and decagons [13, fig.94] and (fig.3).

While this classification is by no means complete, several observations are relevant at this early stage of investigation. Geometry of all vertices is specific and reflects thorough understanding of the underlying constructions. At each vertex, the sum of the angles must equal 360º and this seems to be often accomplished with perpendicular lines and right angles, using one-point matching rules for tiling achieved by means of bisection at midpoints of edges (cf. [6]). Dual tessellations show perpendicular intersections [13, fig.49] and (fig. 5), as do intersecting dodecagons (fig. 2). Nonagons intersect hexagons at right angles (fig. 4). Each nonagon intersects three other nonagons, and each hexagon is surrounded by six nonagons, revealing a six-pointed star in the negative space. Likewise, sets of six dodecagons reveal a six-pointed star in negative space. Nonagons only occur as intersecting polygons with a hexagonal grid, whereas dodecagons occur in a variety of configurations, intersecting with one another, or with triangular and/or hexagonal grids, or forming a network within a square grid [13, fig. 53]. Although the nonagon is considered to be not constructible using compass and straightedge [13, p.38], intersecting nonagons have historical precedent in the 12th-century Gonbad-e Sorkh, Iran [1, fig.7]. *Minbar* screens reached the epitome of virtuosity (fig. 3), often combining several patterns in different sections, including skillful constructions of circular compositions with five-fold and ten-fold radial symmetry in the Şehzadeh Mosque [13, fig.94], Sokullu Mehmed Paşa Mosque [13, figs.116-18], and in the Selimiye (fig. 3).

As far as I know, to date these screens have attracted little scholarly attention. But their potential importance, as *études* or studies in stone may be significant. Although the patterns all fit into today's standard tiling categories [8; 3], they indicate a sustained interest and applied methodology in exploring the geometry of polygonal networks many decades before publication of Kepler's theoretical study [10] of polygons in *Harmonices Mundi* (1619).

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