PLASTER CHARACTERISTICS OF HISTORIC *ESKİ HAMAM* IN AYDIN

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ABSTRACT

PLASTER CHARACTERISTICS OF HISTORIC *ESKİ HAMAM* IN AYDIN

Aydın *Eski Hamam* is a typical example of Ottoman period bath buildings. It had been built during 15^{th}-16^{th} centuries, and subjected to extensive interventions by present. The building was registered in 2001, and excavation, cleaning and measured surveys were carried out in 2016-2017.

The aim of this study is to determine the characteristics of the horasan and lime plasters of *Eski Hamam*. Within this purpose, horasan and lime plasters, joint mortars and building bricks were collected from the bath. Basic physical properties, raw material compositions, microstructural and hydraulic properties of plasters, mineralogical and chemical compositions of binders and aggregates, and pozzolanic activities of aggregates were determined by standard test methods, XRD and SEM-EDS analyses in order to shed light on the restoration implementations.

The results revealed that all the studied samples were of low density and high porosity. Physical, chemical and microstructural properties of plasters did not differ according to the space, level and layer they had been used. Horasan plasters had been prepared by using pure lime and brick aggregates. Lime plasters used on the upper levels had been produced by using pure lime and small amount of fine sand. Horasan plasters were hydraulic due to the use of pozzolanic aggregates. Brick aggregates had been manufactured by using raw material sources containing high amounts of clay minerals, and fired at low temperatures. Lime plasters and mortars had hydraulic properties due to the use of pozzolanic natural aggregates.

ÖZET

AYDIN'DA BULUNAN TARİHİ ESKİ HAMAM'IN SIVA ÖZELLİKLERİ

Aydın Eski Hamam, konumu, planlama özellikleri, yapım tekniği ve malzeme özellikleri ile Osmanlı Dönemi hamam yapılarının tipik bir örneğidir. Yapıdan gelen izlerden ve mimari özelliklerinden 15 ile 16. yüzyıl başlarında inşa edildiği anlaşılan hamam, daha sonra sıcaklık mekanı ve çeşme eklenmesi gibi kapsamlı müdahaleler görmüştür. 2001 yılında tescil edilen yapıda 2016-2017 yıllarında kazı, temizlik ve rölöve çalışmaları gerçekleştirilmiştir.

Bu çalışmanın amacı, Eski Hamam'da kullanılmış horasan ve kireç sıvaların özelliklerinin belirlenmesidir. Bu amaçla, yapının soyunmalık-ılıklık, sıcaklık mekanlarının ve su deposunun farklı seviyelerinden ve sıvaların farklı katmanlarından sekiz horasan sıva, beş kireç sıva, iki kireç harcı ve iki yapı tuğlası örnekleri alınmıştır. Restorasyon uygulamasına ışık tutmak amacıyla örneklerin temel fiziksel özellikleri, hammadde kompozisyonları, mikroyapısal ve hidrolik özellikleri; bağlayıcı kısımların ve agregaların mineralojik ve kimyasal kompozisyonları ile agregaların puzolanik aktiviteleri standart test yöntemleri, XRD ve SEM-EDS analizleri ile belirlenmiştir.

Elde edilen sonuçlara göre, incelenen sıvaların tamamı düşük yoğunluklu ve yüksek gözenekli malzemelerdir. Horasan ve kireç sıvaların fiziksel, kimyasal ve mikroyapısal özellikleri kullanıldıkları döneme, mekana, seviyeye ve katmana göre farklılık göstermemektedir. Horasan sıvaları 1/2 ile 1/1 arasında değişen oranlarda, saf kireç ile tuğla agregalarla, üst seviyelerde uygulanmış kireç sıvalar ise %93-97 arasında değişen oranlarda saf kireç ve çok az miktarda ince kum ile üretilmiştir. Agrega olarak kullanılan tuğlaların puzolanik özellikte olmalarından dolayı horasan sıvalar hidroliktir. Bu tuğlalar, yüksek miktarlarda kil içeren hammadde kaynaklarından hazırlanmış ve düşük sıcaklıklarda (< 900ºC) pişirilmişlerdir. Kireç sıvalarda ve harçlarda kullanılan doğal agregalar da puzolanik olduğundan kireç sıva ve harçlar da hidrolik özelliktedirler.

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CHAPTER 1

INTRODUCTION

Throughout history, human have made use of rivers and have built baths for their cleaning since it was an important activity both physically and spiritually in many societies (Erden 2015, Ürük 2016, Esemenli 2005). Besides their major function, baths have been used as entertainment places as well in some cultures. (Erden 2015). Although, Turkish baths in Anatolia were similar to Roman baths in terms of construction plans, they have been developed quite differently compared to ancient washing places as a result of the usage style and architectural traditions (Önge 1988, Yegül 2009). They have simple architecture due to their functional nature. Cultural influence and climatic conditions were determining factors in the planning. In the Islamic culture, it was believed that flowing water was clean. Hence, pools were not used in the baths except spas (Erden 2015). Baths were either built as a double bath or used at different time slices since men and women could not wash in the same place (Erden 2015).

The Ottoman period was the period in which most of the Turkish baths were built not only for the needs of cleanliness but to show the power of the polity as well (Erden 2015). Bath buildings soğukluk (warm area), ılıklık (warm area), *sıcaklık* (hot area) and water reservoir were developed in this period. Double baths with men and women entrances from different streets were built to provide privacy in this period.

The Ottoman baths were built mostly in masonry system and the building materials are stone, brick and lime mortar in construction; horasan and lime plasters in finishing. Horasan plasters, which play an important role in preserving the architectural characteristics of these buildings and enabling them to reach to present day, were applied on the interior and exterior on the domes, and generally on the interior surface on the walls. On the lower level of the wall surfaces, which more exposed to water from original floor level to ~1.5 m height, horasan plasters were used as one or more layers with a less porous finishing layer. On the upper level of the walls, one horasan plaster layer and one lime plaster as second layer were used.

Eski (Old) *Hamam* is one of the outstanding examples of Ottoman period bath buildings with its location, planning characteristics, construction tachnique and material properties. The bath, which was understood to be built in the 15th and early 16th centuries due to the traces coming from the building and to its architectural characteristics, had been subjected to extensive interventions for three times. The bath had been constructed in a rectangular plan form consisted of a *soyunmalık-ılıklık* space, two *sıcaklık* spaces and a water reservoir. Afterwards, another *sıcaklık* space had been added depending on the needs; later on, the water reservoir had been expanded, a fountain had been built and some of the openings had been closed. The building was registered in 2001, and excavation, cleaning and measured surveys were carried out in 2016. In the bath, somes of the *sıcaklık* spaces, vault of the water reservoir and some of the walls have been largely damaged and studies for the restoration project of the building have been still ongoing.

In this study, the properties of horasan and lime plasters applied on the interior wall surfaces of *Eski Hamam* in two different periods (15th-early 16th and end of 16th-17th centuries) were investigated in order to compare their characteristics according to the construction periods of the bath and to determine the properties of the new plasters to be produced for the restoration works.

1.1. Subject and Aim

The concept of a historic monument embraces not only to large-scale works of art but also to more modest works of the past which have acquired cultural significance with the passing of time (The Venice Charter). This value includes the structural and material properties as well as the architectural features of the cultural assets.

Changes made over time should also be considered a document reflecting the characteristics of the traditional architecture and the original structural and architectural characteristics of the additions must be respected (ICOMOS). The conservation and restoration of monuments must have recourse to all the sciences and techniques which can contribute to the study and safeguarding of the architectural heritage (The Venice Charter).

Historical buildings have original material properties because even if the materials which to be used in historical buildings, within a certain technology, they are produced separately for each building by the skilled work people. For this reason, the materials of a building may not adapt to another building. In this case, both the materials and the building are completely damaged. In addition to all these, the original building materials reflect the building technology of the period when they were built. Therefore the materials of each building should be analyzed and documented in detail, and preserved.

When new material needs to be used, new plaster and mortars should be produced in physical, chemical, mechanical and aesthetically compatible with the original material in accordance with the analyzes determined.

The aim of this study is to sum up the architectural features and historical background of *Eski Hamam* which has not been studied before, in terms of the material characteristics, therewithal to determine the properties of the new plasters in case of producing in the restoration works and also for sheding light on the process.

1.2. Limit of the Study

Eski Hamam is a building that contains additional buildings constructed at different times and it is covered with horasan and lime plaster, which is thought to have different compositions of interior wall surfaces.

In this thesis, the properties of the plasters, mortars and bricks used in the bath were determined. According to the determined results the material properties of the bath were compared with its own addition buildings in two different periods (15^{th}-early 16^{th} and end of 16^{th}-17^{th} centuries) and with some of the other Ottoman bath buildings. If new materials need to be used for restoration, the properties of the new plasters to be produced are given.

Study is limited with determination of properties of original materials, does not include the production of new plaster and mortars.

1.3. Method of the Study

Method of the study started field surveys, followed by collection of samples and experimental studies. According to the field survey, usage of plaster in *Eski Hamam* was determined and level and layers of the plasters applied in two different periods (15^{th}-early 16^{th} and end of 16^{th}-17^{th} centuries) were documented by photographs according to their locations. Depending on the studies, drawings and images were prepared. The samples were collected from every space on the basis of the parts considered as unique, in cases where the physical properties belonging to a space do not show a continuity.

In the experimental studies, basic physical properties and raw material compositions of plasters; pozzolanic activities of crushed brick aggregates and building bricks; mineralogical and chemical compositions and microstructural properties of plasters, crushed brick aggregates and building bricks; and hydraulicity of plasters were determined by using standard test methods, XRD and SEM-EDS in order to shed light on the restoration works.

Within this context, architectural characteristics, plaster usage and present conditions of plasters of *Eski Hamam*, and general information about the Turkish baths and the use of plaster in Ottoman baths were given in the second chapter. In the third chapter, experimental studies were given. In the fourth chapter, results were given and experimental studies were evaluated and discussed. Finally, the conclusions of the study were given in the fifth chapter.

CHAPTER 2

PLASTER USAGE IN OTTOMAN BATHS AND AYDIN *ESKİ HAMAM*

This chapter comprises general information on Ottoman baths and the use of plastering in their construction. Subsequently, information about Aydın *Eski Hamam* is provided and plaster usage in the bath is subsequently characterized.

2.1. Features of Ottoman Baths

Water and sewage systems believed to have survived from approximately 2000 B.C. show that the construction of public baths, born out of the need for purification, had already begun at the time (Eyice 1997). These public baths referred to as baths displayed a variation in time due to the cultural characteristics of civilizations and their interactions. Bathhouses that have survived to present are heritages of this historical development.

The term bath is derived from the Arabic word *hamm* (*hamem*) meaning "hot, to heat." Bath (*hammam*) also means "place of heating and bathing" (Eyice 1997).

The history of baths dates back to 2500-1500 B.C (Eyice, 1997). In addition to the primitive bathhouses found in Egypt, building complexes in ancient Greece had special spaces for bathing (Ülgen 1950).

Roman baths developed from Greek baths and have evolved over time from irregular plan schemes to symmetrical planning. During this period, public bath architecture advanced and bathhouses became places of recreation, relaxation, sports, conversation and discussion in addition to their original function (Wheeler 2004). Byzantine baths continued the Roman tradition of being facilities for both bathing and recreation (Ülgen 1950).

Non-Anatolian Islamic baths retained East Roman public bath culture for the most part. Baths gained prominence in the Islamic world due to the religious emphasis on cleanliness (Ertuğrul 2009). These baths maintained the heating and service spaces in the

Roman fashion and typologically had the same character albeit the difference in religious culture (Önge 1988).

Baths constructed during the Seljuk Period were generally designed to utilize flowing water in accordance with Islamic rules, and Turkish baths differed from ancient period baths (Eyice 1997). In baths built in Anatolia by the Seljuks, bathers washed themselves by pouring water from *kurna*s (basins) and used the *göbektaşı* (navel stone) for perspiration instead of using a separate space (Önge 1988).

Turkish baths in the Ottoman Period originated from Roman bathing practices (Eyice 1997). Although the Turkish bath structure is closely related to Roman baths, they were developed and continued with the principle utilized in Seljuk baths. Interior architectural details were improved and the concept of positioning the entrances to male and female sections on different streets, with entrance of men's sections generally leading to the main street or square and women's entrance to a side street, was maintained. Men's sections are of approximate size as women's sections in some double baths, while men's sections are larger than women's in others. There are also examples where a bath originally constructed as a single bath was converted to double baths with an addition (Önge 1988). Ottoman Period baths were constructed both as a part of a *külliye* and as individual buildings on independent spaces. Baths became a part of social life in addition to their original function of bathing during this period (Ürük 2016). However, spaces such as the *palaestra* and the *atrium* were not implemented in Turkish baths (Eyice 1997).

The names of the main spaces in Turkish baths are derived from *soyunmalık* (*apodyterium*), *ılıklık* (*tepidarium*), *sıcaklık-halvet* (*caldarium*) and water reservoir with *külhan* (*hypocaust*) in Roman baths (Arseven 1943). These spaces in Turkish baths are *soyunmalık (camekan), aralık, ılıklık, sıcaklık,* water reservoir*, külhan* and *cehennemlik* (Önge 1988).

Turkish baths historically consisted of the *soyunmalık, aralık, ılıklık* and *sıcaklık* as the main spaces and hot-cold water reservoirs and the *külhan* (furnace) as service spaces. The main spaces of baths changed over time to comprise the *soyunmalık*, *ılıklık* and *sıcaklık* (Önge 1988).

Soyunmalık (dressing space) is generally the largest space of a bath used for undressing-dressing before entering the bathing spaces (Önge 1988).

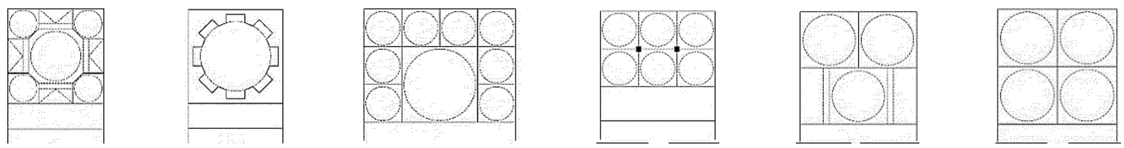
Aralık (mediating space) is a space that functions as a passage between the *soyunmalık* and the *ılıklık* in 12th-13th Century baths. *Aralık* was a feature of early period baths and its dimensions were decreased in the 15th Century to become completely obsolete in the 16th Century, allowing direct passage from the *soyunmalık* to the *ılıklık* (Önge 1988).

Ilıklık (warm space) is the space situated between the *soyunmalık* and the *sıcaklık* and serves to prevent sudden temperature changes when traversing between these spaces. The *ılıklık* involves the toilet and the *traşlık* sections (Eyice 1997). In addition, it was used for bathing by the elderly and by people with blood pressure problems (Aru 1949).

Sıcaklık (hot space) is the primary bathing space in baths (Eyice 1997). Clean water was accumulated in *kurna*s. Terracotta pipes in the walls were used to transport hot and cold water to *kurna*s. Smoke were circulated and discharged via *tüteklik* pipes in the walls, also facilitating the heating of the bath (Önge 1988). One of the *halvets* had an opening to water reservoir called the control window, which allowed inspection of the water level in the reservoir and contributed to the heating of the bath (Erden 2015).

As the *sıcaklık* was the main space for the main organization of Turkish baths, Semavi Eyice categorized Turkish baths in six plan orders (Eyice 1997):

a. Cross-axial plan with four iwans and four corner *halvet*s (units)
b. *Sıcaklık* with a star-shaped plan type
c. Type with *halvet*s arranged around a square *sıcaklık*
d. Type with a multi-domed *sıcaklık*
e. Type with horizontal *sıcaklık* with a domed central *halvet* and two *halvet*s
f. Type with a *soyunmalık,* an *ılıklık* and a *sıcaklık* of a *halvet* of equal size



a. b. c. d. e. f.

The **water reservoir** and ***külhan*** was a single space structure that was attached to the *sıcaklık* wall and independent from the interior spaces of the bath. In the water reservoir was heated by a copper boiler over the burning firewood. The *odunluk* (woodshed) was a separate section located on the outer part of the bath (Önge 1988, Yılmazkaya 2002).

With respect to their architectural characteristics, Turkish baths are plain and modest self-enclosed structures as a result of their functions (Kuban 1977). However, there are some bath examples with rich and ostentatious ornamentations interiors. The plan scheme of Turkish baths is generally discernable from the main mass. The dome of the *soyunmalık* generally dominates the building (Kuban 1977). The stonemasonry walls of *soyunmalık* were generally constructed without much care and the earliest bath examples had blind walls. Beginning from the Beyliks Period in Anatolia, the blind *soyunmalık* walls were replaced with walls with openings, and porticos were also added to the front of the entrances in later periods (Eyice 1997). Some Classical-era baths became relatively more ornamented with the addition of stonework to men's main entrances and *aydınlık feneri* (lantern for lighting) to the *soyunmalık* (Eyice 1997). Artistic stoneworks in baths are mostly found at interior spaces such as marble *kurna*s, *seki*s (stone seats), armrests on the sides of the *seki*s and over the doors (Eyice 1997). The heads of any columns in the *sıcaklık* are adorned with diamond and muqarnas motifs (Eyice 1997). The walls in some baths and the floors were covered with marble after the Principalities Period. Some Anatolian Seljuk baths have hand-drawn decorations over the plastering (Eyice 1997).

Transition elemens of the domes, rather than the walls, were ornamented due to the humid environment of baths (Önge 1988). In Turkish baths, all interior walls, arches, vaults and domes were coated with plaster, and decorations on the wall and door niches, as well as, vault and dome squinches were adorned with profiles, cornices and muqarnas made of plaster (Önge 1988). Modest ornamentations of plaster were applied since early-period baths and retained during the Mimar Sinan Period (Önge 1988), while ceramic glaze ornamentations were observed since the Seljuk Period (Ertuğrul 2009).

The majority of Turkish baths were masonry structures constructed with stones and bricks as building materials, lime mortar as binder, and horasan and lime plaster as plastering. Although stone and brick arrangement varied among buildings, plastering was mostly similar. Horasan mortars were employed as insulant on the domes of some baths due to their resistance to water, and the horasan layer was covered with pantile tiles in many of these buildings. Horasan and lime plasters were generally used on interior faces of all spaces. A less-porous finishing layer over one or more layers of horasan plaster was applied on the lower levels, from the floor to a specific height of generally up to approximately 1.5m or lower, of *sıcaklık* walls for water protection. The higher levels that were less subject to humidity were generally coated with lime plaster over a single layer of horasan plaster, or only had a lime plaster coating (Reyhan 2004, Uğurlu 2005, Reyhan 2011).

2.1.1. Use of Plaster in Ottoman Baths

Lime mortars are characterized in two groups as hydraulic and non-hydraulic (Lea 1940). Non-hydraulic lime mortars are produced by mixing lime and inert aggregate. These mortars harden as lime turns into calcium carbonate by reacting with carbon dioxide in the air. Hydraulic mortars are produced by using hydraulic lime or by mixing pure lime and pozzolans (Lea 1940). Hydraulic lime mortars set with the conversion of lime into calcium carbonate, as calcium aluminate silicates and water produce calcium silicate hydrates and calcium aluminate hydrates (Lea 1940). Hydraulic mortars have greater durability than non-hydraulic mortars due to the formation of these products (Lea 1940, Akman et al. 1986, Tunçoku 2001).

Since 1st Century B.C., terracotta materials such as broken brick or tile pieces were used in lime mortar as artificial pozzolans (Mac Donald 1960). These mortars were called *cocciopesto* in Rome (Massazza and Pezzuoli 1981), *surkhi* in India (Spence 1974) and *homra* in Arab countries (Lea 1940). In Byzantine, Seljuk and Ottoman period, crushed bricks was referred to as *horasan,* and these mortars were named horasan mortars (Akman et al. 1986).

Horasan mortars and plasters, prepared with crushed bricks and lime, were one of the most important bonding materials used in the construction of historic buildings. Numerous researchers have studied the characteristics of the horasan mortars and plasters used in various historic structures. These studies were gathered and categorized by Hansen et al. (2003).

Mortars and plasters with pieces of bricks (i.e. artificial pozzolans) were used in baths, cisterns, water wells, aqueducts, bridges and roofings in Byzantine, Roman, Seljuk and Ottoman periods due to their hydraulicity and water resistance (Akman et al. 2000a, Moropoulou et al. 2002a). Vitruvius emphasized the importance of using fire bricks in the first plaster layer for walls exposed to water and high humidity (Vitruvius 1960).

Mortars with pure lime and pozzolan mixture require water for the reaction of lime with pozzolans. Calcium silicate hydrates and calcium aluminate hydrates formed as a result of this reaction give greater durability and hydraulicity mortars and plasters. The high amount of these reaction products in the chemical structure of horasan mortars and plasters ensure durability against humid environments. This also indicates that hydraulic mortars and plasters gain durability even under water.

Bricks and tiles are terracotta materials prepared with natural raw materials including clay (kaolin, illite, etc.), quartz, feldspar and other secondary minerals. Clay minerals provide plasticity to the raw material mixture, while feldspar reduces the melting point and quartz acts as a filler for cavities. These materials are mixed with water into a paste, dried and fired.

If heating is conducted at 600-900 ºC, the clays have different pozzolanicities depending on the temperature and mineralogic structure (He et al. 1995, Baronio and Binda 1997). At these temperatures, the chemical structure of clay minerals is degraded, and amorphous aluminosilicate is formed (He 1995), which provides the pozzolanicity of the calcined clays. In horasan mortars and plasters, lime reacts with the amorphous silica and alumina in bricks to produce calcium silicate hydrate and calcium aluminate hydrate. For example, kaolin ($Al_2O_3.2SiO_2.2H_2O$), a material used in bricks, turns into metakaolin ($Al_2O_3.2SiO_2$) with pozzolanic properties when heated at approximately 600ºC (Reaction 2.1), and metakaolin reacts with lime to produce aluminum silicate hydrate and calcium silicate hydrate (Reaction 2.2) (Prince et al. 2001).

$$\underset{\text{(Kaolin)}}{Al_2O_3.2SiO_2.2H_2O} \rightarrow \underset{\text{(Metakaolin)}}{Al_2O_3.2SiO_2} + H_2O \tag{2.1}$$

$$\underset{\text{(Metakaolin)}}{Al_2O_3.2SiO_2} + \underset{\text{(Lime)}}{7Ca(OH)_2} + 19H_2O \rightarrow \underset{\text{(Tetracalcium aluminate hydrate)}}{4CaO.Al_2O_3.19H_2O} + \underset{\text{(Calcium silicate hydrate)}}{3CaO.2SiO_2.7H_2O} \tag{2.2}$$

Quartz minerals do not have pozzolanic activity. Calcination temperatures higher than 900ºC lead to the formation of minerals such as mullite and cristobalite and loss of hydraulicity due to the stable structure of these minerals (Lee et al. 1999). The pozzolanicity of kaolin after heating is greater than that of montmorillonite and illite (Ambroise et al. 1985). Feldspars react with lime to produce tetracalcium aluminate hydrate and their pozzolanicity is dependent on their mineralogical structure (Aardt and Visser 1977).

Gehlenite (800ºC), diopside (850ºC) and wollastonite (900-1050ºC) for calcium rich clays and hematite (850ºC) for clays not rich in calcium are important minerals produced at different firing temperatures (Cardiano 2004).

The characteristics of horasan mortars were examined with samples from numerous buildings such as some Byzantine or later-era structures in Rhodes, Venice and Crete, as well as, Hagia Sophia in Istanbul. In these buildings, the lime/brick dust ratio varied between 1/4 and 1/2 (Livingston 1993, Moropoulou et al. 1995 and 2000b, Güleç and Tulun 1996, Biscontin et al. 2002). XRD analysis of these mortars revealed that the binding material comprised calcite crystals produced by the calcination of lime and calcium, silicate and aluminate hydrates that are the products of the reaction between brick dust and lime (Moropoulou et al. 1995 and 1996). The ratios of weight loss due to the loss of water in calcium silicate and aluminate hydrates at 200-600°C and the loss of carbon dioxide in calcite at 700-900 °C provide valuable insight into the hydraulic properties of these mortar samples (Bakolas et al. 1998, Moropoulou et al. 2000b, Biscontin et al. 2002).

Horasan mortars are lighter and have greater tensile strength as the density of the bricks used in horasan plasters as aggregate is lower than that of other aggregates (limestone, granite, basalt, etc.). The mortar used in the dome of Hagia Sophia is one such example. The high porosity and low density of the bricks and the horasan mortar has allowed the construction of a more earthquake resistant dome (Livingston 1993, Moropoulou et al. 2002a).

Studies have mentioned the prerequisite to use new and well-fired bricks in the production of horasan mortar during the Ottoman era (Akman, 1986; Denel, 1982). The prerequisite of using freshly-fired bricks can be explained by the need to prevent loss of reactivity due to contact with water as amorphous silicas activated by water produce silicic acid which reacts with the carbonates likely to be present in bricks and lose their reactivity (Lynch et al. 2002) Good firing might be the requirement of the complete amorphization of all the clays that constitute the raw material of bricks. 550-600ºC is the temperature interval at which the highest amount of amorphous material is produced (Moropoulou et al. 2002a). Bricks must be freshly fired and used without contact with water; otherwise, amorphous silicas activated by water produce silicic acid which reacts with the carbonates in bricks and lose their reactivity (Lynch et al. 2002). The fact that these conditions were designated in old specifications indicate the years of experience as to the preparation of horasan mortar and plaster. This experience was lost with the utilization of cement as a construction material.

The first study in Turkey on horasan mortars and plasters was conducted by Akman et al. (1986). They determined the compressive strength of horasan mortars from a Byzantine cistern and produced horasan mortar for restoration purposes to investigate its compressive strength characteristics. This is an important study as it contains the oldest written sources on horasan mortars.

In later studies on horasan mortars and plasters, researchers examined the physical characteristics and raw material ratios in samples from various historic buildings, and manufactured horasan mortar (Satongar 1994, Güleç and Tulun 1996, Böke et al. 1999).

Another study on the subject involved horasan plasters used in Ottoman baths (Böke and Uğurlu 2008), which revealed that horasan plasters were porous and low-density material produced with pure lime and pozzolanic crushed bricks. The lime/aggregate ratio ranges between 1/2 and 3/2. The plaster has hydraulic properties due to the pozzolanicity of the bricks used as aggregate, which results from the high amount of clay in the raw material and the low firing temperatures. Calcium silicate hydrate and calcium aluminate hydrate is formed on the surface and in the pores of the brick aggregates as a result of the reaction between lime and brick aggregates. Dissolved calcium carbonate precipitates in the pores of the bricks in the mortar, preventing deterioration and promoting plaster durability. These results show that horasan mortars and plasters are the most suitable materials against humidity.

The pozzolanic characteristics of the bricks and tiles in horasan mortars and plasters were investigated by Baronio and Binda (1997). They examined the pozzolanicity of the brick samples, which were fired at 600-900°C, from the Basilica of San Lorenzo in Milan. The results revealed no pozzolanic effect, which indicated that not all bricks used historically and fired at low temperatures had pozzolanicity. The same study also examined the pozzolanic properties of kaolinitic clay mixtures used in making new bricks at 650-750°C. Although these samples did not have any pozzolanic properties, kaolinitic clay displayed pozzolanicity. These results show that firing temperatures below 900°C and a sufficient amount of clay minerals were required for bricks to have pozzolanic properties.

The results pertaining to the characteristics of the horasan plasters from several Ottoman baths (*Ördekli Hamam* in Bursa, *Saray Hamam* and *Beylerbeyi Hamam* in Edirne, *Hersekzade Hamam* and *Kamanlı Hamam* in Urla, İzmir and *Düzce Hamam* in Seferihisar, İzmir) were employed to designate the characteristics of bricks to be used as aggregate in horasan mortars and plasters for restoration purposes (Böke and Uğurlu 2008). The bricks should be manufactured from clay-rich natural raw materials; have high amounts of silicate aluminate and low amounts of iron oxide, low firing temperatures

(600–900ºC), high porosity (>30%) and no contact with water prior to usage; and not contain water-soluble salts. Clay, feldspar and quartz amounts, firing temperature, porosity and pozzolanicity of the bricks should be indicated. Similar results were observed in *Ördekli Hamam* in Bursa (Böke et al. 2006) and *Zeyrek Çinili Hamam* in İstanbul (İpekci 2016).

In conclusion, the bricks to be used in mortars and plasters should be checked for pozzolanicity, and bricks with pozzolanic properties, the fundamental characteristic that ensures hydraulicity of mortars and plasters, should be preferred. This is an issue overlooked in Turkey concerning mortars and plasters for conservation efforts, resulting in the use of mortars and plasters unsuitable for the restoration of historic buildings. A study sponsored by TÜBİTAK was carried out at the İzmir Institute of Technology to determine the characteristics of brick aggregates to be used in horasan mortars and plasters for restoration purposes (Böke et al. 2002).

2.2. Architectural Characteristics and Plaster Usage of *Eski Hamam*

Eski Hamam, located in Aydın city center, is an Ottoman bath believed to have been constructed in the 15th and early 16th centuries (Kürüm 2017) (Figure 2.1). It is also known as *Dutluca Hamam* by residents and referred to as *Rum Hamam*, having been used by the Anatolian Greek population for some time (Kürüm 2017).

Eski Hamam is an important source of information as it retains the characteristic technology, as well as, architectural and cultural structure of Ottoman baths, and substantially reflects the historical developments in its environment until the 20th century. The Aydın province was taken over by the Ottoman Empire in the 15th century (Merçil 1991) and the original construction of the bath dates back to this period, which indicates that *Eski Hamam* represents the earliest examples of Ottoman baths in Aydın (Kürüm 2017).

Eski Hamam has a plan type of “horizontal *sıcaklık* with a domed central *halvet* and two *halvet*s” according to Semavi Eyice’s classification (Eyice 1960, Kürüm 2017). The structure has evolved from a square plan scheme to one with a rectangular plan with additions in various periods (Figure 2.2).

Figure 2.1. *Eski Hamam* – general view from the west
(Source: ANKA Architecture and Restoration Office archive, April 2017)

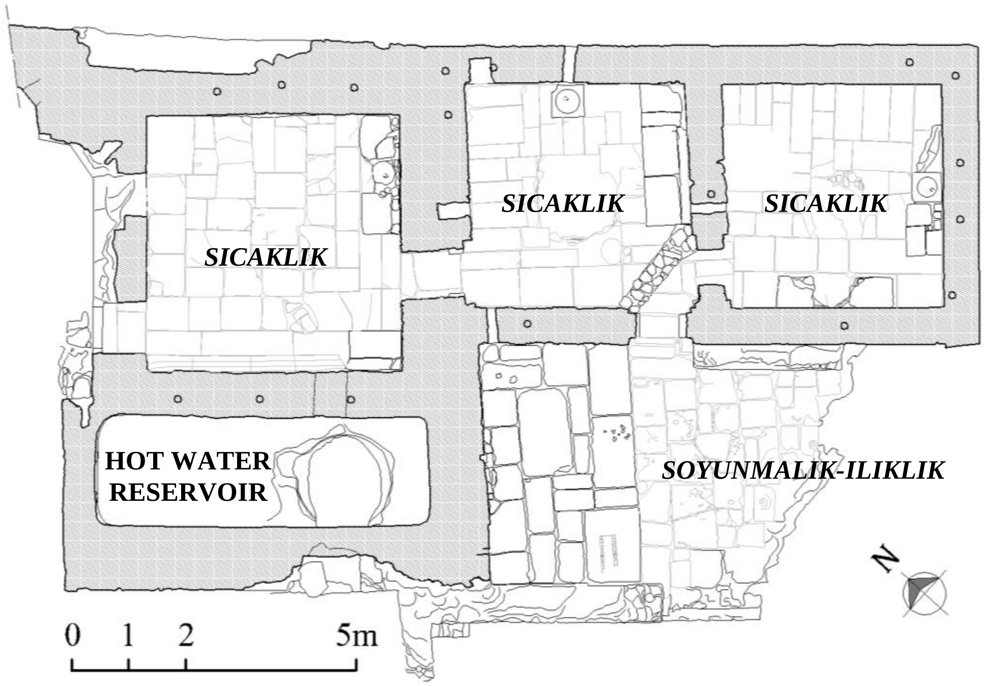


Figure 2.2. *Eski Hamam* plan scheme in 2016
(Drawn by: Fatma Gürhan, 2016, ANKA Architecture and Restoration Office archive)

The bath had stonemasonry walls, with domes and vaults made of brick. Interior and exterior spaces were completely plastered. Horasan and lime mortar was used for interior spaces while exterior spaces were coated with a lime-sand mixture. The domes were covered with round tiles over horasan plaster. Later additions to the building also have an analogous planning and similar material characteristics.

Measured surveys, taking photos and archive information works for *Eski Hamam* commenced in late 2016. During the initial effort, the bath was located on a plot filled with soil up to the ground level of the street located on the northern side, with most of the building underground (Figure 2.3). The originality of the building was mostly preserved with no structural issues with the standing walls; however, the dome and vault, as well as, the *soyunmalık-ılıklık* walls were collapsed, and the floor was damaged in the most places.

Figure 2.3. General view of *Eski Hamam* prior to clearing and archaeological excavation (Source: ANKA Architecture and Restoration Office archive, October 2015)

The bath was unearthed down to *cehennemlik* level with clearing and excavation studies carried out in late 2016 and early 2017 (Figure 2.4), which revealed internal architectural elements such as *kurna*s, *seki*s and plaster motifs in the *sıcaklık*s and floor coverings, and street elements like the fountain on the northern wall and the cobblestone road in front of the fountain. Water channels and terracotta pipes were also uncovered around the structure.

Figure 2.4. General view of *Eski Hamam* after clearing and archaeological excavation (Source: ANKA Architecture and Restoration Office archive, February 2017)

2.2.1. The Current Condition of *Eski Hamam* (2016 to Present)

Eski Hamam is an important public bath that is integrated with its surrounding and that reflects the architectural characteristics and construction technology of Ottoman baths and street pattern. The number of spaces have increased over time and a fountain was added to the building. The addition of a fountain to the bath indicates the bath had a central and busy location and, therefore, was a structure with an increasing historical value. Although the building was partially demonstrated and covered with soil, piles of trash, trees and plants until 2016, the original parts and the original additions that have survived illuminate the building's history and narrate the construction techniques of its period. Therefore, comprehensive studies with various disciplines were conducted to understand and document its historical background, architectural and construction characteristics in detail.

Eski Hamam is situated at Pınarbaşı Street, Zafer District in Efeler, Aydın. The measured survey, restitution and restoration drawings were conducted by ANKA Architecture and Restoration Office in İzmir and the art history report was prepared by Mükerrem Kürüm. The bath is registered on block 113, plot 9 at the land office. It was designated as a cultural property in need of protection on July 28, 2001 and transferred to Efeler Municipality on December 25, 2014.

The documentation work was carried out in three stages:

The **first stage** involved taking photos of the current condition of the building as fully as possible and archiving (Figure 2.5). In the **second stage**, the building was cleared from trash and plants (Figure 2.6) and primary measured survey were completed (Figure 2.7) (Figure A.1-17). The **third stage** comprises the archaeological excavation (Figure 2.8) and the following second measured survey (Figure 2.9) (Figure A.18-36).

Figure 2.5. *Eski Hamam* prior to clearing
(Source: ANKA Architecture and Restoration Office archive, October 2015)

Figure 2.6. *Eski Hamam* after clearing
(Source: Fatma Gürhan, July 2016)

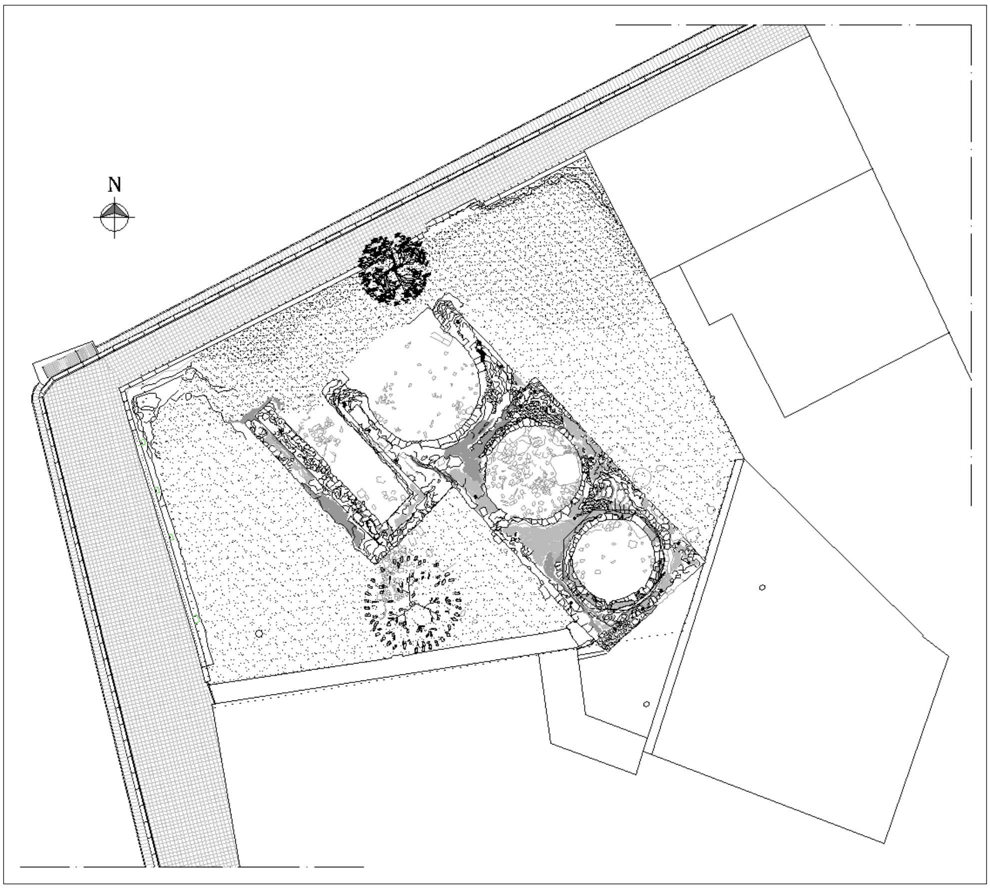


Figure 2.7. *Eski Hamam* plan, primary measured survey after clearing and before archaeological excavation (Drawn by: N. Nur Kocasoy Bağcı, 2016, ANKA Architecture and Restoration Office archive)

Figure 2.8. *Eski Hamam* archaeological excavation

(Source: ANKA Architecture and Restoration Office archive, October 2016)

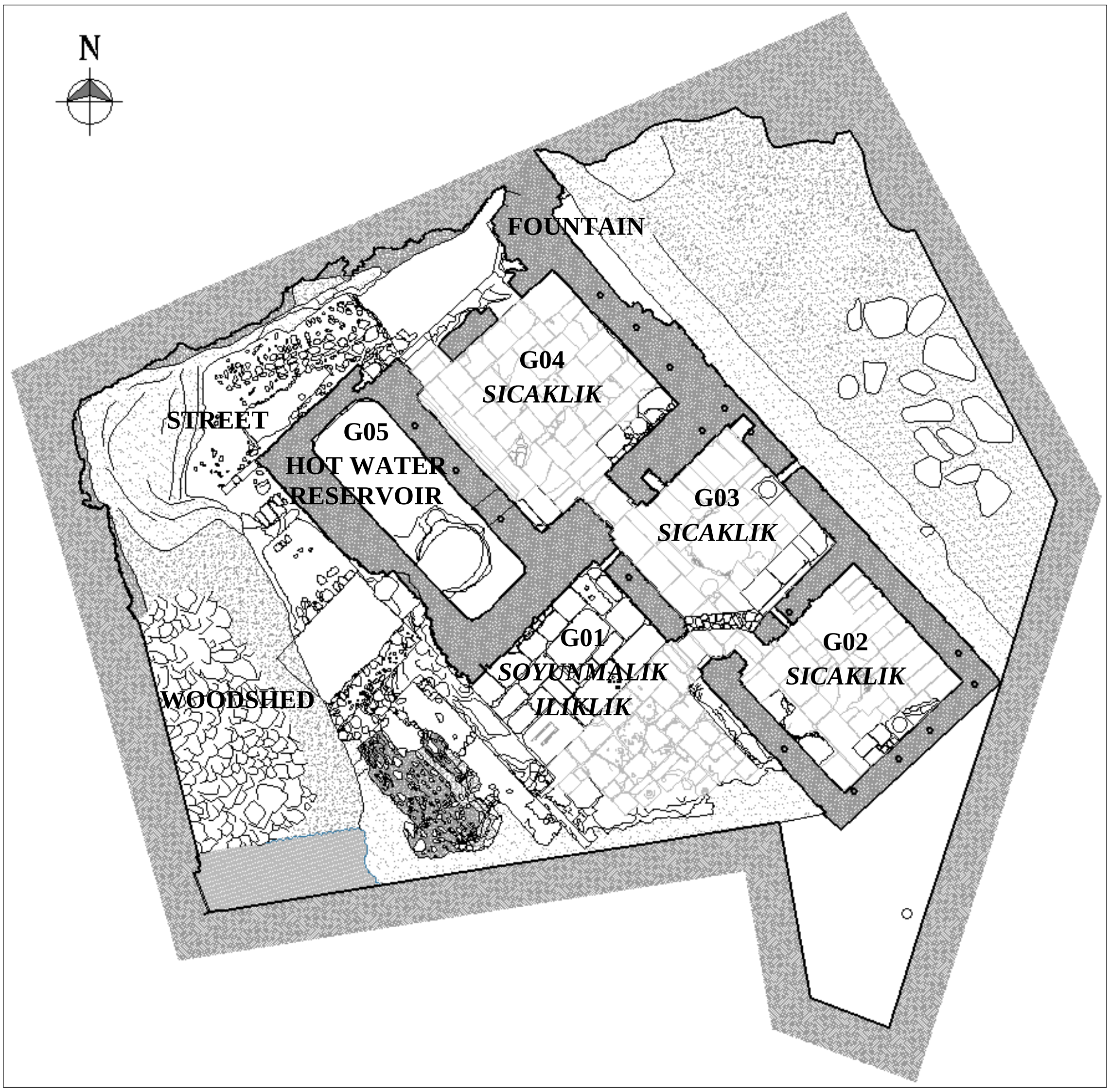


Figure 2.9. *Eski Hamam* plan, second measured survey after archaeological excavation (Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office archive)

The current structure of the *Eski Hamam* building has a plan consisting of five spaces; i.e. a *soyunmalık-ılıklık*, three *sıcaklık*s and a water reservoir (Figure 2.9). In addition, the fountain, the terracotta pipes leading to the water reservoir, the cobblestones, the woodshed and the terracotta jars are considered to be integral parts of the whole.

2.2.1.1. G01 *Soyunmalık-Ilıklık*

The *soyunmalık-ılıklık* was the first space from the entrance into the bath. It hosts a *seki* used for dressing (Figure 2.10). The corners of the walls and the arch remains suggest its spatial dimensions and indicate that the vaults were used as the superstructure. The remains of the southern corner have been lost with the reinforced concrete building erected in the 1970s. However, the horizontal rectangular plan scheme and the vaults can be observed in some 14th, 15th and 16th century baths (Kürüm 2017).

Figure 2.10. *Eski Hamam* G01 *Soyunmalık-Ilıklık*
(Source: ANKA Architecture and Restoration Office archive, December 2016)

The presence of a *seki* for dressing and direct passage to the *sıcaklık* indicate that the *soyunmalık* and the *ılıklık* spaces were resolved in a single space. One of the stone of the *seki* depicts a checkers game (Kürüm 2017). The walls on the side of the water reservoir has a different plastering, which shows that this wall was constructed at a later date. The junction line of the *seki* on the northeastern part of the space indicates that this *seki* was an addition (Figure A.37-44).

2.2.1.2. G02 *Sıcaklık*

The G02 *Sıcaklık* was a space that *kurna*s and *seki*s and was used for bathing (Figure 2.11). This space was accessed through another *sıcaklık* that could be reached from the *soyunmalık-ılıklık*. This opening has two wide concentric pointed arches and a circular addition (Kürüm 2017). The arrangement of the arches reveal that the width of the opening was narrowed later on.

The G02 *Sıcaklık* has one *kurna* and one *seki*. The positions of other *kurna*s and *seki*s can be deduced from their remains. There are no window openings on the walls and the dome has seven pentagonal oculi openings. The midsection of the dome has collapsed but the remaining parts host the best-preserved interior plastering. The squinches end in plaster motifs with curved tips. The damaged sections of the walls allow the determination of the location and the material of the terracotta pipes and *tüteklik*s. The opening of the damaged floor provides a view of the *cehennemlik* underneath. The cehennemlik piers were lain with brick and stone and linked with a depressed arch (Kürüm 2017). The floor is made up of slate stones carried by the piers.

Corners of the walls and arch remains of the *soyunmalık-ılıklık* believed to belong to the original period of construction have survived to present. These remains allow the determination of the spatial dimensions and suggest that the vaults constituted the superstructure. However, the remains of the southern corner have been lost with the reinforced concrete building erected in the 1970s.

The rectangular plan scheme and the vault superstructure is similar to those of *Selahaddin Hamam* in Kayseri (Kürüm 2017). *Radviyye Hamam* in Sitti, Mardin (12^{th} century), *Yeniceköy Hamam* in Tire, İzmir (14^{th} century), *Milet Hamam* (15^{th} century) and *Gedik Ahmet Paşa Hamam* in Afyon (15^{th} century) have examples of *ılıklık* with a horizontal rectangular plan (Kürüm 2017).

The presence of a *seki* for dressing and direct passage to the *sıcaklık* indicate that the space was used jointly as *soyunmalık* and *ılıklık*. One of the stones, believed to be spolia, of the *seki* depicts a checkers game (Kürüm 2017). The walls on the side of the water reservoir has a different plastering, which shows that this wall was constructed at a later date. The junction line of the stone *seki* on the northeastern part of the space indicates that this *seki* was added later (Figure A.45-60).

Figure 2.11. *Eski Hamam* G02 *Sıcaklık*
(Source: Fatma Gürhan, December 2016)

2.2.1.3. G03 *Sıcaklık*

The G03 *Sıcaklık* was one of the bathing spaces which hosted *kurna*s and *seki*s (Figure 2.12) and had similar characteristics with the G02 *Sıcaklık*. These similarities are the blind walls, the structure and the spatial arrangement of *kurna*s and *seki*s, terracotta pipe and *tüteklik* levels, and plaster and material characteristics. The *cehennemlik* below the space continued in the same manner as the G02 *Sıcaklık*. An opening emphasized with two wide concentric pointed arches led from the *soyunmalık-ılıklık* into the space. The top of the arch accommodates a ventilation hole (Kürüm 2017). The G03 *Sıcaklık* provides access to the other two *sıcaklık*s (Figure A.61-68).

Figure 2.12. *Eski Hamam* G03 *Sıcaklık*
(Source: Fatma Gürhan, December 2016)

2.2.1.4. G04 *Sıcaklık*

The G04 *Sıcaklık* is square planned with *kurna* remains and *seki*s used for bathing. Although it has a similar plan, it is differed from the other *sıcaklık*s in respect of the plaster layers. The plain interior space a depiction of a sailboat on the southeastern wall. Sailboat depictions are encountered in 14th, 15th, 16th and 17th century baths (Kürüm 2017). The control window of the bath can be found in this space. The height of the threshold of the control window has bears traces that it was later lowered (Kürüm 2017).

Passage from the G03 *Sıcaklık* to the G04 *Sıcaklık* was through an arched opening. Arch arrangements indicate that the opening to the G04 *Sıcaklık* was opened later on. The junction line on the wall, the bond type and thickness of the wall and the interrupted terracotta pipes support the notion that the G04 *Sıcaklık* was a later addition. The excavation revealed that this opening was deliberately filled in. The fill was removed during excavation. This suggests a timeframe during which the opening was disused (Kürüm 2017). This opening is believed to have been sealed for a time and used as a niche (Kürüm 2017) (Figure 2.13).

Figure 2.13. *Eski Hamam* G04 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, November 2016)

The other door of the space led to the outside. The interruption of the pipes in the wall by this opening indicates that it was opened after the construction of the wall. This intervention reveals that the function of the Z04 *Sıcaklık* was altered. The remains of the niche on the northwestern wall, next to the door leading to the outside is considered as it was constructed to add a new function to the structure (Kürüm 2017). Spatial conversion shows that this space was utilized for a commercial purpose (e.g. a shop) as a result of the increased usage of the bath over time (Figure A.69-78).

2.2.1.5. G05 Hot Water Reservoir

The water reservoir was the section on the north-south axis with a rectangular plan. The boiler space was located on the south side of the water reservoir. The entire of the interior space was coated, and the corners of the walls were rounded on the inside with plaster (Figure 2.14).

The space was constructed adjacent to the *sıcaklık* wall that was added at a later date and the other wall of the space was adjacent to the *soyunmalık-ılıklık* wall. The junction line shows that the water reservoir was constructed later. On the outside of the wall, there was a second adjacent supporting wall. The remains reveal that the superstructure of the water reservoir was a barrel vault. However, the inclination of the vault and the pattern of plastering change near the north end, indicating that the space was expanded later on. The supporting wall continued outside the expanded section as well.

The *külhan* was situated below the water boiler, with the *ateşlik* section visible, and the woodshed was a separate building on the southwest of the bath (Figure A.79-84).

Figure 2.14. *Eski Hamam* G05 Hot Water Reservoir
(Source: Fatma Gürhan, December 2016)

2.2.1.6. Fountain and Street Pattern

The fountain was located at the northern corner of the bath. Water carried by the pipes from the northeast of the bath was stored in a terracotta jar inside the fountain (Figure 2.15). The bath initially constructed as a small structure was later expanded into a bath with a fountain (Kürüm 2017), which is demonstrative of the increasing social significance and client capacity of the bath. The existence of trace of the street pattern (e.g. terracotta jars located to the west of the bath) is critical to understanding the function and the popularity of the bath (Figure 2.16). The historic cobblestones that stretch on the ground along the northwest façade of the bath continue in front of the fountain (Figure 2.17). However, the excavation was limited to the plot where the bath is located and was not extended toward the street remains (Figure A.85-90).

Figure 2.15. The fountain
(Source: ANKA Architecture and Restoration Office archive, January 2018)

Figure 2.16. The terracotta jar remains
(Source: ANKA Architecture and Restoration Office archive, January 2018)

Figure 2.17. The cobblestone road
(Source: Mükerrem Kürüm archive, May 2016)

2.2.2. *Eski Hamam* in the Past

After the excavation, the interventions in *Eski Hamam*'s history were examined in four periods (Kürüm 2017). Information obtained from the building traces itself and architectural characteristics, as well as, similar bath buildings and their period characteristics were examined during the research for the periods of restitution due to the lack of an inscription. Accordingly, the first, second, third and fourth stages of restitution can be dating 15^{th}-early 16^{th} centuries, end of 16^{th}-early 17^{th} centuries end of 17^{th}-early 18^{th} centuries and end of 18^{th}-20^{th} centuries, respectively (Kürüm 2017).

2.2.2.1. 15th and Early 16th Centuries

Data pertaining to the original condition of *Eski Hamam* as it was initially constructed was mostly based on the structure itself and the remains uncovered with the excavation. In this respect, the bath can be evaluated as to have a *soyunmalık-ılıklık*, two *sıcaklık*s and a water reservoir in the 15th-16th centuries (Kürüm, 2017) (Figure 2.18).

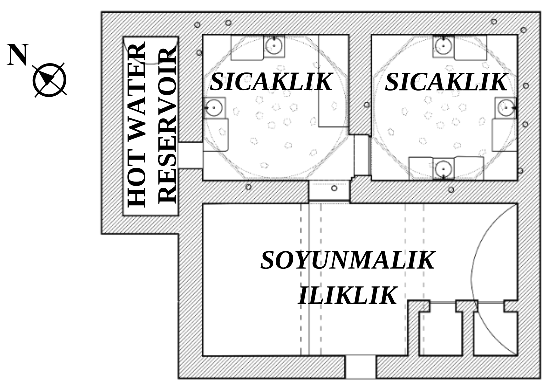


Figure 2.18. *Eski Hamam* restitution plan for the first period (Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office archive)

The *sıcaklık*s can be characterized as a variant of the category with "a central dome, horizontal *sıcaklık* and two *halvet*s" according to Semavi Eyice's classification (Eyice 1960). The two *sıcaklık*s were of approximately the same size and had similar structural and architectural characteristics. The main walls were constructed with the same bond type of stone material. In the *sıcaklık*s, the upper and lower levels of the interior faces of the walls were coated with horasan and lime plaster, respectively, while the domes and the exterior faces were coated only with lime plaster. Both spaces were lighted by pentagonal oculi. The oculi were finished with flat glass at the exterior. In both spaces, the junction points of the squinches were connected by patterns with curved tips. The remains of the original *sıcaklık* domes were covered with pantile tiles. Data indicate that the water reservoir had a rectangular plan with a barrel vault as superstructure and pentagonal oculis.

The remains of the two arches on the southwest wall of the *sıcaklık*s and *seki* on the floor verify the existence of a *soyunmalık-ılıklık* area. The dimensions of the *soyunmalık-ılıklık* can be specified from the inclination of the arch and the south wall remains. The lack of traces of walls or a partition suggests that the *soyunmalık* and the *ılıklık* sections were resolved in a single space, which is supported by the unearthed *seki* that serves to divide the space. The toilet and the *traşlık* were added due to architectural necessity by consulting similar examples. Indeed, the construction of the reinforced concrete building on this corner of the bath has rendered encountering any remains impossible (Kürüm, 2017) (Figure B.1-13).

2.2.2.2. End of 16th and Early 17th Centuries

It is believed that *Eski Hamam* failed to meet the increasing demand with the developing trade in the 16th century and that the water reservoir on the north side was demolished to add another *sıcaklık*. The wall plastering of the new *sıcaklık* was discrepant from other *sıcaklık*s. The walls were coated with horasan plaster up to the squinches, while the squinches and the dome were coated with lime plaster.

The new water reservoir was built on the southwest side, adjacent to the *sıcaklık* and *soyunmalık-ılıklık* walls, with a control window from the sıcaklık looking into the water reservoir. The junction lines on the *sıcaklık* and water reservoir walls confirm that both these spaces were additions.

The bath's plan scheme acquired a rectangular geometry with these addition (Kürüm, 2017) (Figure 2.19) (Figure B.14-26).

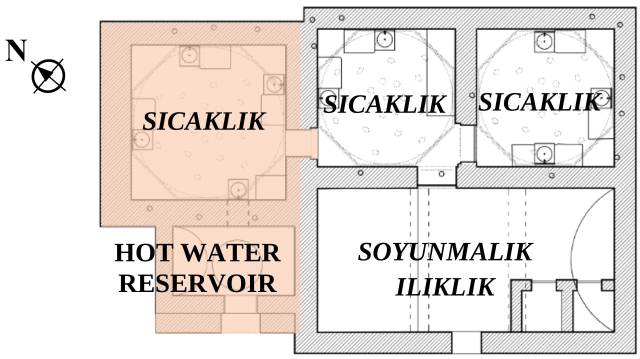


Figure 2.19. *Eski Hamam* restitution plan for the second period (Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office archive)

2.2.2.3. End of 17th and Early 18th Centuries

In the 17th and 18th centuries, the bath remained under the influence of the developing trade. The water reservoir was expanded to increase capacity. This notion is corroborated by the difference in the inclinations of the vault remains and the surviving plastering of interior spaces. The threshold level of the control window opening to the water reservoir was lowered to enlarge the window. In addition, the height of the opening of the *sıcaklık* built as a second period addition was decreased and the widths of the openings in the original *sıcaklık*s were narrowed (Kürüm, 2017) (Figure 2.20).

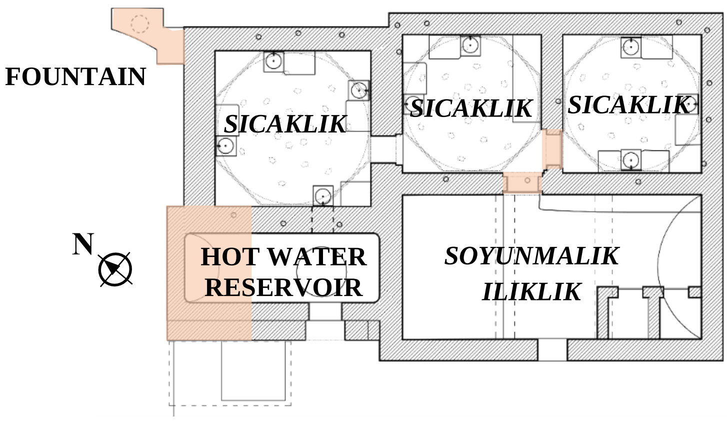


Figure 2.20. *Eski Hamam* restitution plan for the third period (Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office archive)

Furthermore, a woodshed was constructed in front of the *külhan*, stone *seki*s were added adjacent to the northeast wall of the *soyunmalık-ılıklık*, and a fountain was built on the outside of the north wall. The water from the fountain was stored in a terracotta jar. The architectural characteristics of the fountain and the street pattern reflect the characteristics of the period (Kürüm, 2017) (Figure B.27-39).

2.2.2.4. End of 18th and 20th Centuries

Various interventions in the recent past such as the addition of the fountain and the street pattern show the gradual expansion of the layout. Furthermore, it is believed that the opening into the 16th-17th century addition *sıcaklık* from the other *sıcaklık* was sealed and that a new opening and a niche were opened on the northwest wall in order to utilize the space as a shop (Kürüm, 2017) (Figure 2.21) (Figure B.40-52).

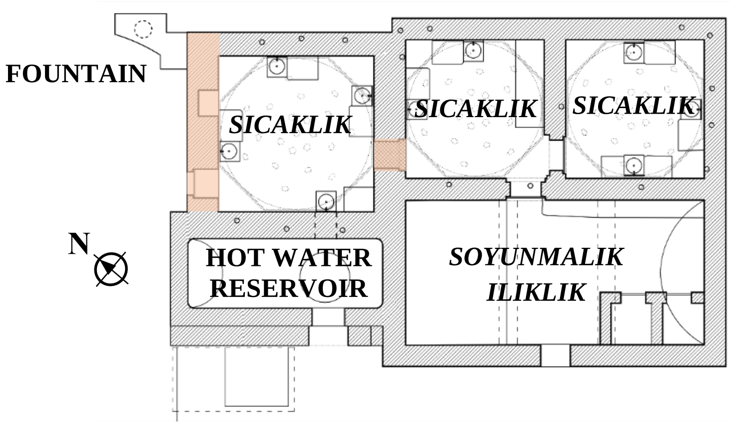


Figure 2.21. *Eski Hamam* restitution plan for the fourth period (Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office archive)

In an aerial photograph from 1937, *Eski Hamam* can be seen standing with the fourth period restitution plan (Figure 2.22). However, the remains of the southern corner have been lost with the reinforced concrete building constructed in the 1970s (Figure 2.23).

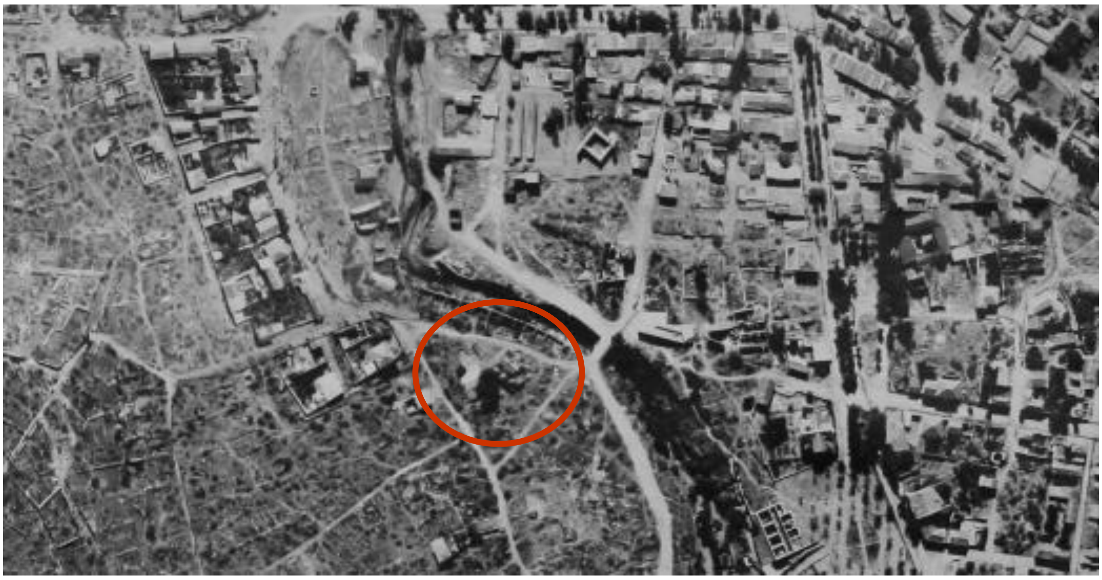


Figure 2.22. Aerial photograph dated 1937
(Source: Aydın Metropolitan Municipality archive)

Figure 2.23. The apartment building on the southern corner of *Eski Hamam*

2.2.3. Plaster Usage in Historic *Eski Hamam*

Eski Hamam was comprised of five spaces in circa 2016; namely a *soyunmalık-ılıklık*, three *sıcaklık*s and a water reservoir. The *soyunmalık-ılıklık* had similar architectural characteristics and plastering with the two southern *sıcaklık*s, while plaster usage in the northern *sıcaklık* and the water reservoir was also similar. These observations support the hypotheses as to the construction dates of these spaces.

The discontinuity of spatial characteristics indicate that various repairs were also carried out during the construction of the additional spaces. These characteristics can be observed in the *sıcaklık* that was added later and the water reservoir that was expanded to increase capacity.

In every *halvet*s, the lime plaster coatings on the upper levels have dissolved with ambient humidity and have reprecipitated on the lower levels to form carbonated lime deposits.

2.2.3.1. G01 *Soyunmalık-Ilıklık* (15th-16th Centuries)

The walls of the *soyunmalık-ılıklık* had two different plasterings. The wall between the *soyunmalık-ılıklık* and the *sıcaklık* was coated with one horasan plaster layer on the lower levels and one lime plaster layer on the upper levels (Figure 2.24). The wall between the *soyunmalık-ılıklık* and the hot water reservoir had a single layer of horasan plaster (Figure 2.25), while the other walls in the space were destroyed.

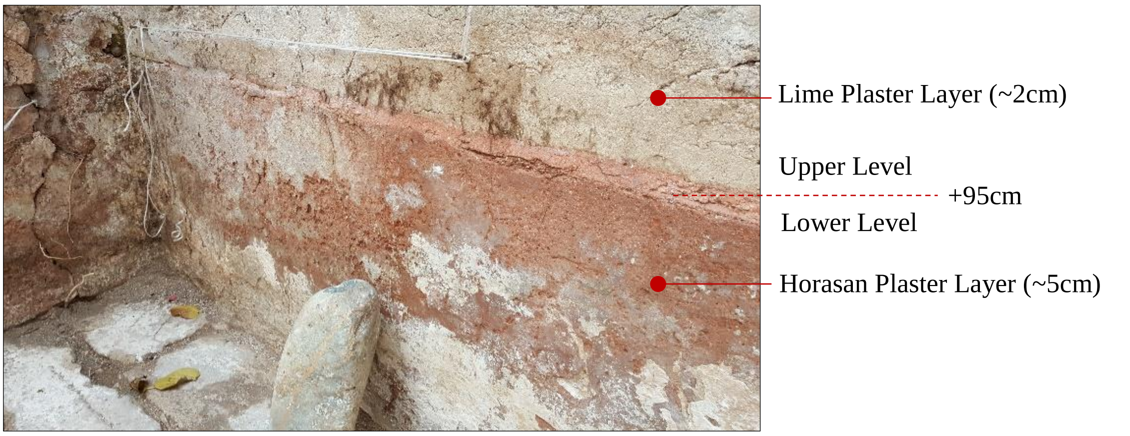


Figure 2.24. Plaster layers of the wall adjacent to the *sıcaklık* in the *soyunmalık-ılıklık* (15th-16th centuries)

Figure 2.25. Plaster layer of the wall adjacent to the water reservoir in the *soyunmalık-ılıklık* (15th-16th centuries)

2.2.3.2. G02 *Sıcaklık* (15th-16th Centuries)

The G02 *Sıcaklık* walls were coated with one horasan plaster layer on the lower levels. The upper levels of the walls and the dome surface had a single layer of lime plaster (Figure 2.26).

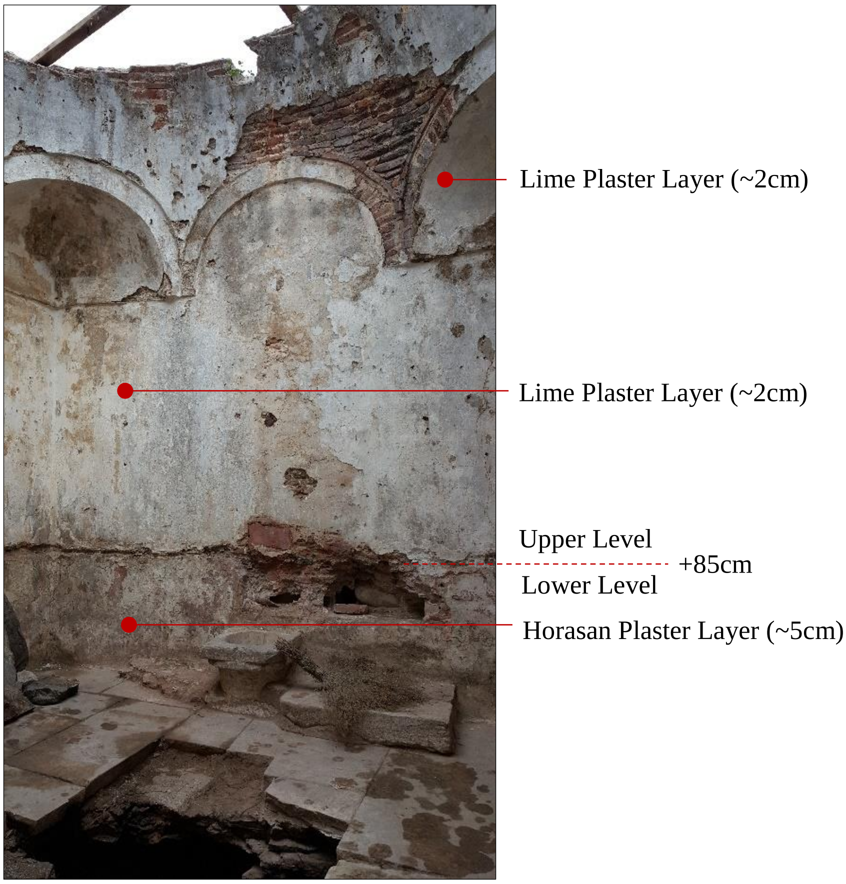


Figure 2.26. Wall plaster layers in the G02 S*ıcaklık* (15th-16th centuries)

2.2.3.3. G03 *Sıcaklık* (15th-16th Centuries)

The plaster layers in the G03 *Sıcaklık* were similar to the G02 *Sıcaklık* plaster layers; however, the plastering on the lower levels of the walls differed from the G02 *Sıcaklık* (15-16th Century). There were two horasan plaster layers on the lower levels and one lime plaster layer on the upper levels of the walls and dome in the G03 *Sıcaklık* (Figure 2.27).

Figure 2.27. Wall plaster layers in the G03 *Sıcaklık* (15th-16th centuries)

2.2.3.4. G04 *Sıcaklık* (16th-17th Centuries)

The walls were coated with one layer of horasan plaster on the lower levels while the upper levels and the dome surface had two plaster layers. The first layer of coating on the upper levels was horasan plaster while the finishing layer on the upper levels was lime plaster (Figure 2.28).

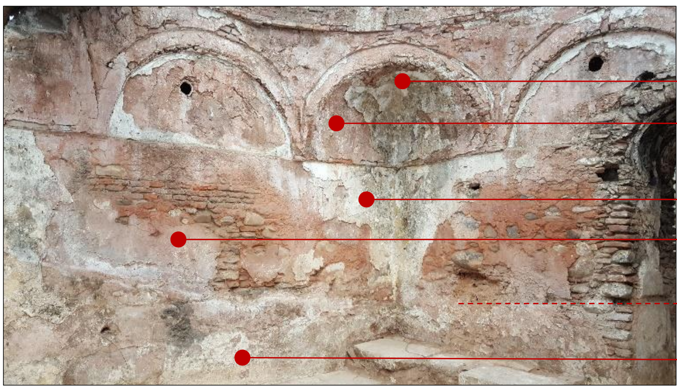


Figure 2.28. Wall plaster layers in the G04 *Sıcaklık* (16th-17th centuries addition)

2.2.3.5. G05 Hot Water Reservoir (16th-17th Centuries)

The walls of the hot water reservoir were similar to the G04 *Sıcaklık* walls (15th-16th century addition) in terms of the plaster layers. There were two different horasan plaster layers on the lower level and one lime plaster layer on the upper level of the walls (Figure 2.29).

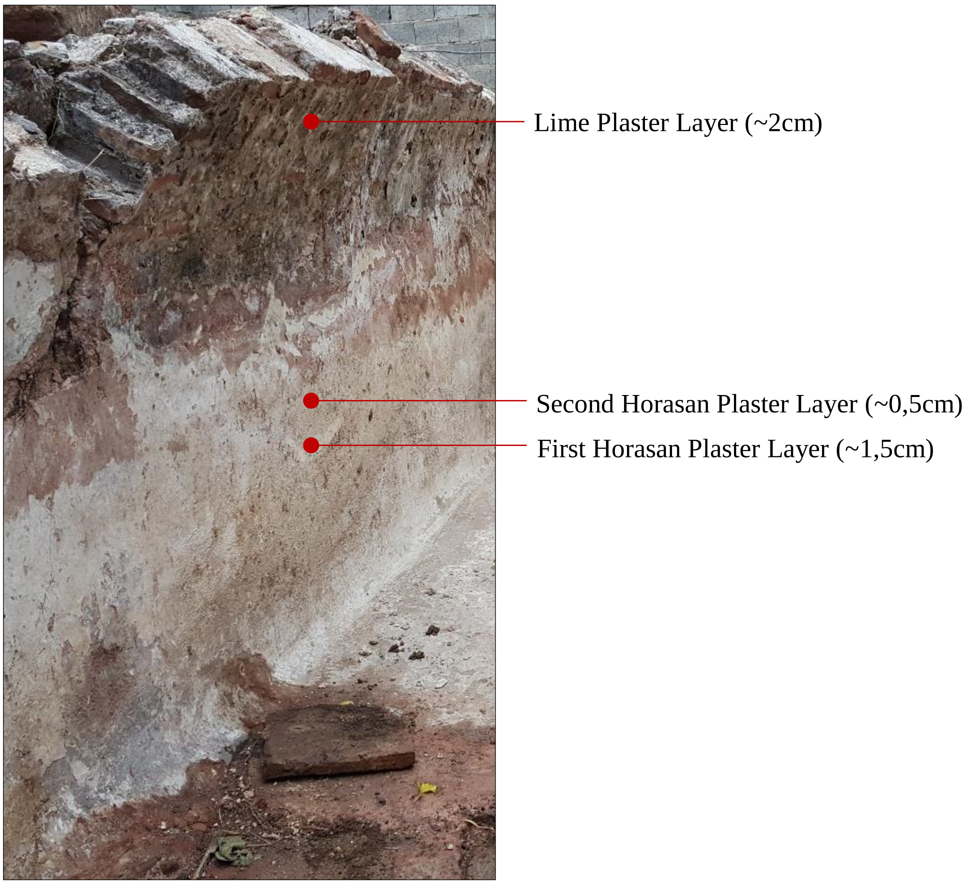


Figure 2.29. Wall plaster layers in the G05 Hot Water Reservoir (16th-17th centuries addition)

CHAPTER 3

EXPERIMENTAL STUDIES

In this study; lime plasters, lime mortars, bricks used in the structure and crushed bricks used as aggregates, collected from *Eski Hamam* were analyzed in order to determine their raw material compositions, basic physical, mineralogical, microstructural and hydraulic properties by using XRD, SEM-EDS and standart test methods.

3.1. Sampling

Eski Hamam consists of one *soyunmalık-ılıklık* space, three *sıcaklık* spaces, and one hot water reservoir space. Two *sıcaklık* spaces were built in 15th and early 16th centuries and the other *sıcaklık* one was built in end of 16th and 17th centuries. Plaster usage of *sıcaklık* spaces (15th and early 16th centuries) are similar with *soyunmalık-ılıklık* space (15th and early 16th centuries). However, plaster usage of later addition of *sıcaklık* space (end of 16th and 17th centuries) is different from the other areas.

There were one or two layers of horasan plaster on the lower level and one layer of lime plaster on the upper level in the early period walls. The two walls were plastered differently in *soyunmalık-ılıklık* space. One of the *soyunmalık-ılıklık* walls was plastered with one horasan plaster layer on the lower level and one lime plaster layer on the upper level. The other wall surface was covered with one horasan plaster layer.

There was a layer of horasan plaster on the upper level of the *sıcaklık* walls in the additional space unlike other *sıcaklık* spaces.

17 samples were collected from *Eski Hamam*. Three plaster samples from G01 *Soyunmalık-Ilıklık* (15th-16th centuries), three samples (two plasters, one joint mortar) from G02 *Sıcaklık* (15th-16th centuries), three plaster samples from G03 *Sıcaklık* (15th-16th centuries), three plaster samples from G04 *Sıcaklık* (16th-17th centuries addition), and five samples (two plasters, one lime mortar, two building bricks) from G05 Hot Water Reservoir (16th-17th centuries addition) were collected. (Figure 3.1).

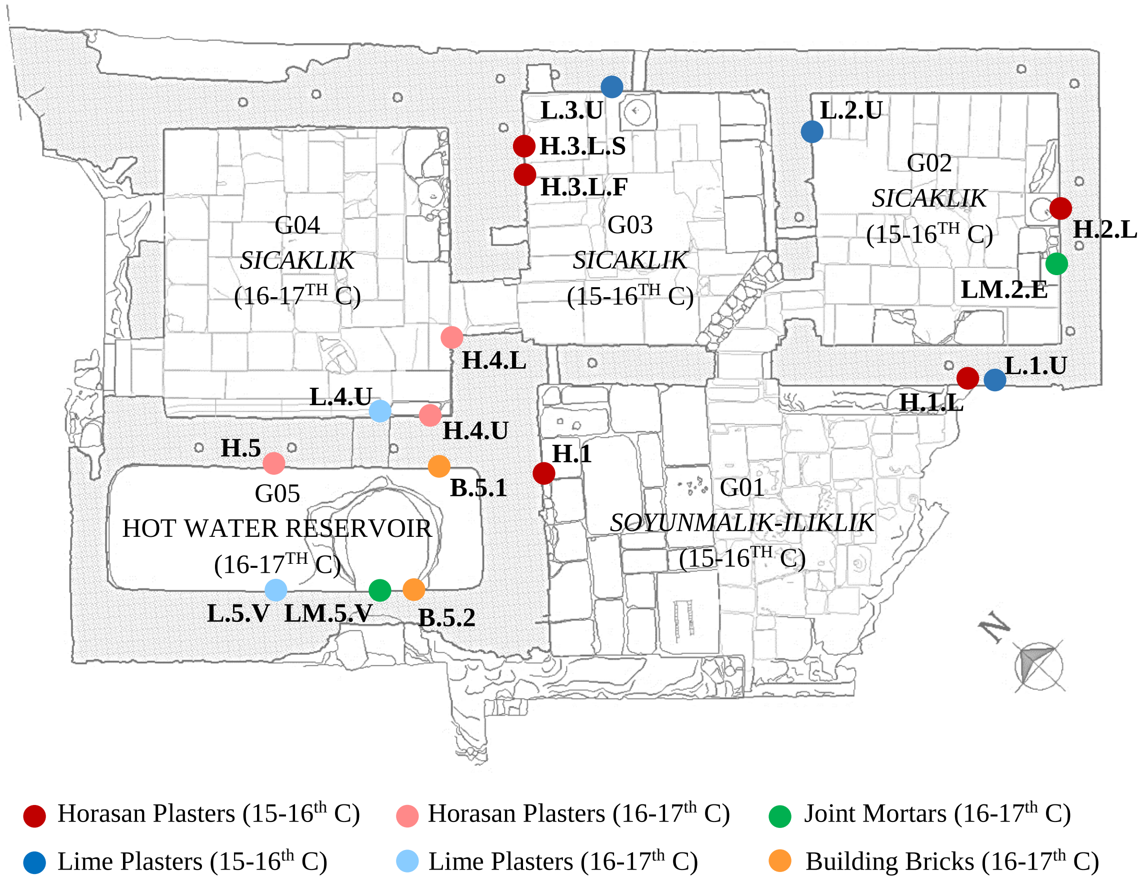


Figure 3.1. Plan of *Eski Hamam* showing the date of the spaces in which samples collected

Sample codes were labelled with materials, space code numbers, levels/locations and layers:

- The first letter indicates the type of plaster and mortar (H:Horasan plaster, L:Lime plaster, M:Mortar).
- The number indicates the space code (G01:1, G02:2, G03:3, G04:4, G05:5).
- The third letter indicates the level of the sample (L:Lower level, U:Upper) or the location of the sample (V:Vault).
- The fourth letter indicates the layer of the plaster sample (F.First layer, S:second layer)

Sample definitions and labels are given in Table 3.1-3.3

Table 3.1. Definition of the collected samples from the G01 *Soyunmalık-Ilıklık* and G02 *Sıcaklık*

	CODE	DEFINITION	SAMPLE
G01 - SOYUNMALIK - ILIKLIK	H.1.L	Horasan plaster collected from the lower level of G01 *Soyunmalık-Ilıklık* space (15^{th}-16^{th} centuries) (Figure 3.2)	
	L.1.U	Lime plaster collected from the upper level of G01 *Soyunmalık-Ilıklık* space (15^{th}-16^{th} centuries) (Figure 3.2)	
	H.1	Horasan plaster collected from the wall of G01 *Soyunmalık-Ilıklık* part (15^{th}-16^{th} centuries) (Figure 3.2)	
G02 - *SICAKLIK*	H.2.L	Horasan plaster collected from the lower level of G02 *Sıcaklık* part (15^{th}-16^{th} centuries) (Figure 3.3)	
	L.2.U	Lime plaster collected from the upper level of G02 *Sıcaklık* part (15^{th}-16^{th} centuries) (Figure 3.4)	
	LM.2.E	Lime mortar collected from the between the terracotta pipes on the wall of G02 *Sıcaklık* part (15^{th}-16^{th} centuries) (Figure 3.3)	

Table 3.2. Definition of the collected samples from the G03 *Sıcaklık* and G04 *Sıcaklık*

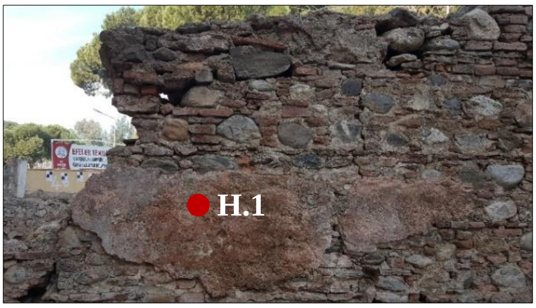
	CODE	DEFINITION	SAMPLE
G03 - *SICAKLIK*	H.3.L.F	The first horasan plaster layer collected from the lower level of G03 *Sıcaklık* part (15th-16th centuries) (Figure 3.5)	
	H.3.L.S	The second horasan plaster layer collected from the lower level of G03 *Sıcaklık* part (15th-16th centuries) (Figure 3.5)	
	L.3.U	Lime plaster collected from the upper level of G03 *Sıcaklık* part (15th-16th centuries) (Figure 3.5)	
G04 - *SICAKLIK*	H.4.L	Horasan plaster collected from the lower level of G04 *Sıcaklık* part (16th-17th centuries) (Figure 3.6)	
	H.4.U	Horasan plaster collected from the upper level of G04 *Sıcaklık* part (16th-17th centuries) (Figure 3.6)	
	L.4.U	Lime plaster collected from the upper level of G04 *Sıcaklık* part (16th-17th centuries) (Figure 3.6)	

Table 3.3. Definition of the collected samples from the G05 Hot Water Reservoir

<table>
<tr><th></th><th>CODE</th><th>DEFINITION</th><th>SAMPLE</th></tr>
<tr><td rowspan="5">G05 - HOT WATER RESERVOIR</td><td>H.5</td><td>Horasan plaster collected from the wall surface of G05 Hot Water Reservoir (16th-17th centuries)
(Figure 3.7)</td><td>
</td></tr>
<tr><td>LM.5.V</td><td>Lime mortar collected from the between the bricks on the vault of G05 Hot Water Reservoir (16th-17th centuries)
(Figure 3.7)</td><td>
</td></tr>
<tr><td>L.5.V</td><td>Lime plaster collected from the vault surface of G05 Hot Water Reservoir (16th-17th centuries)
(Figure 3.7)</td><td>
</td></tr>
<tr><td>B.5.1</td><td>Brick used in the structure collected from the vault of G05 Hot Water Reservoir (16th-17th centuries)
(Figure 3.7)</td><td>
</td></tr>
<tr><td>B.5.2</td><td>Brick used in the structure collected from the vault of G05 Hot Water Reservoir (16th-17th centuries)
(Figure 3.7)</td><td>
</td></tr>
</table>

Seven of the plaster samples collected from *Eski Hamam*, belong to 15th-16th centuries spaces and the other six plaster samples belong to 16th-17th centuries addition spaces. According to the above view; four horasan plaster and three lime plaster samples belonging to 15th-16th centuries were taken and four horasan plaster and lime plaster samples belonging to 16th-17th centuries were collected from the bath.

Location of all samples collected were given according to their space photographs.



(a) (b)

Figure 3.2. Locations where samples taken from the G01 *Soyunmalık-Ilıklık*

Figure 3.3. Locations where horasan plaster and lime mortar taken from the G02 *Sıcaklık*

Figure 3.4. Location where lime plaster sample taken from the G02 *Sıcaklık*

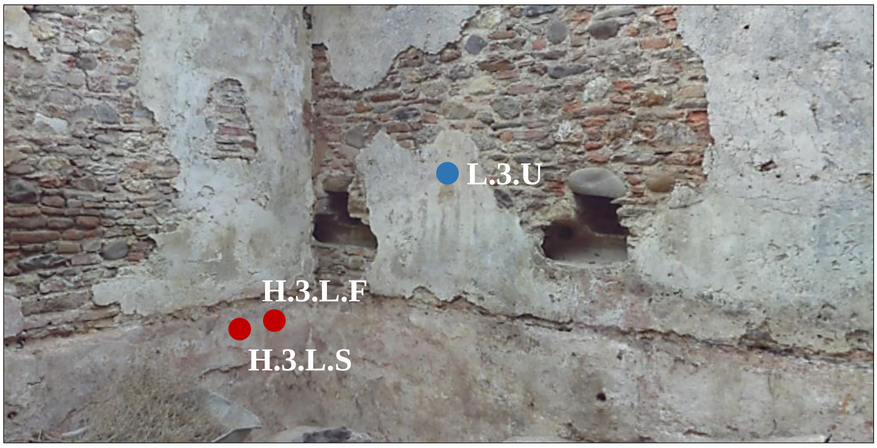


Figure 3.5. Locations where plaster samples taken from the G03 *Sıcaklık*

Figure 3.6. Locations where plaster samples taken from the G04 *Sıcaklık*

Figure 3.7. Locations where horasan plaster, lime plaster, builging bricks and lime mortar taken from the G05 Hot Water Reservoir

3.2. Experimental Studies

Experimental studies includes the determination of the following properties of horasan plasters, brick aggregates in the plasters, lime plasters, lime mortars and bricks used in the structure.

They are;

- Basic physical properties of plasters and mortars
    - Bulk density
    - Porosity
- Raw material compositions of plasters and mortars
    - Binder-aggregate ratios of plasters and mortars
    - Particle size distributions of the aggregates
- Mineralogical and chemical compositions of plasters, mortars, crushed bricks used as aggregates and vricks in the structure
- Microstructural compositions of horasan plasters
- Pozzolanic activities of the crushed brick aggregates of the plasters and bricks in the structure
- Hydraulicity of plasters and mortars

3.2.1. Determination of Basic Physical Properties of Plasters and Mortars

Basic physical properties of bulk densities and porosities of plaster and mortar samples were determined by using RILEM standart test methods (RILEM 1980). Bulk density is the ratio of the mass to its bulk volume of the sample. It is expressed in grams per cubic centimeters (g/cm3). Porosity is the ratio of the pore volume to the bulk volume of the sample, and is usually expressed in per cent (%).

Two samples of each plaster and mortar were used to determine their densities and porosities. Firstly, samples were dried in an oven at 40°C at least for 24 hours in order to evaporate moisture from the samples. Then they were weighed by using a precision balance (AND HF-3000G) to determine their dry weights (M_{dry}). After the dry weights were recorded, they were entirely saturated with water within distilled water in a vacuum oven (Lab-Line 3608-6CE Vacuum Oven). Subsequently, the saturated weights (M_{sat}) and the Archimedes weights (M_{arch}) that were determined with hydrostatic weighting in distilled water by precision balance. After all, bulk densities (D) and porosities (P) of the plaster and mortar samples were calculated by using the formulas given below:

$$D\ (g/cm^3) = M_{dry} / (M_{sat} - M_{arch})$$

$$P\ (\%) = [(M_{sat} - M_{dry}) / (M_{sat} - M_{arch})] \times 100$$

where;

D = Density (g/cm^3)

P = Porosity (%)

M_{dry} = Dry weight (g)

M_{sat} = Saturated weight (g)

M_{arch} = Archimedes weight (g)

M_{sat} - M_{dry} = Pore volume (g)

M_{sat} - M_{arch} = Bulk volume (g)

3.2.2. Determination of Raw Material Compositions of Plasters and Mortars

Raw material compositions of plaster and mortar samples were defined by lime-aggregate ratios and particle size distributions of the aggregates.

Binder-aggregate ratio of the plaster and mortar samples was determined by dissolving of the carbonated lime ($CaCO_3$) from the siliceous aggregates. Two samples of each plaster and mortar were prepared, dried and weighed (M_{sam}) by a precision balance. Then the samples were left in the dilute (%5) hydrochloric acid solution. After the carbonated lime dissolved entirely, aggregates -which were insoluble part- were filtered through a filter paper, washed with distilled water, dried in an oven, and weighed by using a precision balance (M_{agg}). Afterward, ratios of acid soluble and insoluble parts were calculated by the following formula:

$$\text{Insoluble } \% = [(M_{sam} – M_{agg})] \times 100$$

$$\text{Acid Soluble } \% = 100 – \text{Insoluble } \%$$

where;

M_{sam} = Dry weight of the sample (g)

M_{agg} = Dry weight of the aggregates (g)

The lime/aggregate ratio was calculated by the following these formulas:

$$\underbrace{Ca(OH)_2}_{74g} + \underbrace{CO_2}_{44g} \rightarrow \underbrace{CaCO_3}_{100g} + H_2O \quad \text{(Molecular weights)}$$

$$\text{Aggregate \%} = (100 \times \text{Insoluble}) / [((\text{Acid Soluble \%} \times M.W._{Ca(OH)_2}) / M.W._{CaCO_3}) + \text{Insoluble \%}]$$

$$\text{Lime \%} = 100 - \text{Aggregate \%}$$

where;

$M.W._{CaCO_3}$ = Molecular weight of $CaCO_3$ which is 100.

$M.W._{Ca(OH)_2}$ = Molecular weight of $Ca(OH)_2$ which is 74.

Particle size distributions of the aggregates were determined by sieve analysis using an analytical sieve shaker (Retsch AS200) and a series of sieves (Retsch mark) having 53µm, 125µm, 250µm, 500µm, 1180µm.

3.2.3. Determination of Mineralogical and Chemical Compositions of Plasters, Mortars, Brick and Natural Aggregates, and Bricks in the Structure

Mineralogical compositions of fine plaster and mortar matrices called binders, along with crushed bricks used as aggregates and bricks used in the structure were determined by X-ray Diffraction analysis using a Philips X-Pert Pro X-Ray Diffractometer. The analyses were performed on fine matrices which were ground samples of less than 53µm.

Chemical compositions of the plasters, mortars, crushed bricks used as aggregates and bricks used in the structure were determined by Philips XL 30S-FEG Scanning Electron Microscope (SEM) equipped with X-Ray Energy Dispersive System (EDS).

3.2.4. Determination of Microstructural Compositions of Horasan Plasters

Microstructural properties were determined by Philips XL 30S-FEG Scanning Electron Microscope (SEM). The analyses were performed on the pellet samples with the fineness less than 53µm.

3.2.5. Determination of Pozzolanic Activities of the Crushed Brick Aggregates of Horasan Plasters, Natural Aggregates of Lime Plasters and Bricks in the Structure

Pozzolanic activities of the crushed bricks used as aggregates of the horasan plasters, natural aggregates of the lime plasters and bricks used in the structure were measured by using electrical conductivity method (Luxan et al. 1989).

Firstly, electrical conductivity of saturated calcium hydroxide solution (Ca(OH)2) was measured. Secondly, fine aggregates less than 53µm size and saturated calcium hydroxide solution ratio of 5 g/200ml. were mixed. The mix was stirred for two minutes and measured its electrical conductivity. Finally, difference between two measurements (ΔEC in mS/cm) was calculated and determined the pozzolanic activities of the crushed bricks used as aggregates in horasan plaster samples, bricks used in the building structure and natural aggregates used in lime plasters and lime mortar. If the ΔEC is over 1.2mS/cm the aggregates are highly energetic pozzolan and have good pozzolanicity (Luxan et al. 1989).

3.2.6. Hydraulicity of Plasters and Mortars

The hydraulic properties of the plaster and mortar samples were determined by keeping in the oven at 60ºC to remove moisture and heating the samples in a furnace at 200ºC for 2 hours, at 600ºC for 1 hour and at 900ºC for 1 hour. Weight losses of fine ground samples at these each temperatures were measured. Weight loss at 200ºC is due to the loss of hygroscopic (adsorbed) water. Weight loss at 200 to 600ºC is mainly due to the loss of chemically bound water of hydraulic products, such as calcium silicate hydrates and calcium alumina hydrates formed in the samples. Weight loss at temperatures over 600ºC is due to the decomposition of calcium carbonates present as binder in the plasters and mortars. If the ratio of CO_2/H_2O (bound) is between 1 and 10, the plasters can be accepted as hydraulic (Bakolas et. al. 1998, Moropoulou et. al. 2000a).

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, experimental results of main characteristics of horasan and lime plasters in two different periods (15th and early 16th centuries, and end of 16th and 17th centuries), brick aggregates used in horasan plasters and bricks used in the structure were indicated and discussed.

4.1. Basic Pyhsical Properties of Plasters and Mortars

Density and porosity values of horasan plasters, lime plasters and lime mortars were given on the plan of *Eski Hamam* (Figure 4.1). Dark red and dark blue colors indicate with the samples of 15th-16th centuries, light red and light blue colors indicate with the samples of 16th-17th centuries. Green color sembolizes the places taken samples of lime mortar in Figure 4.1.

Density and porosity values of horasan plasters collected from the spaces built in 15th-16th centuries varied between 1.2-1.4 g/cm^3 and 47-53 % by volume respectively. Density values of horasan plasters collected from the 16th-17th centuries addition of the bath varied between 1.2-1.4 g/cm^3 and their porosity values were in range of 45-52 %. Lime plasters used in 15th-16th centuries had density values ranging between 1.3-1.7 g/cm^3 and porosity values ranging between 29-52 %. Lime plasters used in 16th-17th centuries had density and porosity values range between 1.0-1.4 g/cm^3 and 43-60 %. In addition, lime mortar taken from the 16th-17th centuries addition has density and porosity values 1.39 g/cm^3 and 43 % (Table 4.1).

According to the density and porosity values of **horasan plasters** collected from the spaces constructed in 15th-16th centuries and 16th-17th centuries were generaly in the same ranges.

When the density and porosity values of **lime plasters** used in 15th-16th centuries and 16th-17th centuries were compared with each other, it was found that the density and porosity values were also nearly identical.

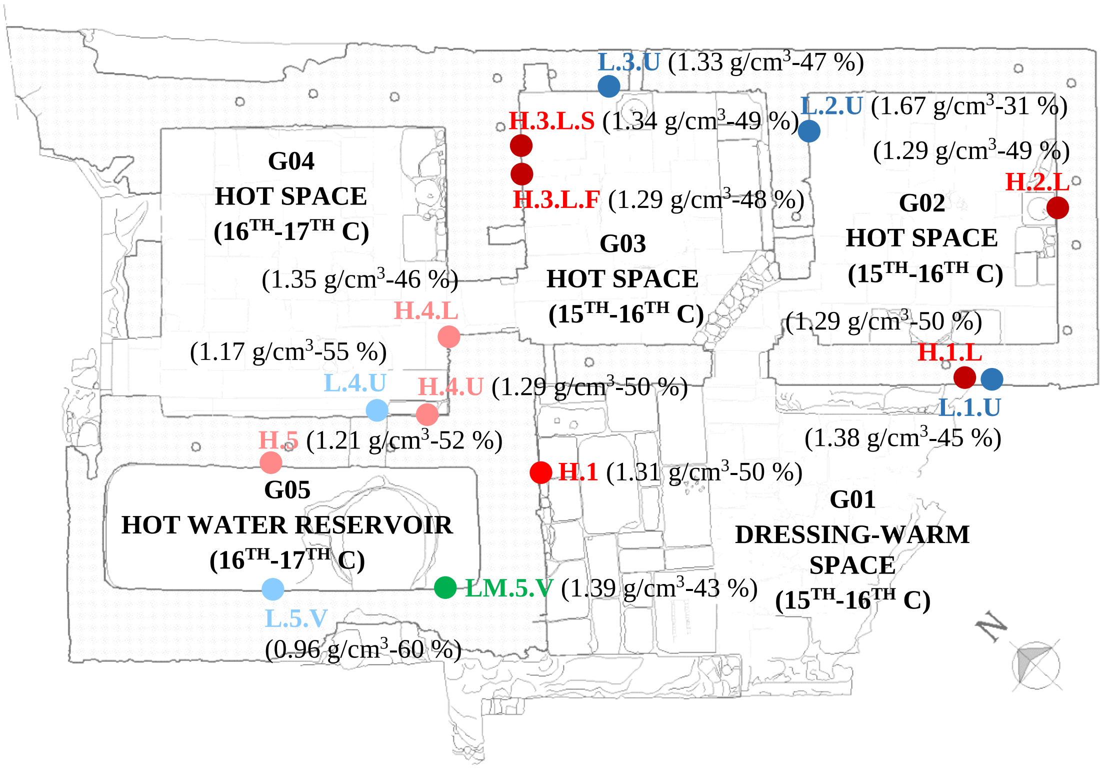


Figure 4.1. Plan of *Eski Hamam* showing density and porosity values of the samples

Table 4.1. Density and porosity values of horasan plasters, lime plasters and lime mortars according to their spaces and periods

Space	Sample	Density (g/cm3)	Porosity (%)
G01 *Soyunmalık-Ilıklık* (15^{th}-16^{th} C)	H.1.L	1.29	50
	L.1.U	1.38	45
	H.1	1.31	50
G02 *Sıcaklık* (15^{th}-16^{th} C)	H.2.L	1.29	49
	L.2.U	1.67	31
G03 *Sıcaklık* (15^{th}-16^{th} C)	H.3.L.F	1.29	48
	H.3.L.S	1.34	49
	L.3.U	1.33	47
G04 *Sıcaklık* (16^{th}-17^{th} C)	H.4.L	1.35	46
	H.4.U	1.29	50
	L.4.U	1.17	55
G05 Hot Water Reservoir (16^{th}-17^{th} C)	H.5	1.21	52
	LM.5.V	1.39	43
	L.5.V	0.96	60

According to the previus studies, horasan and lime plasters had nearly similar density and porosity values in several Ottoman baths because of their low dense and high porous features (İpekci 2016, Uğurlu 2005, Böke et al. 2004).

4.2. Raw Material Compositions of Plasters and Mortars

In this study, percent of lime-aggregate ratios and particle size distributions of aggregates in two differend periods (15th-16th and 16th-17th centuries) were determined.

4.2.1. Lime-Aggregate Ratios of Plasters and Mortars

Lime-aggregate ratios and percentage of lime and aggregate values of horasan plasters, lime plasters and lime mortar were given in the Figure 4.2 and Table 4.2.

Based on these values, **horasan plasters** had percent of lime and aggregate values varied between 32-68% - 47-53% by weight in *Eski Hamam*. Percent of lime and aggregate values of the horasan plasters constructed in 15th-16th centuries varied between 32-68% - 46-54% by weight and 34-66% - 47-53% in 16th-17th centuries (Table 4.2).

Lime plasters had percent of lime and aggregate values varied between 97-3% - 93-7% by weight in the bath. Percent of lime and aggregate values of the lime plasters consctructed in 15th-16th centuries varied between 97-3% - 96-4% by weight. Percent of lime and aggregate values of the lime plasters consctructed in 16th-17th centuries ranged between 96-4% - 93-7% (Table 4.2). In addition to these, lime mortar collected from the bricks had percent of lime and aggregate values ranging from 54-46% by weight (Table 4.2).

According to the previus studies by İpekci (2016), Uğurlu (2005) and Böke et al. (2004), average values of percent of lime and aggregate values of horasan plasters used in the Ottoman bath buildings ranged from 51-49% to 58-42% by weight.

These values demonstrated that averages of the percentage of lime and aggregate values of horasan plasters and lime plaster used in two different periods (15th-16th and 16th-17th centuries) in *Eski Hamam* are similar with the other Ottoman bath buildings (İpekci 2016, Uğurlu 2005, Böke 2004).

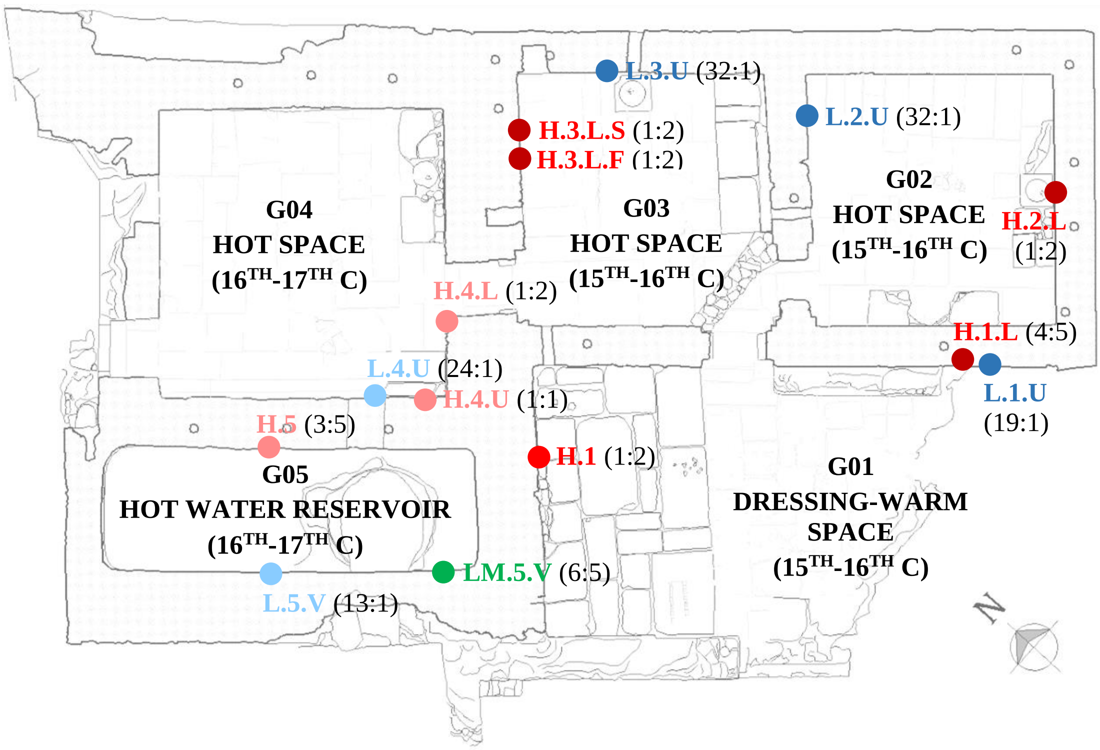


Figure 4.2. Plan of *Eski Hamam* showing lime-aggregate ratios of plasters and mortars

Table 4.2. Percentage of lime and aggregate and lime/aggregate ratios of horasan plasters, lime plasters and lime mortars

Space	Sample	Lime (%)	Aggregate (%)	Lime/Aggregate Ratio
G01 *Soyunmalık-Ilıklık* (15th-16th C)	H.1.L	46	54	4:5
	L.1.U	95	5	19:1
	H.1	32	68	1:2
G02 *Sıcaklık* (15th-16th C)	H.2.L	34	66	1:2
	L.2.U	97	3	32:1
G03 *Sıcaklık* (15th-16th C)	H.3.L.F	35	65	1:2
	H.3.L.S	35	65	1:2
	L.3.U	97	3	32:1
G04 *Sıcaklık* (16th-17th C)	H.4.L	34	66	1:2
	H.4.U	47	53	1:1
	L.4.U	96	4	24:1
G05 Hot Water Reservoir (16th-17th C)	H.5	37	63	3:5
	LM.5.V	54	46	6:5
	L.5.V	93	7	13:1

4.2.2. Particle Size Distributions of Aggregates

Particle size distributions of horasan plasters, lime plasters and lime mortar were classified according to two different periods (15^{th}-16^{th} and 16^{th}-17^{th} centuries) in the following table and graphics (Table 4.3, Figure 4.3-4.6).

Table 4.3. Particle size distributions of the samples according to their spaces and periods

Space	Sample	<53µ	53µ	125µ	250µ	500µ	≥1180µ
G01 *Soyunmalık-Ilıklık* (15^{th}-16^{th} C)	H.1.L	6.77	0.62	10.64	12.80	21.86	**47.31**
	L.1.U	5.16	7.60	19.90	24.78	**33.07**	9.50
	H.1	7.42	1.12	8.99	12.37	26.57	**43.53**
G02 *Sıcaklık* (15^{th}-16^{th} C)	H.2.L	3.86	0.01	7.45	11.01	24.65	**53.03**
	L.2.U	19.18	2.91	29.46	**29.90**	16.76	1.79
G03 *Sıcaklık* (15^{th}-16^{th} C)	H.3.L.F	6.58	0.40	8.93	13.35	26.18	**44.57**
	H.3.L.S	4.49	0.90	11.03	13.25	21.23	**49.10**
	L.3.U	10.66	5.37	27.55	25.74	**29.15**	1.53
G04 *Sıcaklık* (16^{th}-17^{th} C)	H.4.L	4.52	0.47	7.20	11.66	26.97	**49.17**
	H.4.U	2.83	-0.10	6.74	9.08	19.95	**61.49**
	L.4.U	1.88	5.24	20.45	24.21	**46.30**	1.91
G05 Hot Water Reservoir (16^{th}-17^{th} C)	H.5	2.49	0.25	5.00	7.63	23.94	**60.69**
	LM.5.V	1.71	0.06	8.20	11.68	23.03	**55.31**
	L.5.V	5.61	3.02	11.98	16.16	**34.62**	28.61

According to the table and figures, brick aggregates used in the **horasan plasters** belonging to 15^{th}-16^{th} and 16^{th}-17^{th} centuries had similar particle size distributions with each other. Particle size distributions of the aggregates in horasan plasters constructed in 15^{th}-16^{th} centuries are also similar with 16^{th}-17^{th} centuries addition spaces. The major fractions of the aggregates of the two periods (15^{th}-16^{th} and 16^{th}-17^{th} centuries) of the horasan plasters are aggregates with particle size larger than 1180µ. Percentages of the major fraction varied in the range of 44-53 % for the 15^{th}-16^{th} centuries and 50-61 % for the 16^{th}-17^{th} centuries.

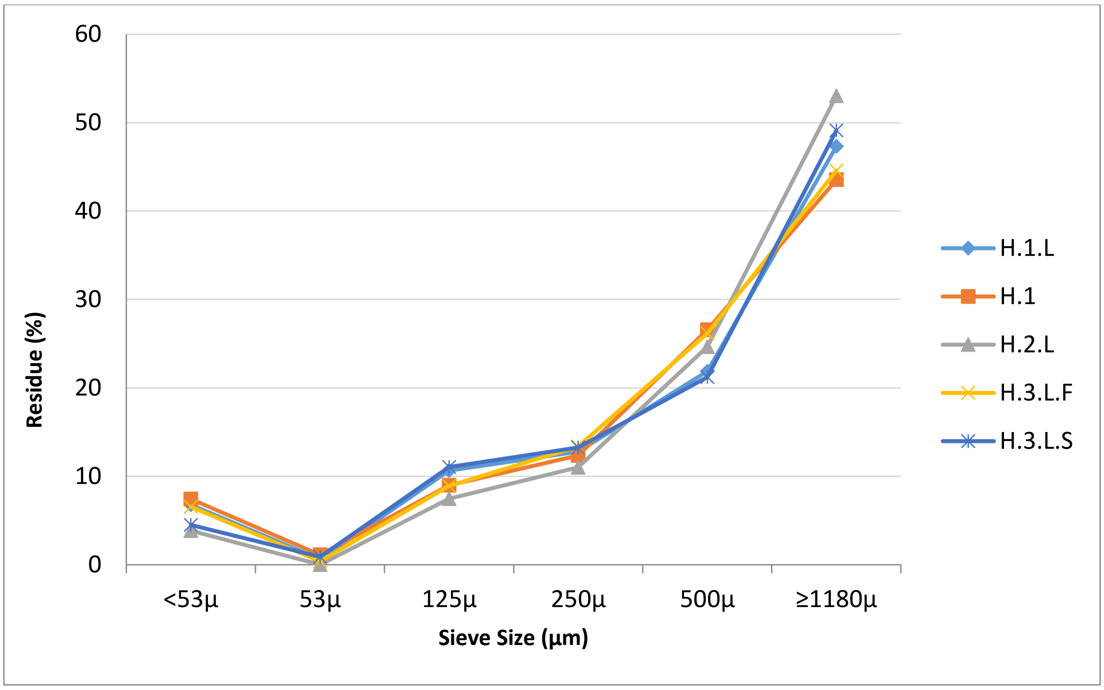


Figure 4.3. Particle size distributions of aggregates of horasan plasters constructed in 15th-16th centuries in *Eski Hamam*

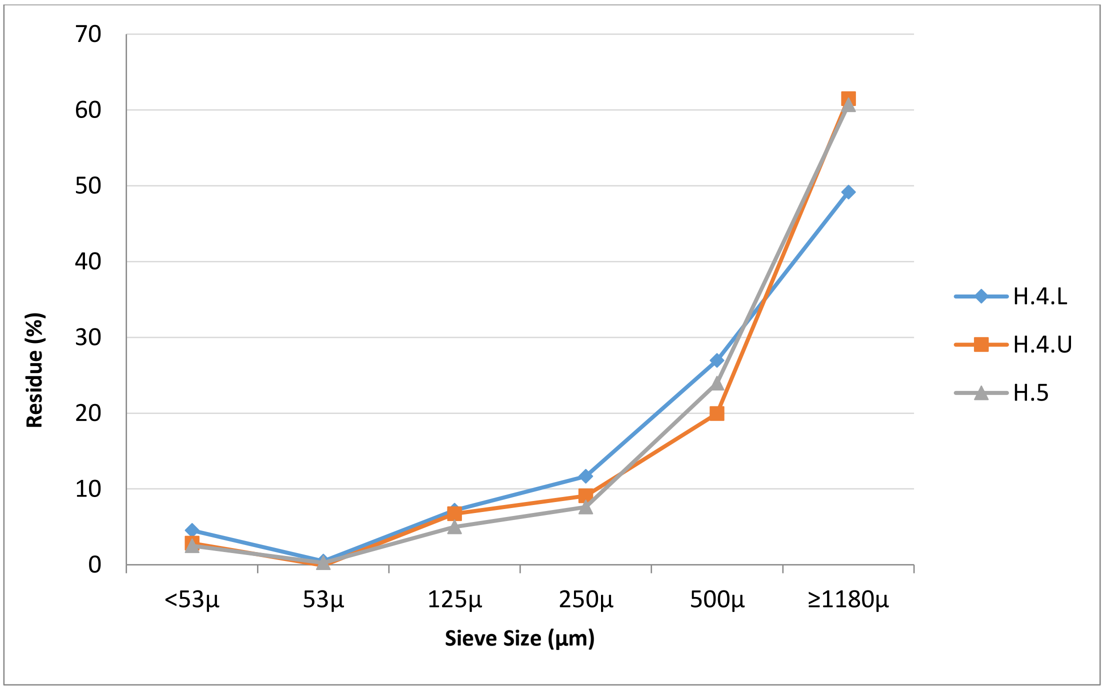


Figure 4.4. Particle size distributions of aggregates of horasan plasters constructed in 16th-17th centuries in *Eski Hamam*

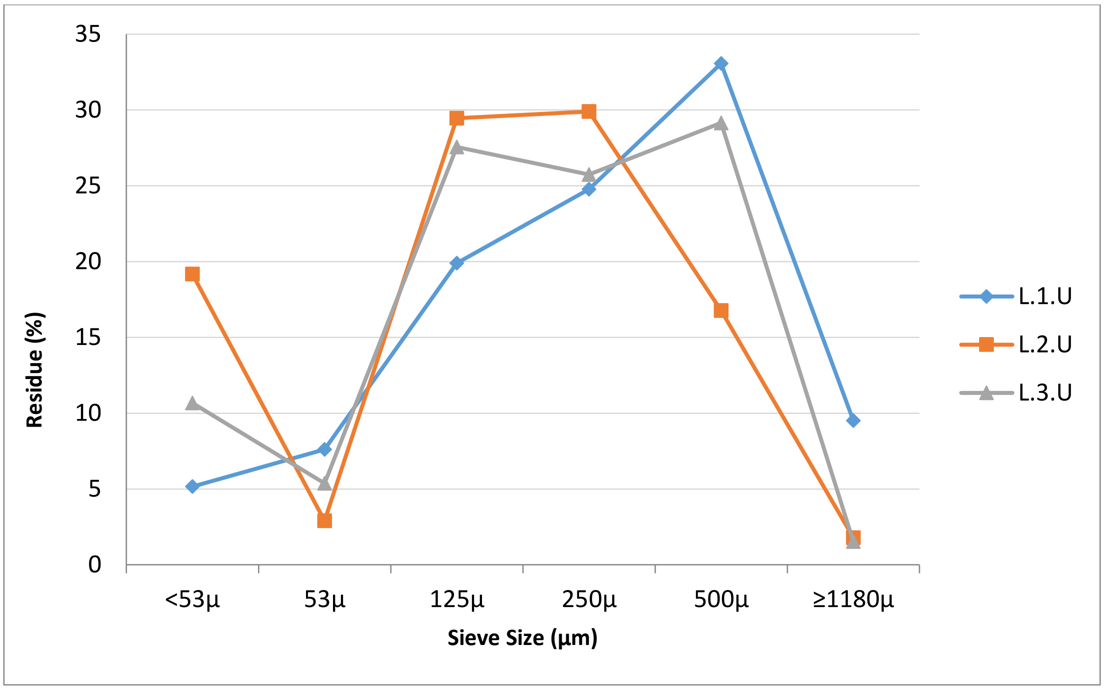


Figure 4.5. Particle size distributions of aggregates of lime plasters constructed in 15th-16th centuries in *Eski Hamam*

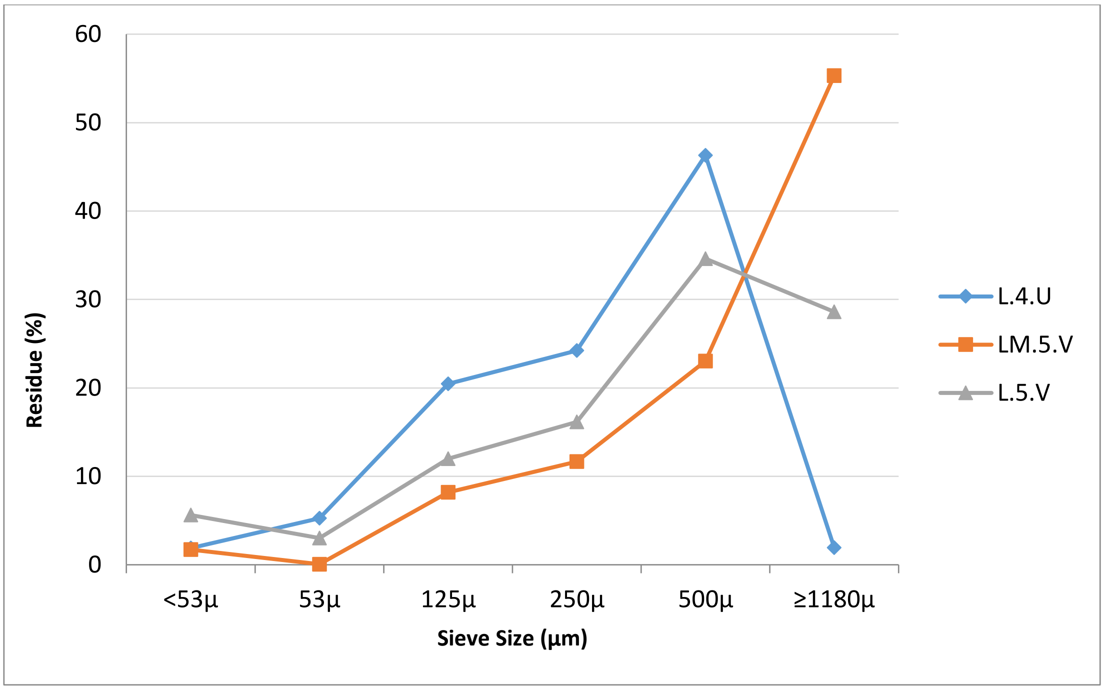


Figure 4.6. Particle size distributions of aggregates of lime plasters constructed in 16th-17th centuries in *Eski Hamam*

Particle size and distributions of the natural aggregates of **lime plasters** belonging to 15th-16th centuries are similar with each other. Their particle size distributions show also similarity with the aggregates of lime plasters constructed in 16th-17th centuries. The major fractions of the aggregates of lime plasters belonging to 15th-16th centuries are particle size 250μ and 500μ. The major fractions of the size of aggregates of lime plasters belonging to 16th-17th centuries is also particle size 500μ. Percentages of the major fraction varied in the range of 29-33 % for the 15th-16th centuries and 35-46 % for the 16th-17th centuries.

In addition, particle size distribution the aggregates of lime mortar sample is similar with the distributions of the aggregates of horasan plasters in *Eski Hamam*. As in horasan plasters, its major fraction is also particle size greater than 1180μ, which is 55%.

According to the previus studies by İpekci (2016), Uğurlu (2005) and Böke et al. (2004), major fractions of the aggregates of the plasters are particle size 500μ and particle size greater than 1180μ. Particle size distributions and major fractions of the aggregates of the samples used in *Eski Hamam* show similarity with the aggregates of the plasters used in several Ottoman baths (İpekci 2016, Uğurlu 2005 and Böke et al. 2004).

4.3. Mineralogical and Chemical Compositions of Plasters, Mortars, Brick and Natural Aggregates, and Bricks in the Structure

Mineralogical and chemical compositions of fine plaster, mortar and building brick matrices were determined by XRD and SEM-EDS analyses.

4.3.1. Mineralogical Compositions of Plasters, Mortars, Brick and Natural Aggregates, and Bricks in the Structure

Mineralogical compositions of the aggregates (crushed bricks) and binders of the horasan plasters, bricks used in the building structure, natural aggregates and binders of the lime plasters and mortars belonging to two different periods (15-16 and 16-17th c) were determined by XRD analyses.

4.3.1.1. Mineralogical Compositions of Brick Aggregates of Horasan Plasters, Natural Aggregates of Lime Plasters and Building Bricks

Mineralogical compositions of the natural aggregates of the lime plasters and lime mortars, brick aggregates of the horasan plasters, and bricks used in the building structure were given in the following table (Table 4.4)

Table 4.4. Mineralogical compositions of the aggregates and building bricks

Space	Sample	Minerals
G01 *Soyunmalık-Ilıklık* (15^{th}-16^{th} C)	H.1.L	Q, A, H, M, K
	L.1.U	Q, A, M
	H.1	Q, A, H, M, K
G02 *Sıcaklık* (15^{th}-16^{th} C)	H.2.L	Q, A, H, M
	L.2.U	Q, A
G03 *Sıcaklık* (15^{th}-16^{th} C)	H.3.L.F	Q, A, H, M, K
	H.3.L.S	Q, A, H, M, K
	L.3.U	Q, A, H, M, K
G04 *Sıcaklık* (16^{th}-17^{th} C)	H.4.L	Q, A, H, M, K
	H.4.U	Q, A, H, M, K
	L.4.U	Q, A, M, K
G05 Hot Water Reservoir (16^{th}-17^{th} C)	H.5	Q, A, H, M, K
	LM.5.V	Q, A, M
	L.5.V	Q, A, K
	B.5.1	Q, A, H, M, K, C
	B.5.2	Q, A, H, M
Q: Quartz, A: Albite, H: Hematite, M: Muscovite, K: Potassium Feldspar, C: Calcite		

Based on the results of the XRD analyses, the aggregate of the horasan plasters belonging to two different periods (15^{th}-16^{th} and 16^{th}-17^{th} centuries) and building bricks used in the structure were composed of basically quartz (SiO_2), albite ($Na(AlSi_3O_8)$), potassium feldspar ($KAl_2Si_2O_5(OH)_4$) and in addition hematite (Fe_2O_3) and muscovite ($KAl_3Si_3O_{10}(OH)_2$) (Figure 4.7-4.15). Some minerals (gehlenite (800°C), diopside (850°C), wollastonite (900-1050°C)) found in the bricks indicate that the bricks were heated at high temperatures. The absence of these minerals in the brick aggregates and building brick in *Eski Hamam* shows that these bricks are baked at low temperatures (<900°C) specially (Cardiano, 2004).

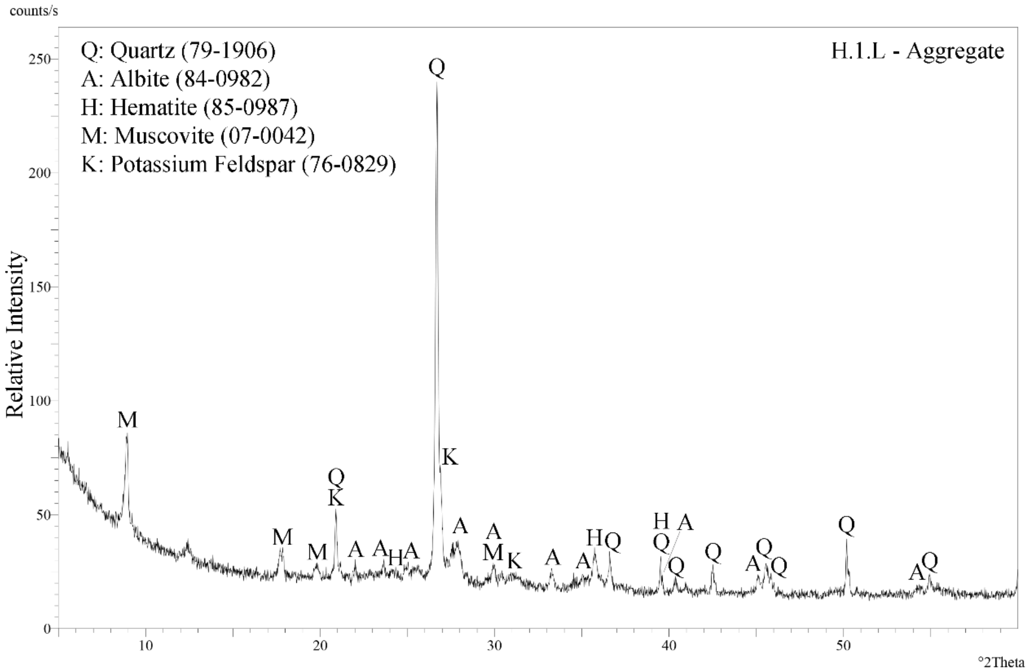


Figure 4.7. XRD patterns of brick aggregates of H.1.L in 15th-16th centuries

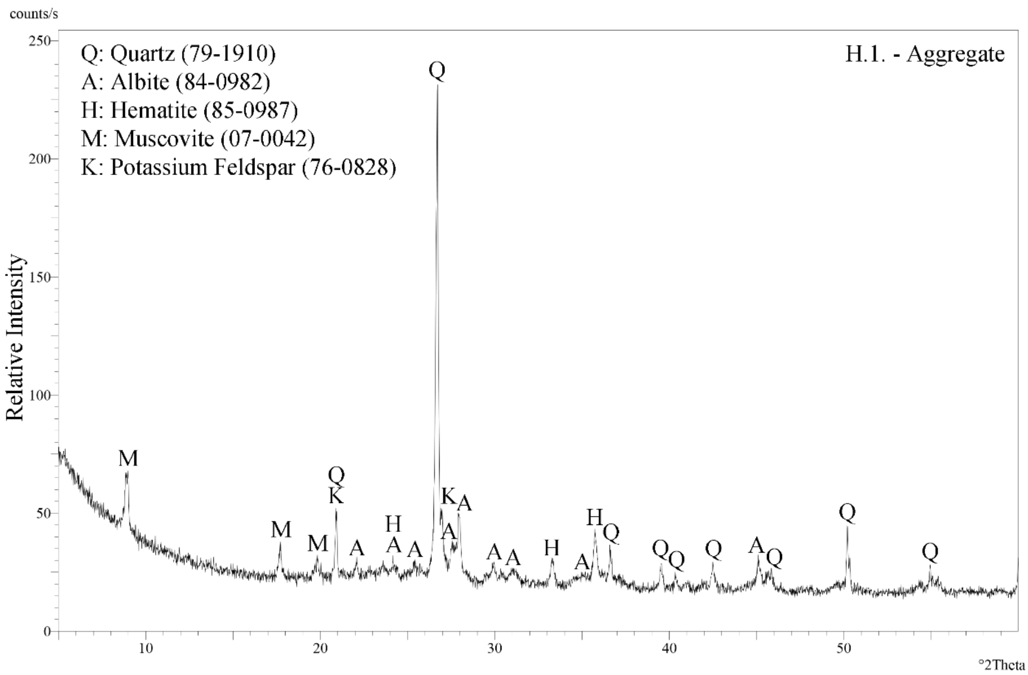


Figure 4.8. XRD patterns of brick aggregates of H.1 in 15th-16th centuries

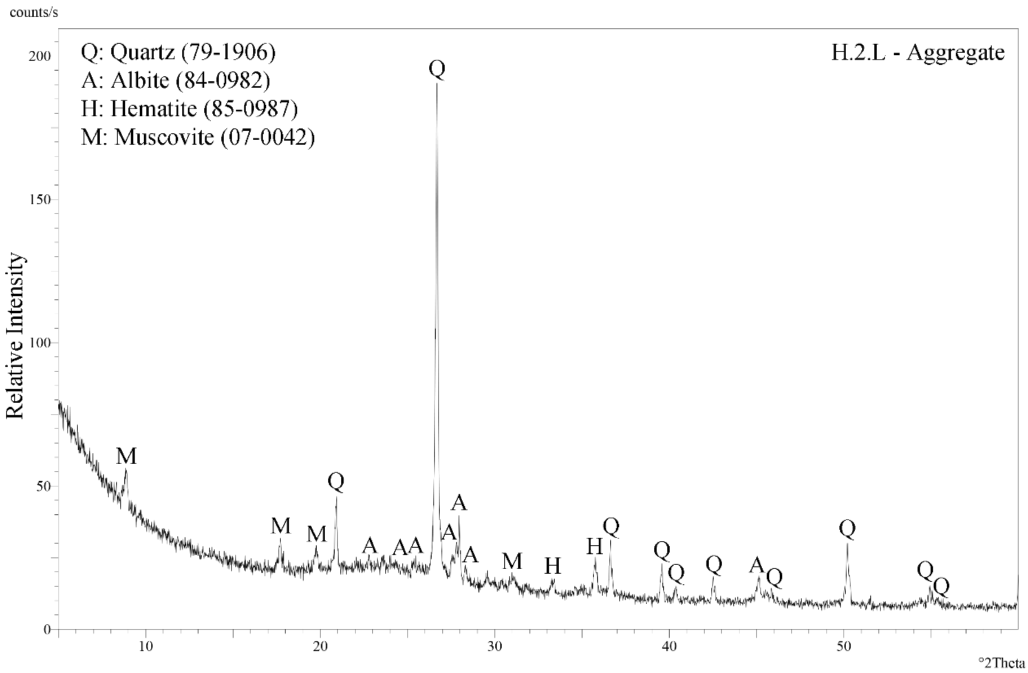


Figure 4.9. XRD patterns of brick aggregates of H.2.L in 15th-16th centuries

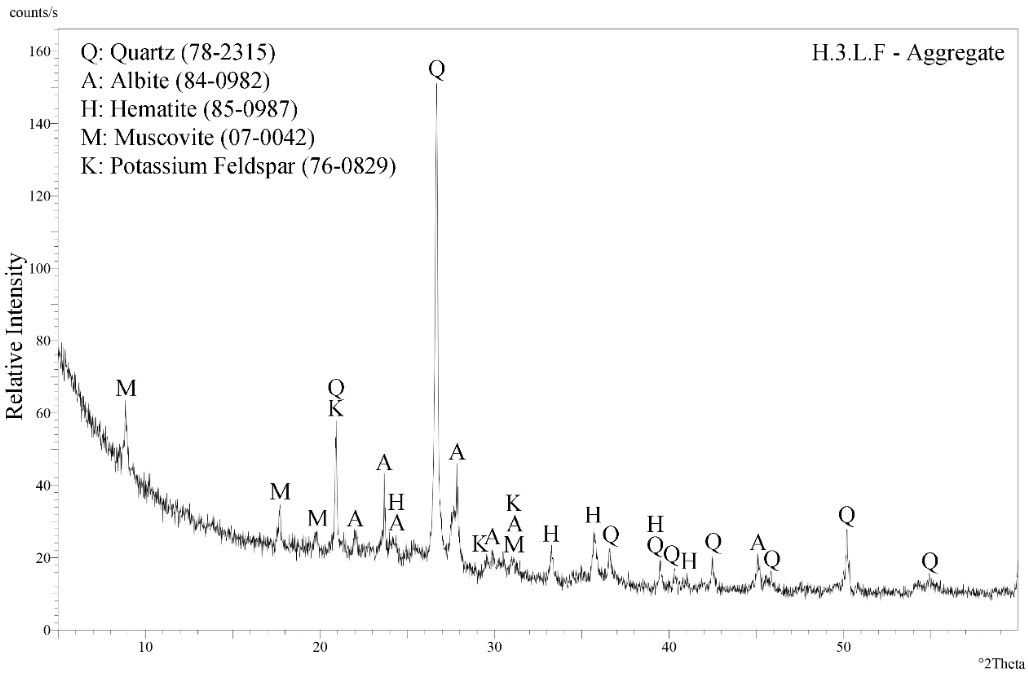


Figure 4.10. XRD patterns of brick aggregates of H.3.L.F in 15th-16th centuries

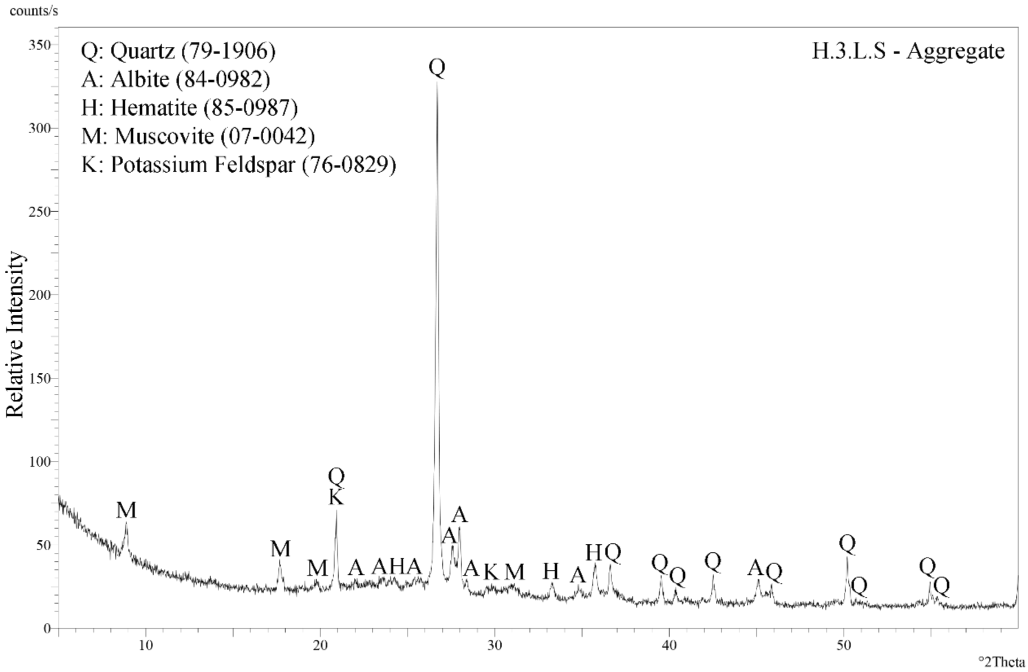


Figure 4.11. XRD patterns of brick aggregates of H.3.L.S in 15th-16th centuries

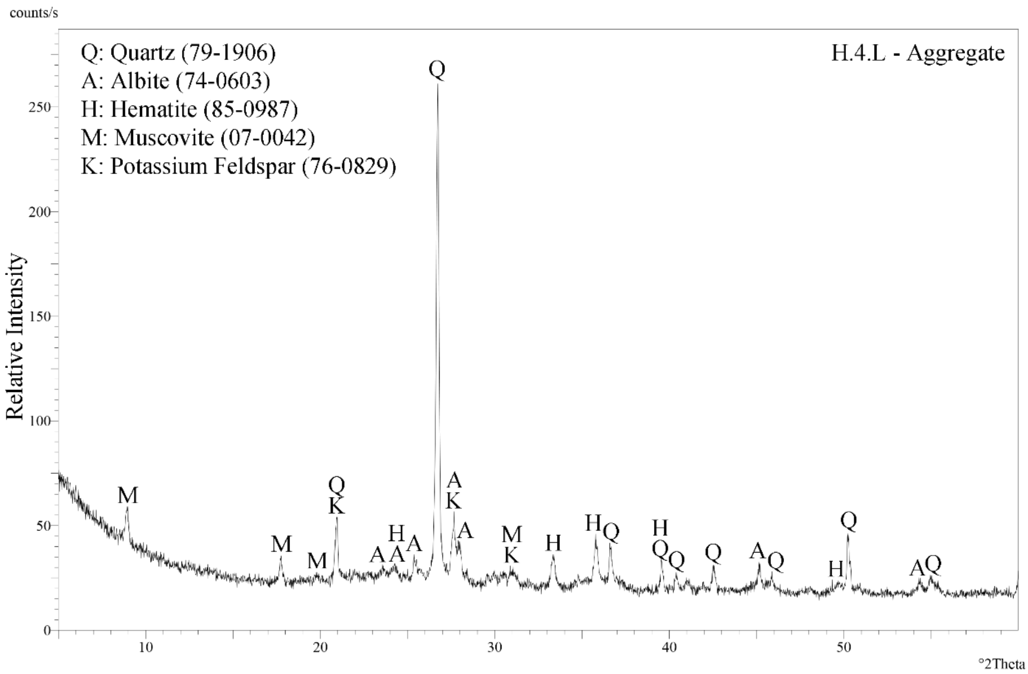


Figure 4.12. XRD patterns of brick aggregates of H.4.L in 16th-17th centuries

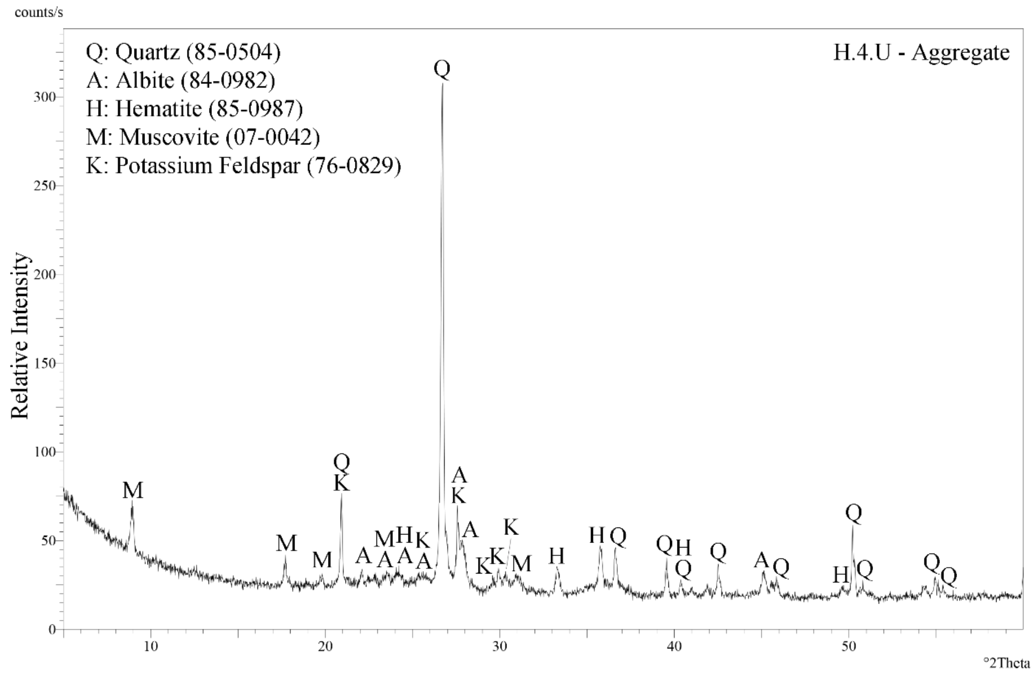


Figure 4.13. XRD patterns of brick aggregates of H.4.U in 16th-17th centuries

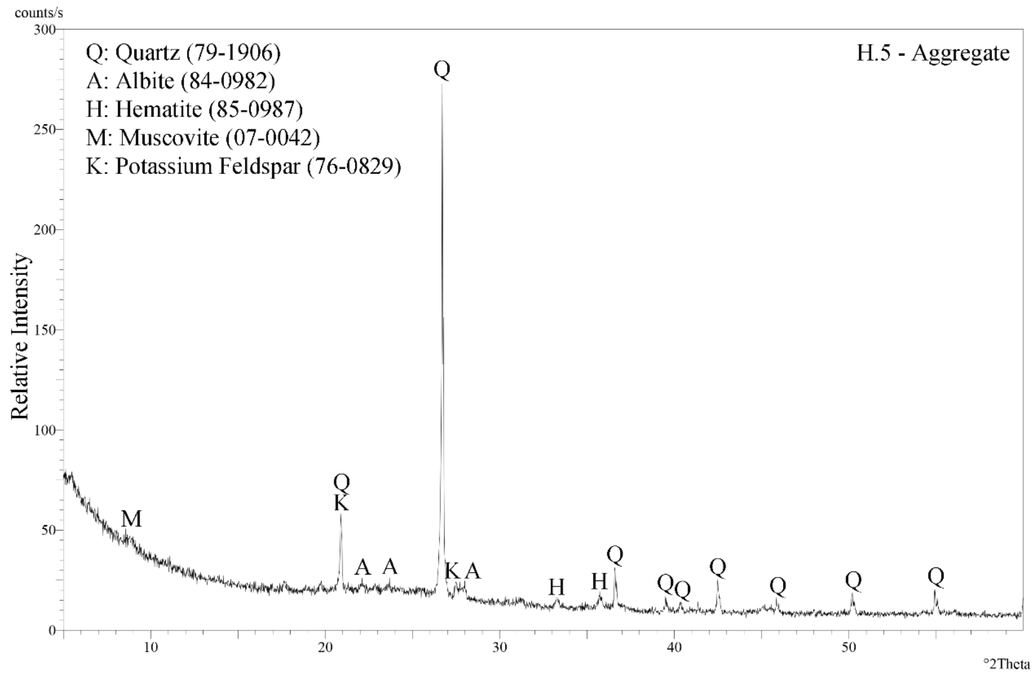


Figure 4.14. XRD patterns of brick aggregates of H.5 in 16th-17th centuries

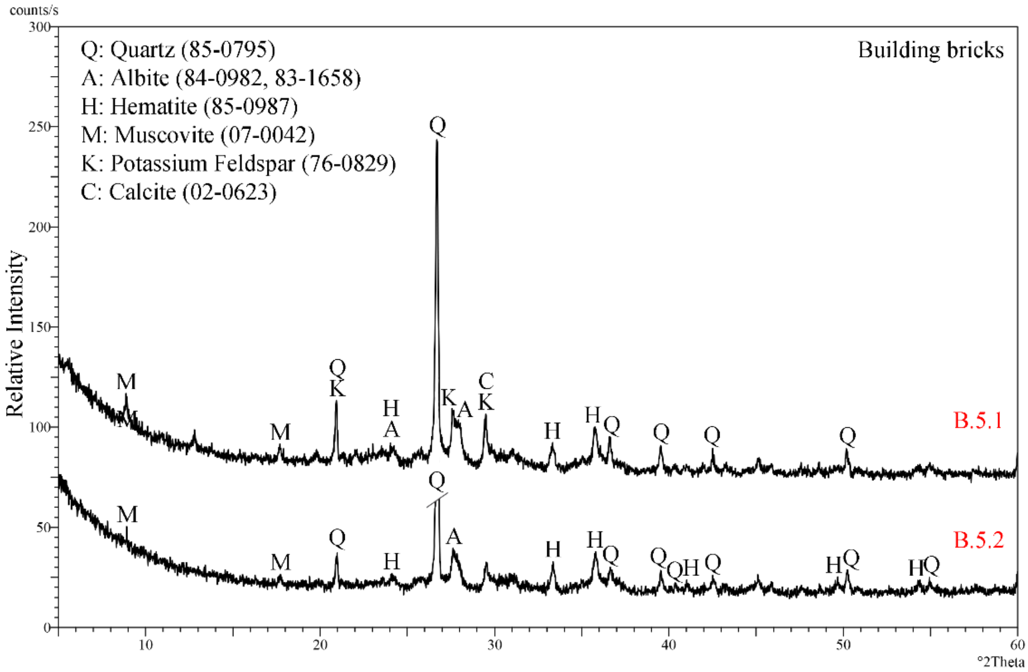


Figure 4.15. XRD patterns of the bricks in the building structure in 16th-17th centuries

XRD patterns of natural aggregates of the lime plasters are similar with these of horasan plasters. Quartz, albite and muscovite minerals were observed in the natural aggregates of the lime plasters (Figure 4.16-4.20).

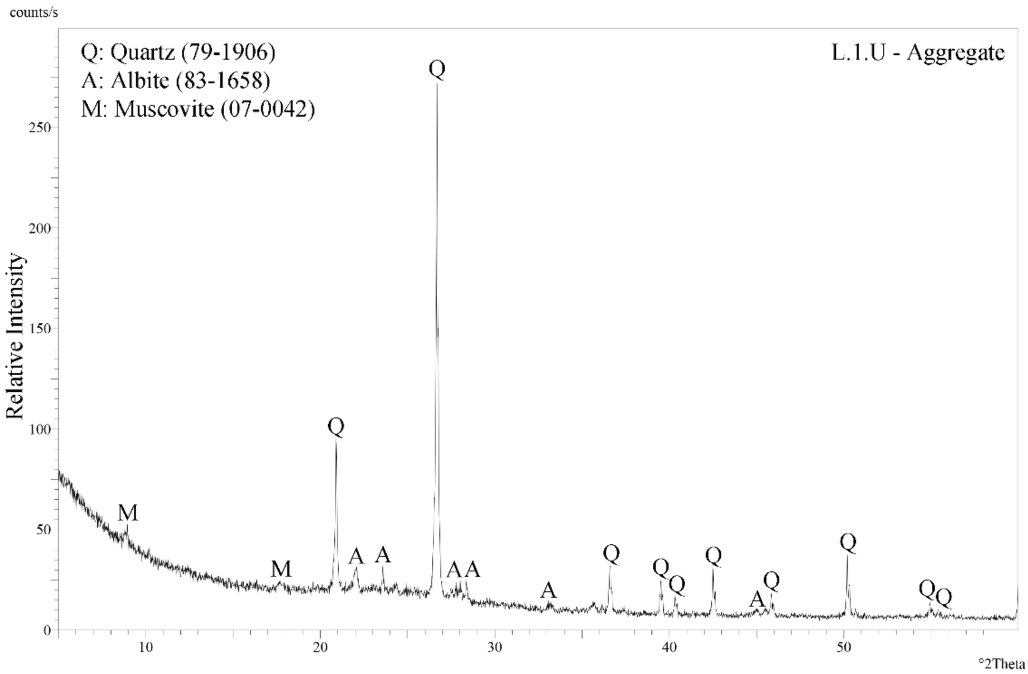


Figure 4.16. XRD patterns of natural aggregates of L.1.U in 15th-16th centuries

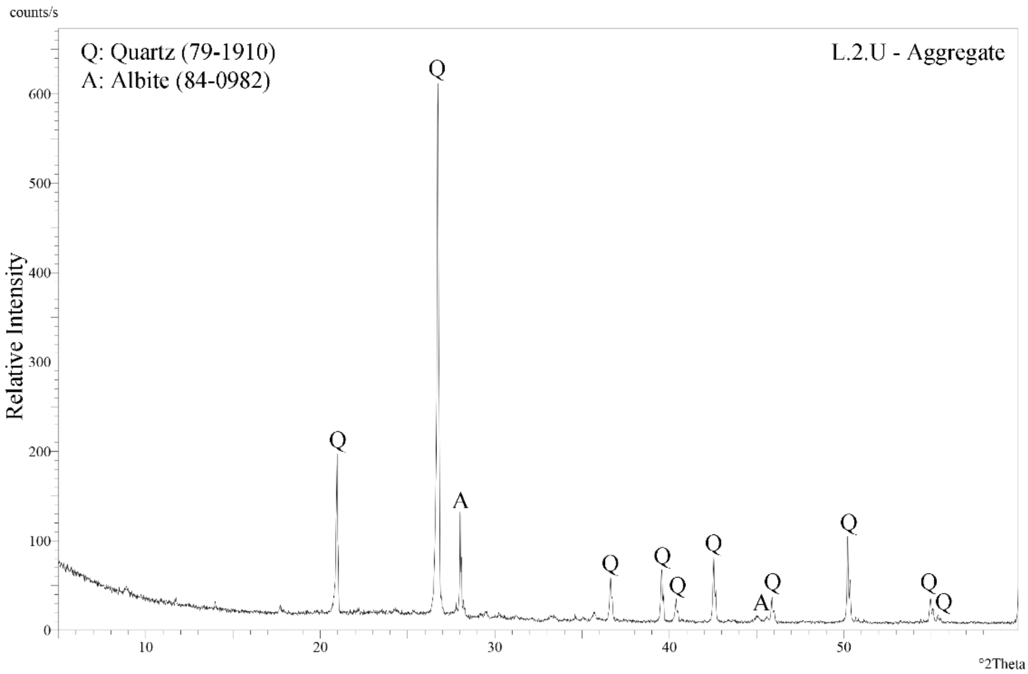


Figure 4.17. XRD patterns of natural aggregates of L.2.U in 15th-16th centuries

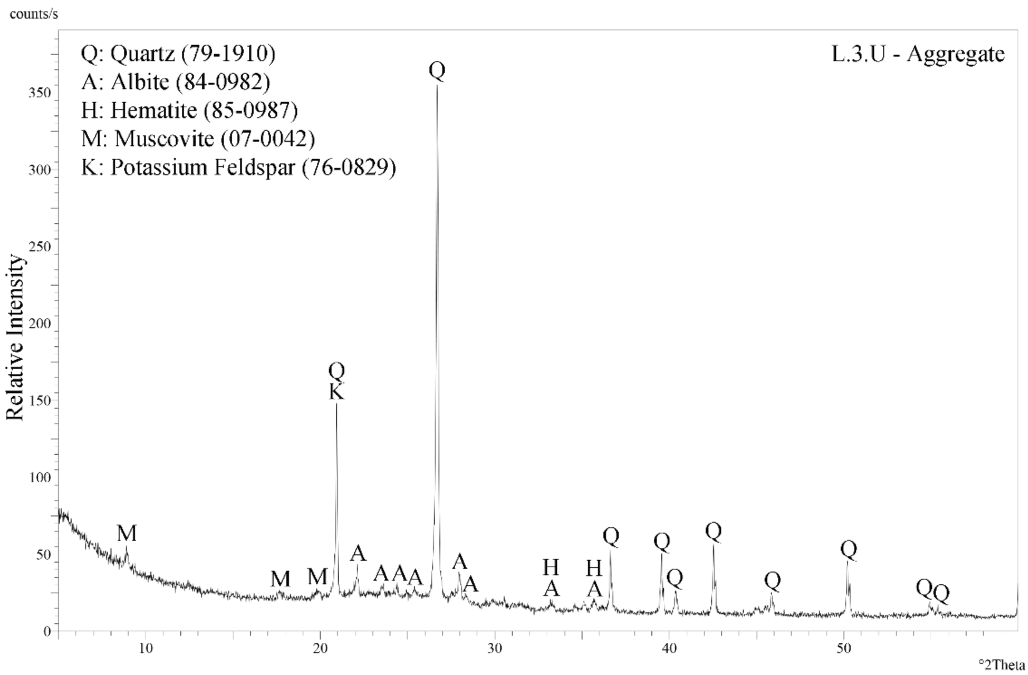


Figure 4.18. XRD patterns of natural aggregates of L.3.U in 15th-16th centuries

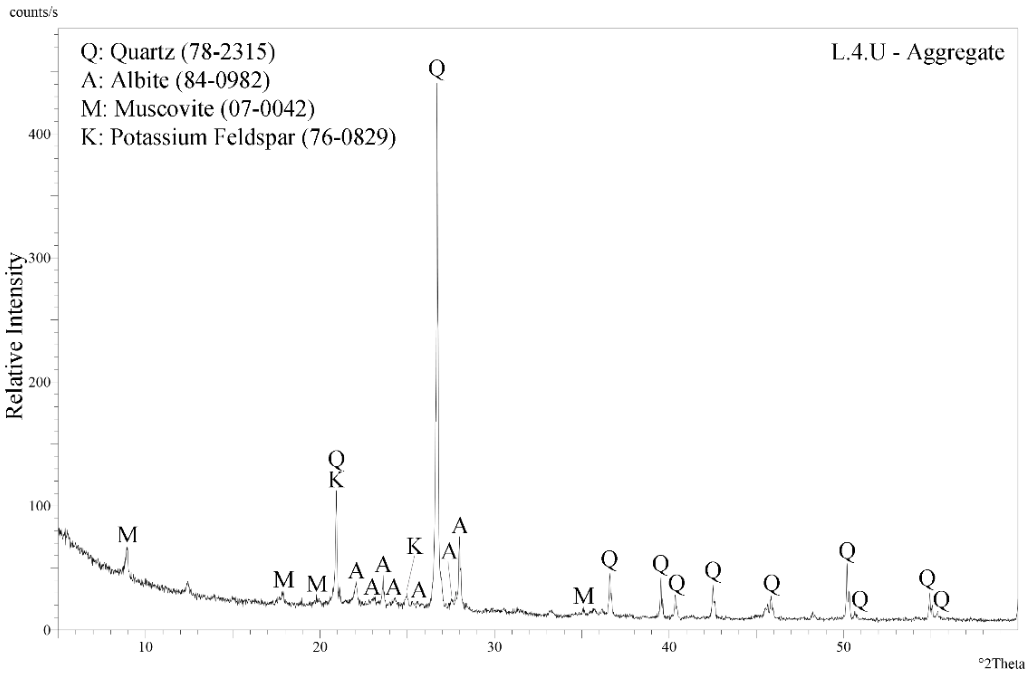


Figure 4.19. XRD patterns of natural aggregates of L.4.U in 16th-17th centuries

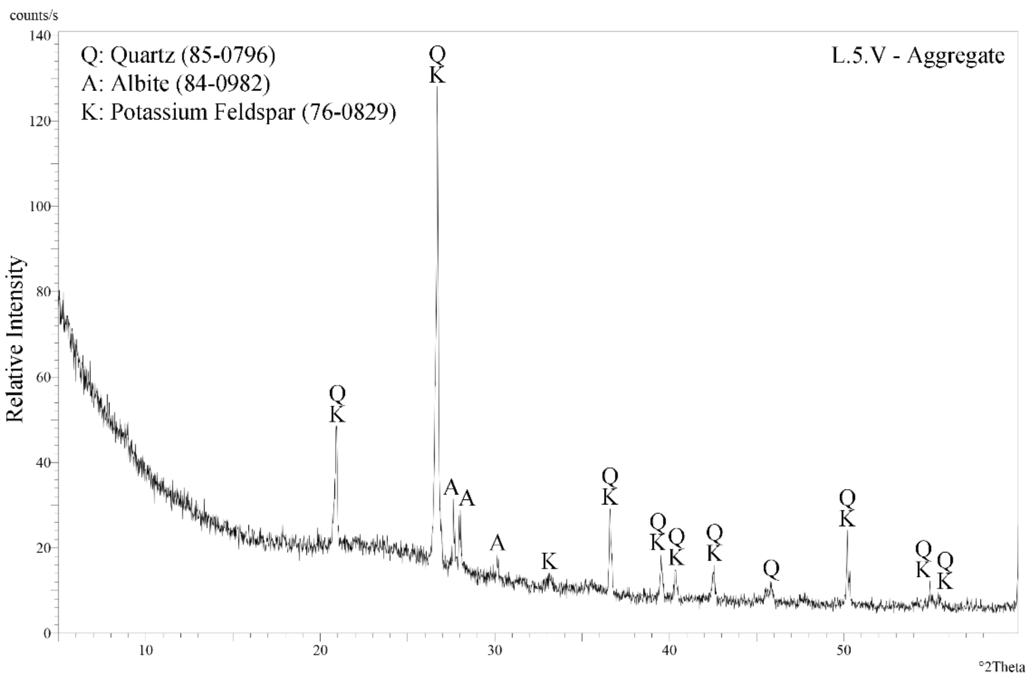


Figure 4.20. XRD patterns of natural aggregates of L.5.V in 16th-17th centuries

4.3.1.2. Mineralogical Compositions of Binders of the Horasan and Lime Plasters

According to XRD analyses, mineralogical compositions of binders of the plasters and mortars were given in the following table (Table 4.5)

Table 4.5. Mineralogical compositions of binders of lime plasters, horasan plasters, and lime mortars

Space	Sample	Minerals
G01 *Soyunmalık-Ilıklık* (15-16th C)	H.1.L	Q, A, M, C
	L.1.U	Q, A, C
	H.1	Q, A, C
G02 *Sıcaklık* 15-16th C)	H.2.L	Q, C, V
	L.2.U	Q, C
	LM.2.E	Q, M, C, V
G03 *Sıcaklık* (15-16th C)	H.3.L.F	Q, A, C
	H.3.L.S	Q, A, H, M, K, C
	L.3.U	Q, C
G04 *Sıcaklık* (16-17th C)	H.4.L	Q, A, H, M, C
	H.4.U	Q, A, H, M, K, C, D
	L.4.U	Q, C, D
G05 *Sıcaklık* (16-17th C)	H.5	Q, C, M
	LM.5.V	Q, C, A
	L.5.V	Q, C
Q: Quartz, A: Albite, H: Hematite, M: Muscovite, K: Potassium Feldspar, C: Calcite V: Vaterite, D: Dolomite		

It was determined that XRD diffration patterns of binders of the horasan plasters are composed of calcite originating from the lime and quartz, albite, muscovite, vaterite and dolomite, vs. minerals originating from the natural aggregates containig silicieous minerals (Figure 4.21-4.28).

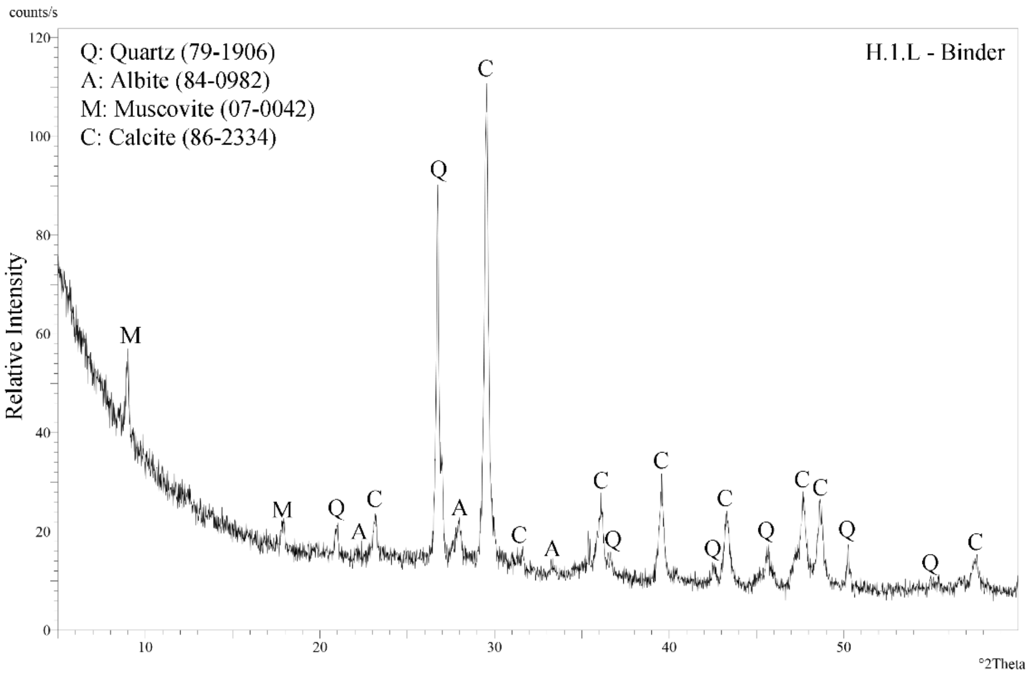


Figure 4.21. XRD patterns of binders of H.1.L in 15th-16th centuries

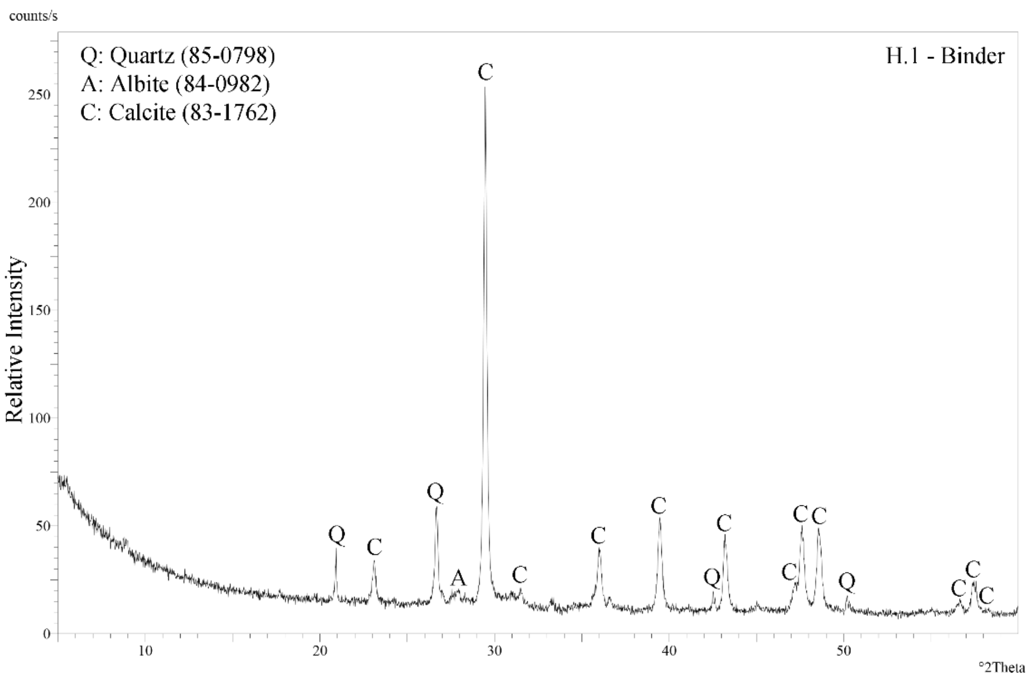


Figure 4.22. XRD patterns of binders of H.1 in 15th-16th centuries

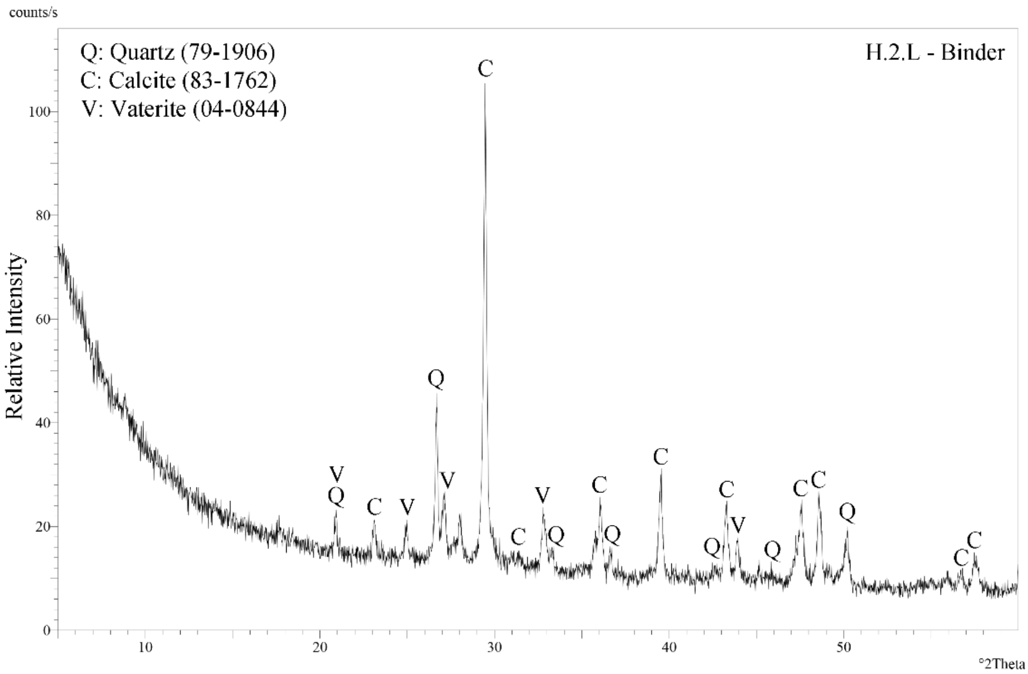


Figure 4.23. XRD patterns of binders of H.2.L in 15th-16th centuries

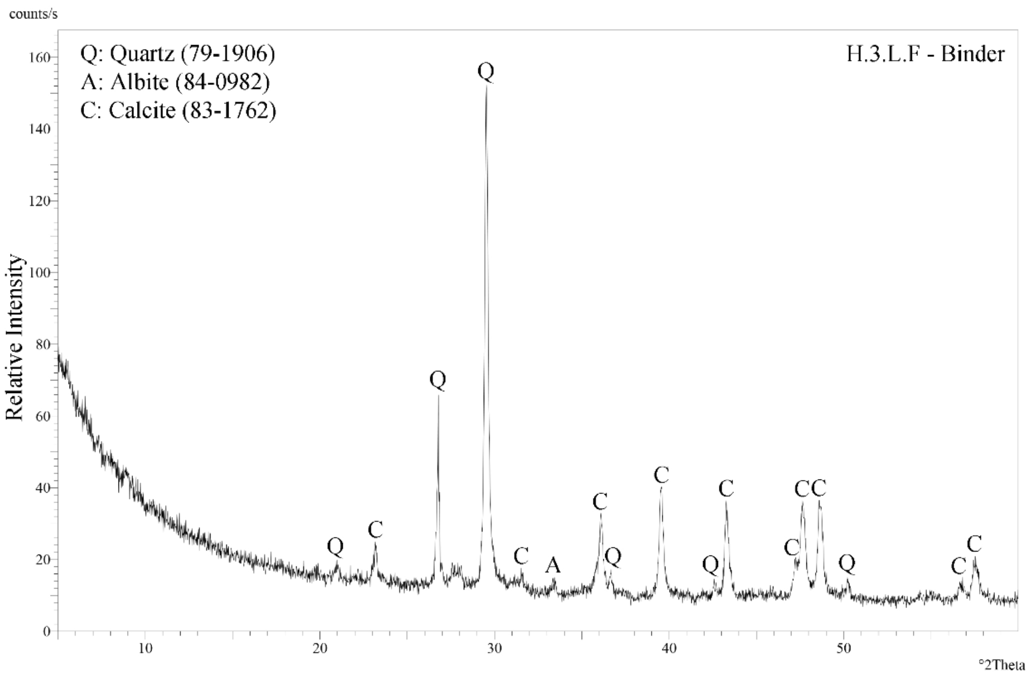


Figure 4.24. XRD patterns of binders of H.3.L.F in 15th-16th centuries

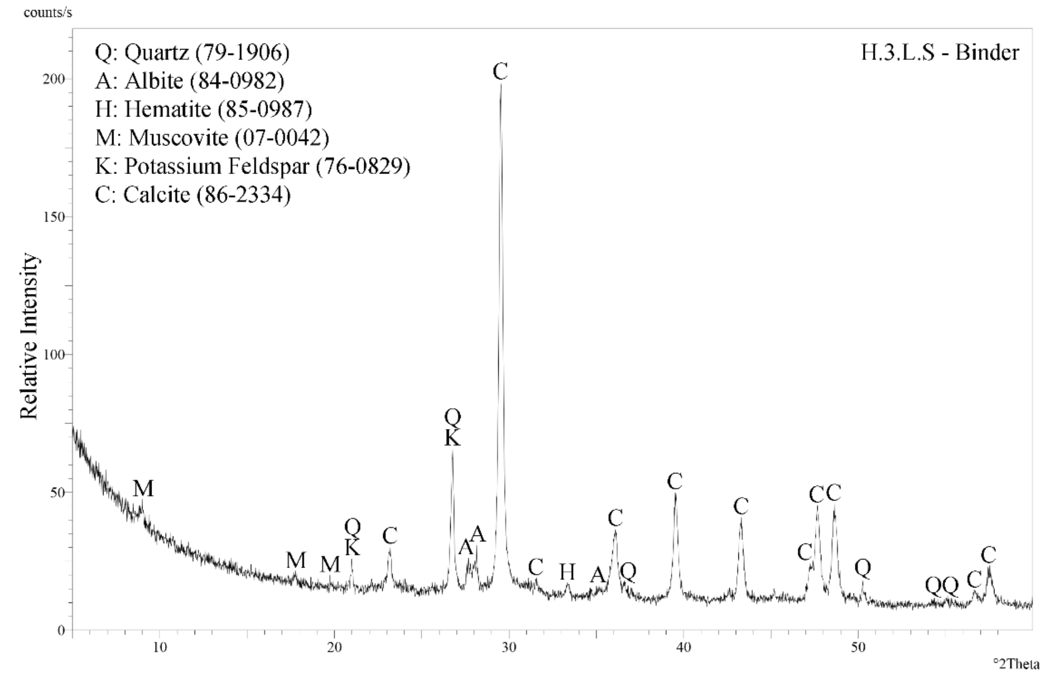


Figure 4.25. XRD patterns of binders of H.3.L.S in 15^{th}-16^{th} centuries

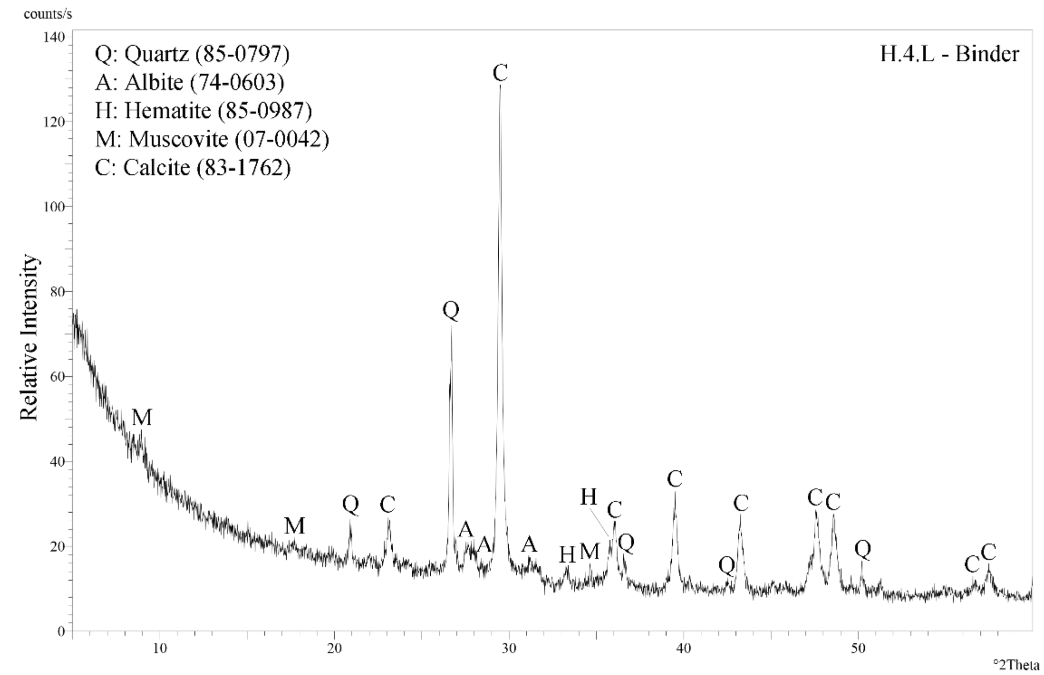


Figure 4.26. XRD patterns of binders of H.4.L in 16^{th}-17^{th} centuries

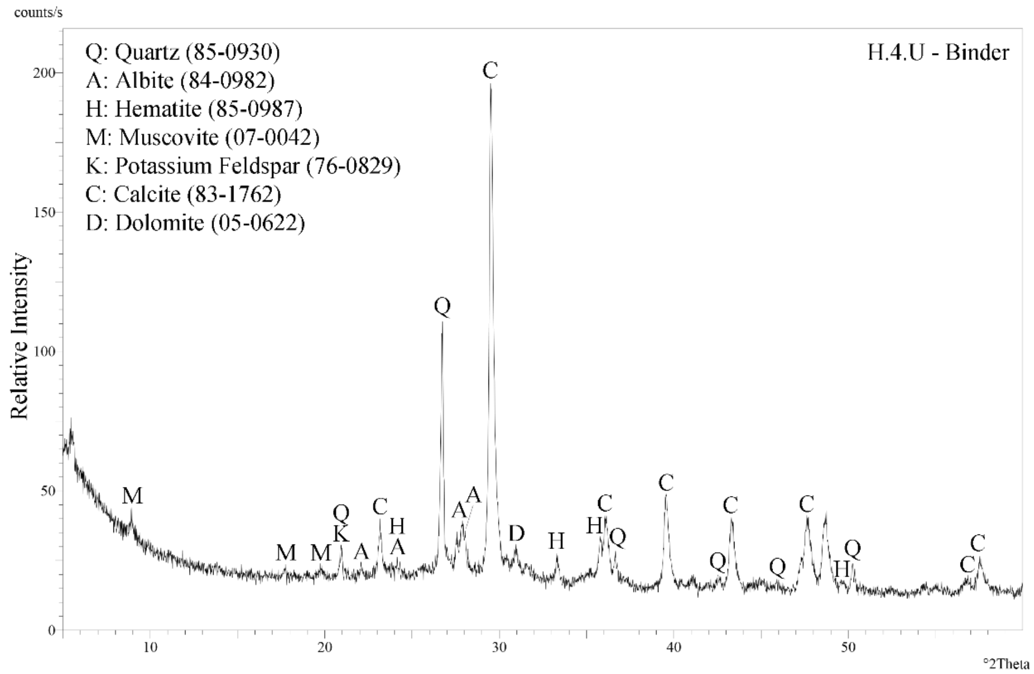


Figure 4.27. XRD patterns of binders of H.4.U in 16th-17th centuries

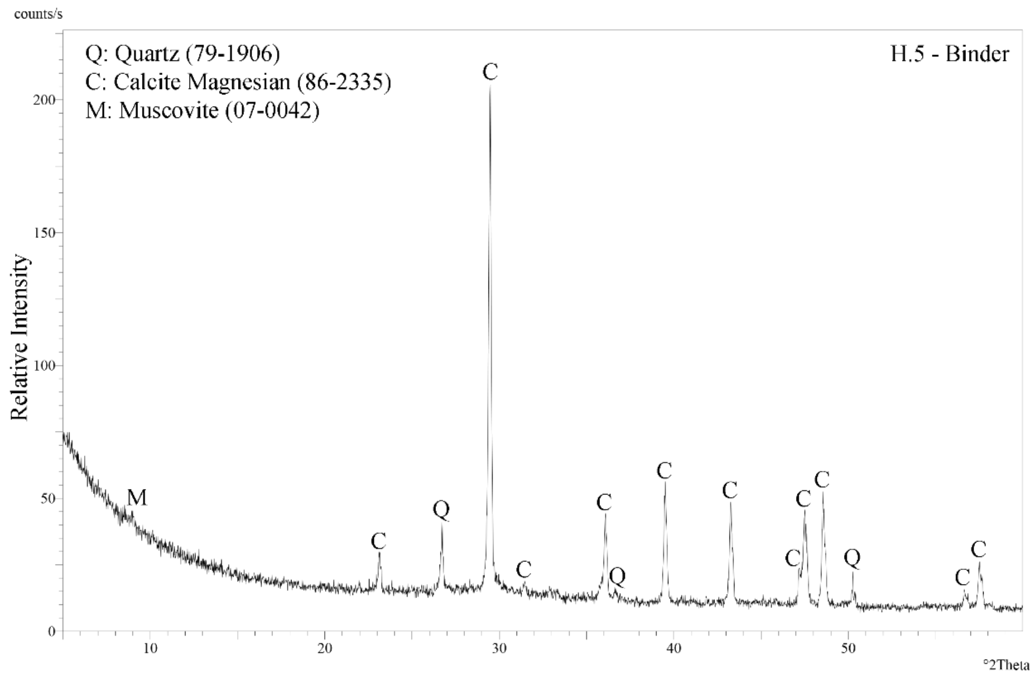


Figure 4.28. XRD patterns of binders of H.5 in 16th-17th centuries

XRD patterns of binders of the lime plasters show that there were mainly calcite minerals coming from the lime in the lime plasters. Quartz, albite and dolomite minerals originating from the natural aggregates were also observed (Figure 4.29-4.33).

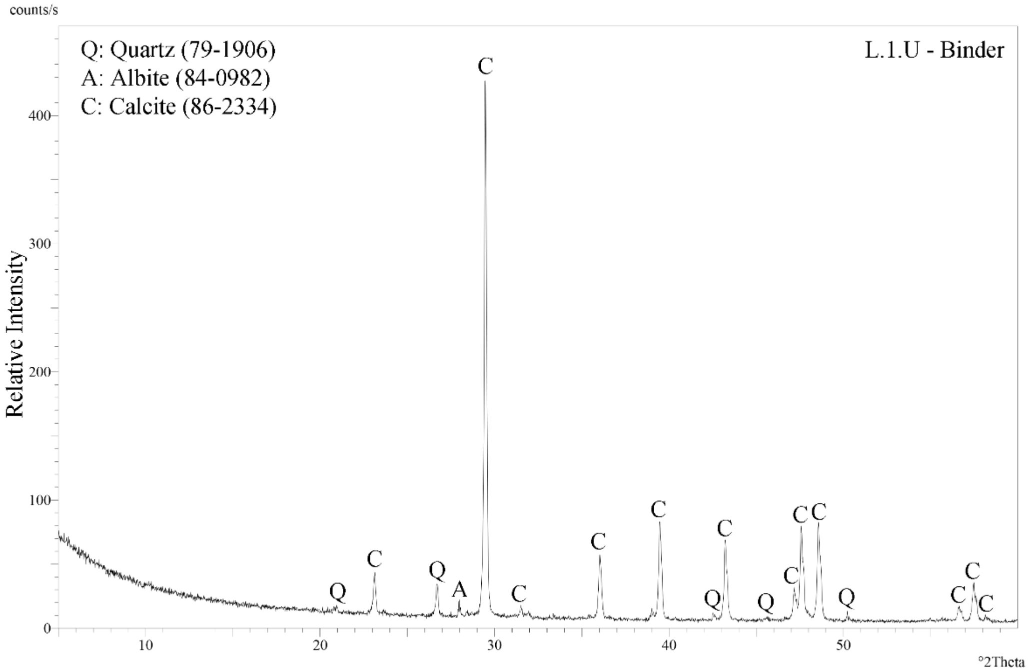


Figure 4.29. XRD patterns of binders of L.1.U in 15^{th}-16^{th} centuries

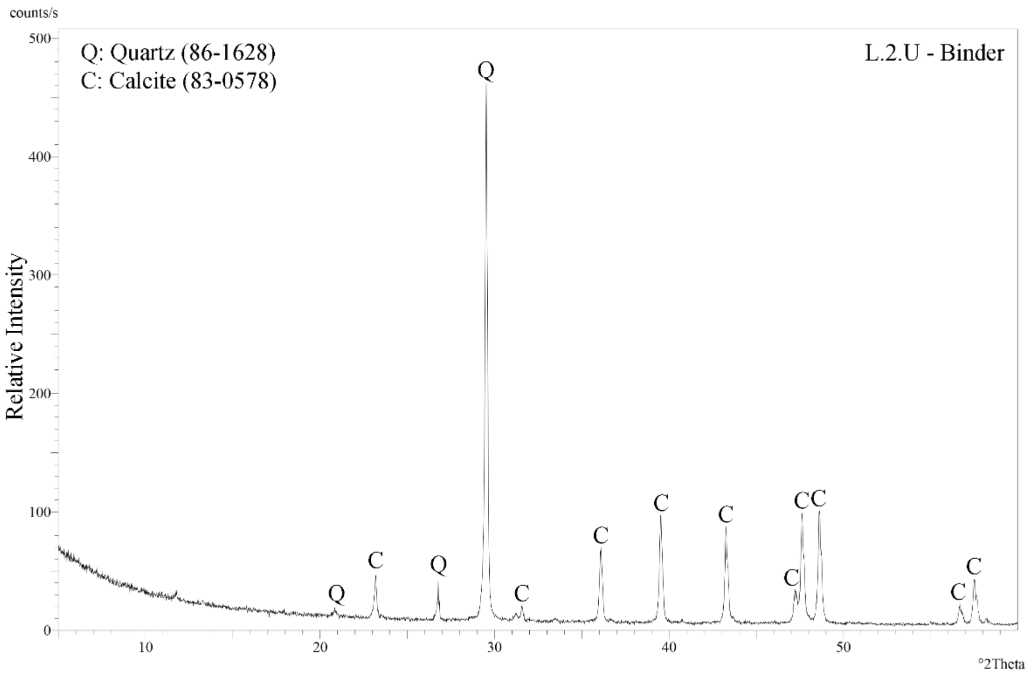


Figure 4.30. XRD patterns of binders of L.2.U in 15^{th}-16^{th} centuries

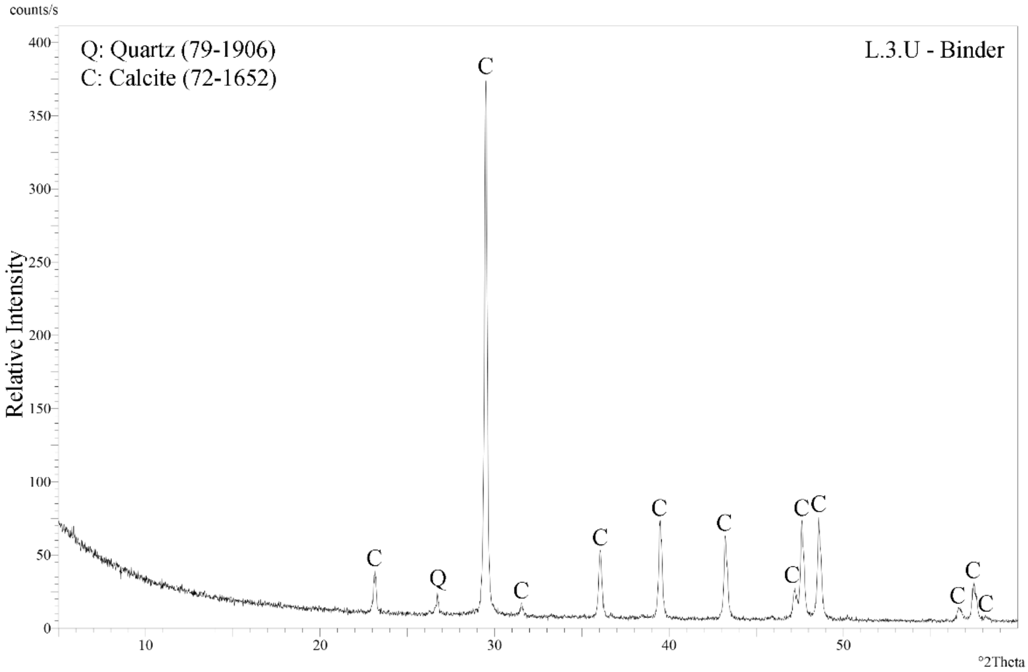


Figure 4.31. XRD patterns of binders of L.3.U in 15th-16th centuries

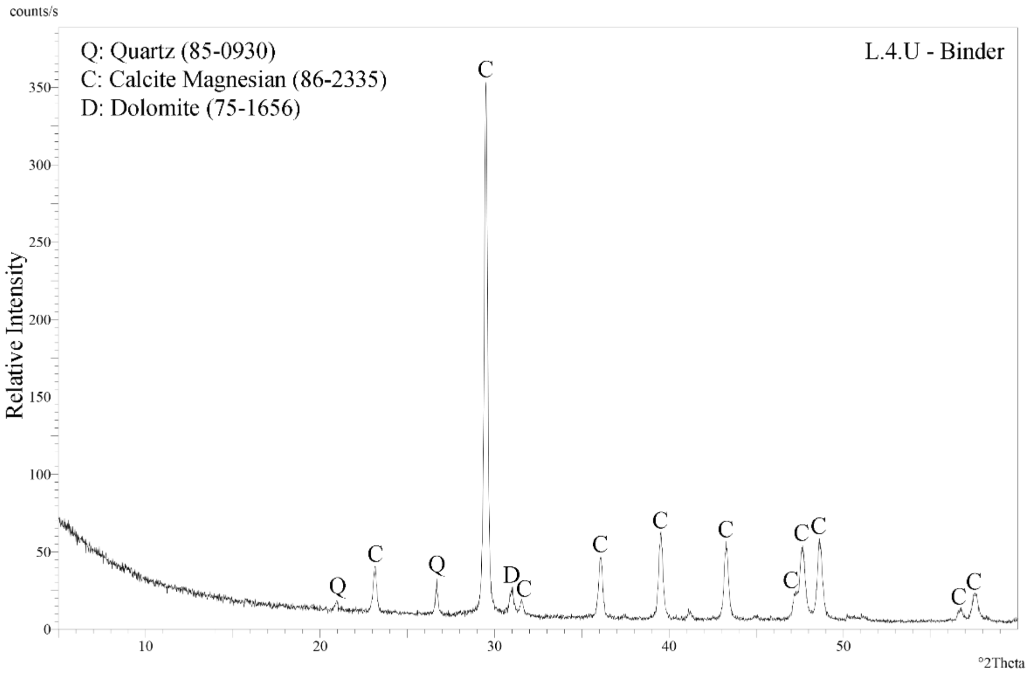


Figure 4.32. XRD patterns of binders of L.4.U in 16th-17th centuries

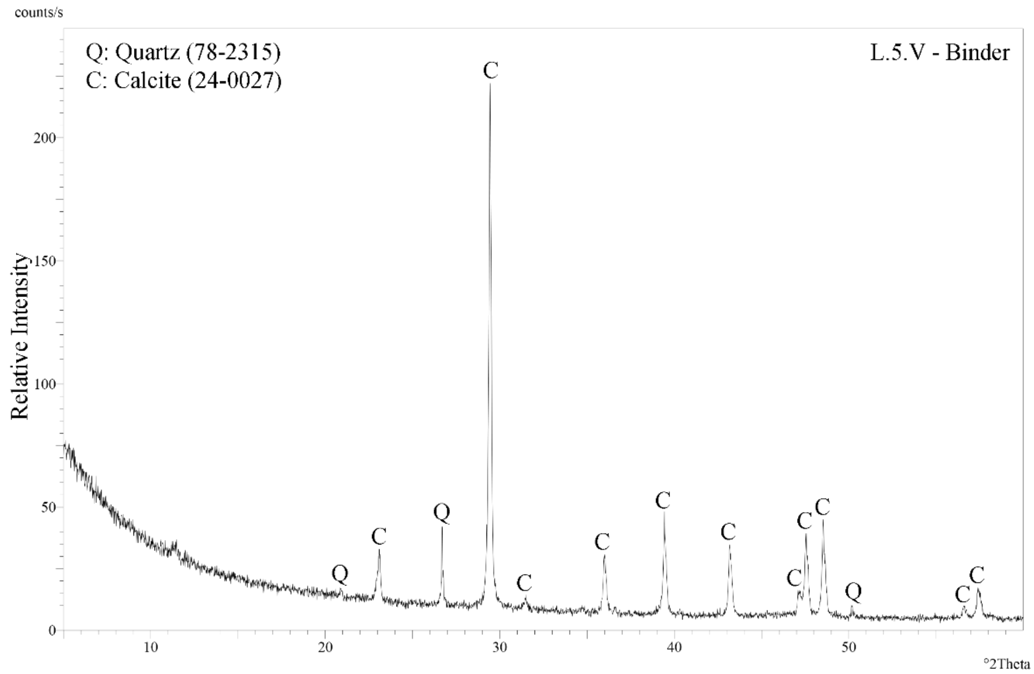


Figure 4.33. XRD patterns of binders of L.5.V in 16^{th}-17^{th} centuries

4.3.1.3. Mineralogical Compositions of the Lime Mortars

According to the XRD pattern of the joint mortar collected from the terracotta pipes, binder of the joint mortar was mainly composed of calcite ($CaCO_3$) originating from the lime and vaterite coming from the natural aggregates and in addition quartz and muscovite minerals based on the natural aggregates (Figure 4.34).

Aggregates of the lime mortar collected from the building bricks was composed of quartz, albite and muscovite minerals (Figure 4.35).

It was observed that mainly composed of calcite originating from the lime and quartz coming from the natural aggregates and in addition albite mineral based on the natural aggregates (Figure 4.36).

In the previus studies, similar mineralogical compositions were determined for horasan plasters, lime plasters, building bricks and joint mortars in several Ottaman bath buildings (İpekci 2016, Uğurlu 2005 and Böke et al. 2004).

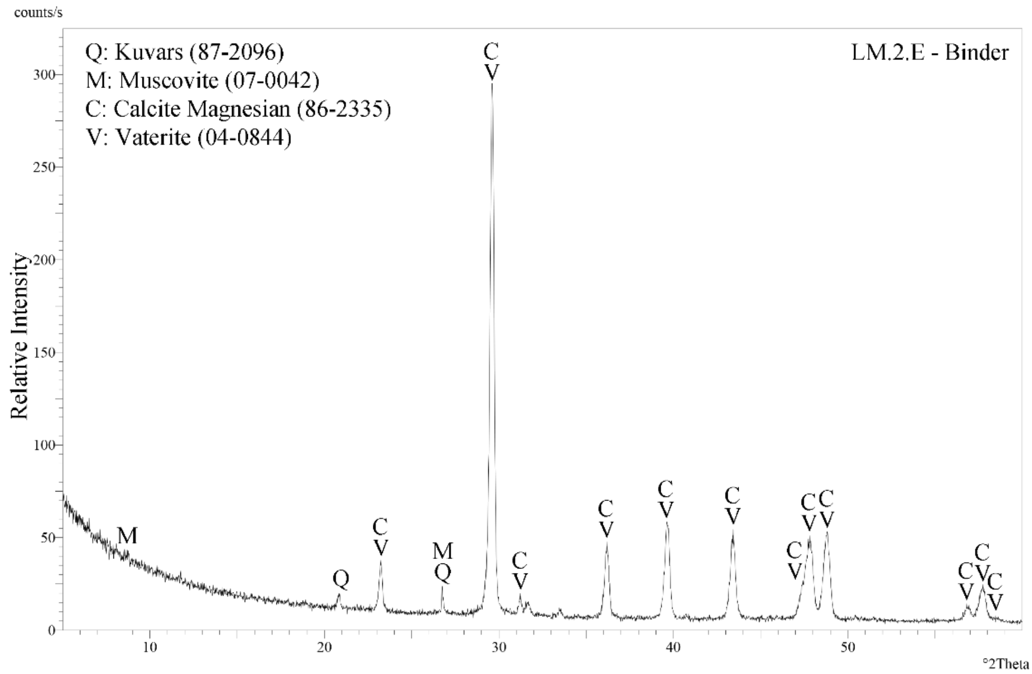


Figure 4.34. XRD patterns of binder of lime mortar used between the terracotta pipes

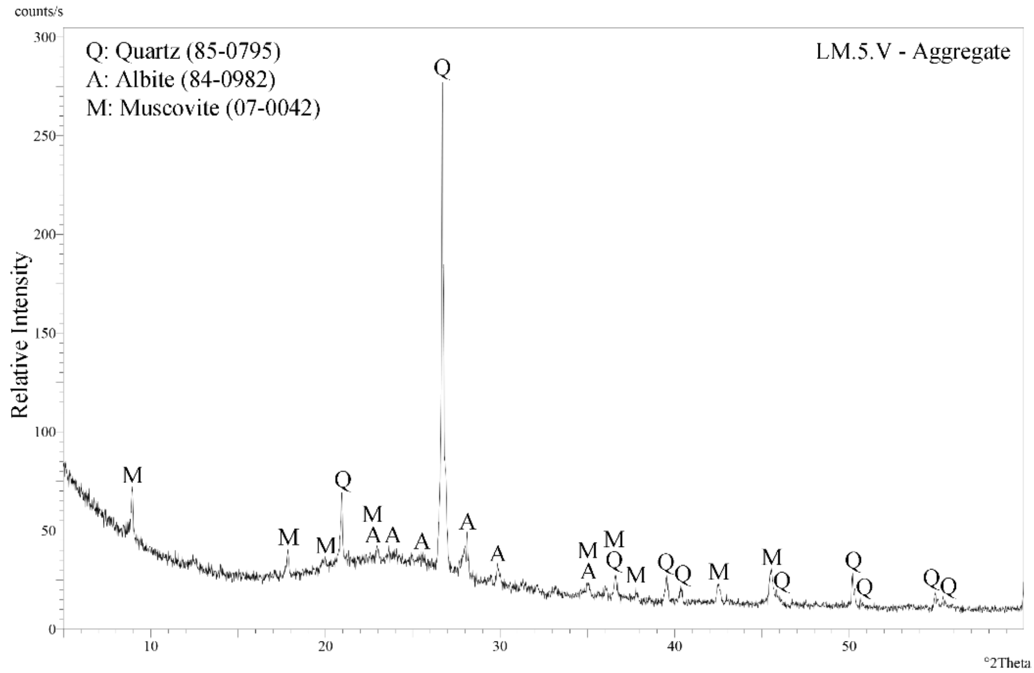


Figure 4.35. XRD patterns of natural aggregates of lime mortar used between the building bricks

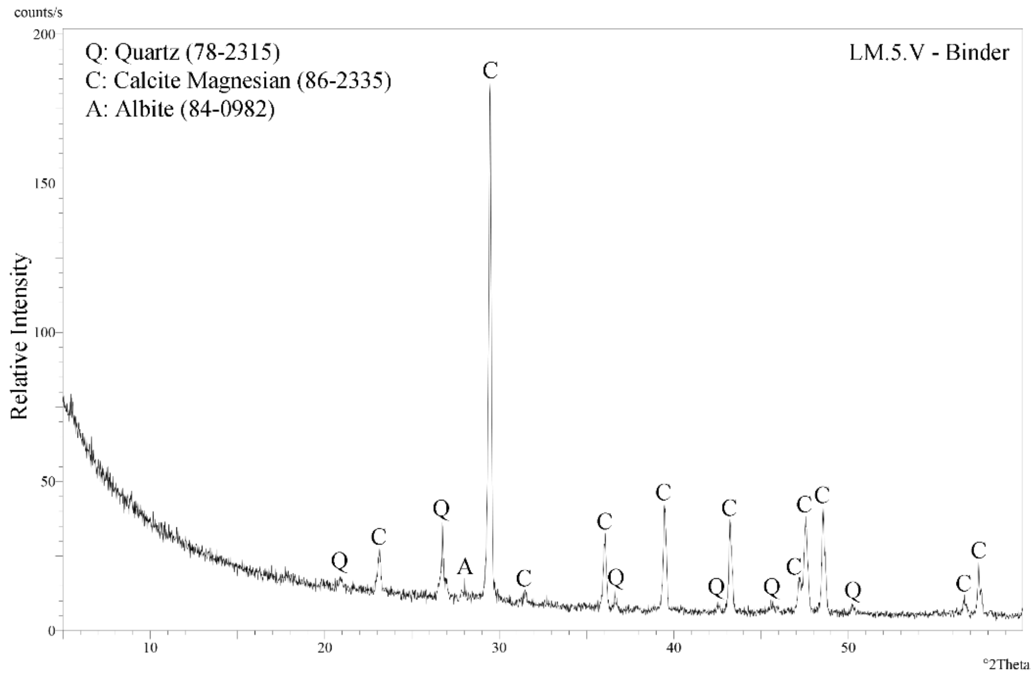


Figure 4.36. XRD patterns of binder of lime mortar used between the building bricks

4.3.2. Chemical Compositions of Plasters, Mortars, Brick and Natural Aggregates, and Bricks in the Structure

Mineralogical compositions of the aggregates (crushed bricks) and binders of the horasan plasters, bricks used in the building structure, natural aggregates and binders of the lime plasters and mortars belonging to two different periods (15^{th}-16^{th} and 16^{th}-17^{th} centuries) were determined by SEM-EDS analyses. Subsequently, average of the results of three different areas of each pellet samples were calculated.

4.3.2.1. Chemical Compositions of Brick Aggregates of Horasan Plasters, Natural Aggregates of Lime Plasters and Building Bricks

Chemical Compositions of brick aggregates of horasan plasters belonging to 15^{th}-16^{th} and 16^{th}-17^{th} centuries and building bricks belonging to 16^{th}-17^{th} centuries were given in the following table (Table 4.6).

Table 4.6. Chemical Compositions of the aggregates of the plasters and building bricks

Period	Sample	Chemical Composition (%)								
		SiO_2	Al_2O_3	FeO	CaO	MgO	Na_2O	K_2O	SO_3	TiO_2
G01 (15-16th c)	H.1.L	63.50	19.36	8.08	1.46	2.65	-	3.95	-	1.00
	H.1	65.30	16.52	8.75	1.96	3.36	-	3.16	-	0.96
G02 (15-16th c)	H.2.L	81.51	10.15	3.77	1.19	1.51	-	1.72	-	0.81
G03 (15-16th c)	H.3.L.F	68.76	16.21	7.32	1.25	2.84	-	3.09	-	0.81
	H.3.L.S	72.52	15.82	4.39	0.66	1.85	0.68	3.23	-	0.85
G04 (16-17th c)	H.4.L	69.76	15.01	7.70	1.00	2.39	-	3.13	-	1.02
	H.4.U	68.80	15.18	7.78	1.56	2.88	-	2.71	-	1.09
G05 (16-17th c)	H.5	83.89	8.18	4.23	0.33	1.45	0.4	1.10	-	0.68
	B.5.1	51.10	21.80	9.77	7.24	4.73	1.08	4.04	-	0.96
	B.5.2	49.22	24.45	10.77	5.42	4.46	1.15	4.09	-	1.85

According to table above, brick aggregate powders in horasan plasters belonging to two different perios (15^{th}-16^{th} and 16^{th}-17^{th} centuries) were composed of high amounts of SiO_2 and Al_2O_3; lower amount of FeO and low amounts of CaO, MgO, Na_2O, K_2O and TiO_2 (Table 4.6). Building brick powders were also composed of high amounts of SiO_2 and Al_2O_3; lower amount of FeO, CaO, MgO and K_2O and low amounts of Na_2O and TiO_2 (Table 4.6). According to the values in the table above, iron content in the bricks used in the building structure is higher than the brick aggregates of horasan plasters belonging to two different periods (15^{th}-16^{th} and 16^{th}-17^{th} centuries). It indicates that preparation of brick aggregates, clay containing low amount of iron oxide was used higher than the building bricks.

In addition, it was determined that the natural aggregates of lime plasters and lime mortar were contained high amounts of SiO_2 and Al_2O_3 originated from the brick powders and low amounts of CaO, MgO, FeO, Na_2O, K_2O, TiO_2 (Table 4.7).

Table 4.7. Chemical Compositions of natural aggregates of lime plasters belonging to 15^{th}-16^{th} and 16^{th}-17^{th} centuries and natural aggregates of lime mortar

Period	Sample	Chemical Composition (%)								
		SiO_2	Al_2O_3	FeO	CaO	MgO	Na_2O	K_2O	SO_3	TiO_2
G01 (15-16^{th} c)	L.1.U	90.92	4.97	1.91	0.86	0.72	-	0.93	-	0.73
G02 (15-16^{th} c)	L.2.U	88.31	4.82	1.94	1.57	0.65	0.64	1.19	1.95	0.66
G03 (15-16^{th} c)	L.3.U	86.37	6.81	2.38	1.28	0.76	0.44	1.48	-	0.87
G04 (16-17^{th} c)	L.4.U	82.36	9.07	3.02	0.92	1.04	0.62	2.11	-	0.86
G05 (16-17^{th} c)	L.5.V	87.99	4.58	3.04	2.38	1.14	-	-	-	0.87
	LM.5.V	89.15	5.96	1.63	0.93	0.45	0.42	1.15	-	0.59

4.3.2.2. Chemical Compositions of Binders of Horasan Plasters, Lime Plasters and Lime Mortars

Chemical compositions analyses indicate that binders of horasan plasters belonging to two different periods (15^{th}-16^{th} and 16^{th}-17^{th} centuries) were consisted of high amounts of CaO originating from the lime, SiO_2 and Al_2O_3 coming from the brick powders; and lower amounts of MgO based on the lime and FeO; and low amounts of K_2O and Na_2O (Table 4.8). Chemical composition analyses of the binders of the lime plasters and mortars were given in the following table (Table 4.9).

According to the table, CaO was used in varying percentage 45 to 90%. It shows that binders of lime plasters were composed of mainly CaO originating from carbonated lime. Beside this, MgO originating from the lime; SiO_2 and Al_2O_3 originating from the aggregates were detected; and low amount of FeO, Na_2O, K_2O and SO_3 were observed (Table 4.9).

Binders of lime mortar collected from the terracotta pipes was consisted of mainly CaO originating from the lime. In addition, SO_3 possibly coming from gypsum; MgO originating from the lime; SiO_2 and Al_2O_3 based on the aggregates were determined in the joint mortar (Table 4.9). Presence of gypsum in the joint mortar used between the terracotta pipes might be in order to provide quick setting for lime.

Chemical composition analysis of the other lime mortar collected between the bricks in the vault demonstraded that binders of the mortars were composed of high amonts of CaO coming from the lime and SiO_2 originating from the aggregates; and lower amount of Al_2O_3 originating from the aggregates; and low amounts of MgO originating from the lime, FeO and K_2O (Table 4.9).

Based on the results, chemical compositions of horasan plasters and lime plasters used in 15th-16th and 16th-17th centuries are similar with each other. Even if the lime mortars mostly similar with each other, as the locations of the usage are different, chemical compositions of the lime mortars show some change.

According to the previus studies, chemical compositions of the horasan plasters, lime plasters, lime mortars and building bricks have similar properties of some of the Ottoman bath buildings (İpekci 2016, Uğurlu 2005, Böke 2004).

Table 4.8. Chemical Compositions of binders of the horasan plasters belonging to 15th-16th and 16th-17th centuries

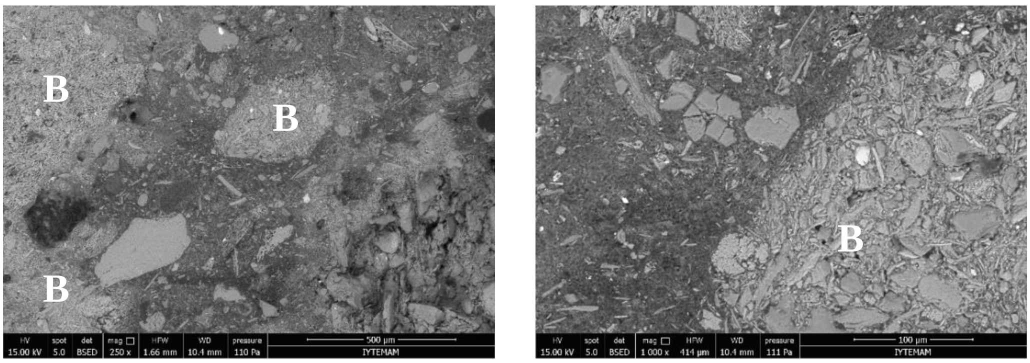
Period	Sample	Chemical Composition (%)								
		SiO_2	Al_2O_3	FeO	CaO	MgO	Na_2O	K_2O	SO_3	TiO_2
G01 (15-16th c)	H.1.L	28.06	15.74	5.23	44.49	3.11	0.98	2.71	1.07	-
	H.1	20.86	8.83	3.45	58.43	5.10	1.05	2.28	1.03	-
G02 (15-16th c)	H.2.L	34.29	15.22	4.62	39.55	4.18	-	2.14	-	-
G03 (15-16th c)	H.3.L.F	24.36	11.40	3.69	52.96	4.59	0.95	2.03	-	-
	H.3.L.S	22.83	12.87	4.19	54.34	3.82	-	1.95	-	-
G04 (16-17th c)	H.4.L	25.50	12.72	4.59	48.54	5.02	1.11	2.50	-	-
	H.4.U	34.30	16.56	5.63	33.85	4.48	0.94	4.56	-	-
G05 (16-17th c)	H.5	33.70	13.59	3.97	41.24	2.97	1.54	3.00	-	-

Table 4.9. Chemical Compositions of binders of lime plasters and lime mortars

Period	**Sample**	**Chemical Composition (%)**								
		SiO_2	**Al_2O_3**	**FeO**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**SO_3**	**TiO_2**
G01 (15-16th c)	L.1.U	6.88	2.31	1.83	80.37	4.72	3.51	1.61	-	-
G02 (15-16th c)	L.2.U	5.04	1.65	1.49	86.79	3.00	1.00	-	2.36	-
	LM.2.E	2.49	0.93	-	89.84	3.29	-	-	3.76	-
G03 (15-16th c)	L.3.U	6.60	3.12	2.16	83.96	3.77	-	-	1.15	-
G04 (16-17th c)	L.4.U	5.05	4.65	1.67	82.39	5.90	1.03	-	1.24	-
G05 (16-17th c)	L.5.V	15.10	6.00	2.56	69.29	6.63	-	-	1.25	-
	LM.5.V	39.19	9.35	1.86	45.17	3.27	-	1.17	-	-

4.4. Microstructural Compositions of Horasan Plasters

SEM-EDS analyses revealed that lime and crushed bricks as binder and aggregates used for preparation of plasters belonging to two different periods (15^{th}-16^{th} and 16^{th}-17^{th} centuries), had strong adhesion with each other and no microcracks at the interface (Figure 4.37).

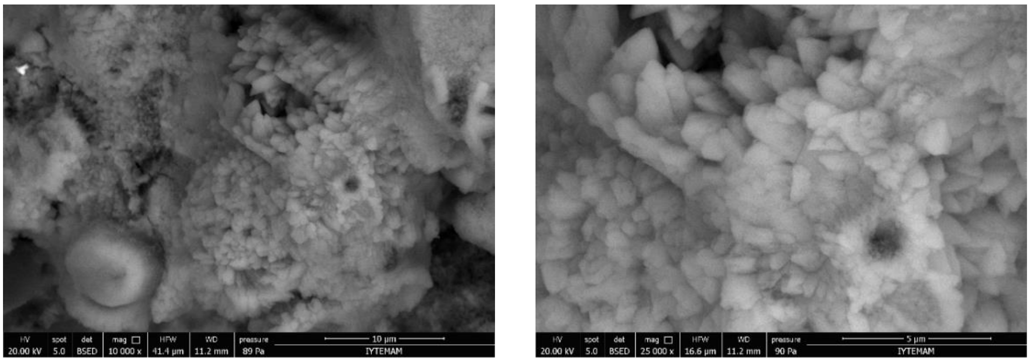


(250 x) (1000 x)

Figure 4.37. Horasan plaster matrices in SEM-EDS (B: Brick Aggregates)

There are the hydraulic products (calcium silicate hydrate and calcium aluminate hydrates) at the interfaces formed by the reaction of lime with brick aggregates and give the hydraulic properties to the plasters.

White lumps (carbonated lime) not mixed with aggregates in the plasters represent the lime used as binder in the preparation of plasters. They were consisted of small calcite crystals (Figure 4.38). The small size of the calcite crystals may indicate the use of aged lime in the praparation of the plasters.



(10000 x) (25000 x)

Figure 4.38. SEM images of carbonated lime

4.5. Pozzolanic Activities of Brick Aggregates, Natural Aggregates and Building Bricks

Pozzolanic activities of brick aggregates, natural aggregates and building bricks were determined by measuring the electrical conductivity value in mS/cm before and after the addition of the aggregate powders less then 53µm to saturated calcium hydroxide solution (Luxan et al., 1989). Aggregates are considered pozzolanic if the difference between the two measurements is greater than 1.2 mS/cm (Luxan et al., 1989).

Results of the analysis demonstrated that the electrical conductivity differences of the **cruched bricks** used as aggregates in horasan plasters belonging to 15^{th}-16^{th} centuries ranging between 6.61-7.80 mS/cm and those belonging to 16^{th}-17^{th} centuries ranging between 7.57-7.96 mS/cm (Figure 4.39 and Table 4.10).

Electrical conductivity differences of the natural aggregates of **lime plasters** belonging to 15^{th}-16^{th} centuries ranging between 6.12-7.13 mS/cm and those belonging to 16^{th}-17^{th} centuries ranging between 6.95-7.09 mS/cm (Figure 4.39 and Table 4.10).

In addition to that natural aggregates of **lime mortar** used between the building bricks had good pozzolanicity with value 7.54 mS/cm (Figure 4.39 and Table 4.10).

The pozzolanicity values of the **building bricks** used were between 0.72-0.86 mS/cm that they can be specified by non-pozzolanic (Figure 4.39 and Table 4.10).

Despite building bricks produced at low temperatures, they didn't show pozzolanic properties due to use of less amounts of clay minerals in their raw materials.

Based on the results, crushed bricks used as aggregates of horasan plasters and natural aggregates used in lime plasters and mortar in two different periods (15th-16th and 16th-17th centuries) have good pozzolanicity; however, bricks used in the building structure are non-pozzolanic in *Eski Hamam*.

According to the previus studies by İpekci (2016), Uğurlu (2005) and Böke et al. (2004), cruched brick aggregates of horasan plasters used in several Ottoman baths have good pozzolanicity and building bricks have not pozzolanic properties.

In the light of this information, crushed bricks used as aggregates of horasan plasters in two different periods (15th-16th and 16th-17th centuries) and building bricks in *Eski Hamam* show similar with those of some Ottoman baths in terms of pozzolanic property. Beside all these, *Eski Hamam* carries being unique Ottoman bath feature because of having a pozzolanic properties in natural aggregates of the lime plasters and lime mortar in *Eski Hamam*.

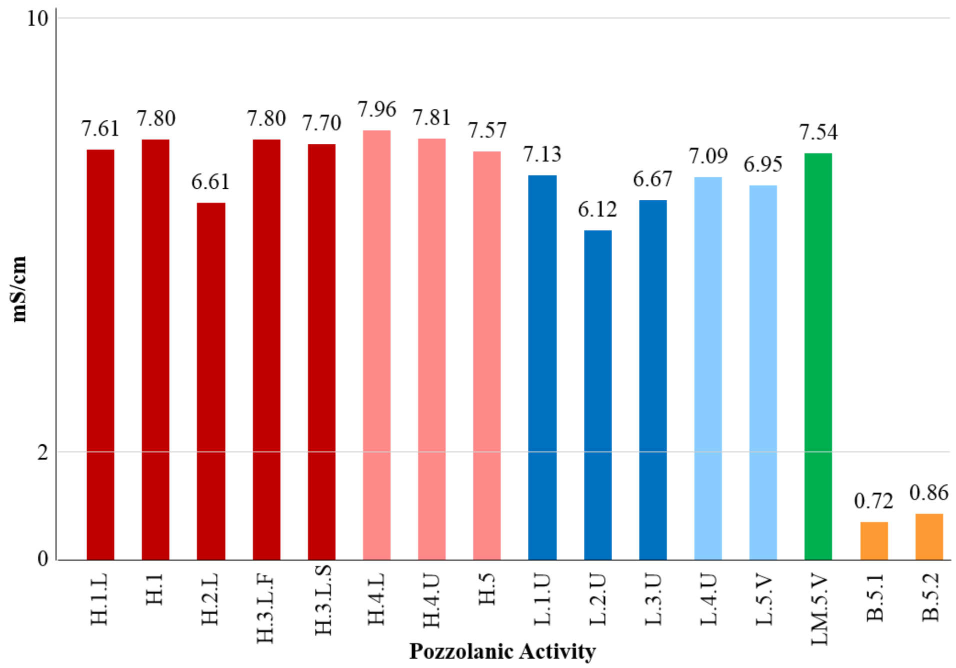


Figure 4.39. Pozzolanic activity of brick and natural aggregates and building bricks

Table 4.10. Pozzolanic activities of brick and natural aggregates and building bricks in two different periods (15^{th}-16^{th} and 16^{th}-17^{th} centuries)

Space	Sample	Electrical Conductivity Differences (mS/cm)
G01 *Soyunmalık-Ilıklık* (15^{th}-16^{th} C)	H.1.L	7.61
	L.1.U	7.13
	H.1	7.80
G02 *Sıcaklık* (15^{th}-16^{th} C)	H.2.L	6.61
	L.2.U	6.12
G03 *Sıcaklık* (15^{th}-16^{th} C)	H.3.L.F	7.80
	H.3.L.S	7.70
	L.3.U	6.67
G04 *Sıcaklık* (16^{th}-17^{th} C)	H.4.L	7.96
	H.4.U	7.81
	L.4.U	7.09
G05 Hot Water Reservoir (16^{th}-17^{th} C)	H.5	7.57
	LM.5.V	7.54
	L.5.V	6.95
	B.5.1	0.72
	B.5.2	0.86

4.6. Hydraulicity of Plasters and Mortars

Hydraulic properties of horasan plasters, lime plasters and lime mortars were determined by calculating the weigh losses at 200, 600 and 900°C. These weigh losses were mainly originated from the loss of adsorbed water at 200°C, loss of chemically bound water (H_2O) at 200-600°C and loss of the carbon dioxide (CO_2) at 600-900°C.

When the ratios of CO_2/H_2O (chemically bound water) of the plasters and mortars are between 1 and 10, they could be regarded as hydraulic; however, if the values are higher than 10, it can be considered that they do not have hydraulic properties (Bakolas et al. 1998).

The results of the analysis were given in the following table and on the plan of *Eski Hamam* (Figure 4.40 and Table 4.11).

According to the analysis result, the CO_2/H_2O ratios of the horasan plasters used in 15th-16th and 16th-17th centuries were lower than 10, ranging between 1.15-4.93 % and 2.14-2.61 % respectively (Figure 4.40 and Table 4.11). The ratios of the CO_2/H_2O in lime plasters belonging to 15th-16th and 16th-17th centuries were lower than 10, ranging between 5.12-8.09 % and 4.67-6.05 % respectively (Figure 4.40 and Table 4.11). In addition, the CO_2/H_2O ratios of the joint mortar collected between terracotta pipes and between the building bricks were lower than 10, which is 2.47 % and 3.64 % respectively due to use of pozzolanic aggregates (Figure 4.40 and Table 4.11).

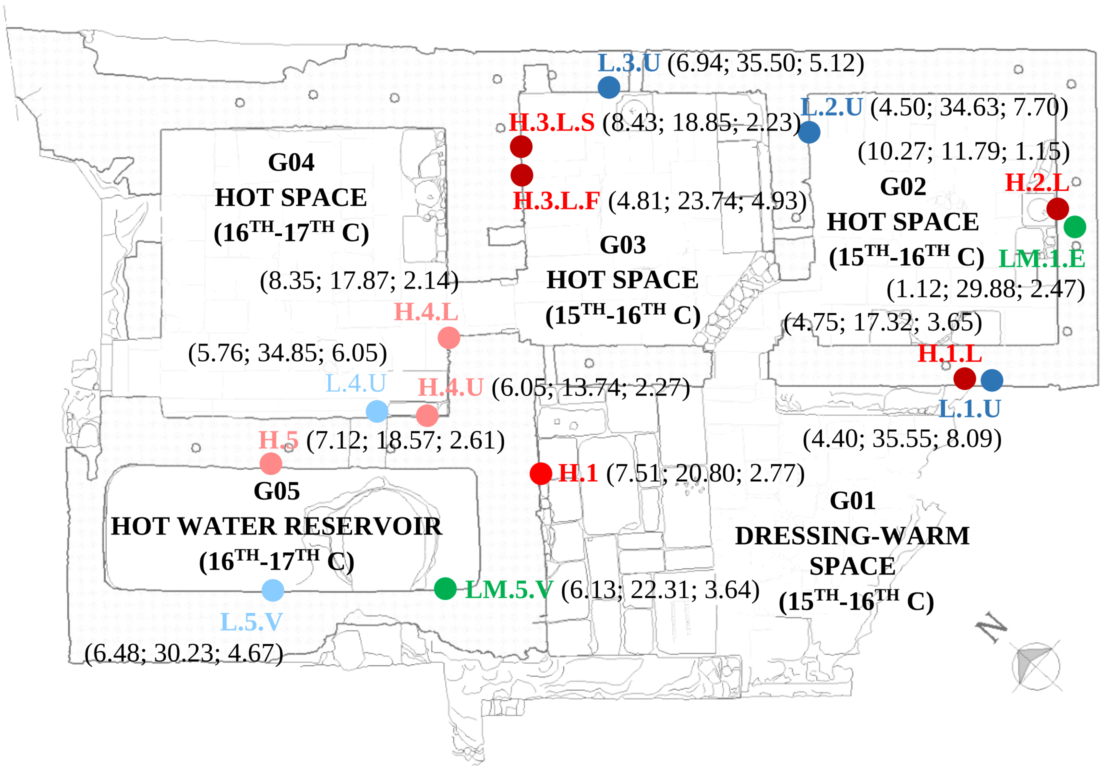


Figure 4.40. Plan of *Eski Hamam* showing hydraulicity of plasters and mortars (H_2O; CO_2; H_2O/CO_2)

Table 4.11. Chemically bound water (H_2O), CO_2 and percent of H_2O/CO_2 ratios of the plasters and mortars

Space	**Sample**	**H_2O (%)**	**CO_2 (%)**	**CO_2 / H_2O (%)**
G01 *Soyunmalık-Ilıklık* (15^{th}-16^{th} C)	H.1.L	4.75	17.32	3.65
	L.1.U	4.40	35.55	8.09
	H.1	7.51	20.80	2.77
G02 *Sıcaklık* (15^{th}-16^{th} C)	H.2.L	10.27	11.79	1.15
	L.2.U	4.50	34.63	7.70
	LM.2.E	12.12	29.88	2.47
G03 *Sıcaklık* (15^{th}-16^{th} C)	H.3.L.F	4.81	23.74	4.93
	H.3.L.S	8.43	18.85	2.23
	L.3.U	6.94	35.50	5.12
G04 *Sıcaklık* (16^{th}-17^{th} C)	H.4.L	8.35	17.87	2.14
	H.4.U	6.05	13.74	2.27
	L.4.U	5.76	34.85	6.05
G05 Hot Water Reservoir (16^{th}-17^{th} C)	H.5	7.12	18.57	2.61
	LM.5.V	6.13	22.31	3.64
	L.5.V	6.48	30.23	4.67

CHAPTER 5

CONCLUSIONS

Aydın *Eski Hamam* is one of the unique building in Ottoman baths in terms of its construction technique and material characteristics. As a result of the needs, new *sıcaklık* space were added in 16th and 17th centuries, adding other functions besides the bathing spaces of the bath, until the 18th century, it continued to undergo changes such as expansion and adding a fountain. For this reason, the additions in different periods of the building are also documented in terms of material properties. The parts of underground of the bath were uncovered, building survey and restitution works were carried out in 2016-2017 and restorastion will be applied.

In this study, it is aimed to document the existing materials of *Eski Hamam* and to determine the properties in case of producing new materials for restoration. In this context, the properties of horasan and lime plaster applied in the *Eski Hamam* in 15th-16th and 16th-17th centuries were determined, the differences between the bricks used in the horasan plasters and the bricks used in the structure were examined, the mortar sample taken between the bricks in the vault and between the pipes were examined. Subsequently, determined characterizations of the samples belonging to 15-16 and 16-17th centuries were compared. The results of the research were compared with some baths built in the same period as the *Eski Hamam* and construction technologies were evaluated.

According to the analysis, density and porosity values, lime-aggregate ratios, particle size distributions and major fractions of the horasan and lime plasters used in *Eski Hamam* in 15th-16th and 16th-17th centuries have similar values and similar to other Ottoman baths constructed in the same periods. Mineralogical and chemical compositions of horasan and lime plasters belonging to 15th-16th and 16th-17th centuries have similar content each other and other Ottoman baths. All aggregates in the plasters and mortars used in *Eski Hamam* are pozzolanic and all plaster and mortars have hydraulic properties. Hydraulic characters are due to the pozzolanic characteristics of natural aggregates and brick aggregates. Hydraulic properties of the natural aggregates are the distinctive feature of *Eski Hamam* from other Ottoman baths. In the binding parts of the plasters belonging to the 15th-16th and 16th-17th centuries, pure lime was used as in other Ottoman baths. The mineralogical and chemical compositions of the bricks used in the structure are similar to the other Ottoman baths and they are not pozzolanic. There are carbonated lime deposits in the lower levels of all spaces in the bath. In addition, most of the plasters have been damaged due to humidity and atmospheric conditions.

The plasters and mortars used in the *Eski Hamam* have homogeneous structure and were produced by mixing lime and aggregates very well. The brick aggregates used in the production of horasan plasters have pozzolanic properties because they contain high amounts of clay and were baked at low temperatures, however, the building bricks used in the vault have low amount of clay and are not pozzolanic. This shows that the building bricks have different raw material properties from the crushed brick aggregates and the bricks used as aggregate were produced specially.

Horasan plasters to be produced for the restoration of bath should have a lime/aggregate ratio between 1/2-1/1 in weight and should be prepared by using pozzolanic brick aggregates. These brick aggregates should be prepared using raw materials containing high amounts of clay and they should be baked at low temperatures (<900ºC). When preparing the plasters, pure lime should be used as binder and lime and crushed bricks must be mixed very well in order to ensure that the plasters are resistant. Lime plasters should have also pure lime ratio of 93-97%, should be prepared using natural aggregates with pozzolanic properties, pure lime should be used as a binder and should be prepared by mixing very well.

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APPENDIX A

MEASURED SURVEYS AND PHOTOS OF *ESKİ HAMAM*

A.1. Primary Measured Survey

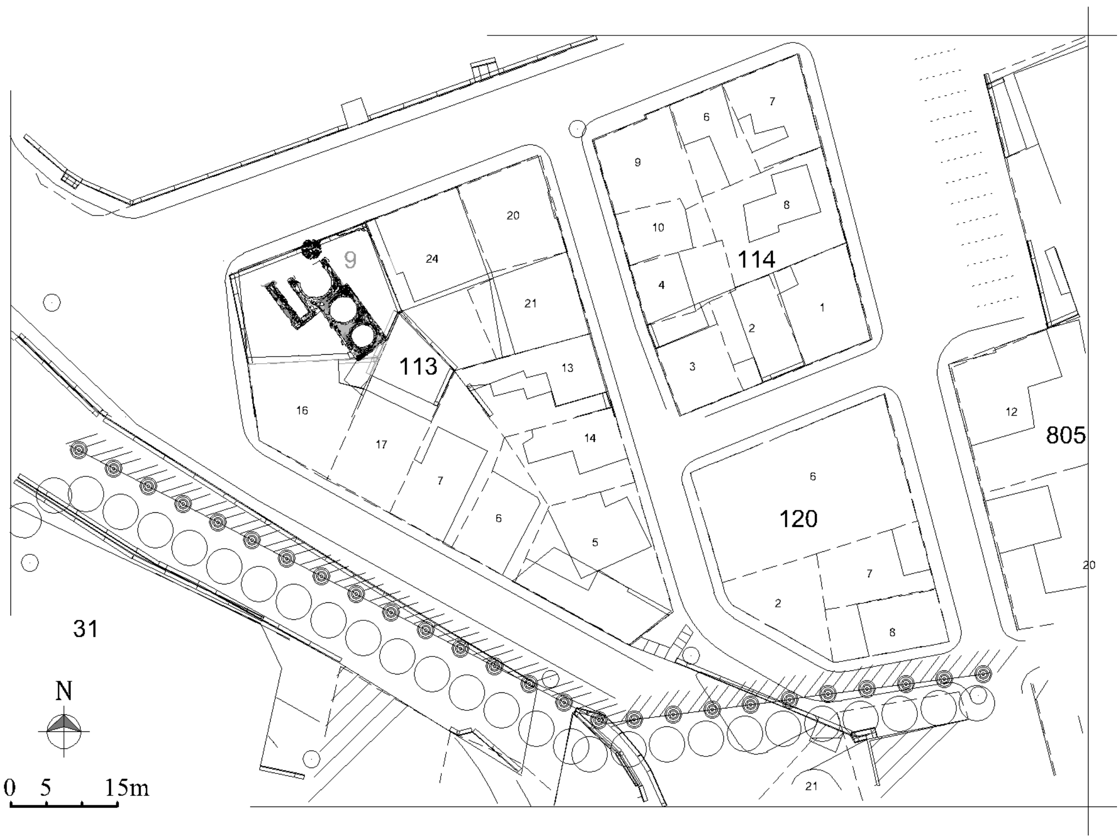

Figure A.1. Site plan of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

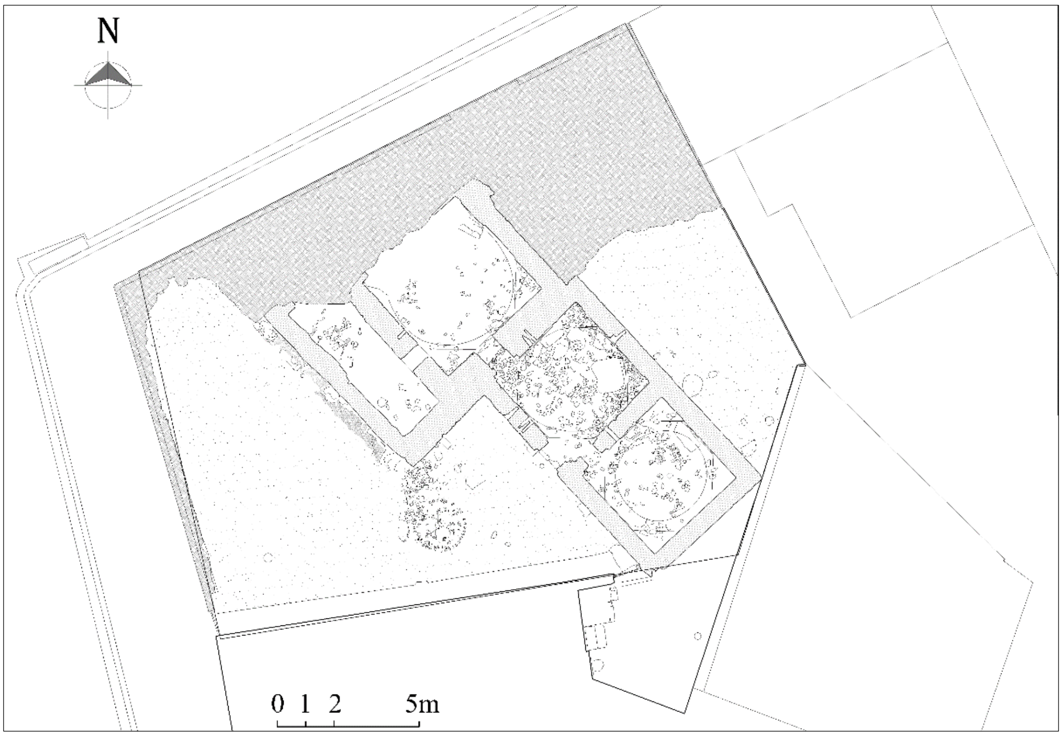

Figure A.2. Floor plan of the primary measured survey
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

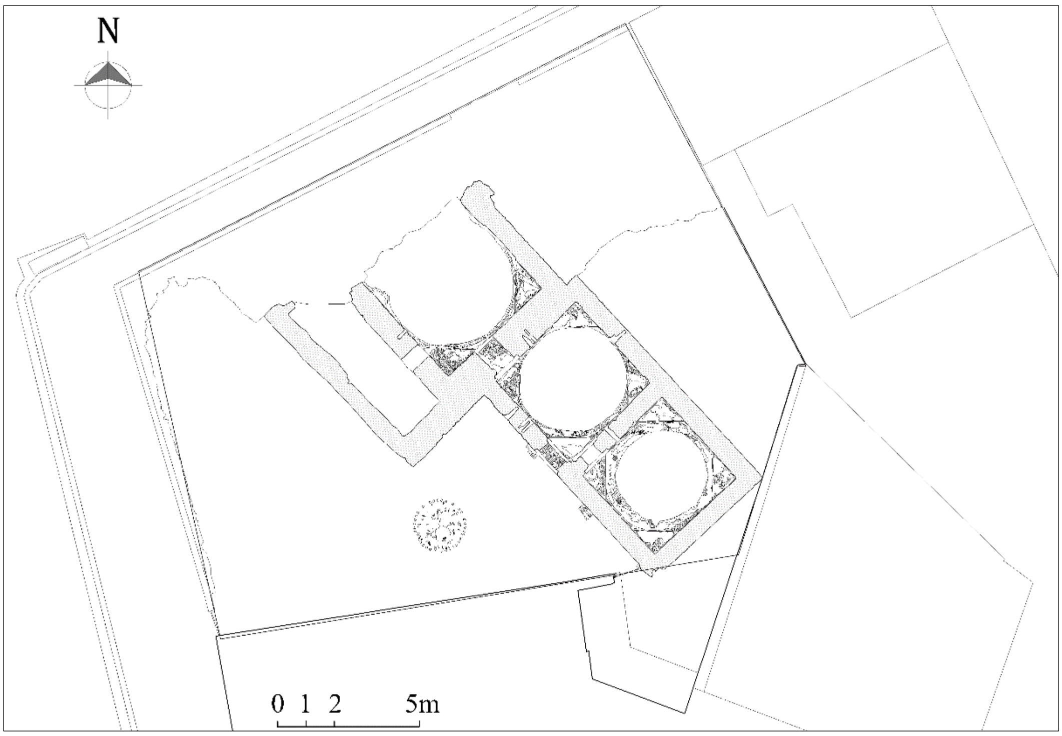

Figure A.3. Ceiling plan of the primary measured survey
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

Figure A.4. Roof plan of the primary measured survey
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

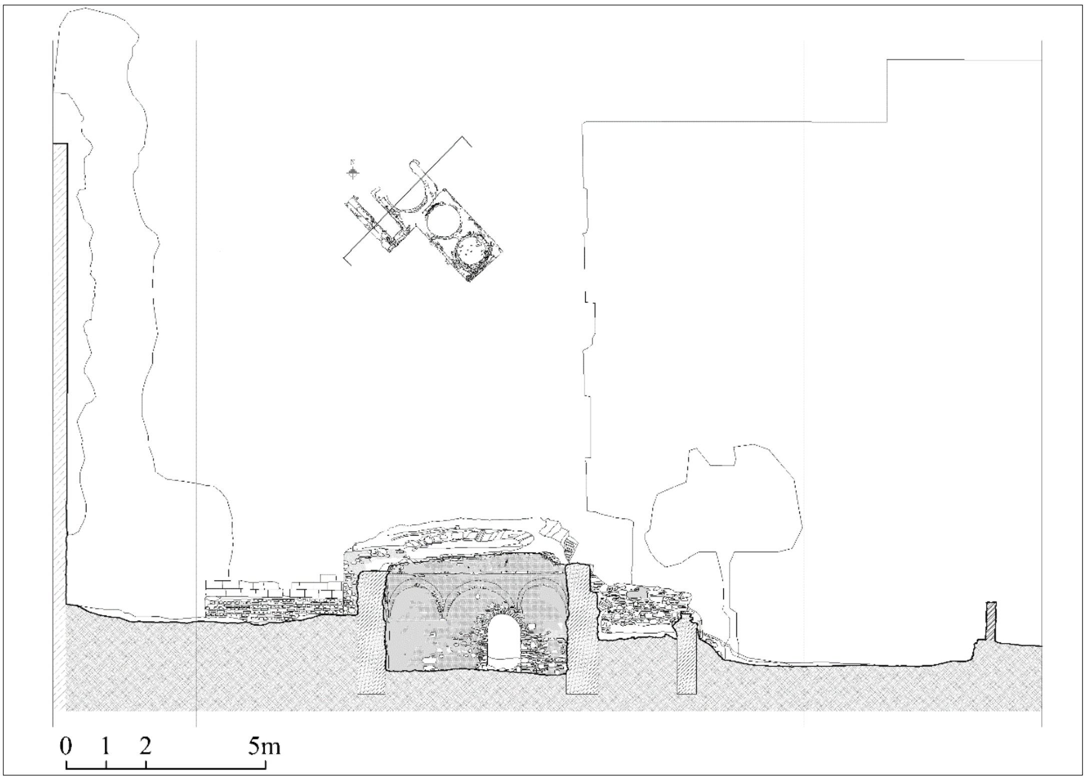

Figure A.5. Section-1 of the primary measured survey
(Drawn by: İpek Düzcan, 2017, ANKA Architecture and Restoration Office)

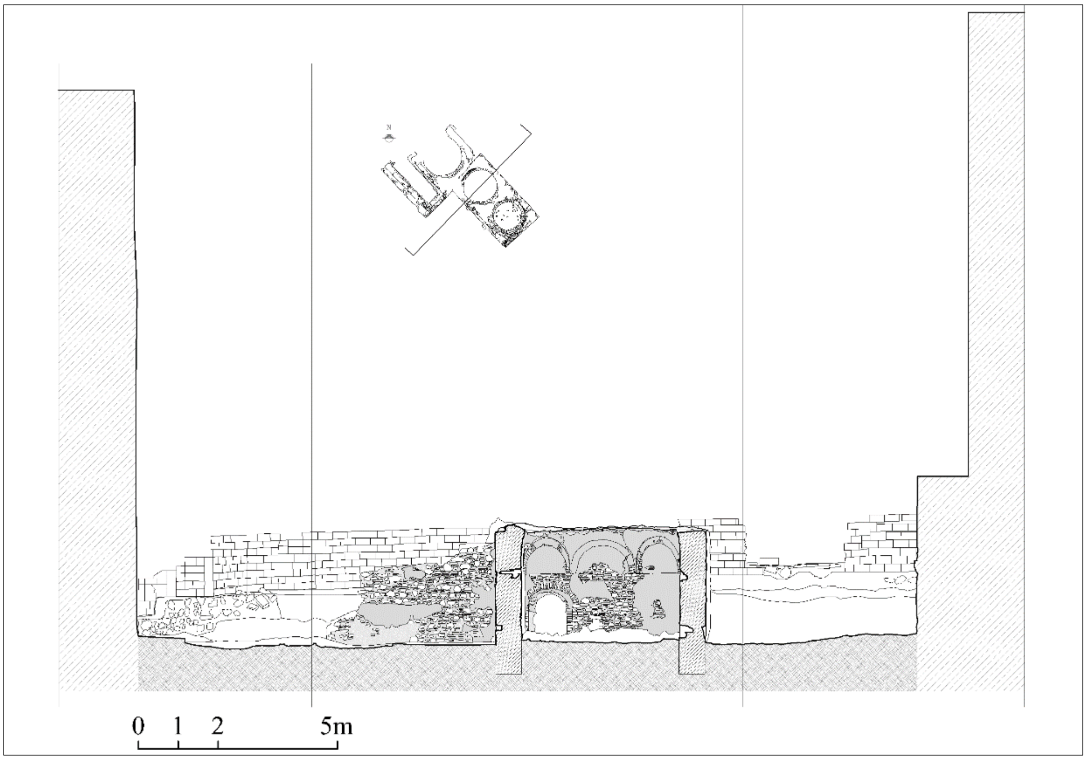

Figure A.6. Section-2 of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

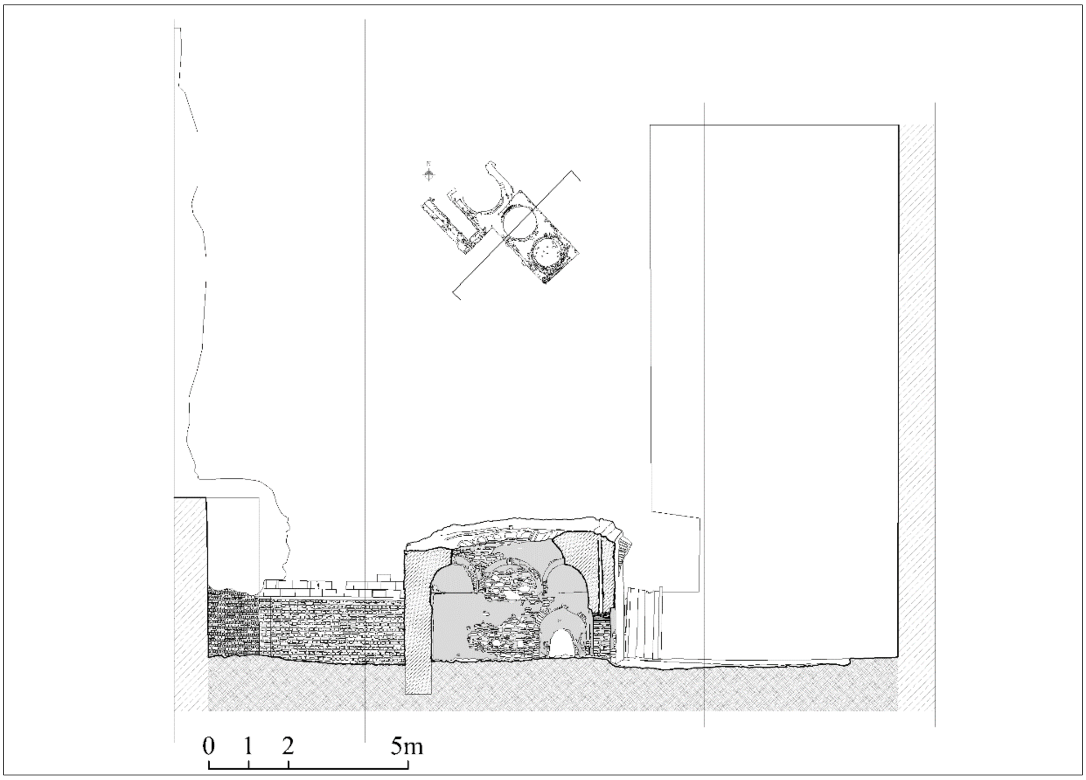

Figure A.7. Section-3 of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

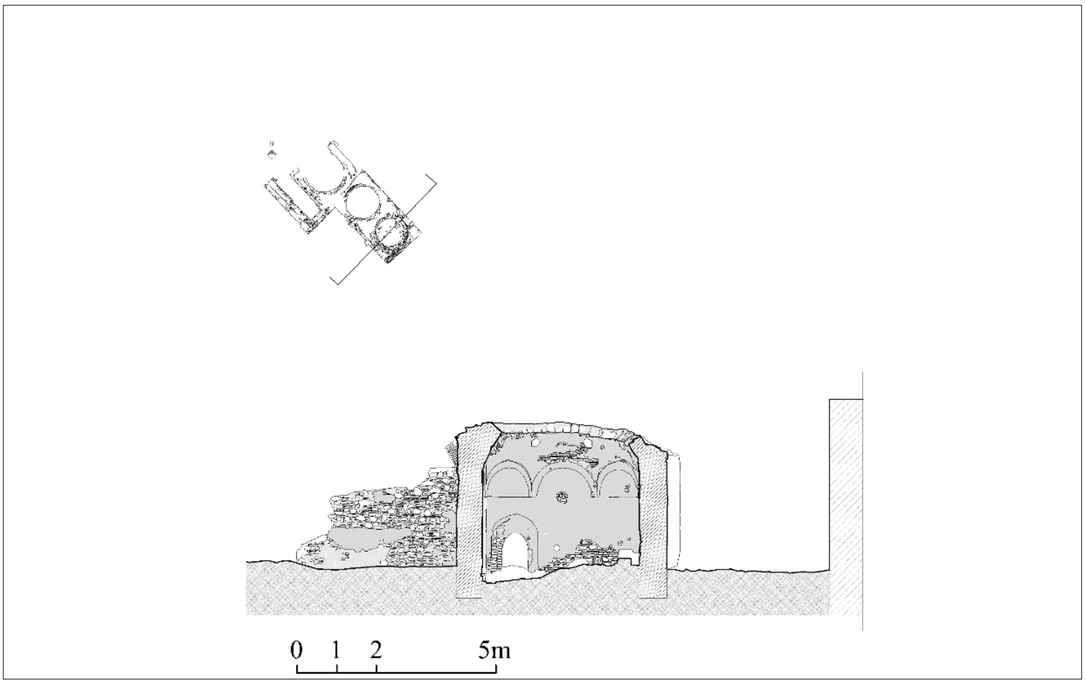

Figure A.8. Section-4 of the primary measured survey

(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

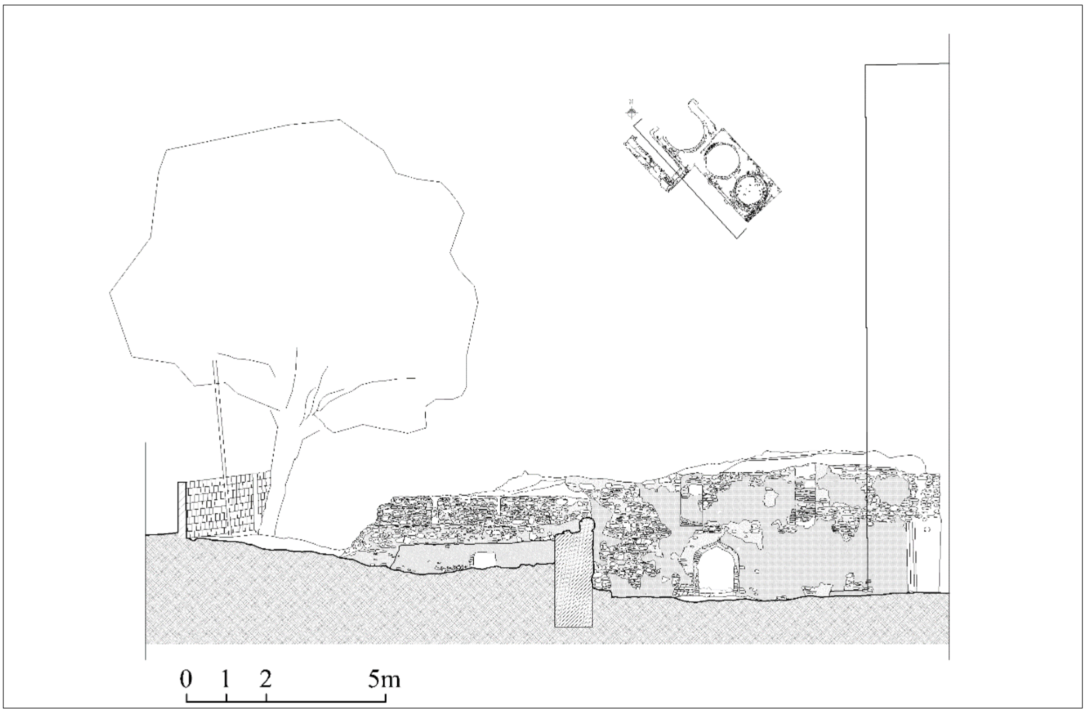

Figure A.9. Section-5 of the primary measured survey

(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

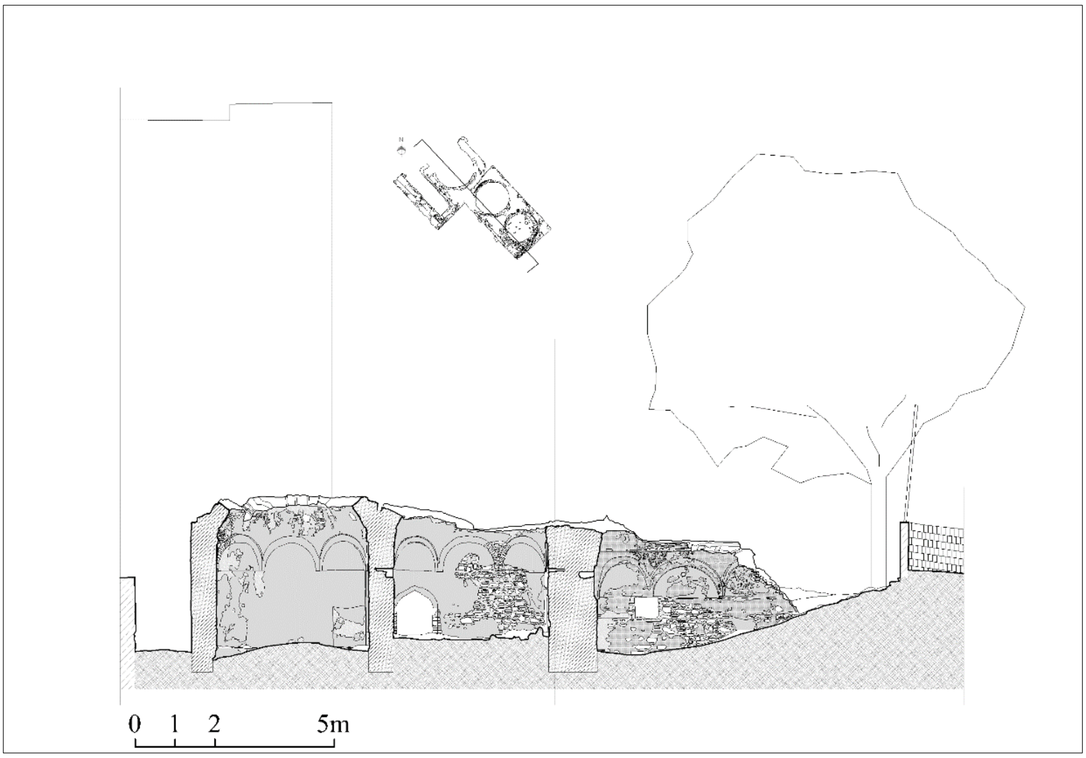

Figure A.10. Section-6 of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

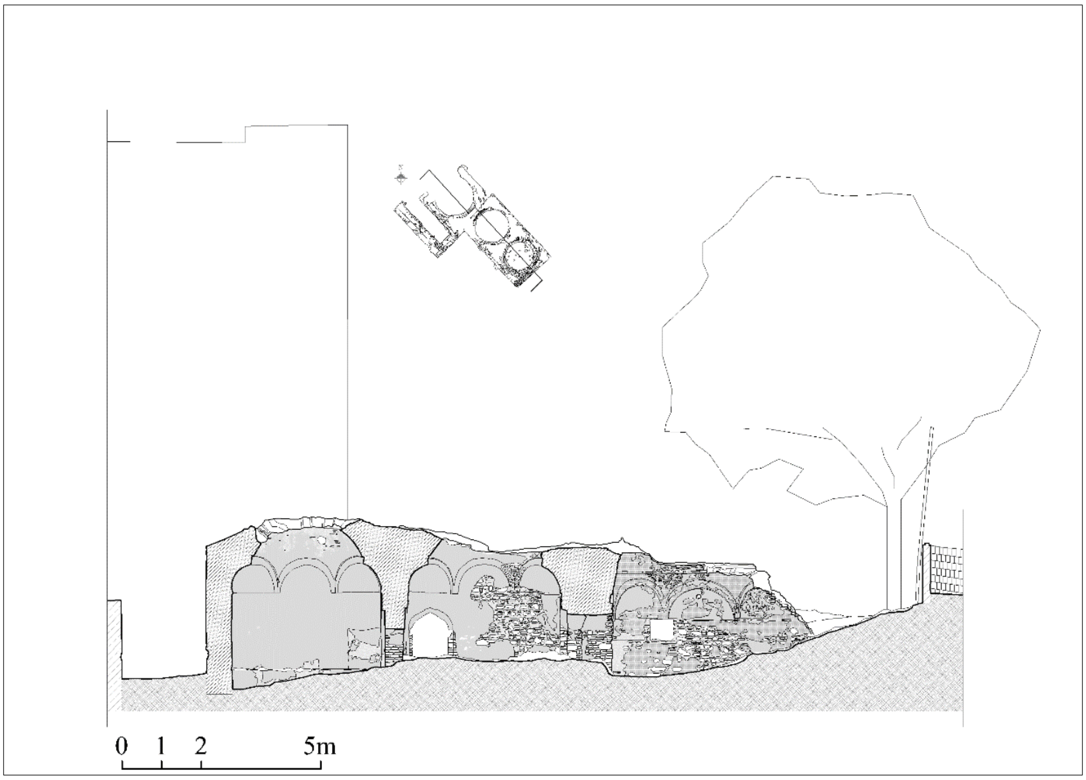

Figure A.11. Section-7 of the primary measured survey
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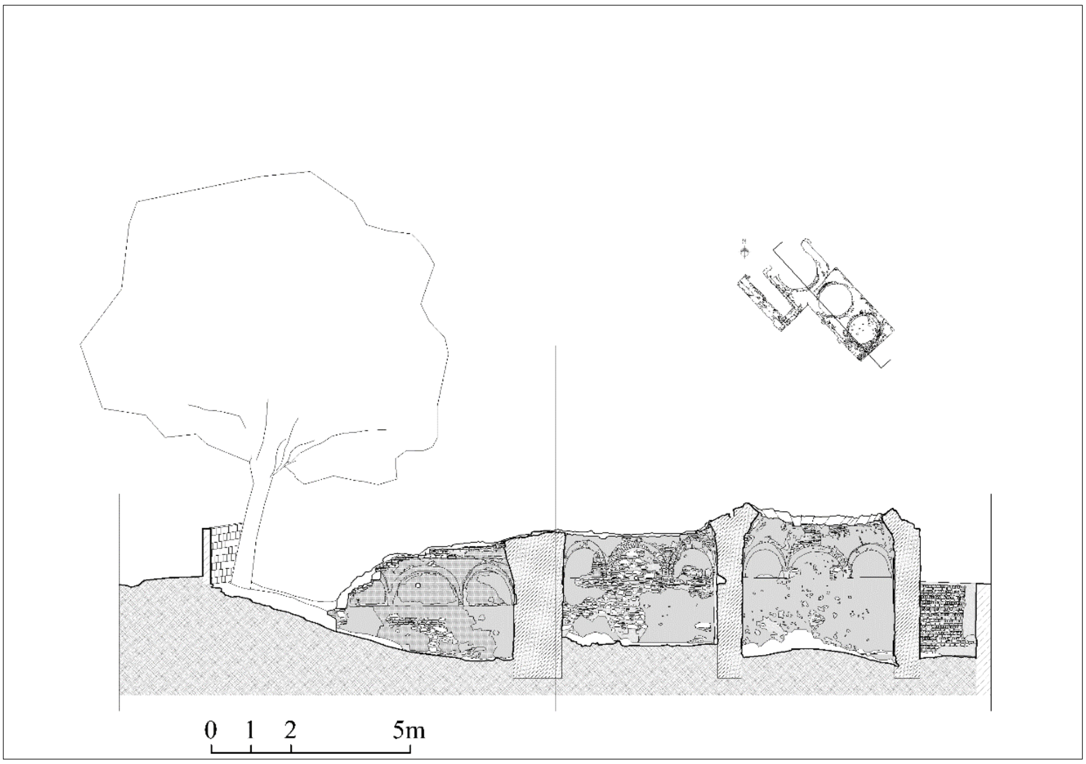

Figure A.12. Section-8 of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

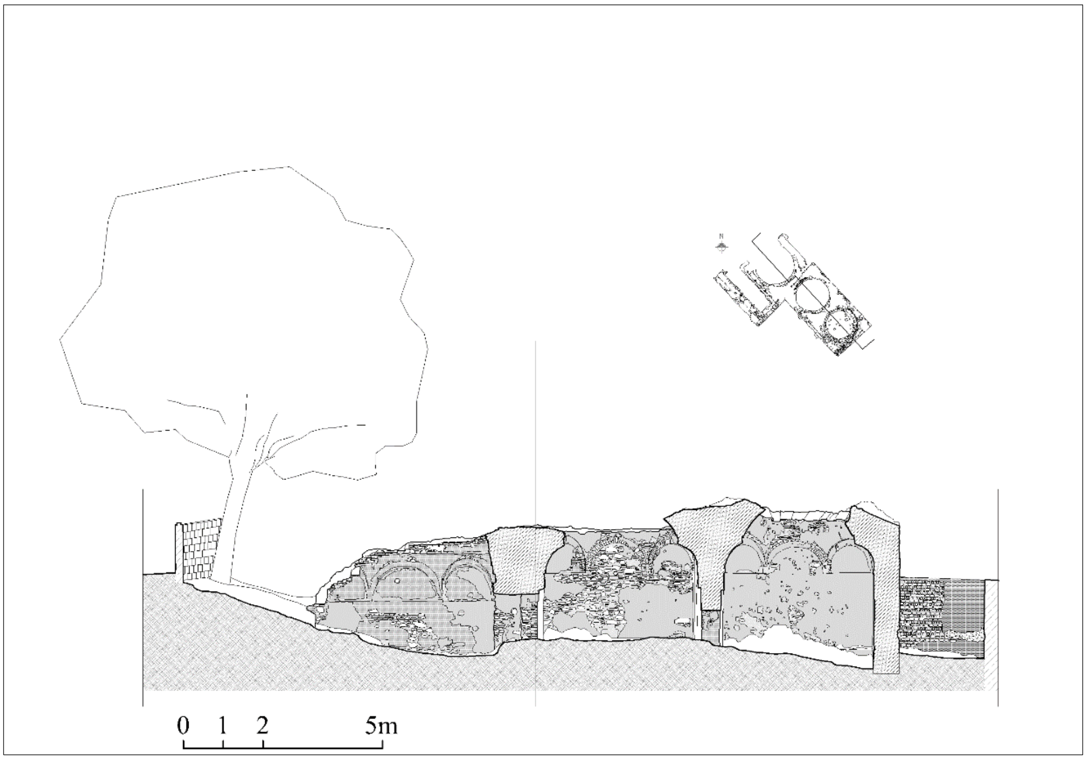

Figure A.13. Section-9 of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

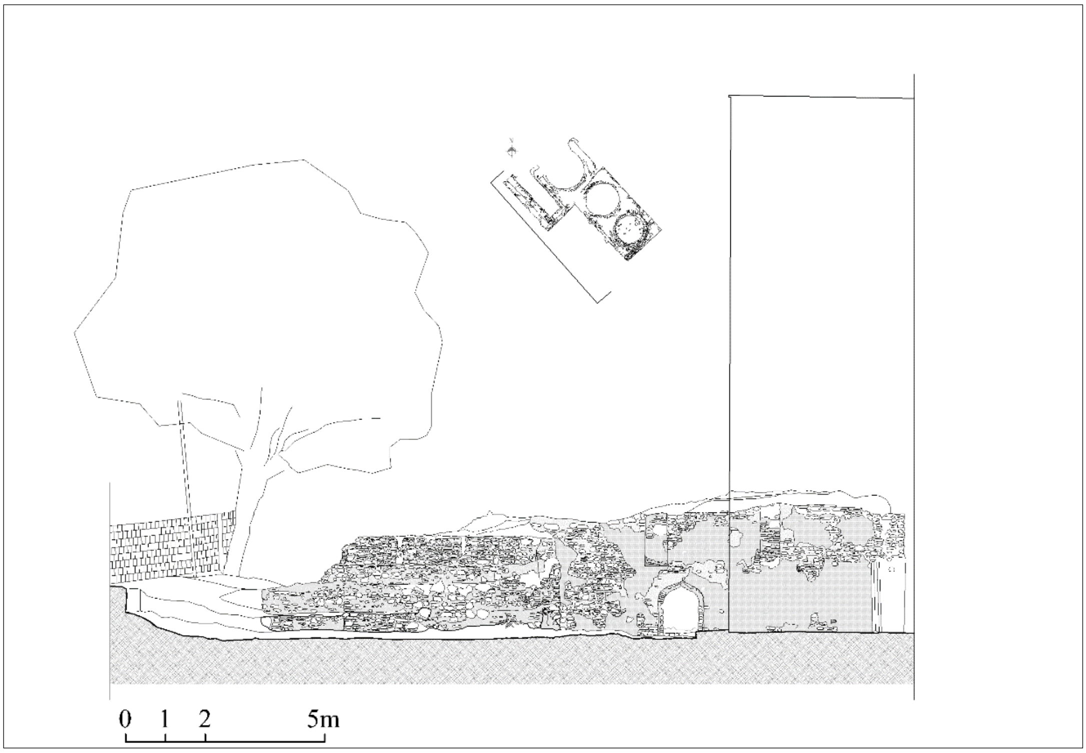

Figure A.14. Southwest elevation of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

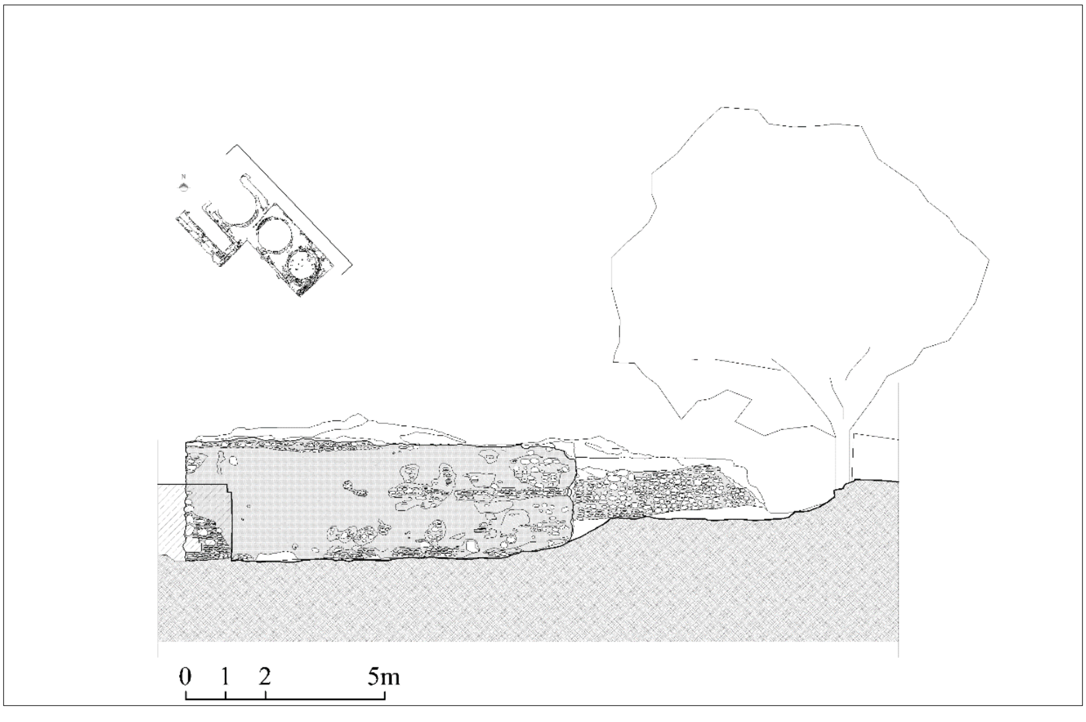

Figure A.15. Northeast elevation of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

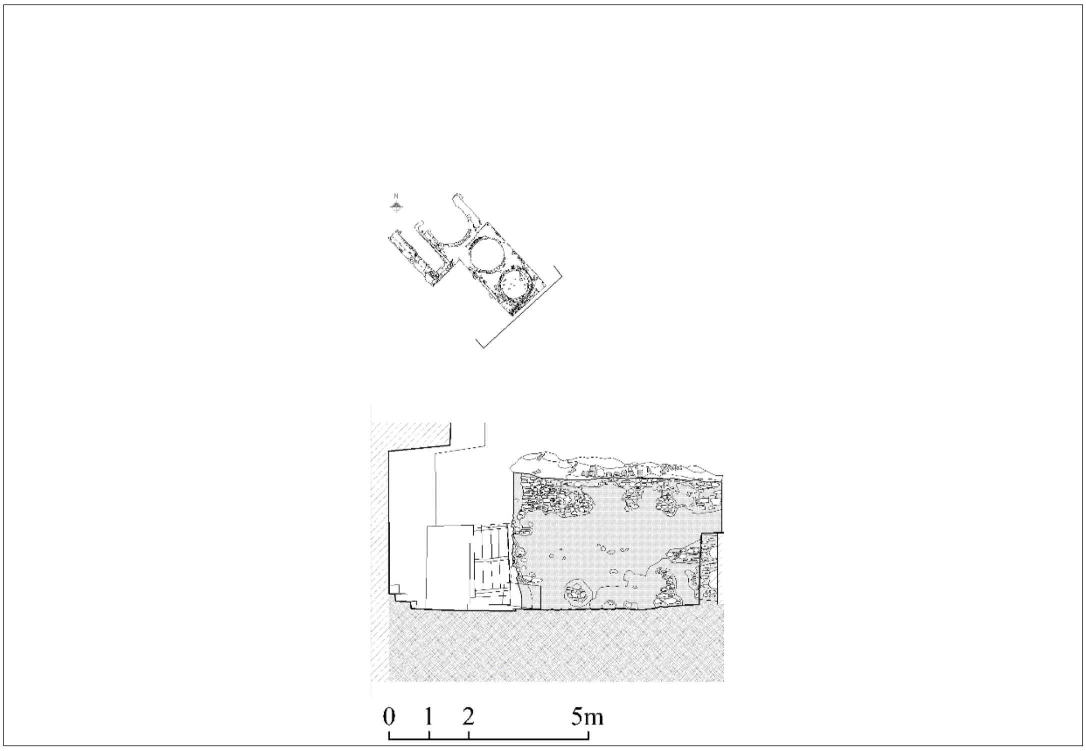

Figure A.16. Southeast elevation of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

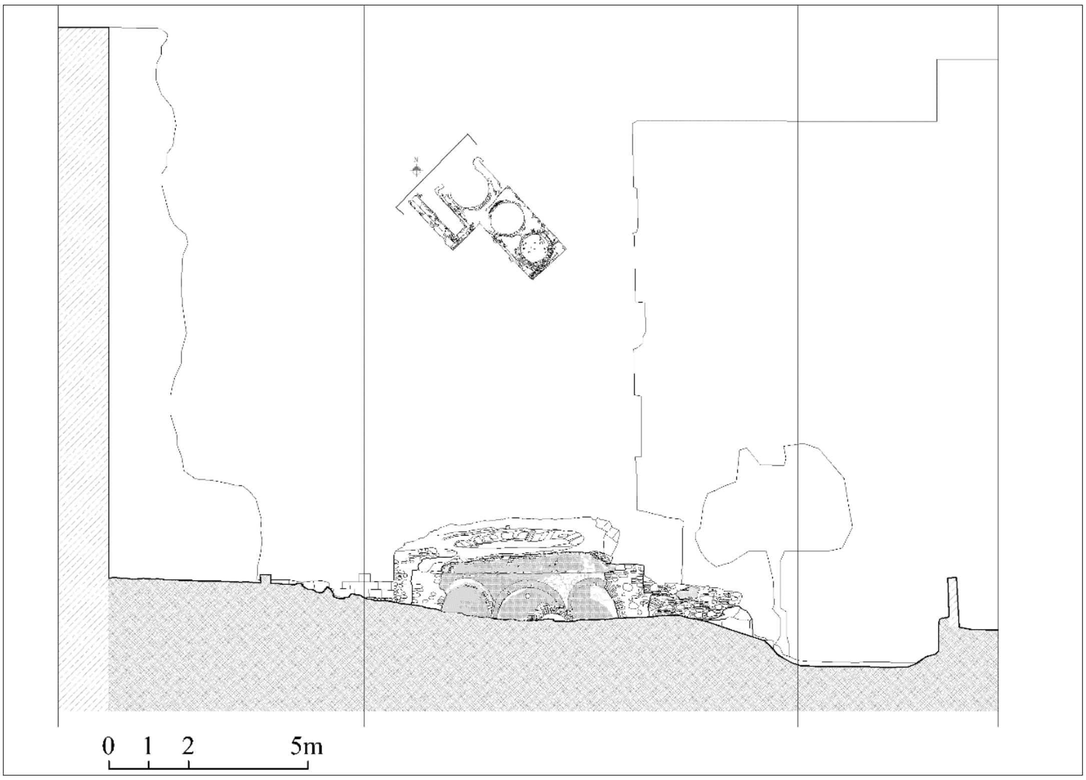

Figure A.17. Northwest elevation of the primary measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

A.2. The Second Measured Survey

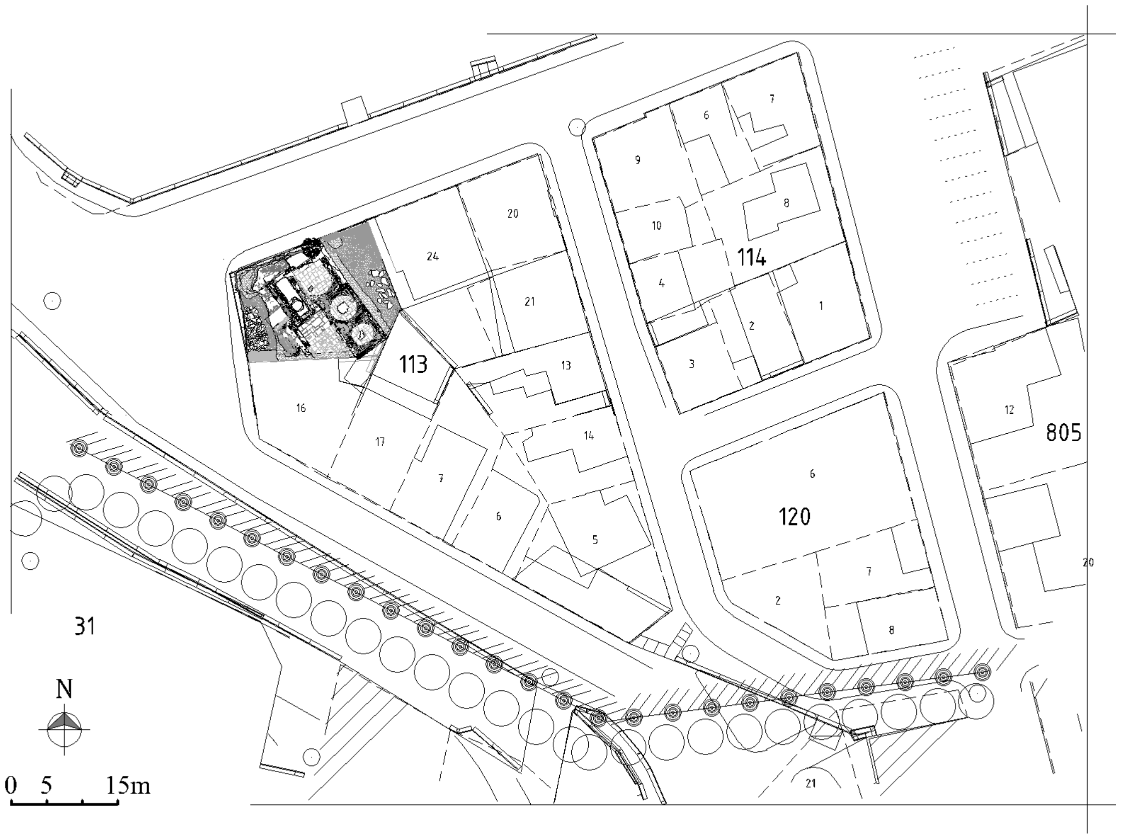

Figure A.18. Site plan of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

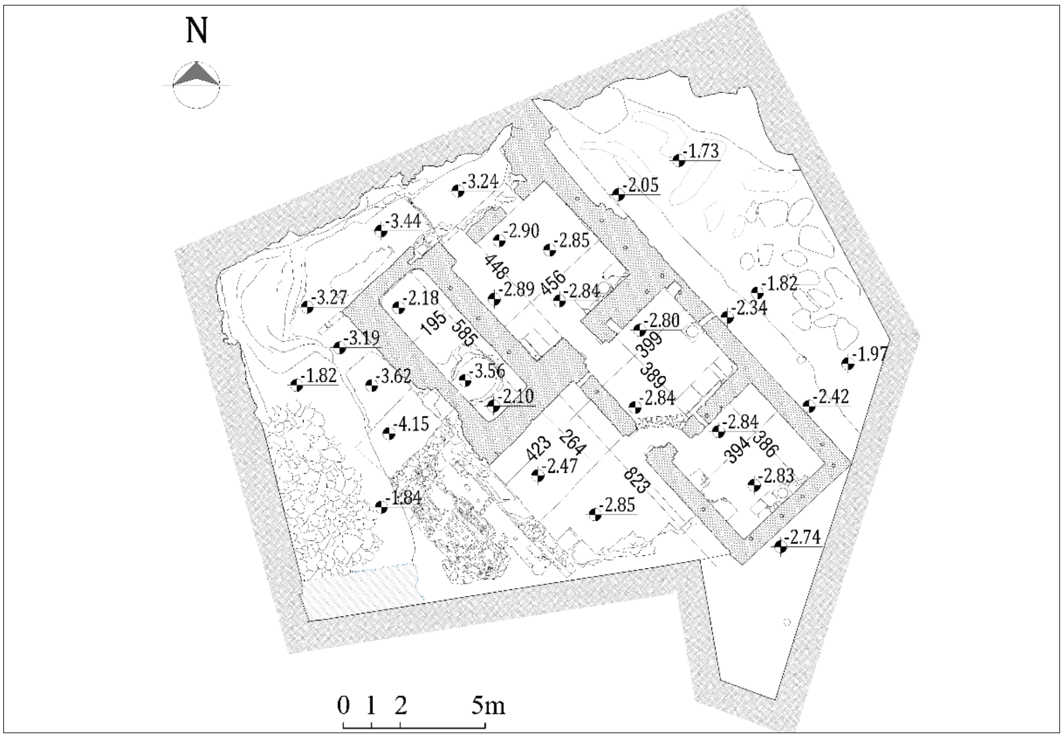

Figure A.19. Dimensioned plan of the bath
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

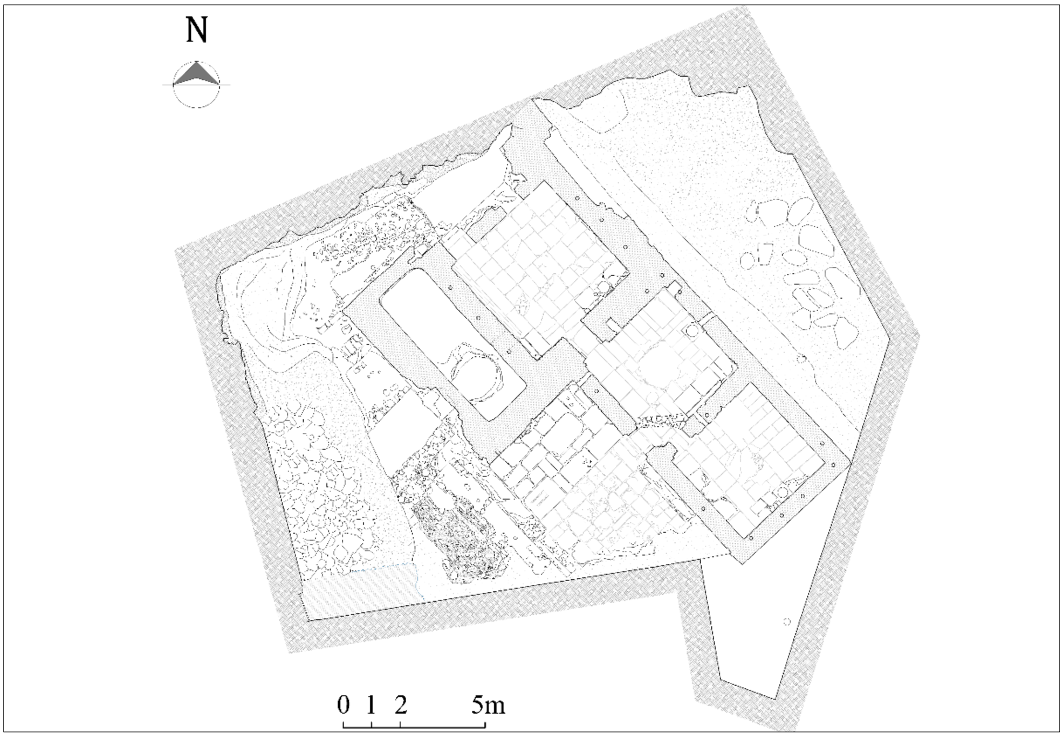

Figure A.20. Lower level floor plan of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

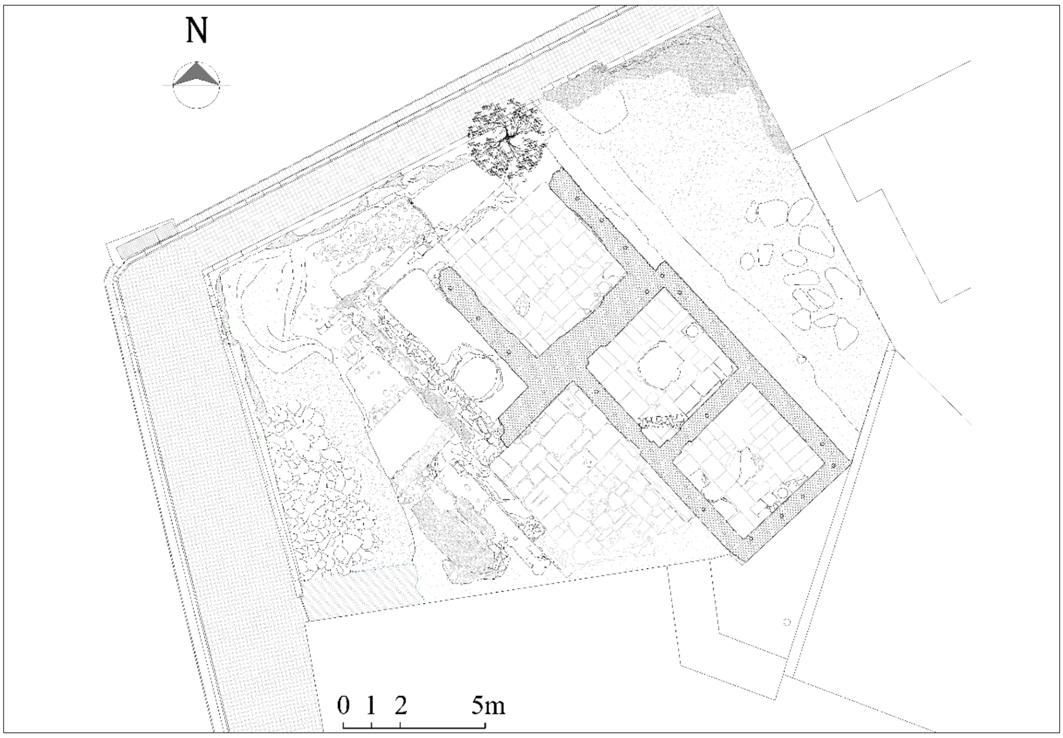

Figure A.21. Upper level floor plan of the second measured survey
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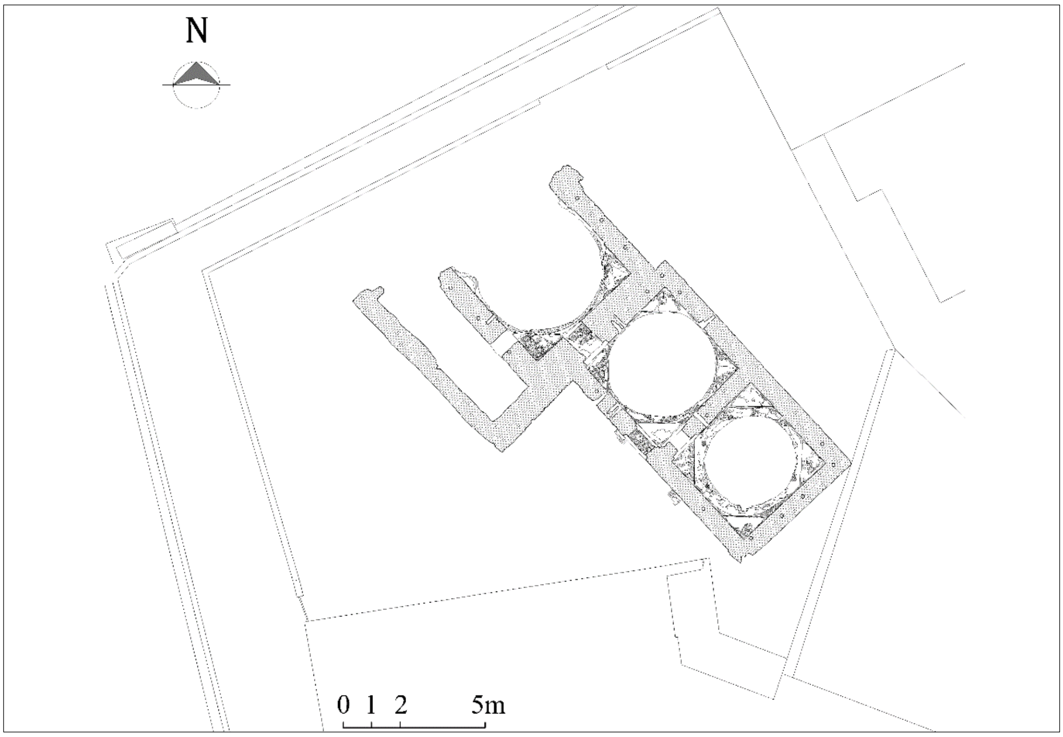

Figure A.22. Ceiling Plan of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

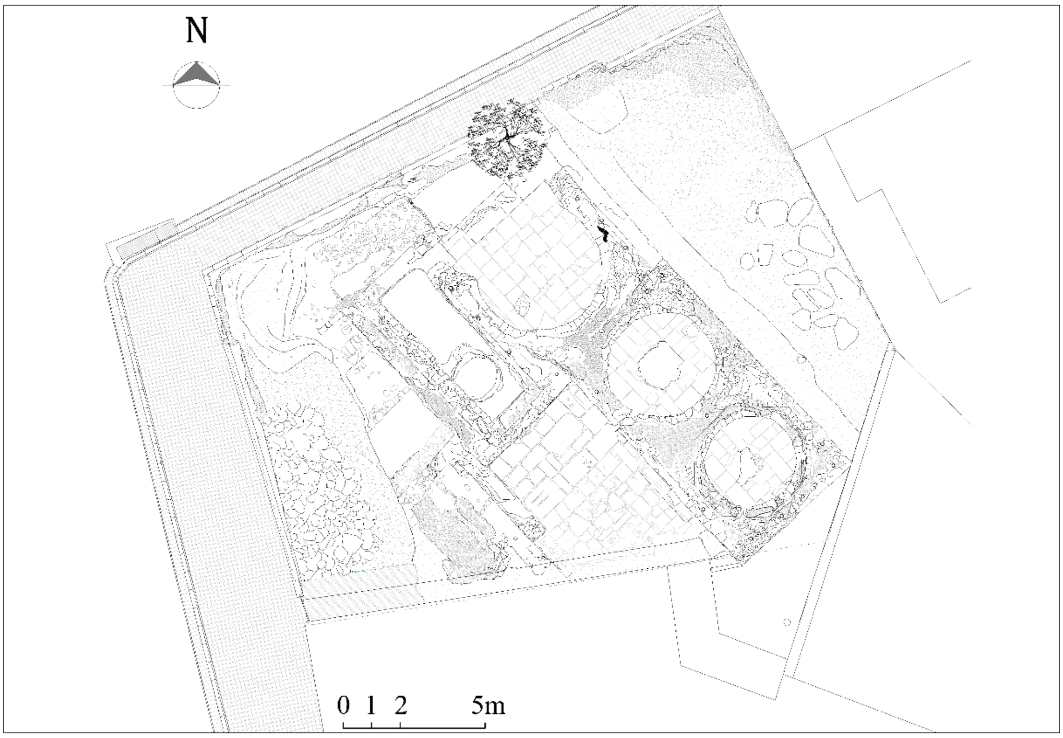

Figure A.23. Roof plan of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

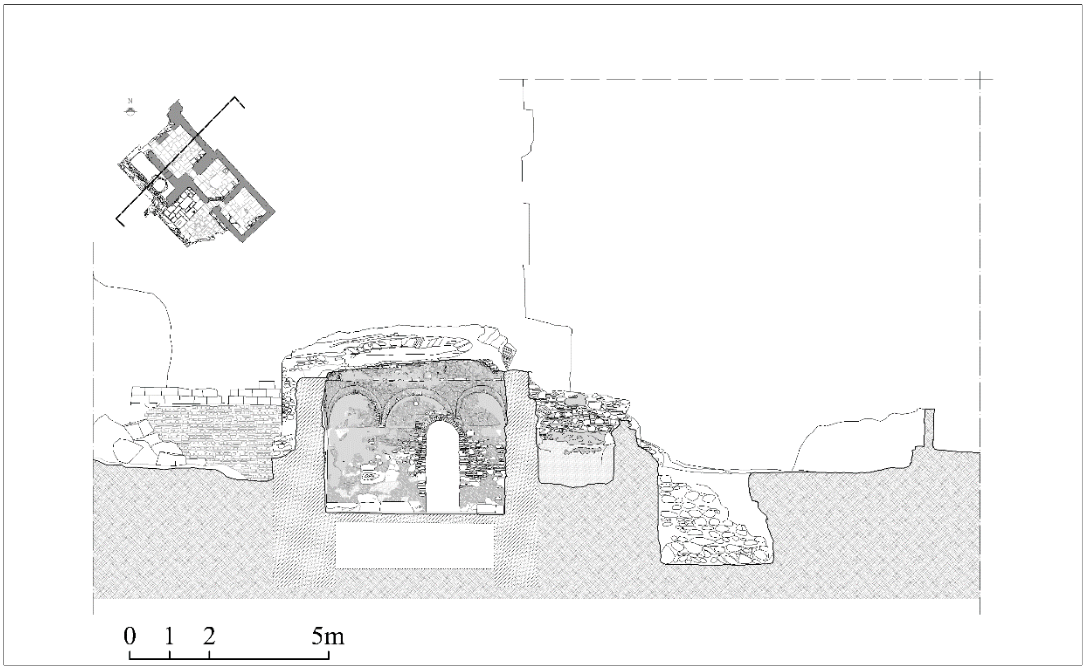

Figure A.24. Section-1 of the second measured survey (Drawn by: İpek Düzcan and Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

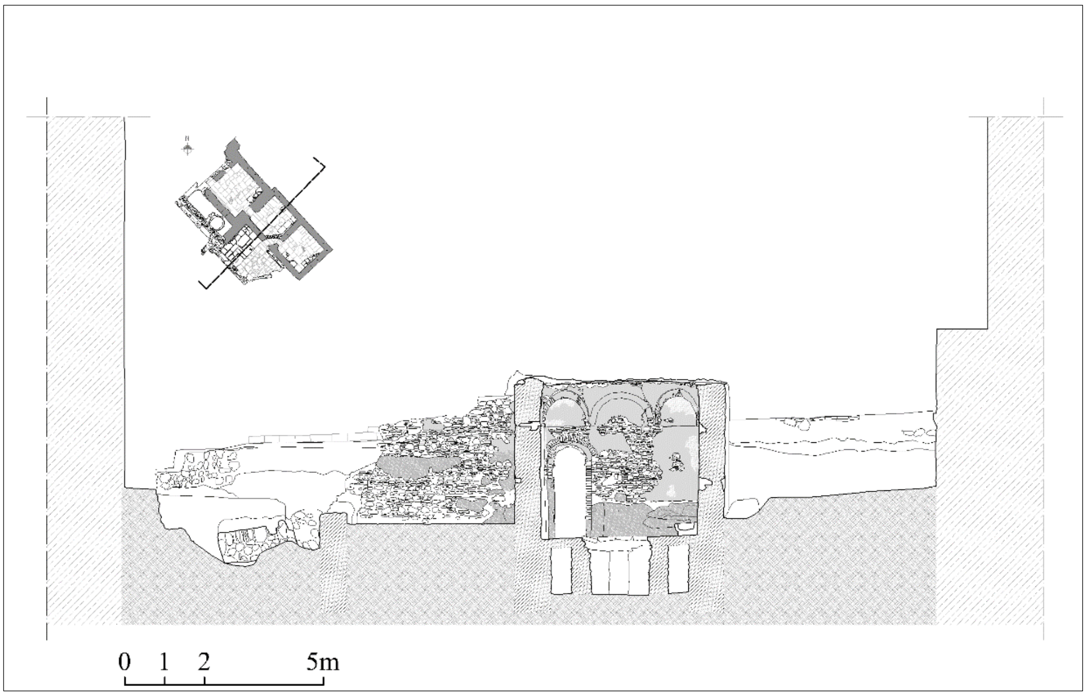

Figure A.25. Section-2 of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

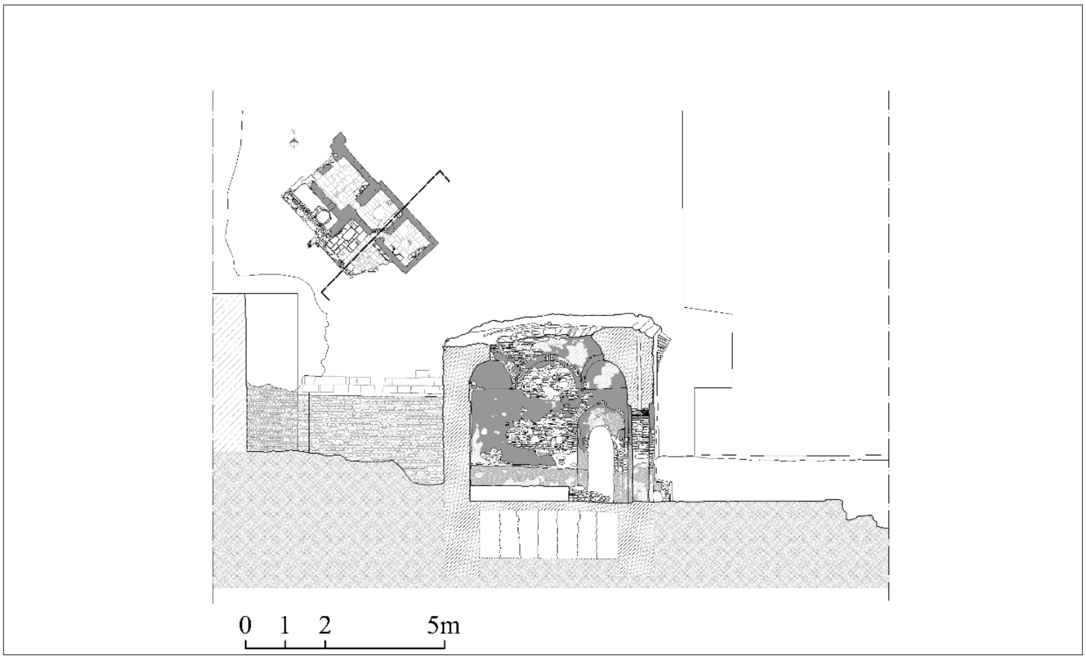

Figure A.26. Section-3 of the second measured survey (Drawn by: Batuhan Zümrüt and Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

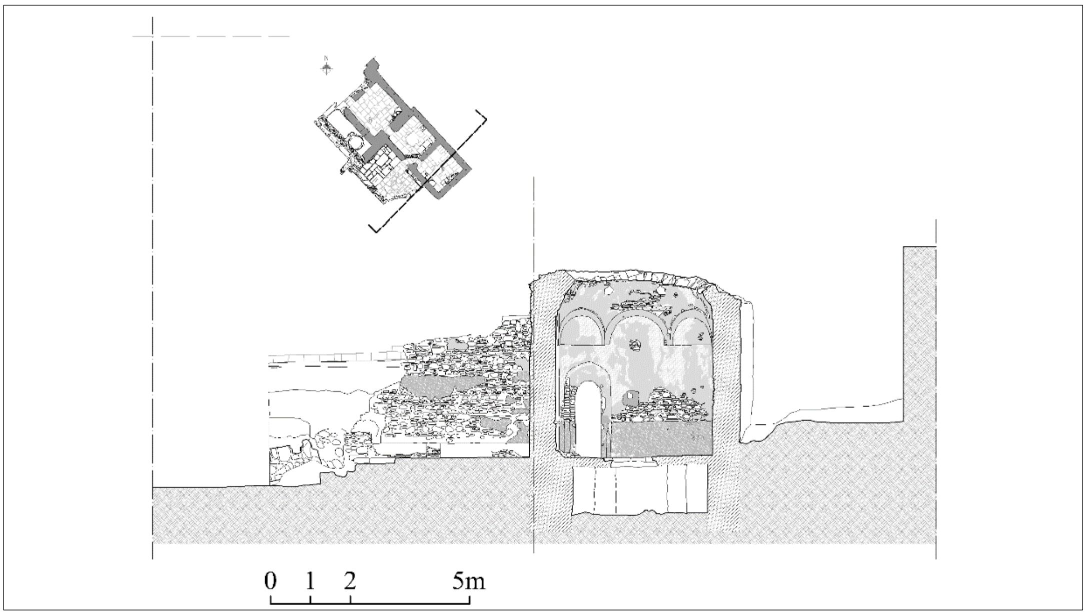

Figure A.27. Section-4 of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

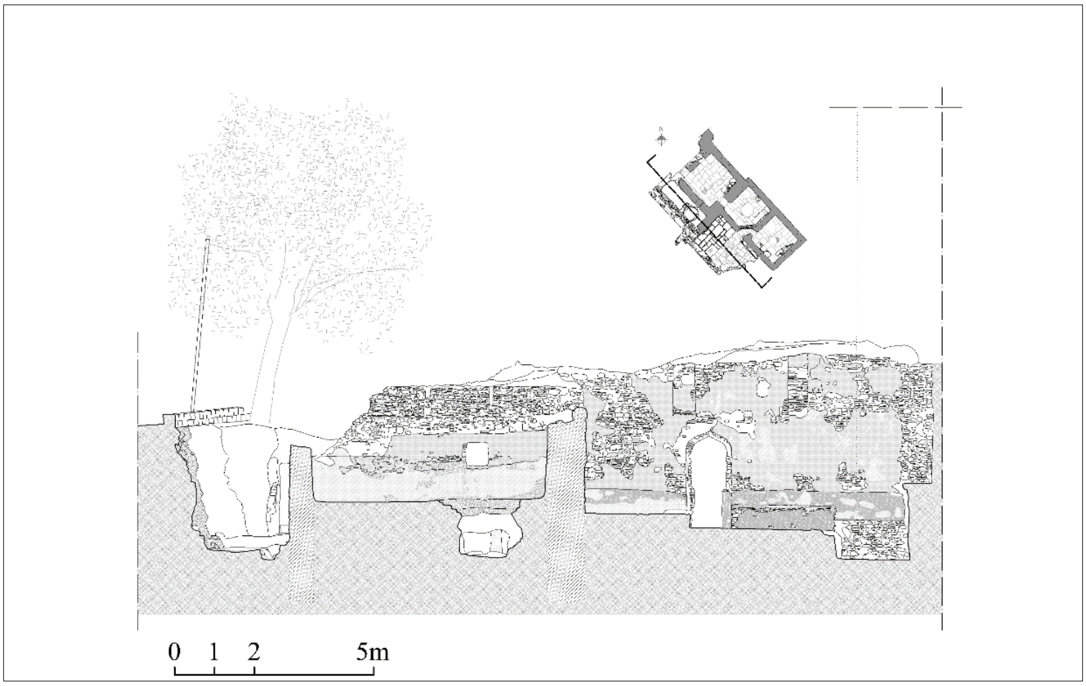

Figure A.28. Section-5 of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

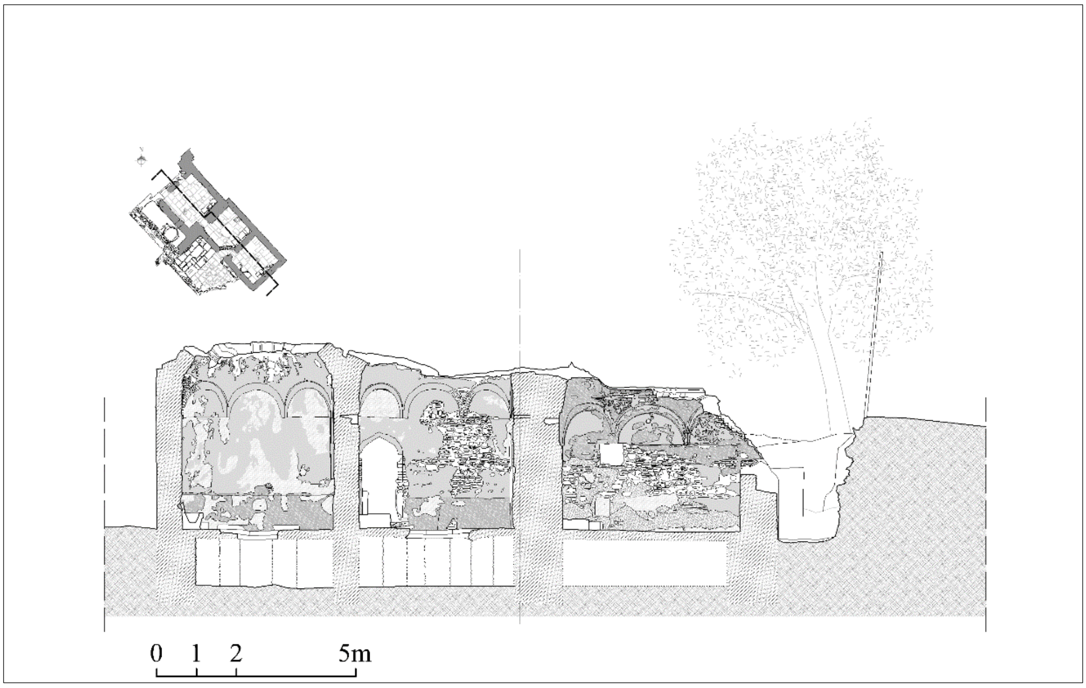

Figure A.29. Section-6 of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

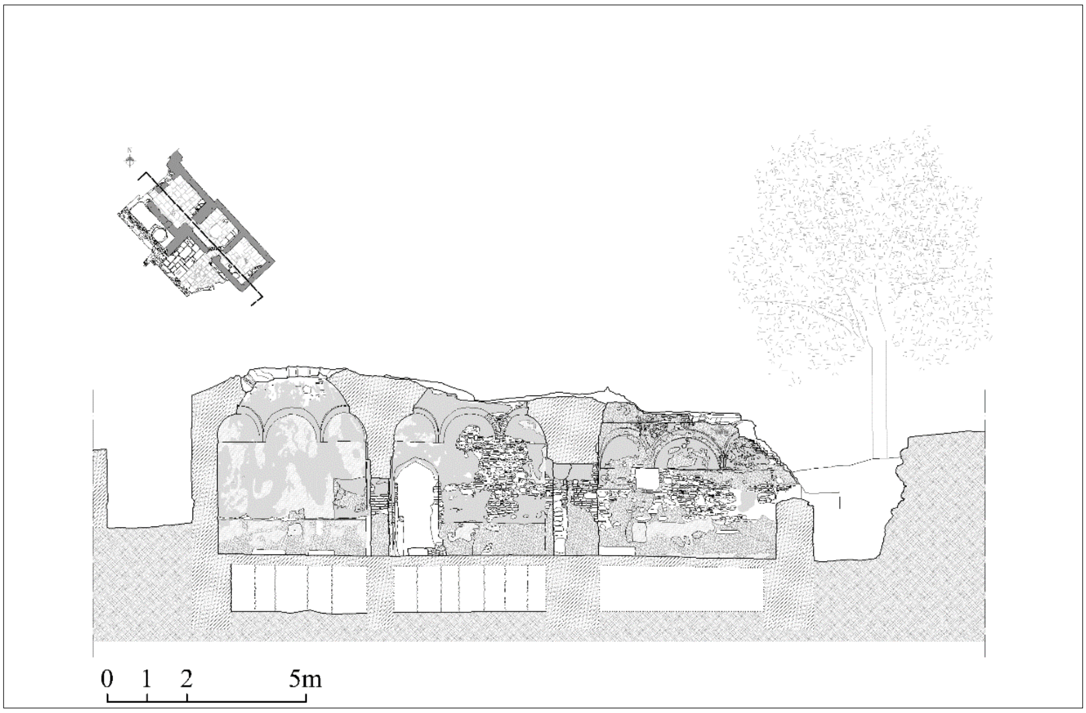

Figure A.30. Section-7 of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

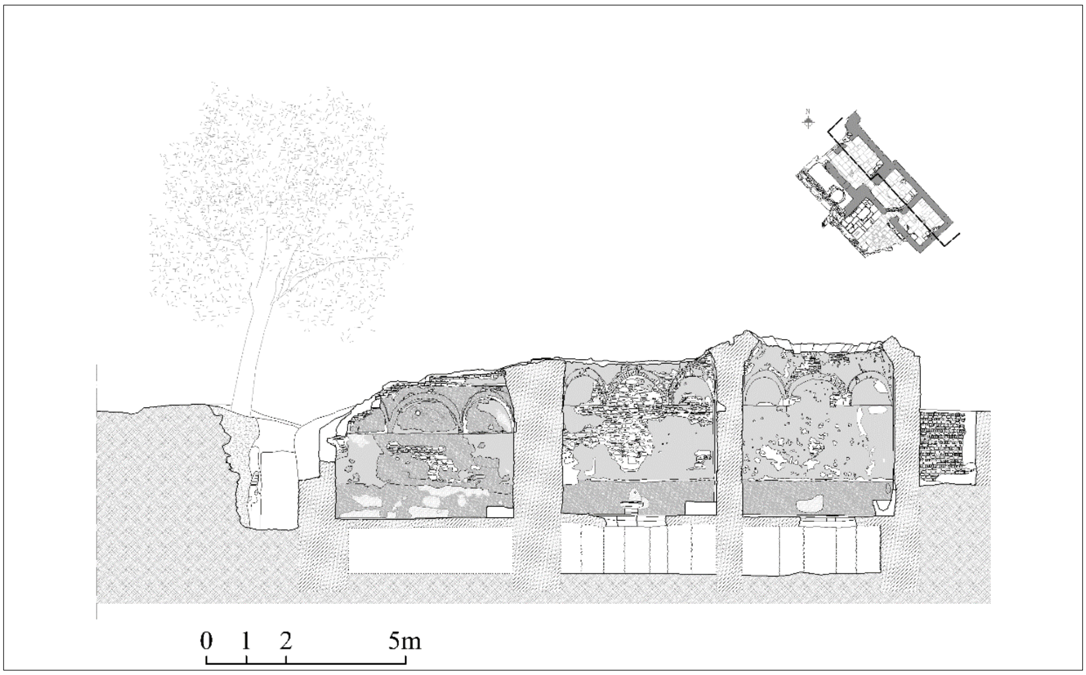

Figure A.31. Section-8 of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

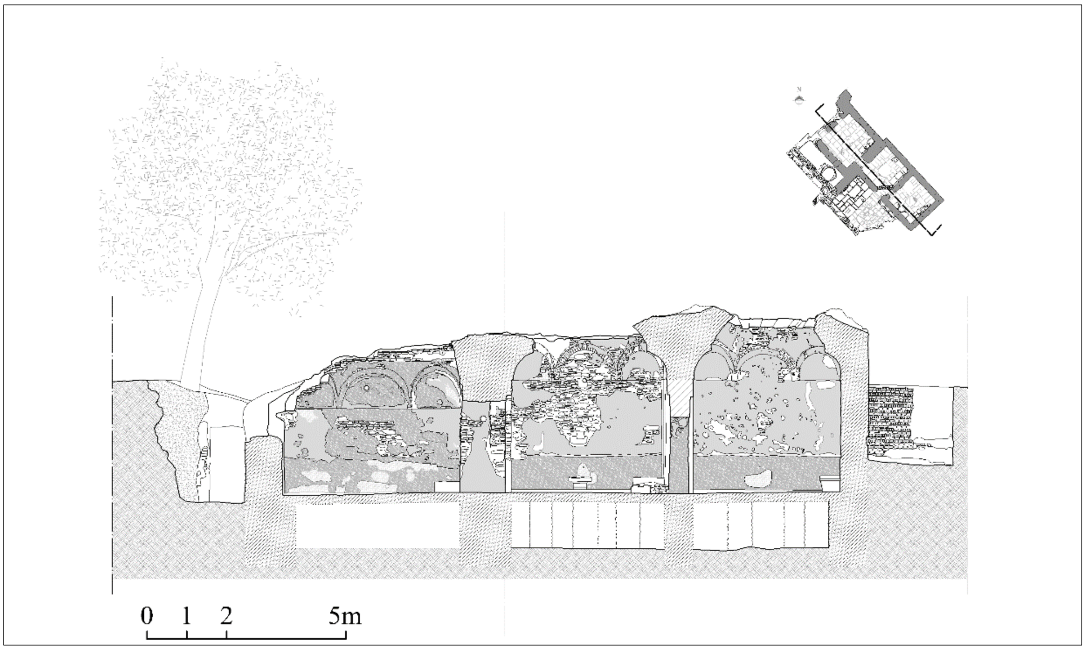

Figure A.32. Section-9 of the second measured survey
(Drawn by: Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

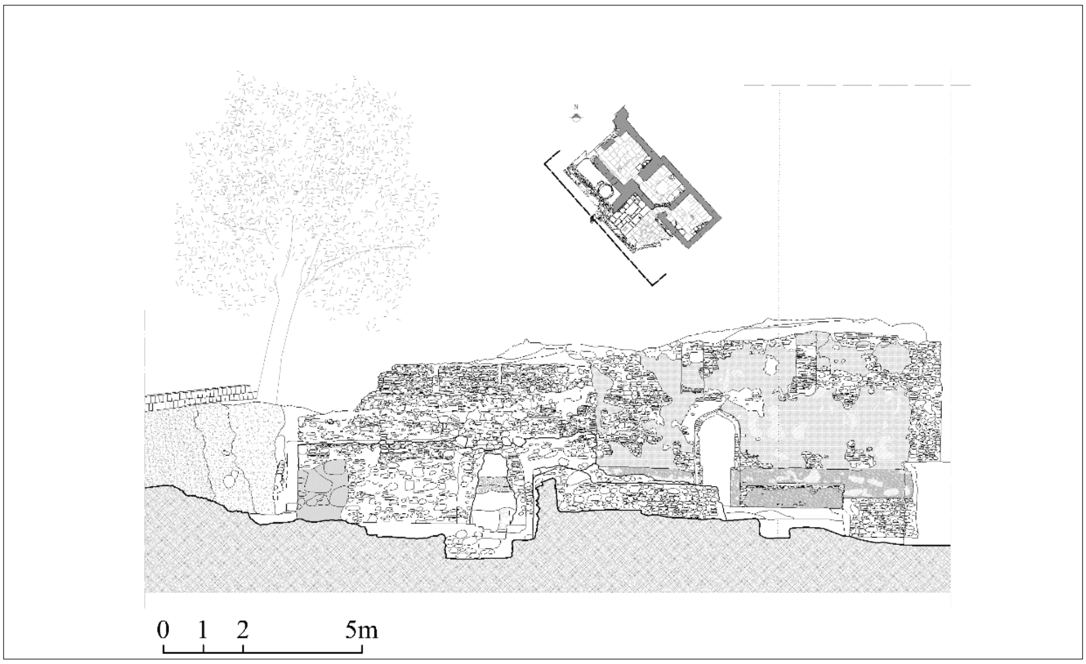

Figure A.33. Southwest elevation of the second measured survey (Drawn by: Batuhan Zümrüt and Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

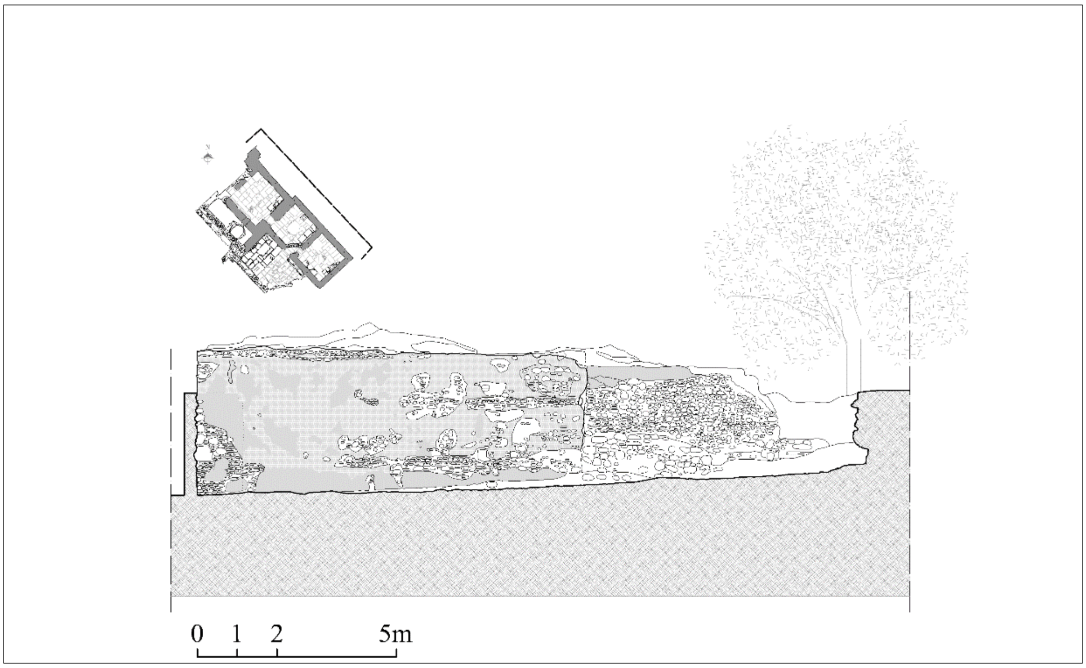

Figure A.34. Northeast elevation of the second measured survey (Drawn by: Batuhan Zümrüt and Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

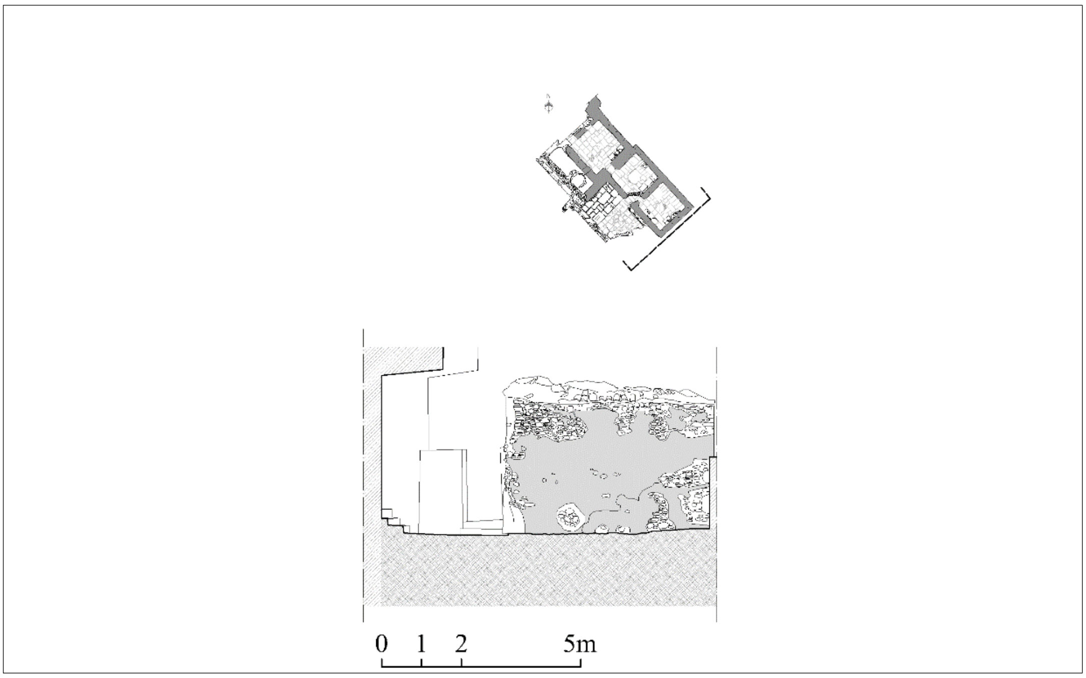

Figure A.35. Southeast elevation of the second measured survey (Drawn by: İpek Düzcan and Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

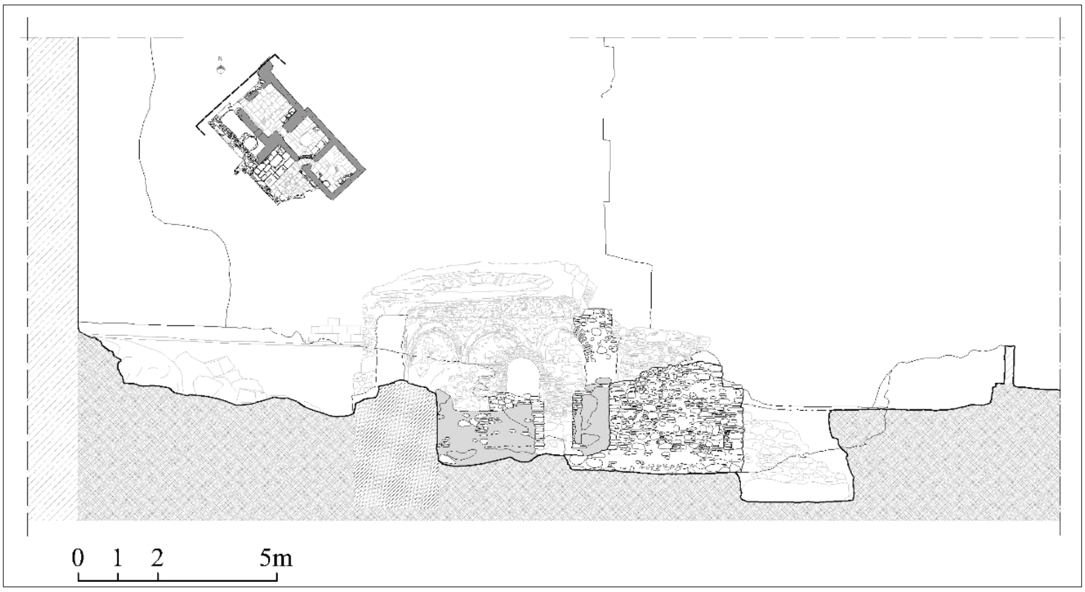

Figure A.36. Northwest elevation of the second measured survey (Drawn by: Batuhan Zümrüt and Fatma Gürhan, 2017, ANKA Architecture and Restoration Office)

A.3. G01 *Soyunmalık-Ilıklık*

Figure A.37. The arch remains
(Source: Fatma Gürhan, October 2016)

(a) (b)

Figure A.38. The left arch remain (a) and the right arch remain (b)
(Source: ANKA Architecture and Restoration Office archive, October 2016)

Figure A.39. The southern corner of the *soyunmalık-ılıklık* space
(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.40. The floor covering of the *soyunmalık-ılıklık* space
(Source: ANKA Architecture and Restoration Office archive, December 2016)

Figure A.41. Transition from the *soyunmalık-ılıklık* to the *sıcaklık* space
(Source: ANKA Architecture and Restoration Office archive, November 2016)

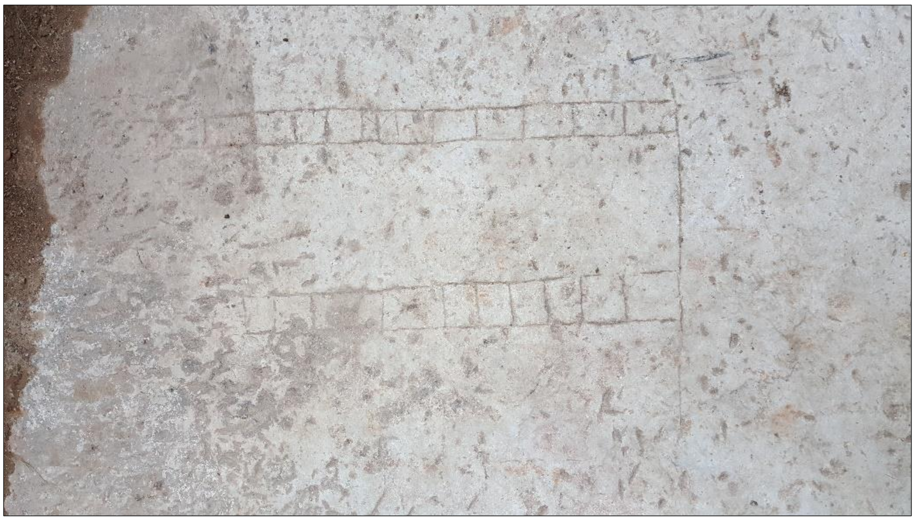

Figure A.42. The depiction of the checkers game on the one of the *seki* stone
(Source: Fatma Gürhan, December 2016)

Figure A.43. The wall of the hot water reservoir & *soyunmalık-ılıklık*
(Source: Fatma Gürhan, December 2016)

(a) (b)

Figure A.44. The left (a) and the right (b) junction line of the *seki* on the *soyunmalık-ılıklık & sıcaklık* wall (Source: Fatma Gürhan, December 2016)

A.4. G02 *Sıcaklık*

Figure A.45. *Kurna* and *seki*
(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.46. *Kurna*
(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.47. Traces of the *kurna* and *seki*
(Source: ANKA Architecture and Restoration Office archive, February 2017)

Figure A.48. Traces of the *kurna* and *seki*
(Source: ANKA Architecture and Restoration Office archive, February 2017)

(a) (b)

Figure A.49. External (a) and internal (b) view of the entrance of G02 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.50. The squinches and the pentagonal oculises
(Source: Fatma Gürhan, July 2016)

(a) (b)

Figure A.51. The pentagonal oculises (a, b)

(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.52. The plaster motifs at the squinch finishes

(Source: ANKA Architecture and Restoration Office archive, November 2016)

(a) (b)

Figure A.53. The left (a) and the right (b) plaster motifs with curved tips

(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.54. The floor covering of the G02 *Sıcaklık* space

(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.55. *Cehennemlik*

(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.56. The dome remain of G02 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, July 2016)

Figure A.57. The dome remain of G02 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, July 2016)

Figure A.58. The dome remain of G02 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, July 2016)

Figure A.59. The dome ruins and horasan plaster layer with crushed bricks (Source: Fatma Gürhan, December 2016)

Figure A.60. The dome ruins and horasan plaster layer with crushed bricks (Source: Fatma Gürhan, December 2016)

A.5. G03 *Sıcaklık*

Figure A.61.*Kurna*, *kurna* remains and *seki* used as a navel stone
(Source: Fatma Gürhan, July 2016)

Figure A.62. *Cehennemlik* piers and the floor section
(Source: Fatma Gürhan, July 2016)

Figure A.63. Transition in the left to G02 *Sıcaklık* space and the entrance in the right from the G01 *Soyunmalık-Ilıklık* space (Source: ANKA Architecture and Restoration Office archive, February 2017)

Figure A.64. The waste water channel formed with bricks between G02 *Sıcaklık* and G03 *Sıcaklık* (Source: Fatma Gürhan, November 2016)

Figure A.65. Transition from G03 *Sıcaklık* to G04 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.66. The junction line between G03 *Sıcaklık* and G04 *Sıcaklık* and the interrupted terracotta pipes (Source: Mükerrem Kürüm archive, May 2017)

Figure A.67. The dome remain of the G03 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, July 2016)

Figure A.68. The dome remain of the G03 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, July 2016)

A.6. G04 *Sıcaklık*

Figure A.69. *Kurna* remain and *seki*
(Source: Mükerrem Kürüm archive, May 2017)

Figure A.70. *Kurna* remains and *seki*s
(Source: ANKA Architecture and Restoration Office archive, October 2016)

Figure A.71. The interior plasters of the G04 *Sıcaklık*
(Source: Fatma Gürhan, December 2016)

Figure A.72. The interior plasters of the G04 *Sıcaklık*
(Source: Fatma Gürhan, December 2016)

Figure A.73. The sailboat depiction
(Source: Mükerrem Kürüm archive, May 2017)

Figure A.74. The control window at the wall of G04 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.75. The entrance of the G04 *Sıcaklık* from the G03 *Sıcaklık*
(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.76. The brick set at the transition between G03 *Sıcaklık* and G04 *Sıcaklık*
(Source: Mükerrem Kürüm archive, May 2017)

Figure A.77. The opening and a niche on the northwest wall
(Source: Mükerrem Kürüm archive, May 2017)

Figure A.78. The interrupted terracotta pipe in the opening on the northwest wall
(Source: Mükerrem Kürüm archive, May 2017

A.7. G05 Hot Water Reservoir

Figure A.79. The control window and the barrel vault remain
(Source: Fatma Gürhan, December 2016)

Figure A.80. The junction line between the vaults with different pitches
(Source: ANKA Architecture and Restoration Office archive, November 2016)

Figure A.81. Example of rounded corner with plaster
(Source: ANKA Architecture and Restoration Office archive, October 2016)

Figure A.82. The junction line between the hot water reservoir and *soyunmalık-ılıklık* wall (Source: ANKA Architecture and Restoration Office archive, October 2016)

(a) (b)

Figure A.83. The water boiler location in water reservoir (a) and *külhan* (b)
(Source: ANKA Architecture and Restoration Office archive, December 2016)

Figure A.84. The woodshed in the left and the supporting wall in the right
(Source: ANKA Architecture and Restoration Office archive, November 2016)

A.8. Fountain And Street Pattern

Figure A.85. The fountain in the north of the bath
(Source: ANKA Architecture and Restoration Office archive, December 2016)

Figure A.86. The fountain of the bath
(Source: ANKA Architecture and Restoration Office archive, December 2016)

Figure A.87. The trough of the fountain
(Source: ANKA Architecture and Restoration Office archive, December 2016)

Figure A.88. The water reservoir of the fountain
(Source: ANKA Architecture and Restoration Office archive, December 2016)

Figure A.89. The street pattern in front of the fountain

(Source: ANKA Architecture and Restoration Office archive, December 2016)

Figure A.90. South view of the bath
(Source: ANKA Architecture and Restoration Office archive, December 2016)

APPENDIX B

RESTITUTION DRAWINGS OF *ESKİ HAMAM*

B.1. 15th and Early 16th Centuries

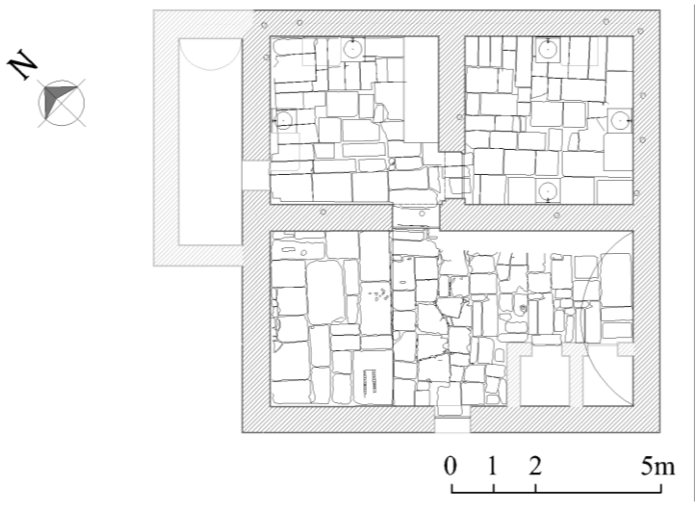

Figure B.1. Floor covering plan of the first period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

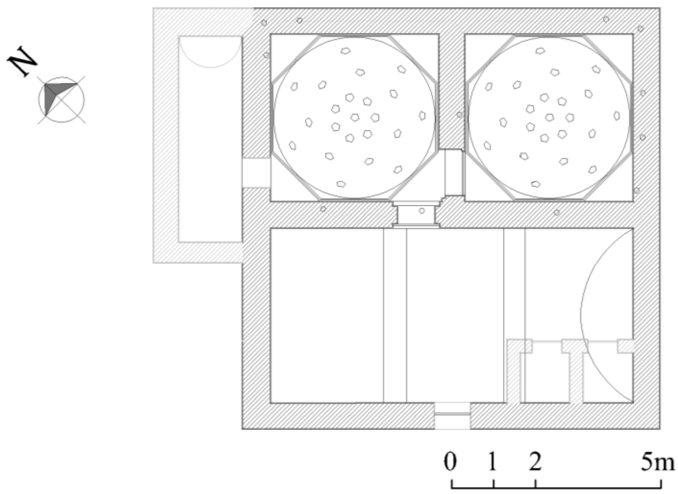

Figure B.2. Ceiling plan of the first period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

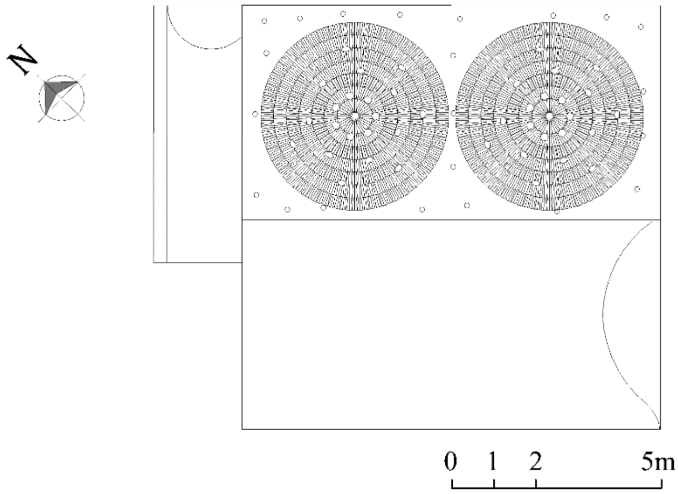

Figure B.3. Roof plan of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

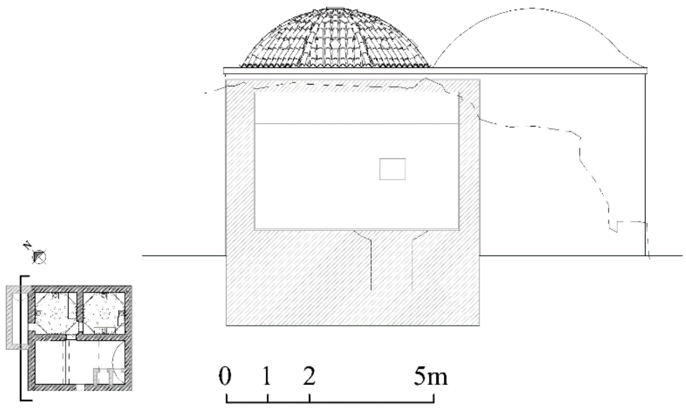

Figure B.4. Section-1 of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

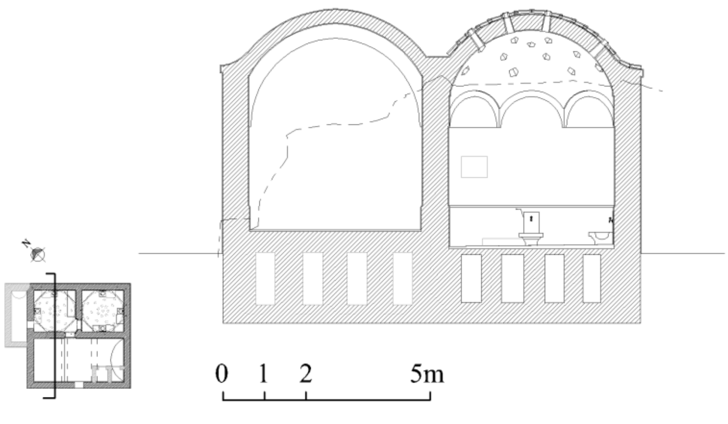

Figure B.5. Section-2 of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

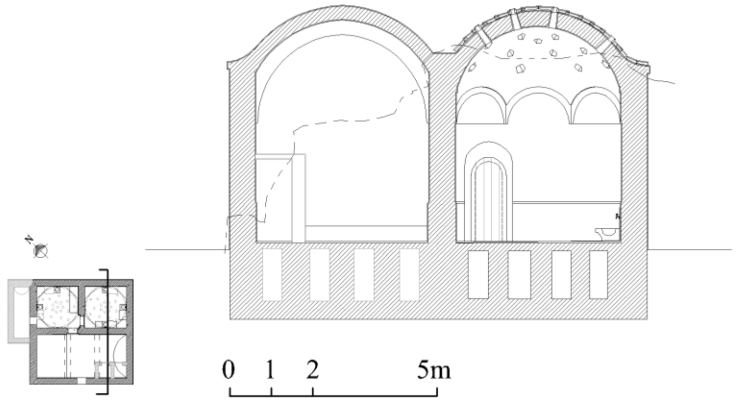

Figure B.6. Section-3 of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

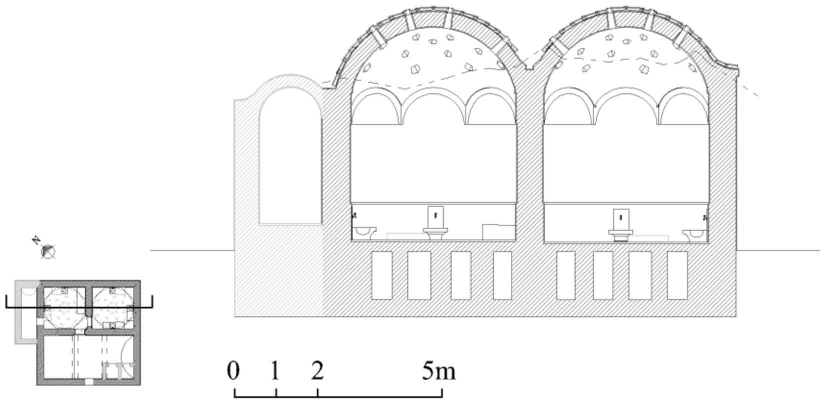

Figure B.7. Section-4 of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

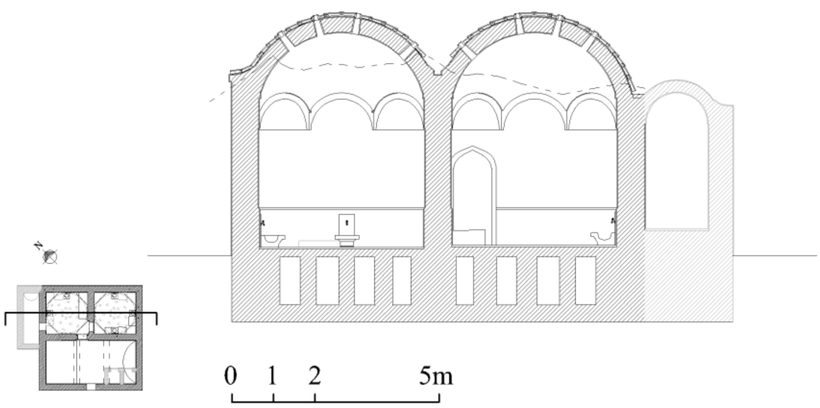

Figure B.8. Section-5 of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

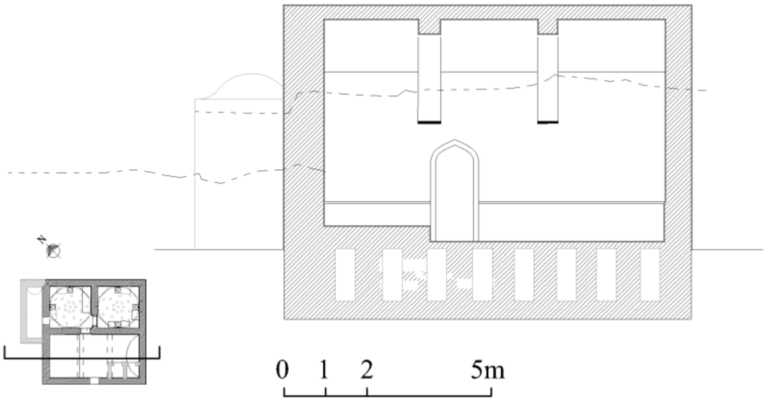

Figure B.9. Section-6 of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

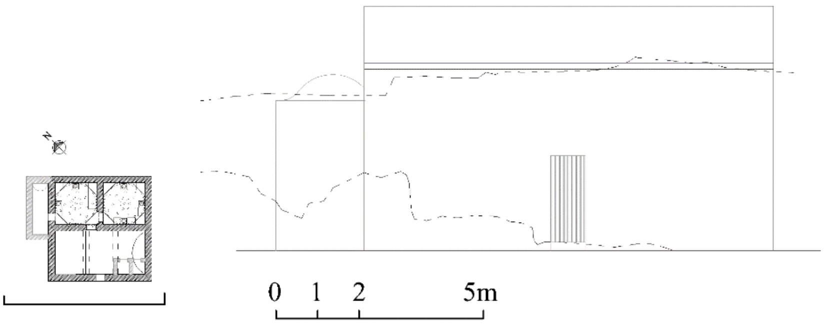

Figure B.10. Soutwest elevation of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

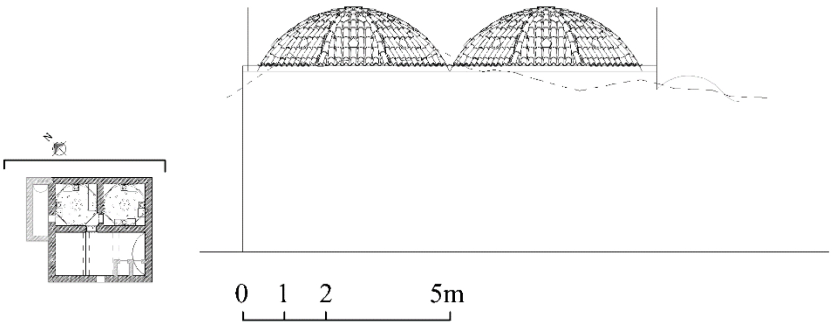

Figure B.11. Northeast elevation of the first period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

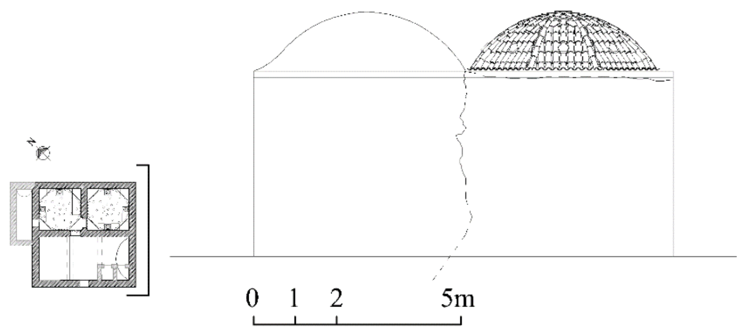

Figure B.12. Southeast elevation of the first period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

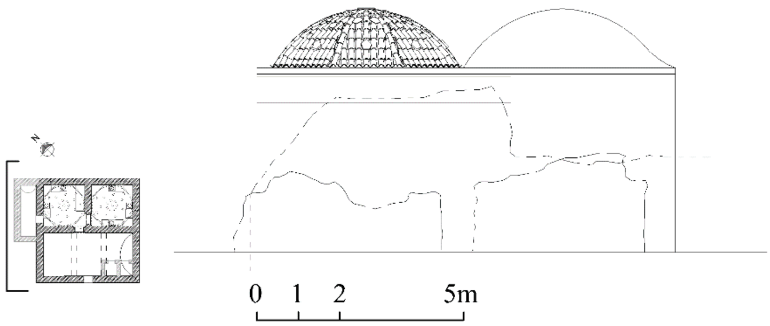

Figure B.13. Northwest elevation of the first period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

B.2. End of 16th and Early 17th Centuries

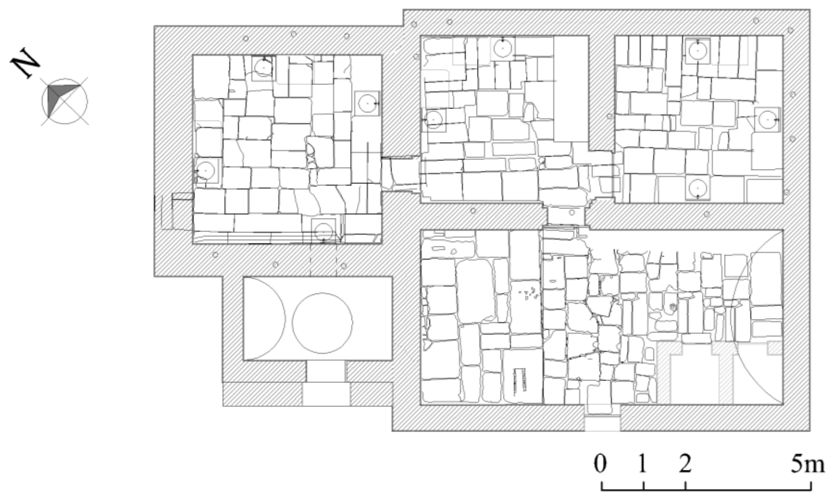

Figure B.14. Floor covering plan of the second period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

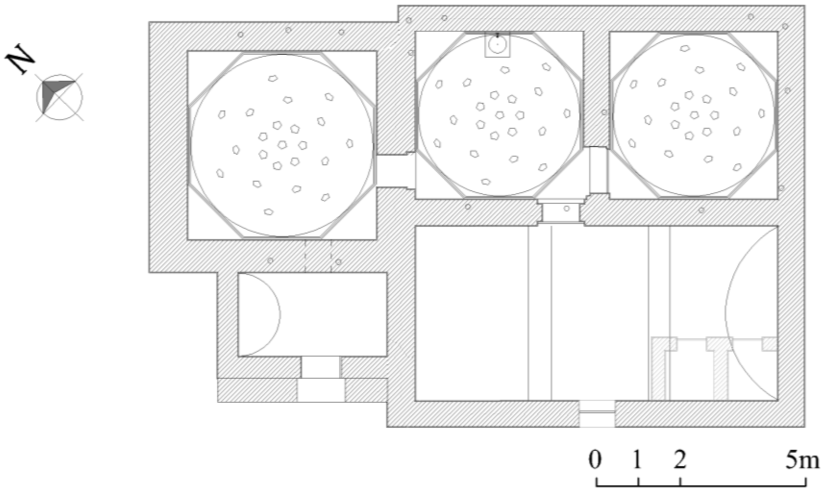

Figure B.15. Ceiling plan of the second period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

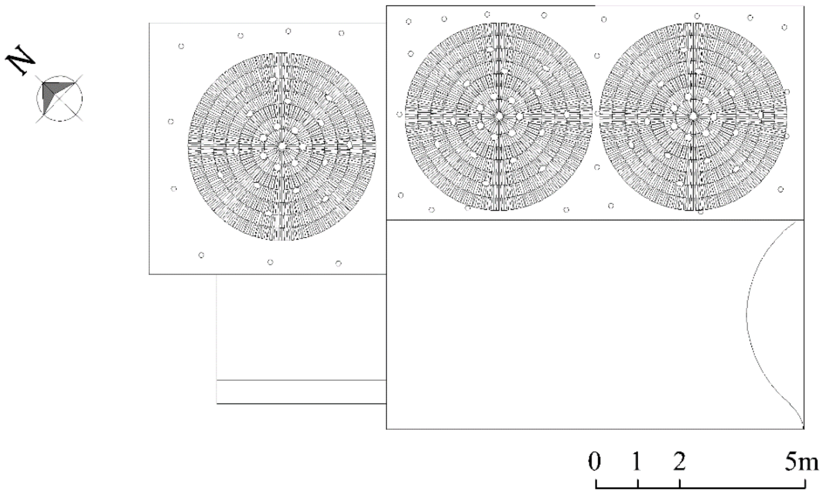

Figure B.16. Roof plan of the second period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

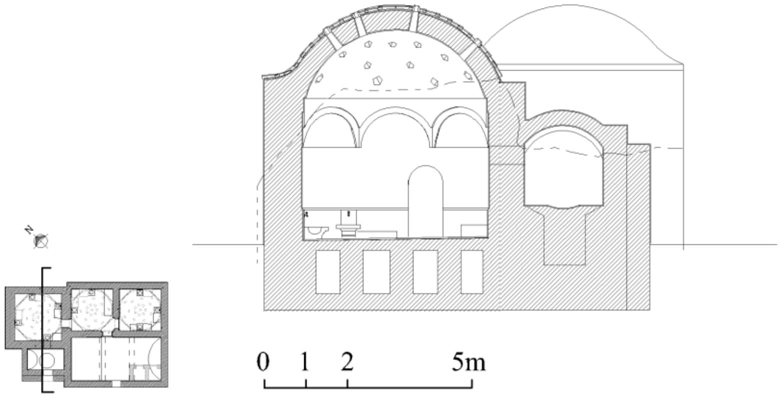

Figure B.17. Section-1 of the second period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

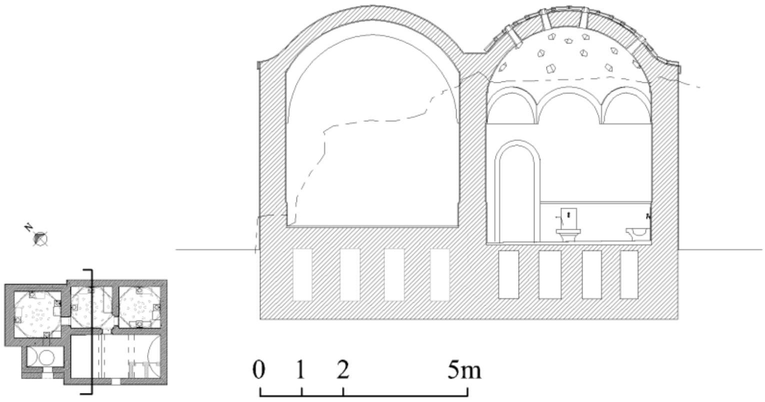

Figure B.18. Section-2 of the second period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

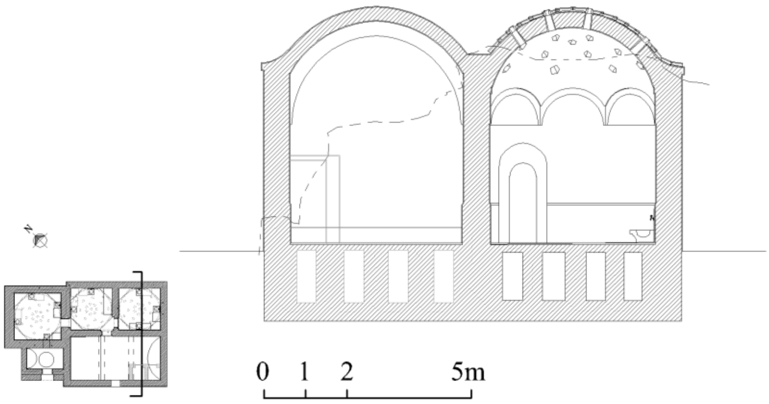

Figure B.19. Section-3 of the second period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

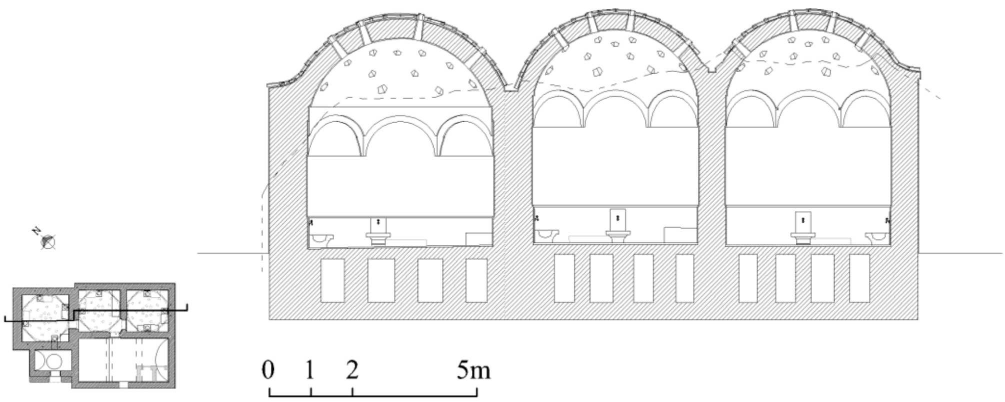

Figure B.20. Section-4 of the second period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

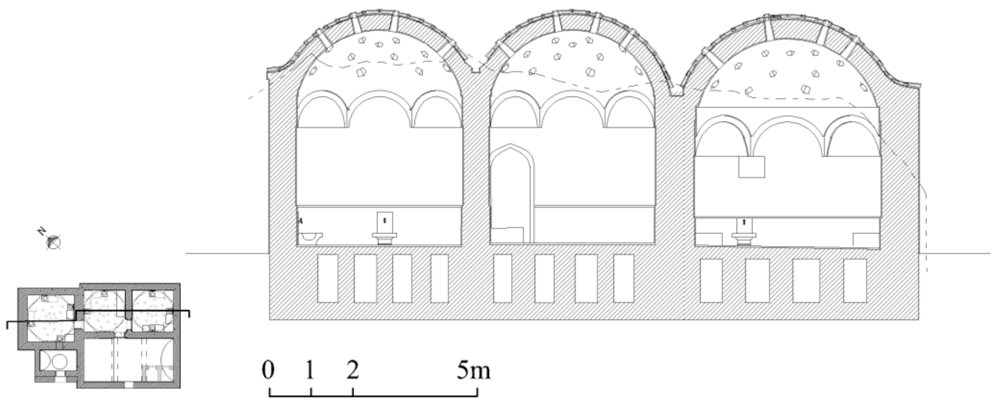

Figure B.21. Section-5 of the second period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

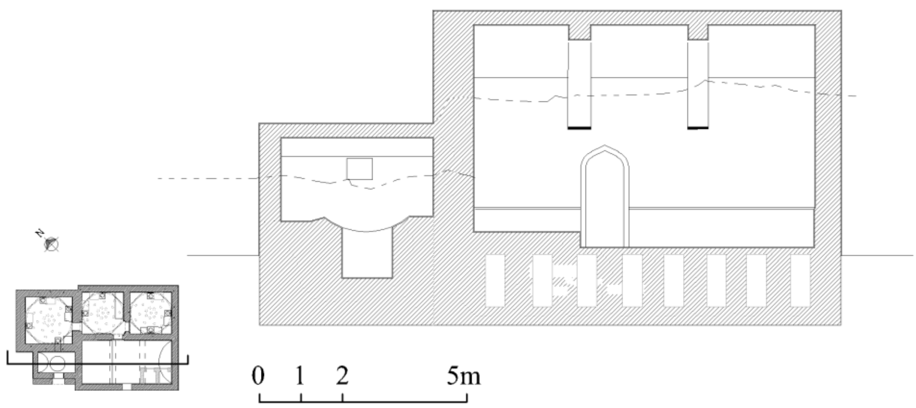

Figure B.22. Section-6 of the second period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

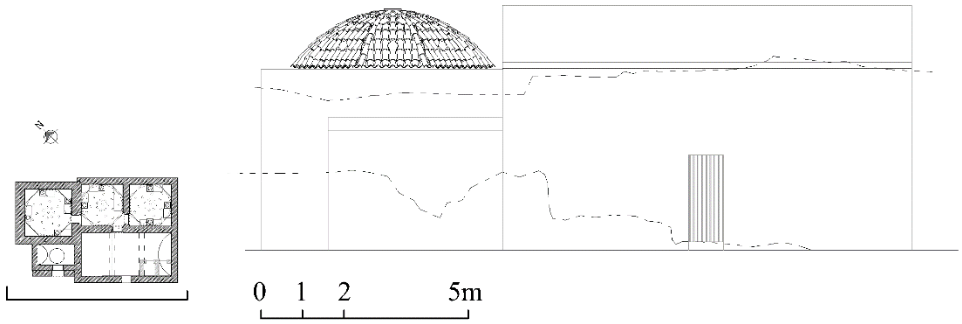

Figure B.23. Soutwest elevation of the second period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

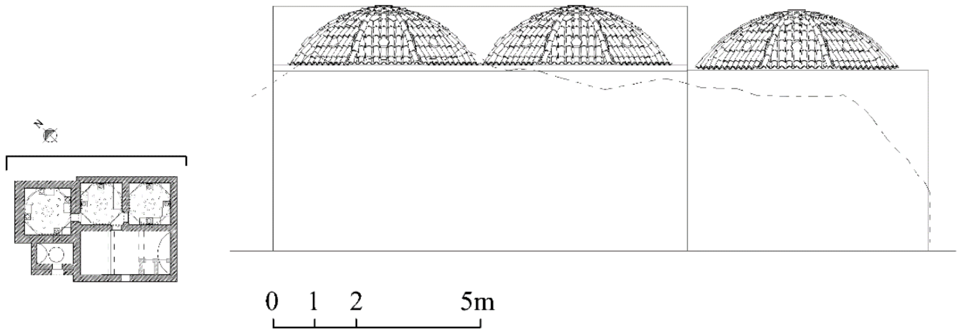

Figure B.24. Northeast elevation of the second period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

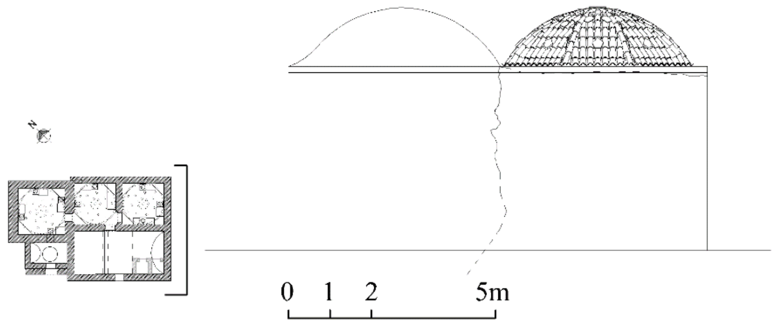

Figure B.25. Southeast elevation of the second period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

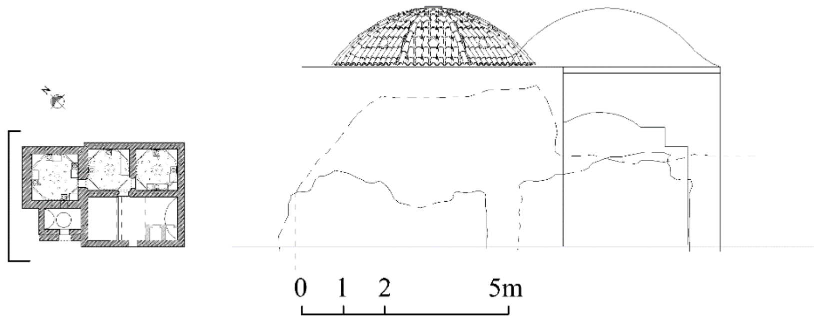

Figure B.26. Northwest elevation of the second period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

B.3. End of 17th and Early 18h Centuries

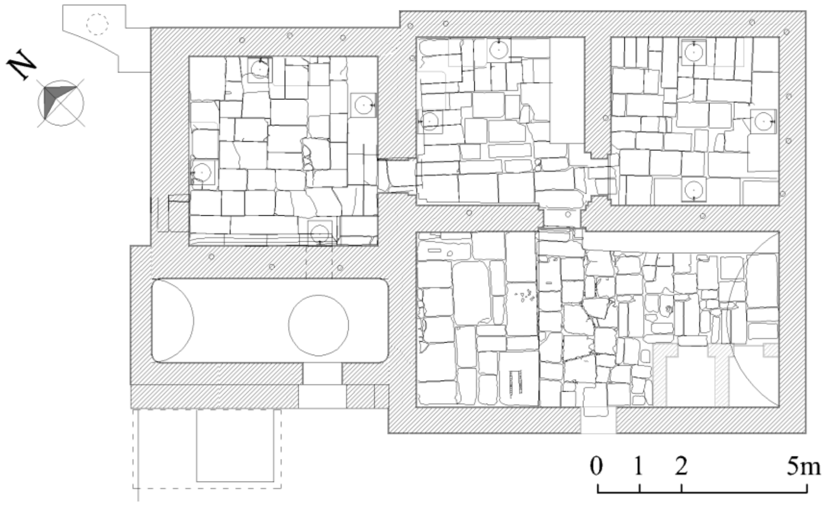

Figure B.27. Floor covering plan of the third period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

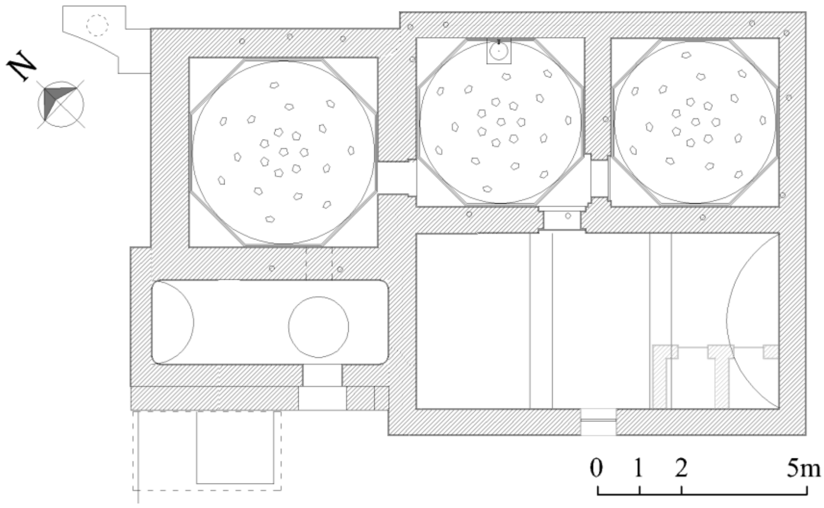

Figure B.28. Ceiling plan of the third period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

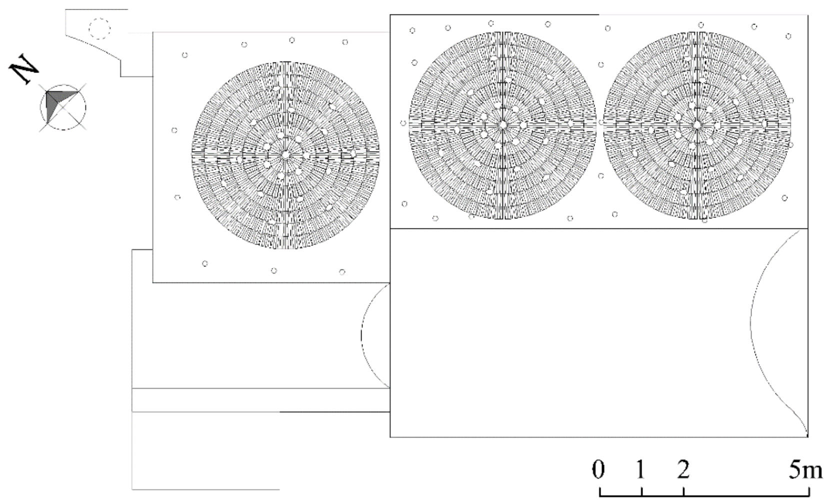

Figure B.29. Roof plan of the third period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office

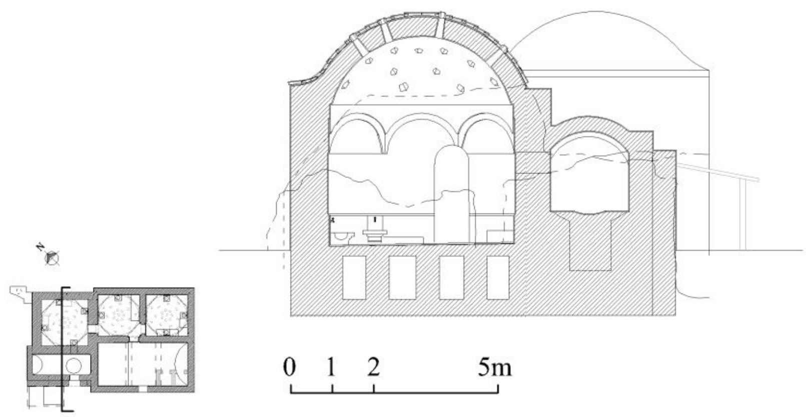

Figure B.30. Section-1 of the third period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

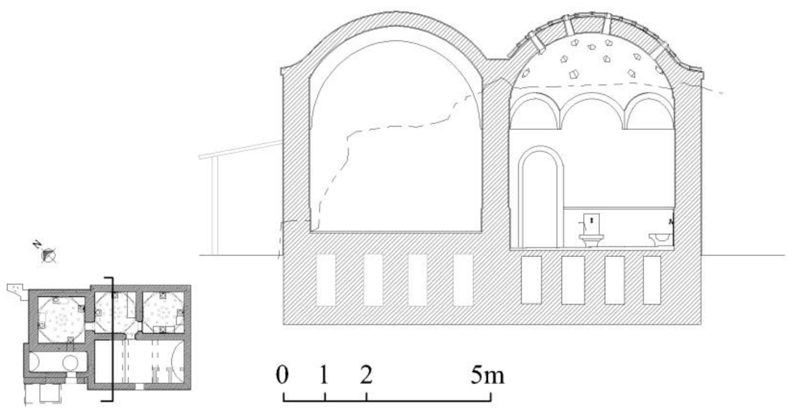

Figure B.31. Section-2 of the third period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

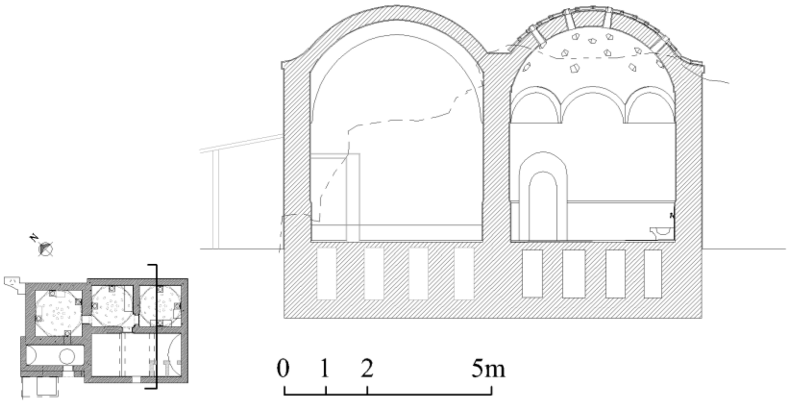

Figure B.32. Section-3 of the third period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

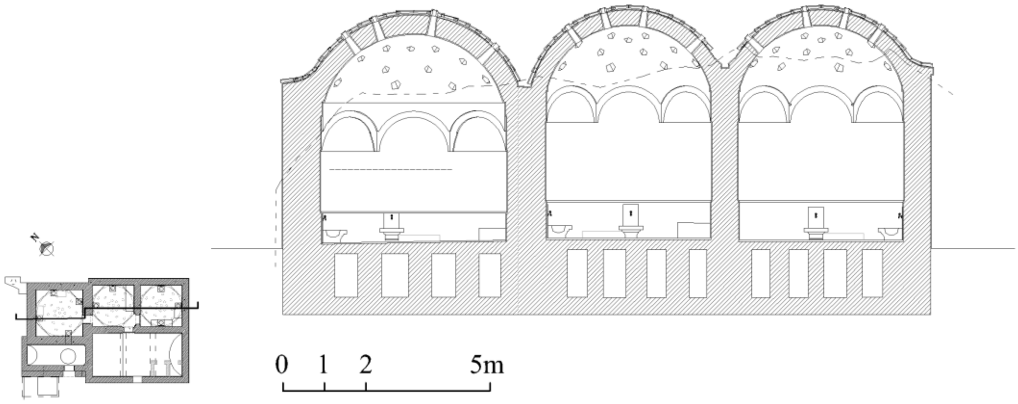

Figure B.33. Section-4 of the third period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

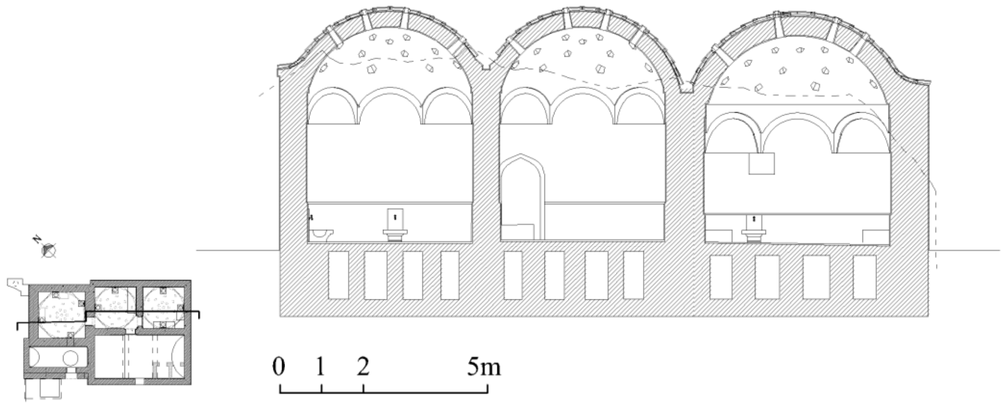

Figure B.34. Section-5 of the third period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

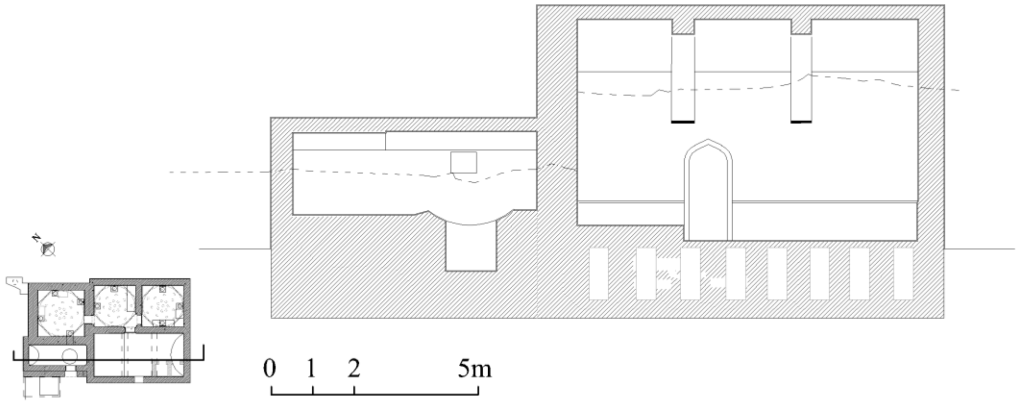

Figure B.35. Section-6 of the third period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

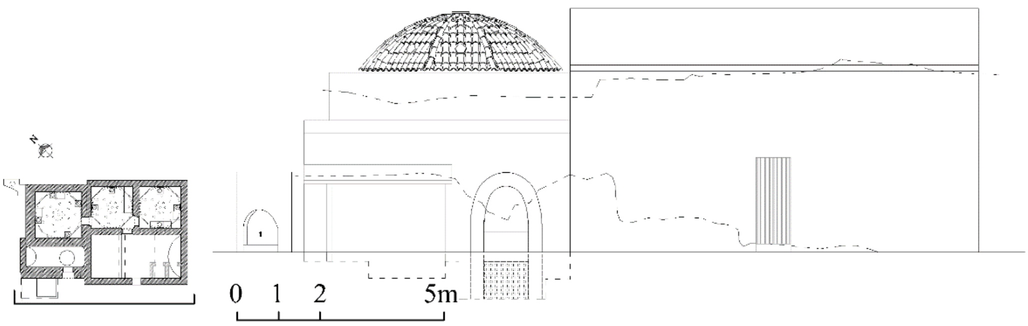

Figure B.36. Soutwest elevation of the third period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

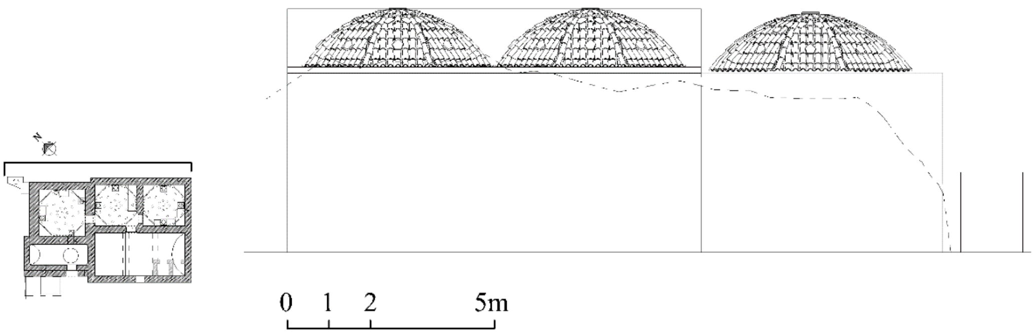

Figure B.37. Northeast elevation of the third period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

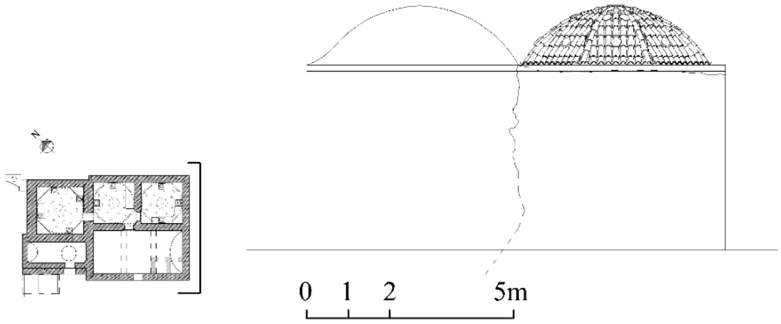

Figure B.38. Southeast elevation of the third period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

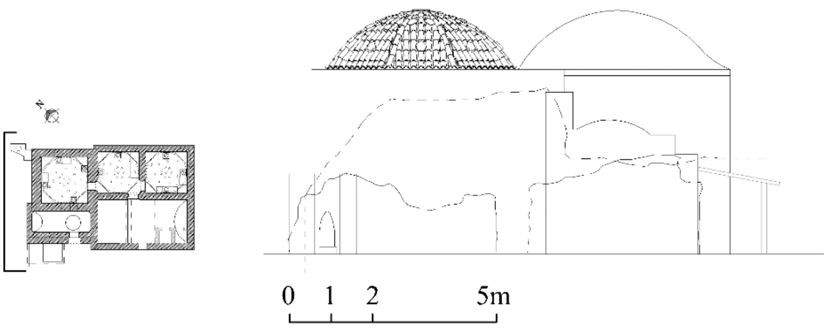

Figure B.39. Northwest elevation of the third period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

B.4. End of 18th and 20th Centuries

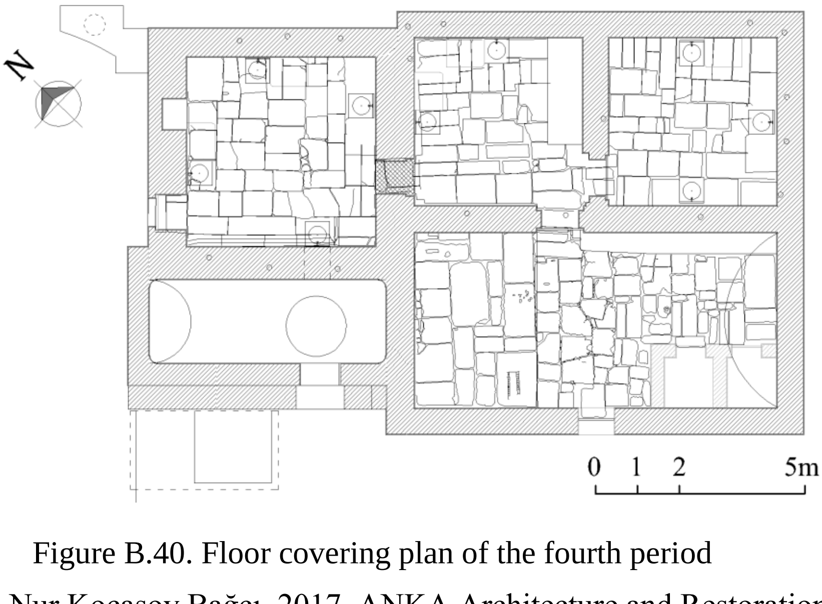

Figure B.40. Floor covering plan of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

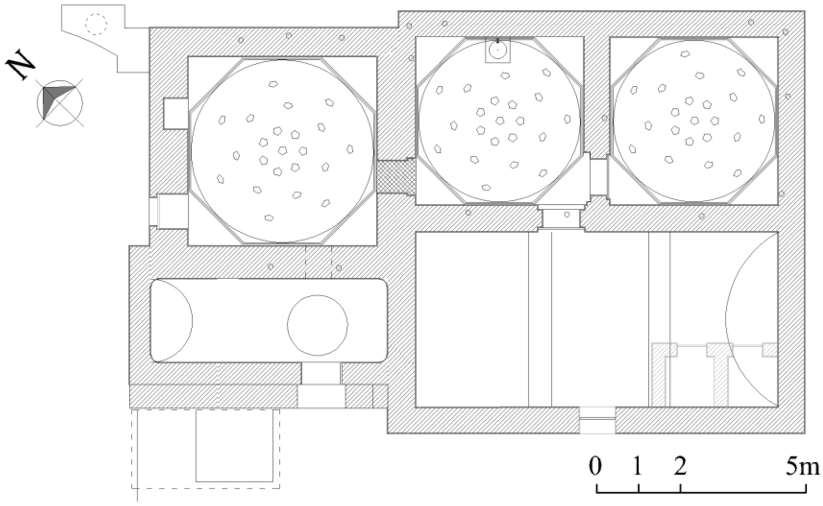

Figure B.41. Ceiling plan of the fourth period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

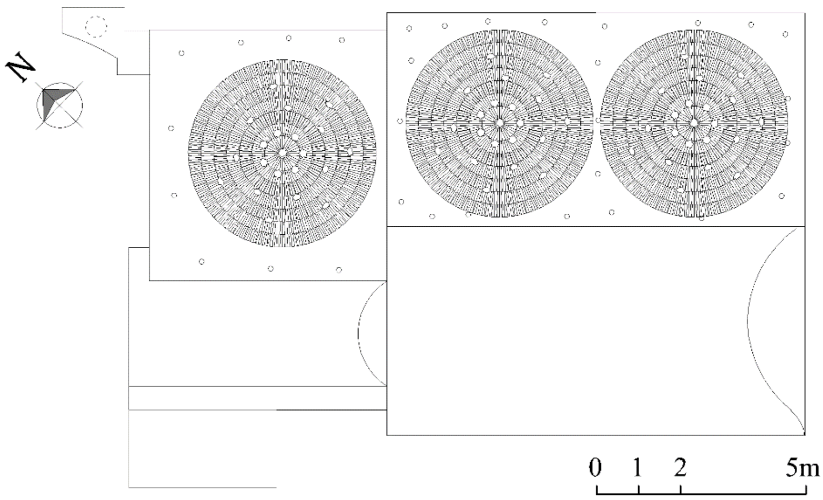

Figure B.42. Roof plan of the fourth period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

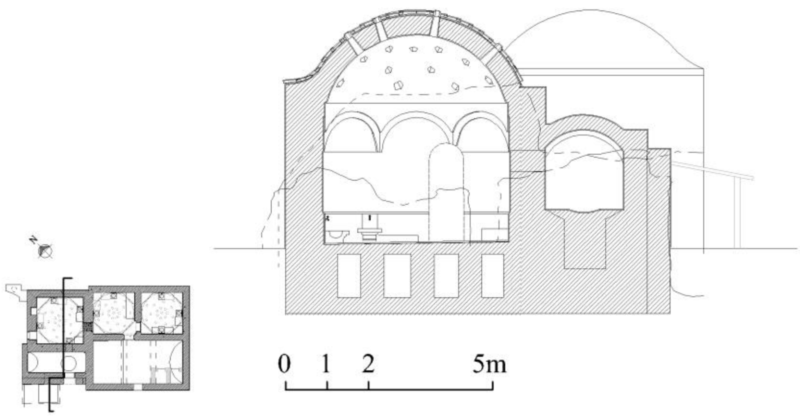

Figure B.43. Section-1 of the fourth period

(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

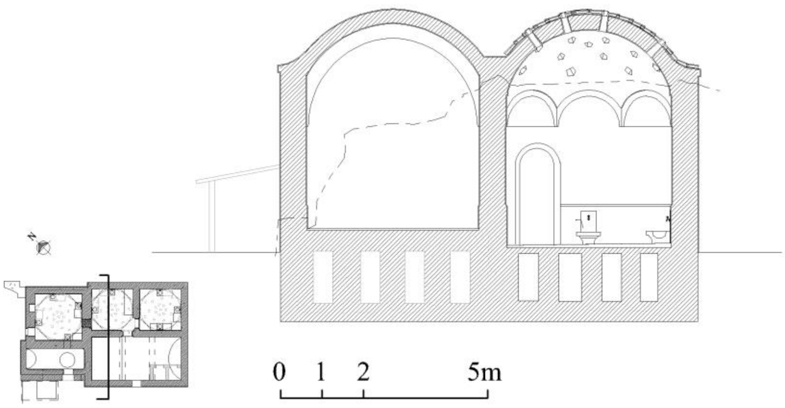

Figure B.44. Section-2 of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

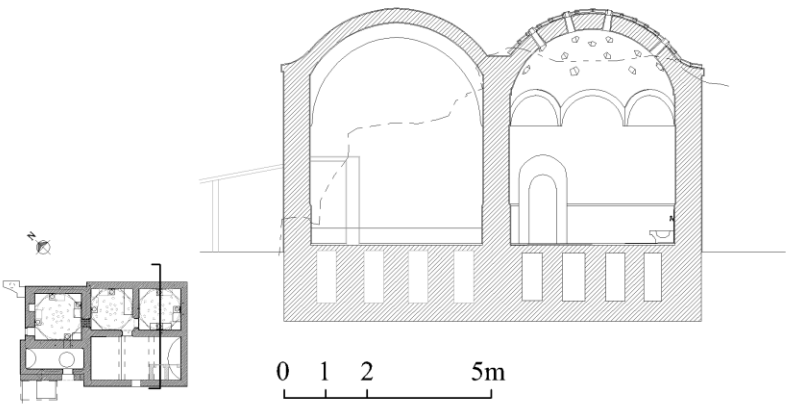

Figure B.45. Section-3 of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

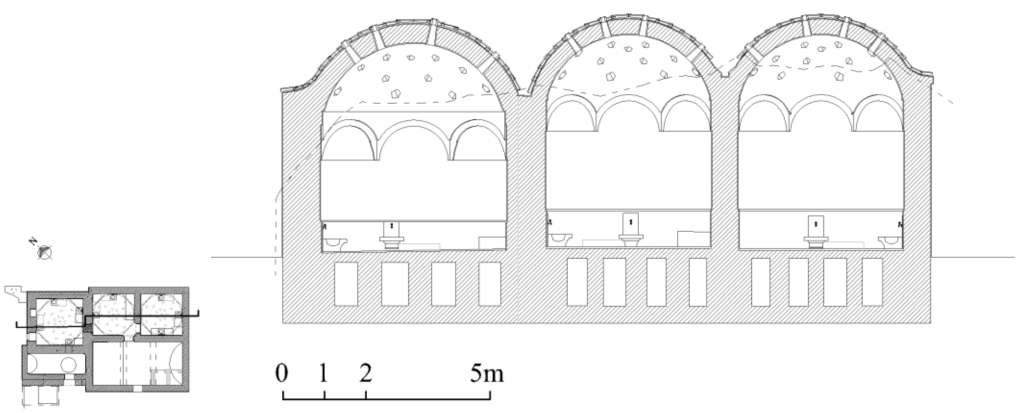

Figure B.46. Section-4 of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

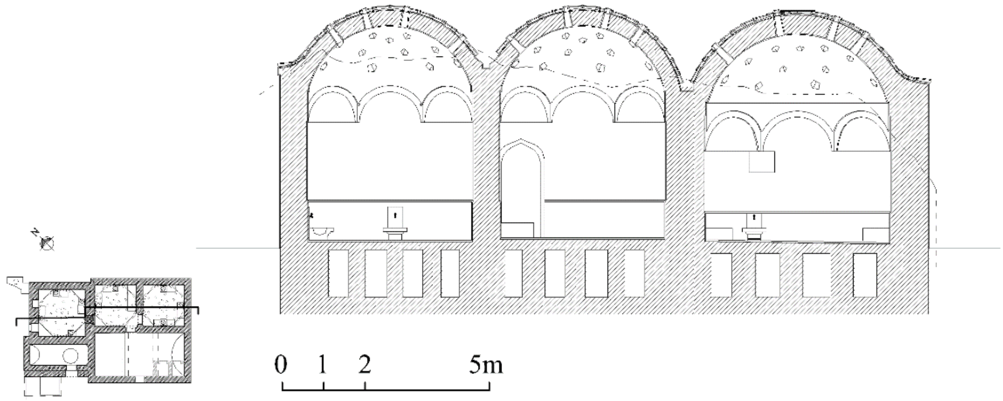

Figure B.47. Section-5 of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

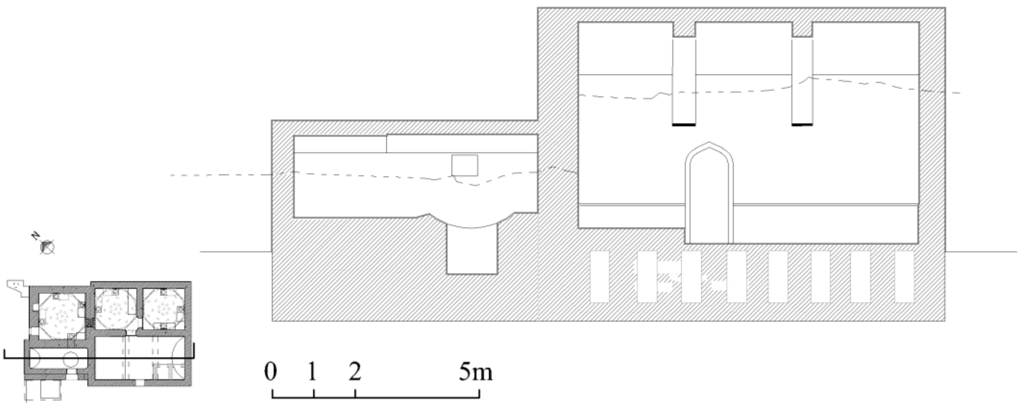

Figure B.48. Section-6 of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

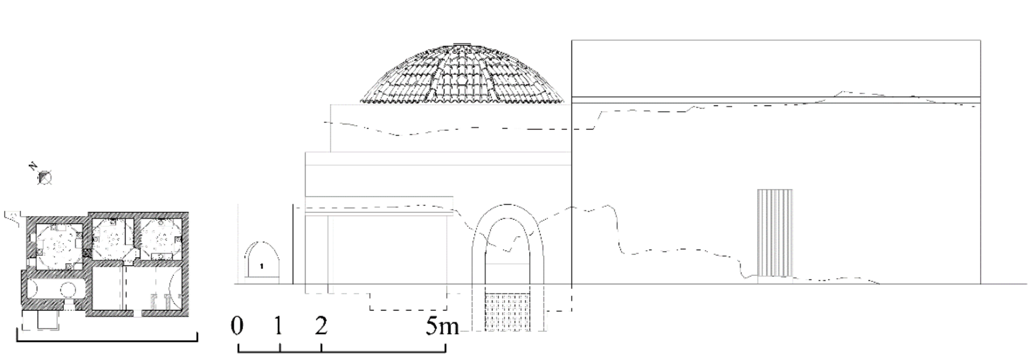

Figure B.49. Soutwest elevation of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

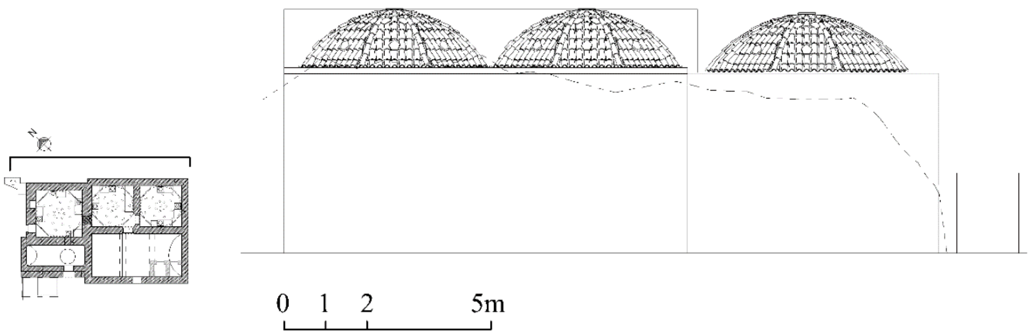

Figure B.50. Northeast elevation of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

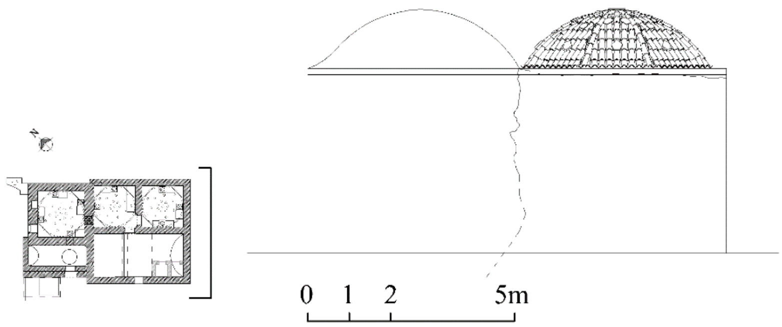

Figure B.51. Southeast elevation of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)

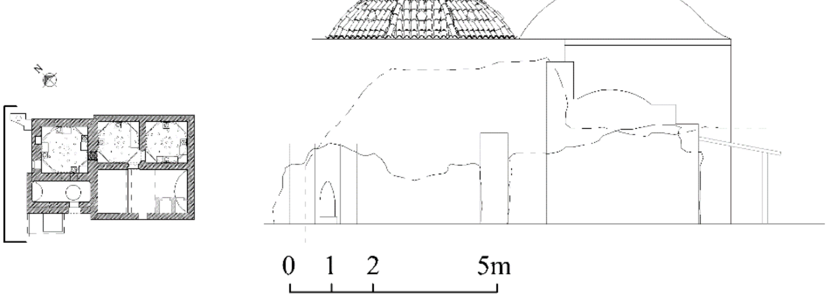

Figure B.52. Northwest elevation of the fourth period
(Drawn by: N. Nur Kocasoy Bağcı, 2017, ANKA Architecture and Restoration Office)