The architect and his career

When he was appointed Chief Imperial State Architect to the Ottoman Empire in 1538 at the age of 48, Sinan was not actually a fully-fledged professional architect. His actual profession was carpentry and his career to that date had been military. Indeed, it is said that because of his background he tried to avoid the appointment. When we consider that he built a mosque, the Haseki Hürrem Sultan Mosque in the year of his appointment which had a dome of 11.30 m in diameter, while the Çoban Mustafa Pasha Mosque at Gebze, which predates the Sinan work by 15 years and is said to have been repaired by him, has a dome measuring 14.5 m in diameter, we understand how cautious and spare of experiment were his first years in the post.

In later years, Sinan worked toward creating more majestic and masterful structures, training himself in the process. In a short time, Sinan, with the strengt of his self-acquired skills was able to claim mastery of and experience in: structural engineering, soil mechanics, statics and strengt of materials, building physics, hydraulic engineering, surveying, bridge construction, urbanism, architectural design, and interior design.

Acquiring a mastery of what amounts, in modern terms, to the equivalent of a training in every branch of at least two faculties, Sinan concentrated mainly in the second part of his career on perfecting his theoretic skills as well as evolving them and creating the technology to realize his innovative ideas. Sinan has the distinction of having built or restored a total of over 10,000 domes and cupolas on a total figure of 344 or 477 structures, and holds the record for stone and/or brick domes, a record which it is hard to imagine will ever be surpassed.

A small number of his works were covered with gable roofs, tunnel or cross vaults, but mostly their superstructure is based on the dome and semi-dome. His domes are hemispherical, his semi-domes are quarter-sphere. His domes and semi-domes are geometrically sound in terms of their form and proportion. Sinan never used either a high or suppressed dome, nor did he employ elliptical or oval domes in his works.

The dome, in a work of Sinan, is not simply a covering. More than a mere superstructural element over space, it completes and complements the space. It is the means by which square or rectangular planned buildings are transformed at the upper level into the final structural statement of the grand central dome. To achieve this a series of transitional elements, such as pendentives, squinches and semi-domes, are used to bear the weight of the dome and transfer its load to the walls surrounding the central space harmoniously as possible. Since there are no extraneous details, such as roofs or decorative towers in works of Sinan, the structure itself is a total reflection of its dynamism — that is, the relationship between internal space and structural mass, or positive-negative space.

Sinan had no tolerance in his work for pseudo-structural features, or exaggeration in any structural element. The only notable divergence from the structural unity was the addition of buttresses and buttress towers to the exterior of his works to counter the horizontal thrust of the dome. As a result of this, Sinan's domes and semi-domes and structures are translucent. That is to say, that it is easy to read the external features of the dome from inside and vice versa. The superstructural features designed to take the horizontal thrust of the dome have to be able to transfer this thrust to the lower courses of the building. The structural system must fulfill the requirements of the building's statics by transferring the load to the ground.

We may clearly trace this system in the main structural walls and structural features surrounding the building in any of Sinan's works. Indeed, in many of his works he used the innovative feature of introducing pilasters to enhance the moment of inertia in supporting members and thinning the walls out where lower forces were acting, thus economizing structurally and providing the building with a greater elegance. Evolving from this is the system he used in the Selimiye mosque in Edirne and the Mihrimah mosque in Istanbul which may be described as "infilled stone framework", as we shall see in the illustrations.

The scale of Sinan's works is directly related to the financial resources of their patrons. The patron's status within the Ottoman State hierarchy was also an important factor, however. The patrons of mosques and other grand public buildings tended to be either a sultan or members of the royal family, grand viziers, viziers or other wealthy members of society. For the reasons mentioned above, the buildings completed under their patronage varied in size, as did their domes. Sinan chose to provide a different plan and structure for each of his commissions.
Without reducing his structures to type, at this point he was concerned with finding a different structural solution for buildings even of the same dimensions, which indicates his architectural approach and technical mastery. It is this, indeed, which renders him a truly universal figure. Naturally he employed simpler systems in his smaller works, those of his more monumental works being more complex, requiring more volume and height. In providing these buildings with a superstructural system which allowed him to use the dome with remarkable flexibility, Sinan gained for himself an important place in the history of architecture.

Dome support system

In considering the superstructure of Sinan’s buildings, centred as they are around the main dome, we may identity the structural support system by which the load and forces of the dome are transferred through the various structural levels via support members and auxiliary elements to the ground. There are three distinct types of support system in the works of Sinan: the square support system, hexagonal support system, and octagonal support system.

These support systems consist of a series of structural measures ensuring its stability and stretching from the square or rectangular surrounding walls of the structure to the mosque.

Throughout his works, Sinan employed five variants of the square support system, four of the hexagonal system and three variants of the octagonal system.

Dome support system employed by Sinan

A) Square support system
The dome rests either on the walls or arches. There may be a drum below it. Transition to the dome from the square-planned main walls is via pendentives or squinches.

B) Hexagonal support system
Dome rests on walls, or horizontal members replacing them, over a hexagonal plan.

C) Octagonal support system
Dome rests on walls, or substituting horizontal members, over octagonal plan.

Variety in the position of the dome in Sinan’s mosques

Sinan treats the dome as the most important spatial element. So in creating different spaces he chose to re-position the dome in relation to the general mass of the structure. The above diagram aims to show how Sinan achieved variety in this respect.

No. 1 is the main subject. The dome, whatever its position, is symmetrical on the axis X, while in no. 1, it is also symmetrical on the axis Y. The variations are achieved by adding spatial areas either to the two lateral sides flanking the dome, or to the facade and rear of the dome, which remains always central. (See diagram below for variants 1.1.1, 1.2.1 and 1.3.1).

With the addition of a mihrab niche, further variation was achieved to the front of the mosque (see 1.1.2, 1.2.2., 1.3.2).

By sliding the dome of the mosque over to the facade wall of the mosque, Sinan introduced a new placing for it; and added flanking spaces to create variants (2.1.1, 2.2.1). This position for the dome was further enriched with variants through the introduction of the mihrab niche (2.1.2, 2.2.2, 2.3).

Sinan created a further placing for the dome, the third, by pulling it back towards the rear wall of the mosque, providing space for additional areas (3.1). Hence, by moving the dome backwards and forwards across the plan and by adding secondary spatial areas, Sinan manages to obtain 12 different structural combinations which provide his works with a variety of spatial compositions.

Some examples of such spatial variety in Plate II, where the support system employed, are also identified. There are some interesting points to be noted in this analysis:

— The support systems of buildings in the same spatial group are not necessarily identical. Sinan preferred variety in interaction between space and structure, avoiding rigid types.
— The use of specific support system bears no relationship to the chronology of his works. In other words, Sinan used whichever system he felt necessary in the building on which he was currently engaged, throughout his career without thought for systematic progression.
Ex. Barbaros Hayreddin
Pasha's tomb.
Beşiktaş...ISTANBUL

Ex. Selimiye Mosque.
EDIRNE

Ex. Sokollu Mehmet Pasha
Mosque.
Azapkapi...ISTANBUL

Different support systems

Different position
of the DOME in plan

1 2 3

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PLATE II

Analysis for the support systems of Sinan’s works and typology based on the spatial features of main area below dome and related flanking areas

Analysis of Sinan’s structural variety

Sinan sought an individual solution for each of his works, avoiding confinement to types. When we examine the system which underlies this varying approach, we see that at its basis is the conception of the position of the dome within the structure, and the use of certain support systems. Considered in two dimensions, this was a system of variants with a variety of support systems on one axis and the position of the dome occupying the other axis, with both elements being employed in conjunction to create a variety of different plans.

Although the above diagram shows a plan which yielded approximately 87 different variations, some of the spatial compositions resulting are less than interesting. About 50 of them may be considered worthy of interest and these were employed by Sinan. However, Sinan employed unrelated structural and spatial solutions in 107 of his mosques, which is twice as many as the 50 successful variations given by the above diagram. In order to improve this variant capability of the plan, Sinan invented variant features of secondary importance, particularly such features as placing pairs of small, semi-domes below flanking semi-domes, altering the scale of the lateral spatial areas and using simple and cross vaults over some of these secondary spaces.

Thus, having outlined the system used by Sinan to provide structural and spatial variety, I would like also to point out certain persistent features related to his use of the dome:

— Sinan regarded the dome as the most essential and dominant feature in the overall dynamism of the mass in his works.

— He selected a static system throughout the sub-structure of the dome based on the relationship between space and form, planning his buildings accordingly.

— The structure of his works clearly shows that Sinan had carefully considered the problem of thrust in relation to earthquakes.

Stability of the dome

Sinan paid great attention in his works to the efficient distribution of horizontal and vertical load, using such features as buttresses, buttress towers, broad arches with enhanced moment of inertia, semi-domes, support piers, walls and engaged piers with great skill.

With the aid of the sketch plans below we can analyse the methods used to provide the domes of these buildings with stability, they provide a relatively realistic view of the structure at various different levels, although there may be some small inaccuracies in the measurements, since the plans had to be prepared in a very short time. All these plans are original, and approximately 85 per cent of them were prepared especially for this symposium.

The works investigated, twelve of Sinan’s mosques, are identified in terms of their support systems, whether they be square-based, hexagonal or octagonal, through horizontal sections of that system at different levels throughout the building.
Zal Mahmut Paşa Mosque, Eyüp

The building was completed in approximately 1580. The dome is 12.40 m in diameter. It is supported by eight buttresses placed at equal distance apart and four support towers. The support structure is square, with the dome resting on arches on three sides and directly on the wall to the front of the mosque. The square sub-system is supported on piers in two corners and walls reinforced with pilasters at the other two corners.

Mihrimah Sultan Mosque, Edirnekapi

Completed in circa 1568, the dome measures 20.25 m. Four buttress towers occupy the four corners around the dome while the dome itself rests on four elongated arches. The walls below these arches are thin and pierced with lights, so much so as to give the appearance of curtain walls. The broad arches rising from four supporting piers render this structure one of infilled stone framework. This is a very important and courageous innovation of Sinan himself. The sub-system is square, with four piers on the lower storey. Each pair of piers is countered by reinforcing pilasters on the façades.

Mihrimah Mosque, Üsküdar

Completed in 1548, the dome of the mosque is 10.70 m in diameter. Eight buttresses reinforce the dome in closely set groups on the corners of the drum, which is square. The dome rests on an arch over the wall to the rear, and on the other three sides is supported by semi-domes connected to other semi-domes. The supporting walls bear pilasters arranged to counter the supporting piers. The building was completed in 1544. The diameter of the dome is 18 m and is supported by four buttress towers and eight buttresses. The sub-system is square. The dome is supported by arches on four sides connected to semi-domes. The four supporting piers are strongly reinforced by supporting pilasters which are positioned so as to counter the piers in the façade walls and arcades are used to mask their
THE KILIÇ 'ALI PASHA CAMI, TOPHANE
massiveness on the side façades. This feature was first used by Sinan.

**Viliç Ali Paşa Mosque, Tophane**

Completed in 1580-81, the diameter of the dome is 12.70 m. The dome is reinforced by eight buttresses set at various intervals around it. There are two buttresses on either side of the dome arches for support at that level, a unique solution, to be found nowhere else. The dome is supported by two broad arches and two semi-domes and arches on the other façades. Massive pilasters reinforce the piers which they counter on the main walls.

**Süleymaniye Mosque, Süleymaniye**

Completed in 1557, the dome is 26.20 m in diameter. It is supported by four buttress towers with a series of buttresses clustered around them, eight in all and two each on the lateral façades. Since there are semi-domes on the portal and qibla façades, buttresses were not possible on the those façades. Broad arches over the lateral façades and arches and semi-domes on the main façades serve to support the dome, which is carried on four main piers. In order to prevent these piers from leaning progressively out of true towards the lateral wall, a series of supporting walls are built in from the level of the buttress towers downwards. No such support system was used in the other façades. All four piers are countered on the surrounding walls by massive pilasters, whose size is masked by arcades on the lateral façade.

**Sokollu Mehmet Paşa Mosque, Kadirga**

Completed in 1571-72, the dome measures 13.00 m in diameter. The dome rests on an hexagonal drum which rests on the walls of the main qibla and portal walls, and on semi-domes tied to a system of semi-cupolas on the two lateral walls. The hexagonal plan allows for the distinct expression of six massive supporting pilasters following the hexagonal support system.

**Molla Elehi Mosque, Findikli**

Thought to have been completed in 1565-66, the dome measures 11.80 m. Four small but tress towers surmount the hexagonal drum on four corners. The dome rests on the entrance façade wall and on arches tied to semi-domes on the other four corners. The hexagonal substructure is clearly reflected in the plan by the inclusion of two piers close to the portal on the main façade and four pilasters on the other façades.

**Kara Ahmet Paşa Mosque, Topkapı**

The mosque was completed in circa 1560, the dome measuring 12.40 m in diameter. Six equidistant buttresses support the dome over a hexagonal drum, and the dome rests on two arches and four semi-domes linked to arches. The hexagonal support system is reflected in the plan by the six piers and six pilasters on their adjacent walls.

**Rüstem Paşa Mosque, Eminönü**

Completed in circa 1562, the dome measures 15.20 m in diameter. Eight equidistant buttresses support the dome, and the octagonal drum is in the form of an elongated arch. The dome rests on four arches and four semi-domes. The octagonal support system is clearly reflected both in plan and on the façade through the four supporting piers and four pilasters.

**Sokollu Mehmet Paşa Mosque, Azapkapi**

Completed in 1577, the dome measures 11.80 m in diameter and is surrounded by eight buttress towers. It rests on eight piers tied to semi-domes. The octagonal support system consists of eight free-standing and two engaged piers, the latter flanking the mihrab niche. The external walls are reinforced by massive pilasters counteracting the main piers which serve to express the support system directly on the façade.

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