Original Water Supply and Heating Systems in a 14th Century Bath: Çukur Hamam in Manisa, Turkey

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Abstract

Today historic baths deserve more detailed research on the characteristics of their water supply and heating systems in terms of efficiency, sustainability, economy and capacity. In this paper, to discuss these characteristics, the original water supply, surface-water discharge and heating systems of "Çukur Hamam" in Manisa (Turkey) are examined in a limited extent. Çukur Hamam, dated to the 14th century, represents the general characteristics of its period, whereas the water supply system providing natural pressure by arranging various levels remains as a unique example. In this presentation, design principles, architectural elements and their construction techniques will be discussed with special references to water supply, surface-water discharge and heating systems.

Keywords

Çukur Hamam; water supply system; surface-water discharge system; heating system; *su haznesi*; *künk*; *kurna*; *tüteklik*.

1 Introduction

The bath tradition in Anatolia extends far back to antiquity. When the Turks arrived in Anatolia, they were confronted with the bathing tradition of Romans and Byzantines. They were inspired by and preferred to build on existing cultural, architectural, technological patrimony and achieved a unique synthesis by adding their own bathing tradition, which had its shape according to Muslim concern for cleanliness and for water usage. This synthesis is known as Turkish bath or so called *Hamam*. The architectural and technological features of *hamam*s are closely interrelated, to get optimum use of

water and heat sources. This is the main design principle behind of the water supply and heating systems of *hamam*s.

1.1 General Features of *Hamam*s

*Hamam*s are mainly composed of three sections: changing section, bathing section and service section. (In Roman baths, changing section is called frigidarium while bathing section is composed of tepidarium and caldarium.) In early examples, there existed an additional space between changing and bathing sections, which was composed of toilet(s) and a cell. It is explained as a space providing control of heat transfer between cold and hot rooms. In later examples, it was replaced with a shaft, which is located between cold and hot sections; toilet(s) and cell become part of the bathing section.

1.1.1 Changing section (soğukluk, soyunmalık, camekan, camegah)
This section is used for the purposes of changing clothes, waiting and resting. It is usually the largest among all the other spaces. The main entrance to the *hamam* is from this section directly or from a preliminary entrance space attached. The space is illuminated by a lantern (*fener*), placed on the middle of dome or timber roof. A small pool (*şadırvan*) is placed under the lantern, on the center of the space, for cooling. There are also benches (*seki*) surrounding the space and in some examples, the walls are adorned with niches.

1.1.2 Bathing section
It is composed of two main sections: *ılıklık* and *sıcaklık*
Ilıklık section is the space, where the body is gradually adapted to heat, before entering hot rooms. It is usually composed of a main space, toilet and a cell (depilatory room). The main space is illuminated by skylights on the dome. The walls are surrounded with *seki*s in most examples.
Sıcaklık is the bathing section, which is composed of a central space surrounded by iwans (*eyvan*) and cells (*halvet*s). The alternatives in the composition of *eyvan*s and *halvet*s create variety in plan schemes. The skylights on the dome illuminate the central space and *halvet*s while ones on the vaults illuminate the *eyvans*. There is a bench constructed of marble slab (*göbektaşı*) in the central space, which is the hottest section of the *hamam*. There are also stone basins (*kurna*) for bathing.

1.1.3 Service section
It is composed of two service spaces: water tank and furnace (*külhan*)
Water tank lies along one side of the *sıcaklık* section. It has a connection to the *sıcaklık* by a small window and steps just behind, for the purpose of access for maintenance and control. There is a boiler (*kazan*) in the middle of the water tank to heat water.
Külhan serves dual function of heating the hypocaust and the *kazan*. It is located behind the water tank and placed on the same axe with the *kazan*.

2 Çukur Hamam in Manisa

Çukur Hamam that will be introduced with its water supply, surface-water discharge, and heating systems is in Manisa, at western Turkey. It is located on the slopes of the

Mountain Spil, in the vicinity of the antique castle of the city. The *hamam* lays north-south direction, parallel to the topography. Because of the slope, the west wall of the *hamam* is below the ground.
Çukur Hamam is a public bath, dated to 14th century (1360s), Principalities Period (Saruhanoğulları Principality). It is one of the few examples that have survived from the period until today. The *hamam* is a part of a complex, which is composed of a mosque (Ulu Cami), a tomb and a madrasa, donated by İshak Çelebi. Today, it is in a ruined condition as being out of use.

Figure 1 – General view of *hamam*

Figure 2 – *Sıcaklık* space of *hamam*

This single story massive building is constructed of rubble stones in walls and bricks in superstructure, transition elements and openings (doors, windows, niches). Marble stones are also employed at floor coverings, on the corners of exterior walls and as architectural elements. Interior surfaces of the walls are plastered with lime plaster while exteriors are exposed. As superstructure, rooms in square plan are covered by domes while vaults cover the *eyva*ns, water tank and toilet. Today, vaults and dome of *soğukluk* and main space of *ılıklık* sections are still standing but the rest are collapsed.

2.1 Methodology

The restoration project of Çukur Hamam was prepared within the graduate course in the Restoration Department, METU, in the spring of 2003. The *hamam* was documented by using the traditional measuring techniques (optical distance measurement method, hand measurement, and documentation with photograph). The measured survey was drawn in 1/50 and 1/20 scale.

2.2 Plan

Çukur Hamam is composed of *soğukluk, ılıklık*, *sıcaklık* sections and service spaces. The main spaces are square while service spaces are rectangular in plan. (figure 3)
Soğukluk (room A), a width of 7.25 m, is entered through an arched opening at south façade. The walls are adorned with a serious of rectangular niches. There are also *seki*s in front of the walls. According to the written sources, there was a *şadırvan* in the center of *soğukluk* but it was removed in the recent past.
Ilıklık is composed of three rooms. The space functioning as a passage between cold and hot spaces (room B1) measures 3.20 m in width at the west and 2.87 m. in width at the south. The toilet is set off from the room B1 by a brick parapet wall. Main space (room

B2), a width of 4 m, is surrounded by *seki*s along the three walls. There are also two niches on the south and west walls. Depilatory room (room B3) is a width of 2.80 m.
Sıcaklık has a centralized plan scheme; the central space is surrounded by four *halvet*s and four *eyvan*s. *Halvet*s (room C2, C4, C6, C8) are located at the corners of *sıcaklık*, which are a width of 2.85 m. They are the hottest rooms in the *hamam*. *Eyvan*s (room C1, C3, C5, C7) are a width of 2.70 m. At the central space (room 9), there is an octagonal *göbektaş*ı, 7 *kurna*s and a pool.
Water tank (room D) is a rectangular space, 2.6 m wide and 10 m long. It is connected to the room C7 by a window, 0.65 m wide and 0.97 m height.

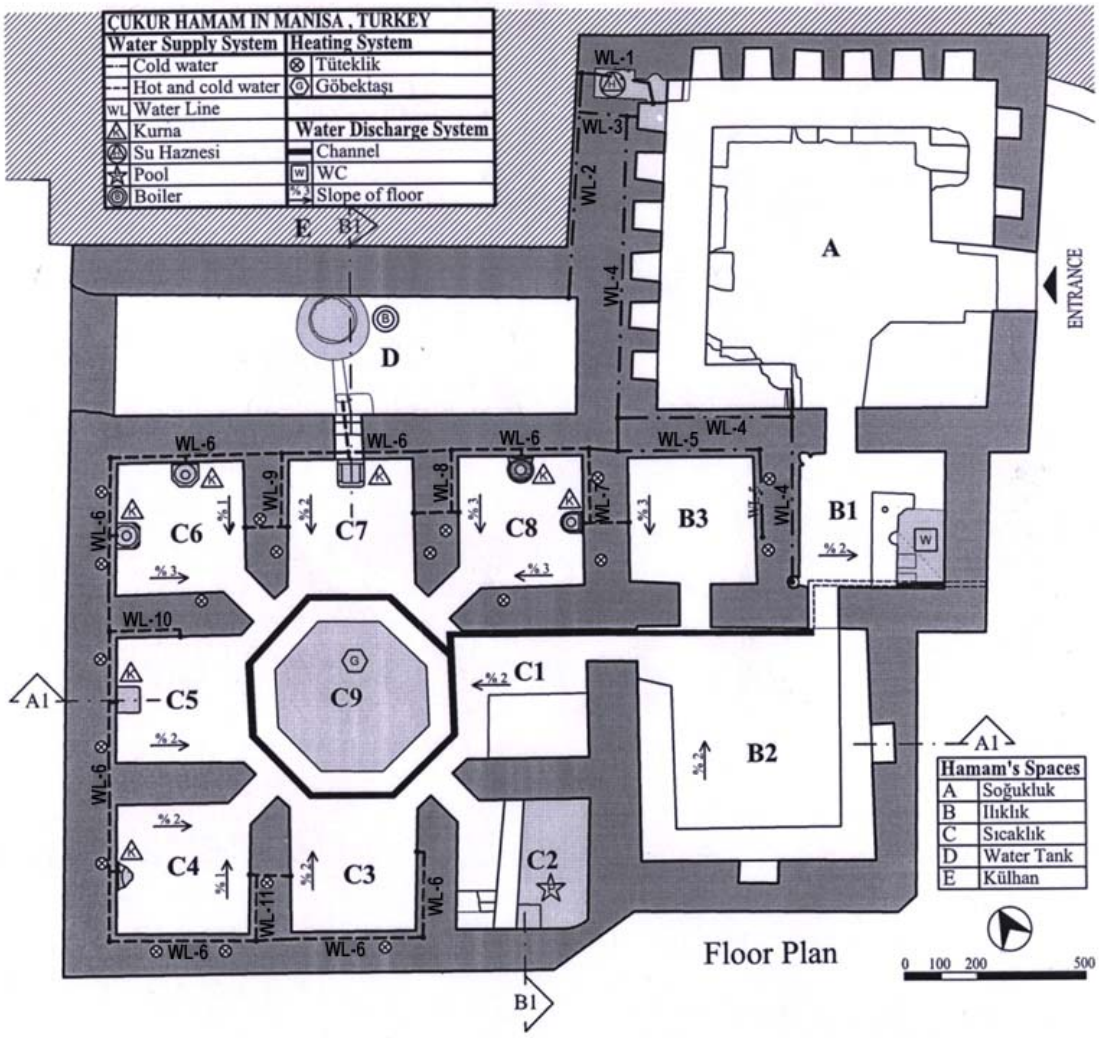

Figure 3 – Plan of Çukur Hamam

3 Water supply, surface-water discharge and heating systems of Çukur Hamam

The investigation on water supply, surface-water discharge and heating systems of Çukur Hamam aims to document all data including design principles, architectural elements and construction techniques, as a part of the restoration project of the *hamam*.

In this paper, the water supply system is defined by means of distribution of hot and cold water, levels and slope for an effective water flow, providing balance of water pressure before the distribution of water, and architectural elements of the system. As a drainage system, only surface-water discharge system is observed in Çukur Hamam. Finally, heating system is defined by means of vertical and horizontal flow of smoke under floor and walls, multi-use of heating source for both heating water and spaces and architectural elements of the system.
As a methodology, measurements are taken in relation to a reference line (±0.00) established along the walls by using traditional techniques. During the documentation phase, the traces of water supply system on the walls allow us to make some comments about hot and cold water supply systems circulated round the *hamam*. The architectural elements of the water supply system are mostly in-situ. Moreover, the floor covered by the deposits is cleared that allows us to measure the slope of water discharge system. Furthermore, the vertical hollows in walls (*tütekliks*) as a part of the heating system are observed both inside the *hamam* and on the roof. Unfortunately, there is no information about the most important elements of heating system, *külhan* and the space (*cehennemlik*) under the floor of *sıcaklık* and *ılıklık* sections because they are below ground and inaccessible. Finally, these three systems are documented in 1/20 scale drawings and photographs.

3.1 Water supply system

The investigation of water supply system can be broken down into two parts, a consideration of the question of how water is fed into Çukur Hamam and second, a consideration of how water is circulated in it.
First, there has originally been an aqueduct in the form of a channel, which supplied water from the mountain. The channel is on the south of the Çukur Hamam, passing approximately 5 m distant from the *hamam*. Possibly the water fed by the channel should enter Çukur Hamam from the north-east corner of the *soğukluk*.
Second, there are two water supply systems in Çukur Hamam that distribute cold and hot water by terracotta tubes (*künk*). The continuous and vertical systems are embedded inside the wall and carry water with the force of gravity down and around the *hamam*.

3.1.1 Cold Water Supply System

Cold water supply system connects to the main water source by a vertical *künk*, which distributes water on three horizontal lines in two levels. The first water supply system starts on +0.79 m level and the other systems start on +0.72 m level. (Figure 3 and 4)
The first water system (WL-1), composed of *künk*s at +0.79 levels, runs vertically along the deep niche (*su haznesi*) at the north-east corner of the room A. The system in the niche works as an inverted siphon; the pressure of the water coming from the main water source is balanced before it is distributed to the *hamam*. The excessive water is discharged from the main supply system by a drain at the base of corresponding niche.
The second system (WL-2), connecting the main water source to the room D (water tank), runs along the north exterior wall of room A between +0.72 m and +0.36 m level.
The third system is connected to the main water source at +0.72 m level. It distributes water first to the *soğukluk* section and then to the rest of the *hamam*. There are two water lines, here. The first line (WL-3) that supplies water for the *soğukluk* section has an outlet on the surface of back walls of niche, adjusted to the *su haznesi*. The second

line (WL-4) runs first the north and west walls of room A and then along the north wall of room B3. The system, 14.09 m long, has a slope of 3.5%. The water is discharged from the toilet.

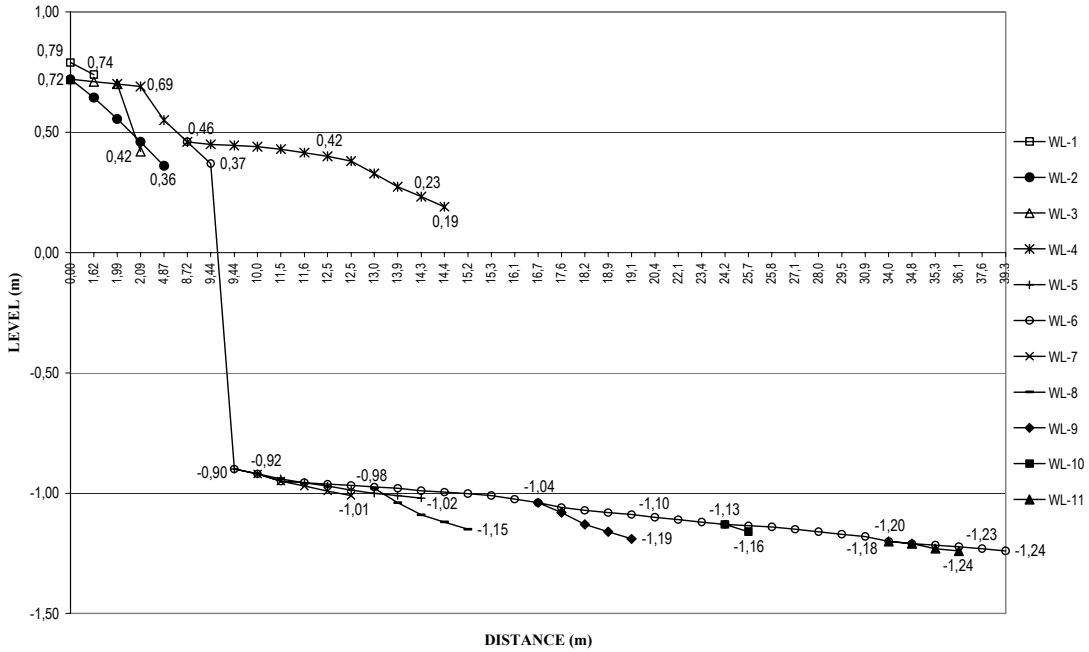

Figure 4 – Cold water system

Two water lines (WL-5 and WL-6) are connected to the WL-4 at the north-east corner of room B3 by a vertical *künk*, running between +0.37 m and -0,90 m levels. The WL-5, 4.98 m long, runs along the east and south walls of room B3 and has a slope of 2%. There is no trace of any water outlet or *kurna* in this room.

The WL-6 supplies cold water for the hot spaces, which runs along the east, north and west exterior walls of the *sıcaklık*. The water line is approximately 29.88 m long and constructed in a minimum efficient slope (1%). There are five sub-systems (WL 7- 11) passing along the interior walls in the *sıcaklık*, which are fed by WL-6. The lengths of these systems vary between 2.10 m and 2.45 m.

3.1.2 Hot Water Supply System

The hot water supply system is constructed using in the same principle; the pipe composed of *künk*s runs inside the walls of *sıcaklık* section, parallel to the cold water supply systems but on a lower level. It differs from the cold water supply system by means of the heating of water (figure 5). The water collected in the water tank (room D) is heated by the fire set directly beneath the *kazan*, which is fixed on the floor of the tank, on the center of the plan, above the heat source. From the room D, with forces of convection and gravity (slope), heated water is fed to room C7 at –1.20 level.

The hot water carried from the water tank is distributed in two continuous hot water supply systems lay on north-south direction; the first one supplies hot water for room C8 and B3 while the second supplies water for the rest of the sıcaklık. The first water line is 7.75 m long and the slope of the system is approximately 0.77%. The second line is 23.95 m long and the system lies in the same slope. There are also sub-water lines (WL 7-11), which carry hot water to the other outlets of the *sıcaklık* section.

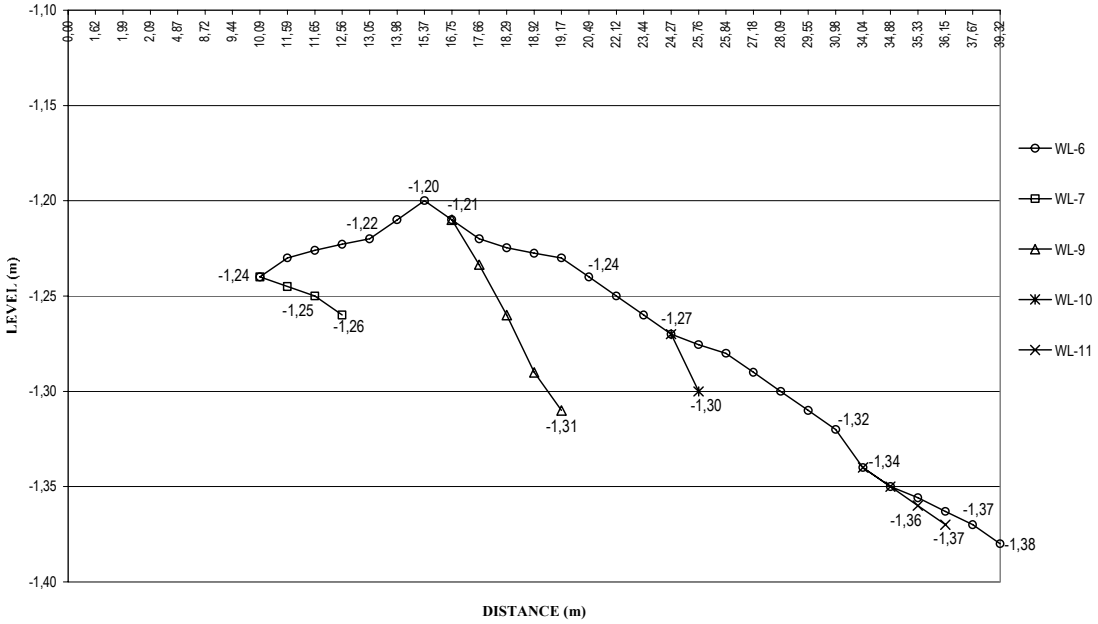

Figure 5 – Hot water system

3.1.3 Architectural Elements of Water Supply System

The water supply systems of Çukur Hamam are composed of *su haznesi*, *künk*s, *kurna*, pool, and *kazan* as architectural elements.

Su haznesi:

The north-east corner of the room A is adorned by two niches, one next to other. The deeper niche is named *su haznesi* because possibly a waterspout should be restored here (figure 6). The space is 65 cm wide, 160 cm long and 72 cm in height. It is constructed with bricks in the vault on the façade and cut stones in the walls and ceiling. The second niche is 65 cm wide, 60 cm long and 90 cm height. There is a basin with a drain at the bottom of the niche. The outlet, 15 cm in diameter, of WL-3 is set into the face of the wall, in the center of the back wall.

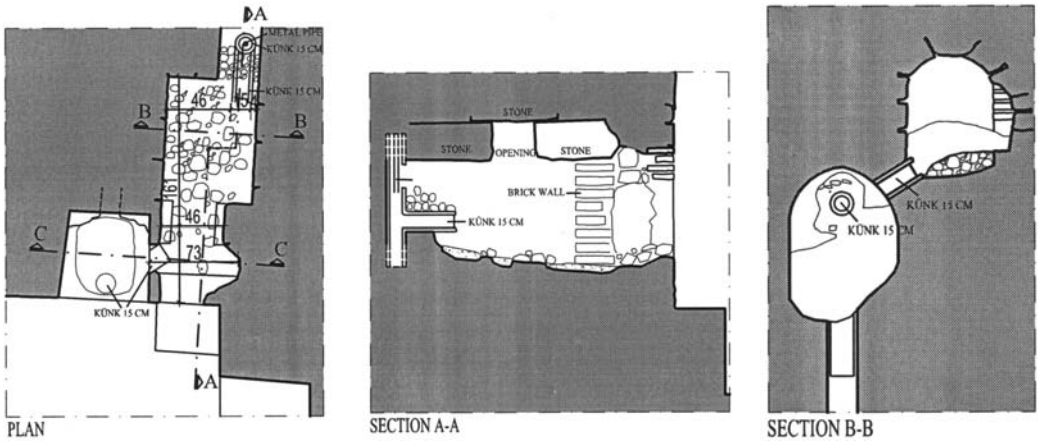

Figure 6 – Detail of *su haznesi*

Künks:
The *künk*s observed in Çukur Hamam are made of terracotta and generally have conic sections (figure 7). They are produced in standard dimensions as unit elements: the examples in the hot rooms (room B3 and room C1-C9) are 29 cm long and a width of 14 cm-10 cm at the ends of conic *künk*s. The examples in room A are larger in diameters, which are preliminary to the others within the water supply system. In some examples, lead pipes in 4 cm diameter are installed inside the *künk*s (examples in room A and C7). The *künk*s are approximately 8 cm inside from the surface of rubble wall and embedded in the thickness of the mortar with an efficient minimum slope. Instead of rubble stone, a course of brick is laid flat above the *künk*s because brick is installed easily comparing to the rubble stone. The mortar between the surfaces of cold and hot water pipes provide insulation for heat loss or transfer as well as prevent any kind of water leakage.

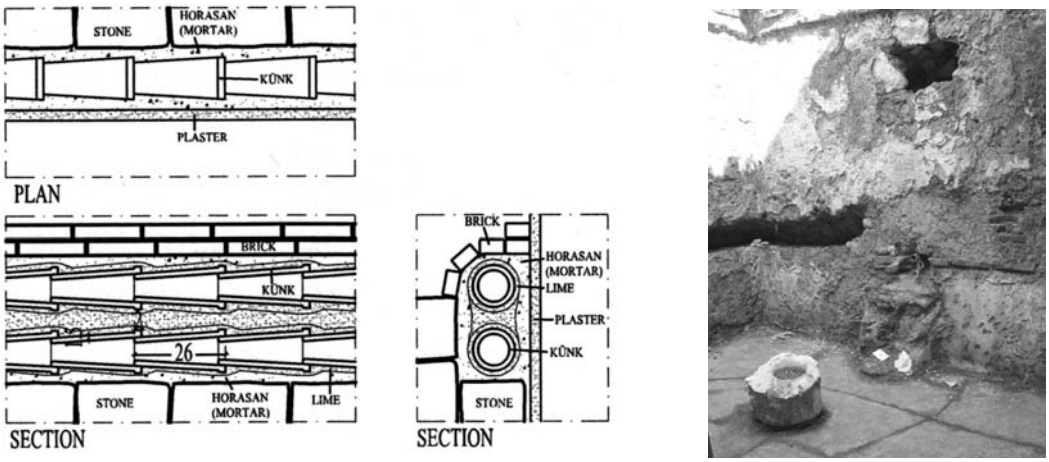

Figure 7 – Detail of *künk*

Kurna:
There are 7 *kurna*s in Çukur Hamam, located in the *sıcaklık* section (figure 8). However, the water outlets and traces on the walls indicate more *kurna*s in the *sıcaklık* section and room B3, which were removed in the recent past. In original plan, there are generally 3 *kurna*s in each room and they are located in the center of the walls. Each *kurna* has two outlets for hot and cold water. Moreover, the water capacity of each *kurna* is approximately 0,02 m^3.

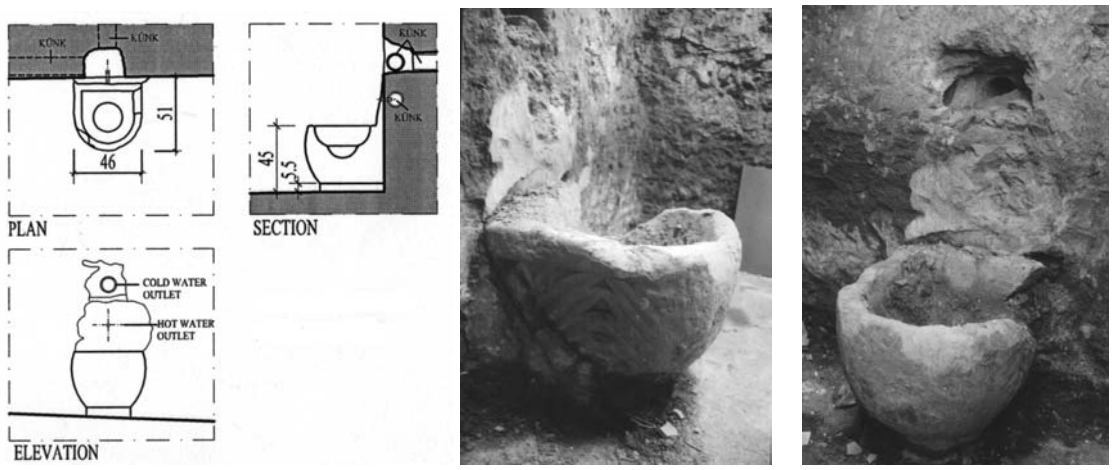

Figure 8 – Detail of *kurna*

Pool:
The pool, 150 cm wide, 285 cm long and approximately 150 cm height, is not a part of the original plan of room C2 (figure 9). The original kurnas were removed and it was placed against the north wall of the room. The base of the pool is covered with deposits so the water outlet or drainage system is not observed.

Kazan:
The *kazan*, as an element of hot water supply system is set 70 cm below the floor of water tank, on the center of the plan, above the heat source. The circular metal, 100 cm in diameter, was removed (figure 10).

Figure 9 – Pool

Figure 10 – Water Tank

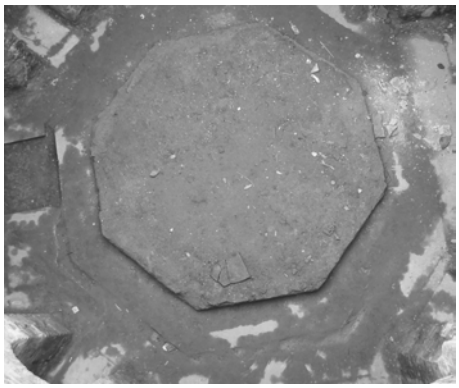

Figure 11 – *Göbek taşı*

3.2 Heating system

Çukur Hamam is heated by hot water steam and smoke. Heating by steam happens when the hot steam, coming out of the hot water tank, flows to the *sıcaklık* section through the window of room C7 or when hot steam rises from the *kurna*s during the bathing. Smoke heating is done by the hypocaust system, which is defined as the circulation of smoke through the *cehennemlik* and *tütekli*ks, which heats floor and walls of the *hamam* (figure 12).
During the field study, *külhan* and *cehennemlik* were not examined but there is a certain amount of information about *cehennemlik* in the sources. Smoke produced by the *külhan* (room E) flows first inside the vaulted channels under the floor of room D and then circulates round the *cehennemlik*. The floor of the hypocaust is supported by pillars (0.60-0.80 m on centers) and creates a suspended floor, approximately 1.00 m in height. The floor itself is constructed of two layers of stone (marble slabs in 5 cm thick and slate stone slabs in 6 cm thick) with a layer of mortar. The pillars are constructed of square bricks, 23 cm wide and 4 cm thick. The bricks used between slate stones and pillars have larger surface to reduce the surface pressure.
During the field study, 16 *tütekli*ks are observed in the *sıcaklık* section and room B3, three of them open to the roof (figure 13). The *tütekli*ks on the exterior walls are 50 cm inside the wall surface and approximately 25 cm in diameter. The *tütekli*ks in room C4, C5 and C6 indicates that originally, there are two *tütekli*ks on the exterior walls of each rooms. The *tütekli*ks on the interior walls are 35 cm - 40 cm inside the wall surface and approximately 20 cm in diameter. There are two *tütekli*ks on the interior walls, each of

them are close to the wall surface of one room. *Tütekliks* are constructed as a hole inside the massive rubble stone walls but there are *künks* inside two *tütekliks*
It is possible to say that *tütekliks* as elements of heating system is designed to support hot water supply system in Çukur Hamam, and details are produced to interrelate water supply and heating systems. Besides heating, *tütekliks* on the exterior walls provide control of heat loss or transfer while ones on the interior walls keep hot water circulates at a certain temperature inside the *hamam.*

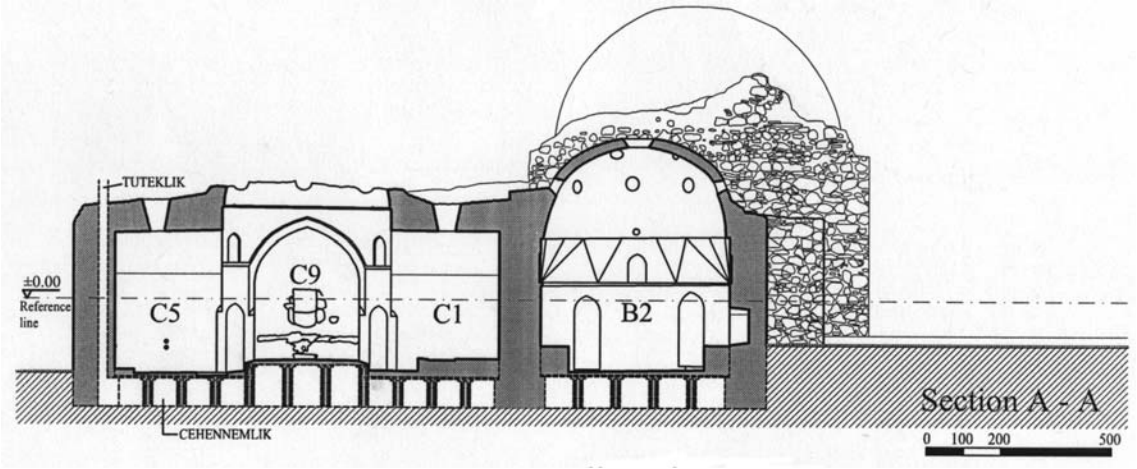

Figure 12 – Section A-A

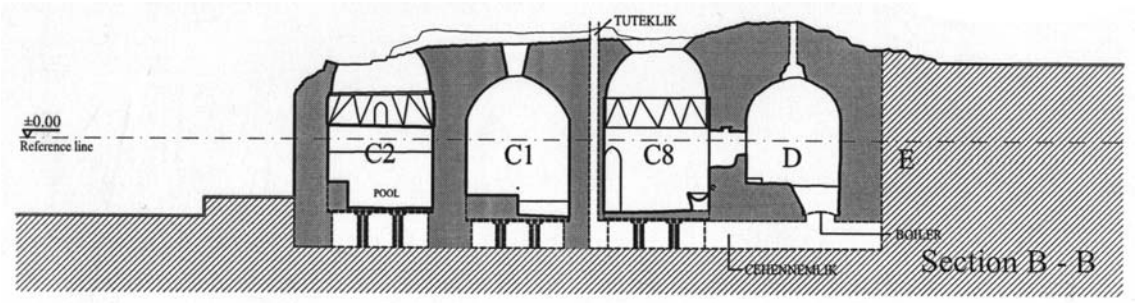

Figure 13 – Section B-B

3.3 Surface water discharge

In Çukur Hamam, only the surface-water discharge system is observed. The waste water flows on the surface of floor, which slopes from *sıcaklık* to *ılıklık* sections in 2% or 3% incline. The marble floor slopes to the door opening in the *halvets* while it slopes to the central space in the *eyvans*.
By the slope of floor, the waste water is collected and directed to the open channels on the floor, which are 14 cm wide and a depth of 4 cm. The open channel first circuit rounds the octagonal *göbektaşı*, approximately 0.47 m far from the *göbektaşı* (figure 11). Then it runs along the east wall of room C1 and B2 as a line and run beneath the sill of the doorway, connecting room B2 to B1. The floor of rooms B2 and B3 slope to the channel in 3% slope. Finally waste water runs below the floor of B1 by a pipe in 20 cm in diameter. The traces in the toilet indicate the exact position of the main drainage pipe, which is located along the north wall of the toilet.

4 Conclusion

Çukur Hamam is an example for 14th century bath, which attains original characteristics of water supply and heating systems with most of their components. Studying this building is important not only for history of architecture and conservation of cultural heritage but also for today's architectural practices for giving inspiration and the chance to utilize the experiences collected in centuries.
The water supply and heating systems of Çukur Hamam served for 700 years as a consequence of rational solutions in its design. This study is sort of a pre-study, which defines heating and water supply systems in Çukur Hamam as an example but not define efficiency, capacity and economy of these systems. Thus this study can possibly provide bases for other research approaches, from many other disciplines, in the future.

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