IAN RITCHIE ARCHITECTS

Water – under, over and through

Mimar Sinan was a mechanicus – an architect engineer. Ian Ritchie explores the rich blend of science and art to be found in the bridges and aqueducts designed by the 16th-century architect

TEAM *IAN RITCHIE ARCHITECTS*
Ian Ritchie

The Büyükçekmece Bridge

Sinan registered the bridges he built in his autobiography, with the Büyükçekmece Bridge referenced as 'the bridge built in Büyükçekmece', which means 'Great Coming and Going' of waters.

The Büyükçekmece Bridge opened for use in 1567. The earlier Roman-Byzantine bridge had been destroyed by floods on 20 September 1563 after a 24-hour deluge and heavy autumn rains (chronicled by Ogier Ghiselin de Busbecq, Flemish ambassador for Ferdinand I of Habsburg to the Ottoman court of Sultan Süleyman I.) The bridge's arches collapsed under rising water pressure caused by uprooted trees and bushes, timber from demolished buildings and the drowned bodies of cattle, sheep, goats, horses and humans washed down from swollen streams and landslides. At the time, Süleyman was at his hunting lodge at Halkadere, a little further inland from Büyükçekmece, where the shallow, marshy and almost landlocked cove was a spectacular area for migrating birds. Apparently he was lucky to survive the deluge.

Financed by the sultan and his son, Selim II, who inherited the throne upon his father's death, Sinan conceived the new Büyükçekmece Bridge with the knowledge of how the detritus had destroyed the earlier bridge. His concept expressed his aesthetic genius and his profound knowledge of hydrodynamics.

After an examination of the area, Sinan chose a site further towards the sea where the ground was firmer and the water shallower. Then, instead of a regular set of arches, he envisaged a series of four hump-backed bridges linked by three flat low points some 20 to 30 metres long and not much

ABOVE Ian Ritchie's iPhone digital sketch of Büyükçekmece bridge showing how flood waters flow over the bridge, a technique devised by Sinan to avoid structural damage

above normal high water level. This allows any rising flood waters to pass over these parts of the bridge, creating a negative pressure at the arches blocked on the upriver side with detritus. Thus the detritus is sucked out from the arches, the water level subsides and the pressure on the shaped stone piers is reduced. People using the bridge could wait at the high points until the low areas were clear of water.

The three low points are built on three irregularly shaped, grassed artificial islands. The islands' foundations are constructed of waterproof timber coffers, with stones set at their base, and lead poured into the joints between them. The same is true of each pier supporting the arches. As Sinan recounts in his autobiography, *Record of Construction*:

> *'A cofferdam [sandik] like a galleon was constructed for each of the piers [payanda ayak], and … drew out the seawater with pumps and large skin sacks and emptied them. And piles made from fine, strong columns the length of two or three men were driven into the foundations with a pile driver, large stones were clamped over them with strong iron clamps [kenet], lead was poured between them and they were joined as a single piece.'*

Sinan's idea was to establish immovable massive bases. On these bases, the islands were filled with stones inside the timber coffers. The edges appear as solid stone embankments. Sinan understood soil mechanics, which he would have learned when building temporary and permanent structures while in the army, and would have calculated for a period of soil stabilisation before loading the foundations of these islands. This may have taken up to two years. He took the same precautions with other buildings – notably the Süleymaniye Mosque – one of the reasons his buildings and aqueducts have survived in a geographic area plagued with frequent earthquakes.

The bridge runs east to west. Travelling from Istanbul, the first bridge (158 metres long) has seven pointed arches rising seven metres before falling to the first island, the second (135.5 metres)is also of seven arches, the third (102 metres) has five arches and the fourth (184.7 metres) has nine arches and rises just over 12 metres above mean water level. Overall the bridge is nearly 670 metres long, and travellers arriving from the west at sunset would be met by the illusion of the seven-metre wide roadway appearing as four red-gold plates.

Equally, the sight of thousands of plumed Janissary soldiers appearing and disappearing as they crossed the bridge would have looked magnificent when in May 1565 the sultan and grand vizier set out on the road to Hungary – Sultan Süleyman's 13th and final campaign. The Büyükçekmece Bridge was still unfinished and its road surface was not yet completed. Sawdust was spread to facilitate a more comfortable passage in a carriage by the infirm sultan, who was no longer fit enough to ride a horse.

Sinan built a caravanserai and public fountain at one end of the bridge. A masjid (place of worship) was added by the grand vizier Sokollu after Süleyman died during the campaign in Hungary in 1566. It was fully completed in 1568, two years after Süleyman's death.

On its completion, Sinan signed his work at the west end of the bridge – the only structure or building that is known to have his personal signature: 'Joseph Son of the Slave of God'. This is not his official Islamic Janissary name, yet he felt confident enough to sign Yusuf Abdullah and not Sinan Abdülmennan (with this particular surname denoting that he was a Christian convert). The bridge completed the strategic Istanbul-Edirne highway and presented an impressive entrance to the Ottoman capital.

TOP & ABOVE Ian Ritchie's Büyükçekmece bridge model in his studio

Istanbul's aqueducts – water to Istanbul

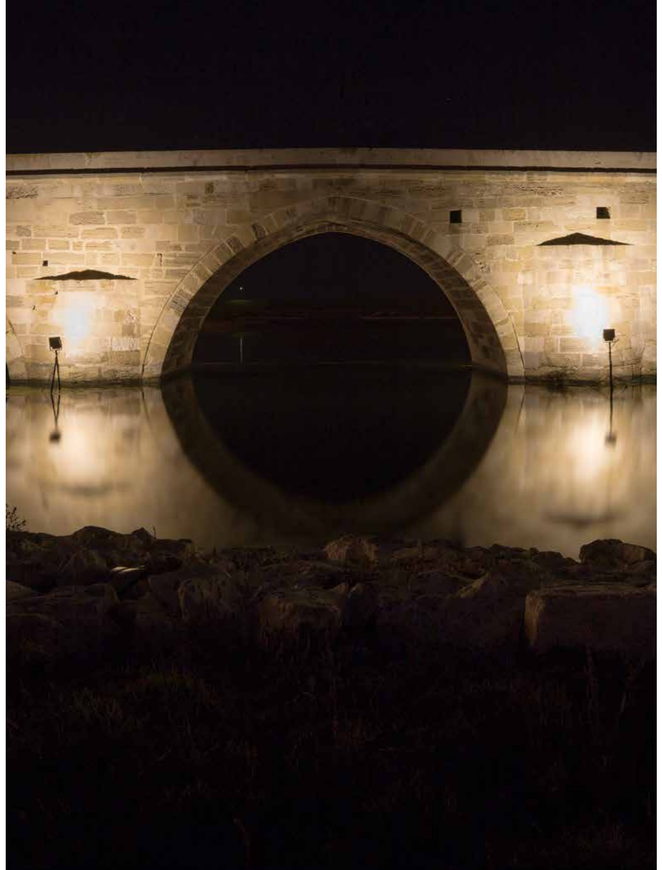
In Islam, water is considered sacred – running water is a necessary part of religious purification – and the mention of rain, fountains and rivers pervades the Quran. Access to water was considered a basic human right and its denial to anyone was forbidden if survival were at stake. The Romans and Byzantines had established a significant water infrastructure to serve Istanbul, but much of it had been destroyed by the Crusaders in 1204 when they sacked Constantinople.

With the expansion of the city, Sinan was tasked by Süleyman in circa 1558 to solve the recurrent problem of Istanbul's inadequate water supply, which had first been addressed by Sultan Mehmed II after the Ottoman conquest in 1453. The works were completed in seven years, despite an earthquake in 1564 bringing down one of the largest two and three tiered arches of one aqueduct. Sinan, as architect of the Empire (mimar-başi) and superintendent of works, would have had a master of the waterways – an important and senior official – heading a team of assistants.

The main source of water for Istanbul was from springs rising in the Belgrade Forest, some 15 miles to the north of the city on the Black Sea. The forest was named after Süleyman's successful campaign of 1521 – the first year of his reign – at which Sinan had been in action as an engineering cadet. There were two historic techniques for conveying water to Istanbul: the 'su terazileri', which are water towers connected by pipework (Roman or earlier Islamic origin) and aqueducts (Roman and Byzantine) supplying both open and underground cisterns, over which it was not uncommon to find that the Byzantines had constructed churches, and the Ottomans had done the same with mosques.

Sinan appears to have focused upon the aqueduct system, studying in detail the Roman constructions and also the extant water towers constructed in order to maintain water pressure. Istanbul's water was conveyed by gravity to the city over valleys along aqueducts, and underground through distribution chambers located at various points in the city and thence to the growing number of buildings and fountains within Istanbul. In his autobiography, Sinan describes how, during the preliminary studies and in the company of the sultan, he surveyed the ruins, using an astrolabe-like instrument, an 'aerial balance', to measure 'the heights and depths of the valleys' to repair and design aqueducts and bridges, and how he constructed a dam 'in accord with the science of engineering (that is to say geometry)'.

Sinan rehabilitated the ancient waterworks – aqueducts, hidden waterways, cisterns – by uncovering 'reservoirs and marble conduits built by the infidels' (Roman and Byzantine), and also discovered additional water sources in the surrounding countryside, increasing the city's water supply by building new aqueducts of outstanding beauty and design. The precise measurements and calculations Sinan made in the construction of the water supply lines, aqueducts and accumulation pools were as reliable as those made today, and parts of the system located outside Istanbul's city walls have been functioning for more than 400 years.



OPPOSITE Detail of arches of Büyükçekmece bridge

Sinan built four new aqueducts in the Kirkçeşme supply system, completed in 1563: Uzun Kemer, Kovuk Eğri Kemer, Güzelce (Gözlüce) Kemeri and Mağlova Kemeri. Even in the driest months of the year the Kirkçeşme system, with a discharge of 4,200m³ per day, was able to supply 158 different locations (94 public drinking fountains, 19 wells, 15 watering troughs, 13 public baths and seven palaces among others). The Halkali water distribution system supplying water to the city was also built by Sinan and included the 50 kilometre-long Süleymaniye waterduct, which conducted water to the Süleymaniye neighbourhood.

Aside from the homes of the wealthy, the public fountains and hammams (public baths) to which Sinan directed the new water supply were often part of külliyes. These consisted of mosques and an ancillary complex of buildings – composed of a religious school, hospital or clinic, hammam, bakery and other buildings used for charitable purposes. They were maintained by endowments – vakif – which were enshrined in Islamic law, and supplied a great range of public facilities in perpetuity. Also bridges and fountains were often built as an act of piety, and maintained by endowments. An enormous amount of the Ottoman Empire's wealth found its way into charitable foundations. Elite sponsors enjoyed the prestige they acquired from supporting the arts and sciences – it was important for their status in society. The more renowned a court became for its power, wealth and refinement, the more artists and intellectuals it attracted, and patronage was one of the key factors in setting standards for excellence – an artistic and architectural arms race toward beauty, as it were.

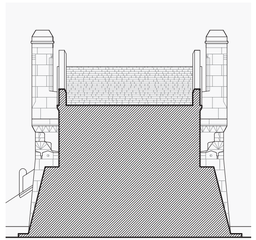
Under Sinan the distinctive silhouette of a large-domed mosque and slender minarets became the dominant urban element, and the urban structures associated with külliyes and the vakif system spread throughout the empire as the Ottomans took their artistic taste to newly conquered lands along with their administrative and political systems.

The achievement of Sinan's külliye complexes in Istanbul lies in the grouping and arrangement of the various buildings and their disposition in turn throughout the city. Because Istanbul is a hilly region, rather than level large areas to create flat surfaces, he engineered the külliyes to the topography, while creating terraces and extensive foundations.

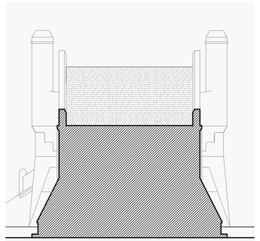
However, underpinning the entire physical and religious urban strategy was water and drainage, without which neither the expansion nor the functionality of these urban structures would have been possible.

In the Süleymaniye Mosque, Sinan used water from the adjacent külliye's hammam to heat the mosque's interior by digging water channels under its floor, through which the flow of warm water from the hammam was channelled. This heated the air flowing over the water, which was directed through outlets in the mosque's floor. In the summer, cold water directed through the channels served the reverse purpose.

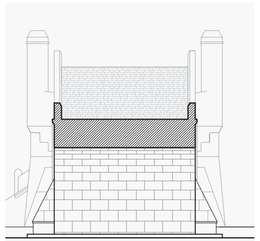
ABOVE Ian Ritchie's Büyükçekmece bridge model in his studio



Büyükçekmece bridge – section A-A



Section B-B



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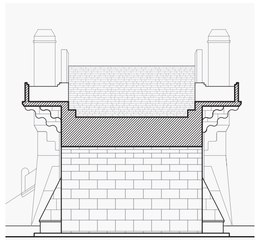

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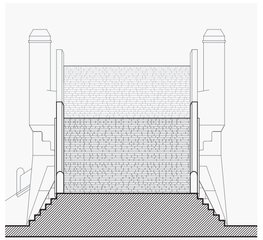

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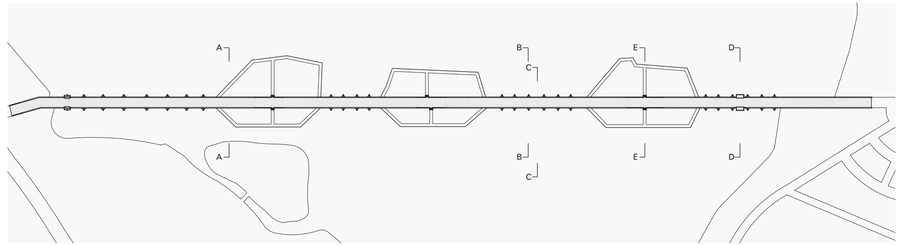
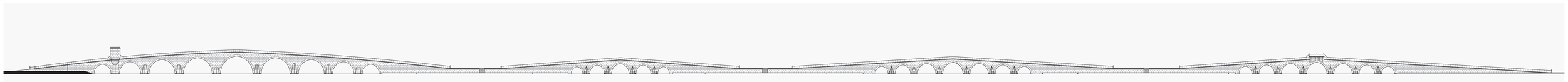
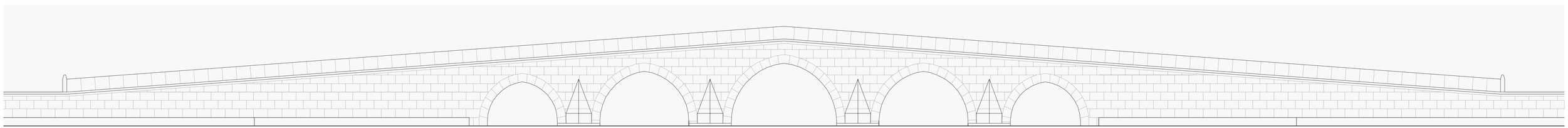


Büyükçekmece bridge – plan



Büyükçekmece bridge – elevation



Büyükçekmece bridge – elevation (detail)