THE RESTORATION PROJECT OF A XIIIth CENTURY ANATOLIAN SELJUK "MESCİD" IN KONYA WITH THE EMPHASIS ON THE MATERIALS AND RELATED PROBLEMS

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ABSTRACT

THE RESTORATION PROJECT OF A XIIIth CENTURY ANATOLIAN SELJUK "MESCID" IN KONYA WITH THE EMPHASIS ON THE MATERIALS AND RELATED PROBLEMS

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A XIIIth Century Anatolian Seljuk monument, Tahir ile Zühre Mescidi in Konya has been selected to be studied. The study starts with the documentation of the present state of the building. The major problems of the building have been studied at the site and in the laboratory. Dampness survey has been done by moisture measurements. The laboratory analyses were done to determine the basic physical properties and components of the deteriorated and sound parts of the original materials and intervention materials. Laboratory analyses were also done to determine the sources and distribution of salt in the materials.

Architectural and historical evaluations, comparative analysis and restitution work have been carried out to define the original characteristics of the monument and to evaluate the monument within the other "mescid"s of the same period. All these studies have

defined the major problems of the monument, scope and content of the interventions to be applied for their solution as a restoration proposal.

Keywords: XIIIth Century Mescid, Historic Bricks, Historic Mortars, Materials Compatibility, Intervention, Restoration.

Science code: 601.04.01

ÖZ

KONYA'DA XIII YÜZYILA AİT BİR ANADOLU SELÇUKLU MESCİDİ İÇİN MALZEME VE SORUNLARINA YÖNELİK RESTORASYON ÖNERİSİ

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Tez çalışma konusu olarak Konya'da yeralan XIII Yüzyıl Anadolu Selçuklu Dönemine ait Tahir ile Zühre Mescidi seçilmiştir.

Çalışma, anıtın bugünkü durumunun belgelenmesi ile başlamaktadır. Yapının ana problemleri, gerek yerinde gerekse laboratuvar çalışmaları ile irdelenmiş ve bugün içinde bulunduğu nem sorunlarıda nem ölçümleri ile saptanmıştır. Laboratuvar çalışmaları yapıyı oluşturan özgün yada geç dönem müdahalelerine ait malzemelerin temel fiziksel özelliklerini saptamaya ve sağlıklı kalabilmiş yada bozulmaya uğramış bu malzemeleri etkileyen bozulma faktörlerini tanımlamaya yöneliktir. Laboratuvar çalışmaları aynı zamanda önemli sorunlardan bir diğeri olan tuz sorununun kaynaklarını ve malzemeler içindeki dağılımının saptanmasını da amaçlamıştır.

Aynı çalışma kapsamında yeralan mimari ve tarihsel

değerlendirmeler, karşılaştırmalı çalışmalar ve restitüsyon çalışması, yapının özgün karakterinin anlaşılmasına ve aynı döneme ait diğer mescidler içindeki yerinin saptanmasına yöneliktir.

Yapılan tüm bu çalışmalar yapının ana sorunları ve çözümlerini tanımlayarak restorasyon önerisine esas olacak müdahalelerin kapsam ve niteliklerini belirlemiştir.

Anahtar Kelimeler: XIII. Yüzyıl Mescidi, Tarihi Tuğlalar, Tarihi Harçlar, Malzeme Uyumu, Müdahale, Restorasyon.

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CHAPTER I

INTRODUCTION

In this work the aim is to study a historic building, specifically concentrating on its physical fabric examining the causes and processes of decay that the fabric is subjected to, while considering its historic, stylistic and architectural features. The study includes a restoration proposal solving the major problems of the monument and complying with the generally accepted restoration principles.

Serving for this purpose, Tahir ile Zühre Mescidi, in Konya City (of Central Anatolia) belonging to the Anatolian Seljuk Period (XIIIth Century) has been selected to be studied. A "mescid", in a broadest sense, is a small scale mosque in which "Cuma namazı" (Friday noon common prayer) and "Bayram namazı" (religious festival common prayer) are not performed (Aslanapa, 1984: 129). This brings the absence of the deliverance of the "khutba" (the preach which is delivered following those prayers) and the "minbar" (one of the most prominent architectural elements of mosques on which the "khutba" is delivered to the congregation by the imam in charge) respectively. Tahir ile Zühre is composed of a prayer hall with an entrance hall and a "türbe" (mausoleum) and it is built of stone and brick.

The study is started with the site surveys in June 1st, 1991. By the same time the actual restoration work which was given to

Çeki-San İnşaat Şirketi (Çeki-San Construction Company) by Vakıflar Genel Müdürlüğü (The General Directory of Pious Endowments) on the basis of competitive bid in November, 1989 had already been initiated following the completion of the expropriation of the house of the former owner of the "mescid" which is situated 1m away from the east side of the building with two neighbor parcels, No:2 and No:7, besides its own, No:3 (Figure 2). The following jobs were already completed by the contractor:

1. The house of the former owner, the former property walls which were surrounding the building from the North, and north-west and the garage building that was located in the neighbor parcel No:7 were demolished.

2. The cornice stones of the roof and the all window frames and the door on the north wall of the prayer hall that were supposed to be placed in 1958 intervention which is the only dated intervention in the past (Konyalı, 1964: 519) were removed.

3. A door-like hole was opened at the east wall of the entrance hall beneath the remains of the portal.

4. The entire ground surfaces of the interior and exterior were leveled with lean concrete.

5. The cleaning (of rubbles and plants) and replacement of the cornice stones of the roof were almost completed.

6. The all plasters that were supposed to be applied in 1958 are scraped off from the exterior faces of south and west facades and the entire surfaces of interior.

All those recent changes and further interventions at the building and the site necessitated to determine some certain limits to establish a constant scope for the study clarifying that in which state we have undertaken the building and the site to make our own evaluations to develop our own restoration proposal Those limitations concerning the site and the building are as follows:

The site: It is accepted with the boundaries formed by the latest expropriations with no other buildings (neither the garage nor the former owner's house) and with no property walls that were demolished.

The building: It is accepted without window frames and doors as well as the former cornice elements of the roof that were removed to be replaced with the new ones. The recent application of lean concrete on the exterior and interior surfaces of the ground (except for the concrete application on the "türbe" floor together with the concrete application on the roof both supposed to be applied in 1958 intervention) is also excluded from the scope of the thesis. But the door-like hole with an amorphous shape which was opened at the east wall of the entrance hall, is considered as the entrance of the "mescid" in the scope.

Thus, the all data utilized throughout the study are obtained by the surveys which had to be realized within two weeks, and by use of the measured drawings of Vakıflar (for the previous state of the building before the restoration e.g. the levels and the structure of the foundations, original levels and the materials of the floors of exterior and interior) as well as the old photographs and publications in which Tahir ile Zühre is examined alone or mentioned with the other "mescid"s of the same period (Konyalı, 1964; Akmaydalı, 1982).

As the aim and scope have been explained, this study should be considered not the one by which the concept of a specific building type or the entire technology of a historic period is covered, but as a small contribution to the implementation phase of restoration projects, during and after which most of the problems arise, even though concentrating on a modest structure within a limited scope and time.

CHAPTER II

THE METHODOLOGY OF THE STUDY

Since the aim of this study is to diagnose the main problems of the monument and to develop a restoration proposal to control and solve them, certain phases had to be undergone.

The first step was actually to have a concrete knowledge about the present state of the building which necessitates to carry out the surveys at the building and the site forming the initial part of the study. Laboratory studies follow the surveys aiming to define the characteristics of the materials and decay problems. Following the completion of the evaluation of the existing situation of the building by the data obtained from those studies, the work proceeds with the historical research and comparative analyses of other "mescid"s of the same period. This helps to make a complete evaluation of the "mescid", as Tahir ile Zühre, giving way to the restitution scheme as well as specifying the content and the range of the interventions in a restoration proposal.

2.1 Surveys

It consists of the measurements of the site and the building, moisture measurements at the building, collection of the material samples and descriptive notes to be used for the descriptive analyses of the building.

a. The Measurements of the Site and the Building

The site and the building is measured by using two different techniques. The plan measurements were carried out by using theodolite. The entire site and immediate surroundings were connected to the building by determining coordinates and station points to be used for triangulation. Following the completion of the measurements of the site, the plan measurements were taken by the same technique. In case of the vertical measurements, however, the conventional method is adopted by using steel-tapes, plumb-bob, water level and rods by establishing a datum line to which all those measurements are referred. Horizontal and vertical measurements are provided in the accuracy of centimeter in 1/50 scale drawings. Different from the measurements above, the very detailed ornamentation patterns applied in the "mihrap" and the interior of the superstructure of the prayer hall and the entrance hall are documented by the use of photogrammetric technique using Zeiss SMK-40 Stereometric Camera provided by the Photogrammetry Center of Architecture Department of Middle East Technical University.

b. Moisture Measurements

The moisture readings were performed to check the dampness conditions at the masonry by using Gunn Hydrometer. The entire facades, both interior and exterior, were recorded intensively from the ground up to all accessible levels. The moisture readings were taken from the mortars of the masonry. The results of these measurements are indicated on the drawings.

c. The Collection of Material Samples and Their Analysis

All samples, of sufficient amounts, collected from the building are packed in polyethylene bags and labeled on their data cards identifying their kind and places they were taken. All the spots from where the materials collected are indicated on the drawings.

The laboratory studies were focused on those analyses which will reveal the nature and extent of the existing problems in the monument and the methods of dealing with their solutions. Therefore the analyses were done to define the important physical properties of original and intervention materials such as water absorption capacity, porosity, density and wetting and drying rates, to determine the characteristics of some raw materials in the composition of brick and mortars, and to understand the sources and distribution of salts in the monument.

d. Description of the Building and Site

All descriptions are based on the notes taken during the surveys. It consists of the detailed descriptions of; the location of the "mescid", the site, the plan layout, the exterior and the interior of the building, and physical deteriorations by visual observations. All descriptions of the building facades (both exterior and interior) are given in counterclockwise direction, from right to left and from general to detail. Vertical measurements (as levels of; +,-) are referred to the datum line throughout the descriptions of exterior and interior facades except the total dimensions of facades, openings and other elements.

Material deteriorations detected by visual observations to be combined and evaluated together with the laboratory studies have not been included in the descriptive analysis of the building. They are explained separately.

All the outcomes of these surveys have been documented in different sets of drawings by 1/50, in case of photogrammetric drawings in 1/20 scales, in the following titles;

a. Measured drawings (the plans of the site and the building, sections and elevations)

b. The materials of the building (plans, sections and elevations)

c. Moisture readings (sections and elevations)

d. Observed weathering forms (plans, sections and elevations)

e. Photogrammetric drawings (a longitudinal section towards the "mihrap" and the plan of the superstructure)

f. Restitution (plans, sections, "mihrap" and portal)

The survey study is also supplemented by a photographic documentation. Complete understanding of the text is only possible by referring to the particular set of drawings where needed.

2. 2 Historical Research

This research is done first to have a basic knowledge about the historical background of Konya questioning how far the settlements and construction techniques extends back throughout the periods before Anatolian Seljuks and second to understand Tahir ile Zühre together with the historical and social background of the other "mescid"s. A brief history of Tahir ile Zühre is also given in this part basing on the archive investigations of İbrahim Hakkı Konyalı (Konyalı, 1965: 518).

2. 3 Comparative Analysis of "Mescid"s

The existing state of Tahir ile Zühre indicates that it has no missing spaces. But it has some architectural elements some parts of which are missing like the "mihrap" and the portal, and elements like windows and doors or some materials like rendering, roofing, flooring and paving that are completely missing. Therefore, comparative analysis in case of Tahir ile Zühre aims to determine its right place in the general classification of the groups of other "mescid"s of the same period and try to find clues for partially or completely missing elements and materials in comparison with the other "mescid"s of the same period. These comparisons are made in terms of their plan layouts, structural systems, architectural elements and materials of construction.

2.4 Restitution Scheme

As the reasons were explained in the methodology of comparative analyses the restitution work mostly concentrates on the completely missing elements and the elements some parts of which are missing. The utilized sources are; the building itself, an old photograph of the "mescid" (Konyalı, 1965; 517), finds obtained by the latest excavations that are indicated on the drawings of Vakıflar, and comparative studies.

2.5 Restoration

The evaluations of the site surveys, laboratory studies, historical research, comparative studies and restitution work have determined the scope and the content of our interventions forming the restoration proposal.

CHAPTER III

DESCRIPTIVE ANALYSIS OF THE BUILDING AND THE SITE

3.1 The Site and the Location

Tahir ile Zühre Mescidi is in Beyhekim District which is located, to the south-west of Alaaddin Hill one of the ancient parts of Konya City. The former name of the area was Çeşme Kapısı, attributed to one of the gates of the ancient citadel and many fountains around that are not in existence now (Konyalı, 1965: 518). A few other "mescid"s of the same period, like Hoca Hasan, Abdülaziz, Abdülmümin, Beyhekim and Zevle Sultan are also located very close to this area at the walking distances of five to fifteen minutes to Tahir ile Zühre (Figure 1).

The area, in which Tahir ile Zühre is located, remains between Gazi Lisesi (junior high school) and Kazım Karabekir Boulevard that is one of the three main arteries leading to the center, together with Ankara-İstanbul Highway and Hükümet Boulevard. The building is situated where İmam Bağavi Street (inclining to the South) ends and intersects with Muzaffer Hamit Street. The south and west side walls of the "mescid" directly rest upon the north edge of Muzaffer Hamit Street and the east edge of İmam Bağavi Street. Today the site is surrounded by four to six storied blocks of flats on the East, North and the West. At the South, it faces to the property wall of the play ground of Gazi Lisesi which rests on the southern edge of

Muzaffer Hamit Street.

The site covers the parcels of No: 2-3-7 and a small extension of the parcel No: 8 with the latest expropriations. The total area including the "mescid" is approximately 335 square meter, externally 19m at the West, 15.50m at the East, 15.40m at the North and 18m at the South. Parcels of No: 2 and 3 are placed at the level of -0.45, parcel of No: 7 and the extension of No: 8 are placed at the level of +0.65. The building is placed at the south-western part of the site longitudinally in the East-West direction (Figure 2).

3.2 The Building

Tahir ile Zühre is composed of a prayer hall and an additional part formed by an entrance hall and a "türbe". It has a rectangular plan and externally measures 8.95m at the East, 7.95m at the West, 11.35m at the South and North (Figure 3). The prayer hall is reached by an arched opening through the entrance hall which is accessed by the portal. The "türbe" has no direct access that one can easily get in neither from the entrance hall nor from the prayer hall. The only possible access is the rectangular continuation of the arched opening placed at the south of the east facade which is filled with brick at the present. However, it is visually connected to the other spaces by means of small windows. The square planned prayer hall and the "türbe" are surmounted by domes and the entrance hall is surmounted by a vault.

The building is built of stone used in the foundations and the lower parts of the walls, and brick at the upper parts of the walls and throughout the superstructure. Glazed ceramic tiles and gypsum renderings are also widely used in the ornamentations.

3.2.1 Exterior

a. The east facade forms a rectangle with the dimensions of 8.95m long and 6.50m high from the existing ground. Within this frame it has two openings; the one to the North placed in a rectangular frame 3.85m long, 2.75m high and recessed by 0.06m is a one centered-tangent arch providing the entrance to the "mescid" through the portal. The span of this arch is 3.15m and 1.75m is the height. The second opening to the south belonging to the "türbe" framed by a two centered tangent arch is also placed in a rectangular frame 1.35m long, 2.10m high and recessed by 0.06m same as the first opening. The span of this arch is 0.85m and it is 1.35m high. Some remains of ceramic tiles are perceived at the spandrils of this arch. The third one is the downwards continuation of the same opening with the dimensions of 0.85m wide and 1.45m high. It is filled with brick at the present (Figure 4).

The remains of the portal almost more than 3/4 of which is missing seem to be on the brick wall built within the entrance arch. The external width of the portal is 2.70m and it makes a 0.20m protrusion from the wall surface. The present state of the portal does not give way to derive direct information about the entire format. Just a small part of the exterior border, of the north side exists with a few low reliefs of gypsum that are alternatively used with cut brick bands forming geometric interlaces where polygonal shaped ceramic tiles in purple are embedded. The threshold stone of the entrance is placed at the bottom level of -0.93 of the portal.

The lower part of the facade, below the timber tie beam which is placed at the average level of +1.45, is of large and finely cut rectangular blocks of travertine in varying dimensions. The upper part above the tie beam is of brick which is composed of horizontal bonds. The material of the arches is also brick.

b. The north facade forms a rectangular frame with the dimensions of 11.35m long, including the diagonal protrusion at the East (0.90m from the surface of the western part) and 6.40m high (Figure 5). It has two openings that are placed at the West on the same vertical axis but with different dimensions and profiles. The first one above placed in a rectangular frame which is recessed by 0.06m is 1.40m long and 1.71m high (placed at the level of +2.65) and it is framed by a two centered-tangent arch 1.00m wide and 1.44m high. The second arch below the first one is spanned by a 1.35m wide segmental arch with a 0.68m height rests upon a timber tie beam placed at the level of +1.42. The rectangular downwards continuation of this arch has the measures of 1.35m wide and 1.93m high and placed between the levels of -0.62 and +1.30. The lower part below the timber tie beam is of finely cut rectangular blocks of travertine and the upper part is brick same as the east facade. Some courses of brick remain between the levels of +437 and +5.03 of the protrusion at the East are missing. There are a few courses of rubble stone placed between the levels of +4.21 and +4.92 on the western part of the same facade.

c. The west facade is also a rectangle measuring 7.95m long and 6.50m high. It has only one opening placed at the level of +2.55 with the same profile and dimensions of the one above the north facade but it has no a rectangular frame (Figure 6). On the contrary of the east and north facades the stone masonry of random rubble of andesites on this facade extend over the timber tie beam to the approximate level of +2.15. In addition to this, there is a second tie beam 0.75m below the first one. The length of this tie beam which is not running throughout the facade is 5.00m. A certain part of the facade, which is approximately 2.20 square meter and placed to the South where the second tie beam ends is damaged as the discharges of mortar in the joints indicate. A few layers of rubble, in fact, the continuation of the ones at the west of the north facade, is seen between the levels of +4.25 and +4.92 to the north side of this facade.

d. The south facade has a rectangular frame of 11.35m long and 6.50m high. It has no opening but two different types of relieving arches are the prominent elements in the overall facade (Figure 7). The first one to the West is a segmental arch with a span of 1.50m and 0.38m high from the timber tie beam placed at the level of +1.40. The second arch to the East is a one centered tangent arch. The span of this arch is 2.25m and 1.35m is the height measured from the tie beam. The extension of the rubble layers, till the level of +2.25 above the tie beam is also seen at this facade. The brick arch at the West remains within this zone.

e. The roof consists of two domes and a flat part inclining towards the north-east corner. It is reached by a horizontal opening through the stairs which are accessed by the north wall of the entrance hall (Figure 8). The edges of this opening are damaged. Exterior face of the larger dome with the approximate external diameter of 6.75m has eighteen spurs nine of which are missing. They are placed around the dome with the almost equal intervals of 0.75m at the approximate level of 1.05m from the roof surface. The smaller dome has 2.5m external diameter and 0.75m high from the roof surface. It is plastered. The flat part at the north-east corner and the other flat surfaces where the domes rest are covered with cement, applied in later years probably in 1958, for the purpose of insulation.

3.2.2 Interior

a. The entrance hall: It has a rectangular plan and internally measures 3.78m at the West, 2.60m at the North and South and 3.73m at the East (Figure 3). The interior of the walls of this space is divided by several tie beams passing through different levels into stone (of andesite) below and brick above. It is also pierced by several openings that are connecting it to the prayer hall and the "türbe".

The first opening is placed on the west wall at the distance of 0.95m from the north corner (Figure 11). The above part of this opening is spanned by a one centered-tangent arch 1.45m wide and 1.09m high resting upon the timber tie beam at the level of

+0.92. The rectangular downwards continuation, which measures 1.45m wide and 1.82m high from the first stone step that is placed at the level of -1.00, forms the entrance to the prayer hall. The next opening the south side of which is recessed 0.12m in the continuation of the south wall of this hall is also composed of two parts. The above part is spanned by a two centered-tangent arch is 0.80m wide and 1.10m high. It rests upon the tie beam at the level of +0.62. The rectangular downwards continuation of this arch measures 0.80m wide and 1.10m high. Above these two arched openings there is another rectangle opening at the north corner of this hall. It measures 0.80m wide and 1.70m high providing access to the roof by means of stairs starting from the timber tie beam which is located at the level of +2.45. The bricks of 1958 intervention are used together with the original bricks on either sides of this staircase especially towards the opening to the roof. The north side of this access is recessed by 0.20m into the north wall. There is a timber lintel of 1.50m long at the upmost level of (+4.25) this access. By the reason of the damage in the staircase the definite number of the stairs can not be predicted. The doors opening to the entrance hall and to the roof (Figure 8) are missing. There is no access to this staircase from the ground. The brick arches of those two openings remain within the rubble zone. The remains of the original gypsum plaster are visible at the spandrils of the larger arch.

The south wall of this space has a one centered-tangent relieving arch of 2.25m wide and 1.70m high from the timber tie beam placed at the level of +1.45 (Figure 14). A small rectangular window of 0.42m wide and 0.75m high which is in a rectangular recesses s of 0.80m wide and 1.10m high is placed on this wall. This recess is located at the distance of 1.15m from the west corner deviating from the vertical axis of the arch towards the East. A second timber tie beam of 1.00m long is placed at the level of +0.80 to the West. The extension of rubble above the tie beam is around 0.50m. The window the bottom level of which is -0.80 serves as "hacet" window (arranged for the purpose of praying for the faith of the noble people who are believed to be buried in the tomb). Some remains of stalactites above and hardly recognized remains of the border reliefs of the original frame are placed around this recess. A very few and small pieces of glazed ceramic tiles are seen around the frame.

The interior face of the entrance arch on the east wall is same as the outer face having no dimensional change but it has no rectangular frame as the exterior face does (Figure 12). There is a timber tie beam, which is not seen from the exterior, placed at the level of +2.00 where the brick wall ends. A certain part of this wall, approximately 2.40m wide, makes a protrusion towards the entrance hall (Figure 3). The north wall of this space has no opening (Figure 13). But it is articulated into two parts by a timber tie beam that is placed at the level of +1.45. The rubble zone extends over the beam to the level of +2.35 whereat the brick masonry starts. A timber lintel is placed at the level of +4.25 as the continuation of the one placed at the west wall forming the upper frame of the roof access. This access makes a recess of 0.30m wide and 0.15m deep at this wall. The superstructure of this space is a segmental profiled cloister vault resting on a drum with a rectangular plan (at the approximate level of +4.40) made of bricks of three courses (Figure 11 and 13). The central zone of this vault is decorated with glazed ceramic tiles in turquoise and purple. Some of those glazed ceramic tiles are missing. The original floor cover is missing. The existing floor is earth.

b. The prayer hall: It has a square plan of 6.10m x 6.10m (Figure 3). The walls of this space are pierced by arched openings that have different dimensions as well as different profiles. They are also articulated by timber tie beams that are placed at different levels.

The west wall has a top window 1.00m wide and 1.44m high which is placed at the level of +2.62 (Figure 9). It remains within the transition zone composed of Turkish triangles that are converting the square plan to the circular plan of the dome and surrounding the whole space. The height of this zone is 1.45m. This wall is articulated by timber tie beams placed at the levels of +0.60m and +1.40 remaining within rubble masonry. The extension of rubble over the tie beams is around 0.90m. The traces of two windows with the shapes of deformed rectangles are noticed beneath the tie beam (at the average level of -0.60) at the either sides on this wall. The first one to the South is placed 1.10m from the south wall and the second is 0.35m from the north wall at the level of -0.55. They are both around 0.75m wide and 0.90m high. Some remains of mud plaster between the edges of the windows and rubble infill in them and the remains of the plaster of 1958 intervention with pinkish whitewash are seen at the bottom.

The south wall is also articulated by a timber tie beam that is placed at the level of +1.40. It is extended over by the rubble masonry till the level of +2.65 whereby the transition zone starts (Figure 6). This wall houses the "mihrap" niche (1.45m wide, 0.45m deep and placed at the level of -0.90) topped by a crowning arch and a stalactited half dome. This is then framed by a rectangular framework. The external width of the frame of the "mihrap" is 2.74m and it makes a 0.25m protrusion from the surface of this wall (Figure 3). The border on outermost rises to the starting level of Turkish triangles. The framework of the "mihrap" is composed of several borders and zones. The first border is made of hexagonal shaped glazed ceramic tiles in turquoise blue and triangular units in purple. The next border which is rather wider, around 0.20m, is composed of a geometric interlace delineated with gypsum in low reliefs with polygonal shaped glazed ceramic tiles in turquoise blue inserted in the openings between the crossing bands. The spandrils on both sides of the stalactited half dome are covered with square ceramic tiles glazed in turquoise blue. A rectangular panel placed horizontally above the stalactited half dome is covered with square tiles in purple. These zones are separated from each other by narrow borders, in fact bands, delineated with gypsum and covered with palmettos in low relief. The exterior face of the opening of the crowning arch has a stepped outline where the steps are corresponding to the rows of stalactites. Five rows of stalactites are complete but considerable parts of the lower rows together with the lower parts on either sides of the rectangular framework are missing.

A two-centered tangent arched recess, of 0.12m, is placed

The east wall has three openings and a recess. It is also divided into several horizontal zones by timber tie beams (Figure 10). The first window opening to the "türbe" is placed on the south of this wall, the wall is again divided into two parts by the tie beam at the level of +0.65. The upper section is spanned by a two centered-tangent arch 0.80m wide and 1.08m high from the beam. The lower rectangular section is 0.80m wide and 1.10m high placed at the level of -0.60. The other two openings placed at the same wall have been described in the interior description of the west wall of the entrance hall. The arched recess on this wall is placed at the same level of the one which is located above the "mihrap", has the same profile and dimensions. At this wall use of brick and rubble are more diversified. If compared with the other walls, it is seen that some parts are resembling patchwork. The arches, of brick, of all openings are resting on brick layers but they remain within rubble zone. Some remains of original gypsum plaster are observed at the inner faces of the windows that are placed at the lower parts.

Excluding the recess which is framing the top window, the openings on the north wall of this space have the same profile and dimensions of the openings of the exterior face of the same wall as explained in the description of the exterior of the north wall. These two openings are also placed at the central axis of this space as well as others (Figure 13). A rectangular recess of 0.17m is placed at the east part with the dimensions of 1.70m wide and 2.20m high. It remains below a beam of 1.25m long which is placed at the level of +1.05. The segmented arch (of brick) rests on the partial brick layers but remaining within rubble zone. The extension of rubble zone above the tie beam which is placed at the level of +1.40 is around 1.00m.

The superstructure of this space is of a hemispherical (at the lower part)-conical (at the upper part) dome with a diameter of 6.00m and it is stilted about 0.15m (Figure 13). It rests upon a band of sixteen sided polygon 0.30m thick whereat the transition zone ends. The conical part of the dome is cut by a flat circular planned roundel with a diameter of 0.95m decorated with glazed ceramic tiles. The finds during the last excavations proved that the original flooring material is brick. The existing floor is earth.

c. The "türbe": It has a square plan measuring 3.30m x 3.30m (Figure 3). This space is also articulated by timber tie beams at different levels and pierced by openings. It is formed of four niches, all spanned by one centered-tangent arches that are recessed 0.30m. They have almost same dimensions and profiles. The first niche, 2.31m wide and 3.10m high from the existing ground, is placed at the west wall (Figure 11). It houses the window opening to the prayer hall. This window is placed at the distance of 0.74m from the south face of the same niche and 0.77m from the north face. Other features of this opening have been given in detail in the description of the east wall of the prayer hall. There are two beams articulating this wall. The first one placed at the level of +0.65 divides the window. The either sides of this opening above the first beam is of brick on which the arch of this opening rests on. The arch itself remains in rubble zone 0.60m high. Thereafter brick zone starts. This zone is divided by a tie beam which is placed at the level of +2.44. This beam remains within the arch of the niche

(Figure 11).

The south niche has no opening (Figure 16). A single beam divides it into two. Rubble face extends 0.60m above this beam. The caves in which the acoustic pitchers were inserted are placed at the level of +2.25.

The niche on the north wall has a rectangular opening which is "hacet window" 0.48m wide and 0.8m high at the distance of 1.23m from the west face while 0.60m from the east face of the niche (Figure 15).

The niche on the east wall 2.30m wide and 3.16m high has an opening, the all characteristics of which were given in the description of the exterior of the east facade is placed above a tie beam at the level of +0.75. A rectangular recess, in fact, an opening but filled with brick, 1.00m wide and 1.50m high placed below the same beam. Two other beams are placed on either sides of this arch (at the level of +1.50). The lower parts of this brick arch remains within the rubble zone (Figure 4). The superstructure of this space is a hemispherical dome with a diameter of 2.45m. It is stilted 0.15m and it rests upon a twelve sided polygonal drum 0.15m thick where the Turkish triangle zone ends. The vertical height of this transition zone is 1.00m (Figure 11 and 15). The bricks of 1958 intervention together with original bricks are perceived in the layers towards the center of the dome.

3.3 Construction and Materials

The structural scheme of the building is basically composed of; two domes and a vault that form the superstructure, and entirely load bearing walls on which this superstructure rests upon. The loads of the superstructure are imposed to the walls by the use of Turkish triangles in the prayer hall and the "türbe", while the vault of the entrance hall directly rests upon the walls. All openings are spanned by arches with different dimensions and profiles.

Within this structural scheme the building can be analyzed under the headings of walls and superstructure. Because of the concrete application on the entire surfaces of ground the foundations of the "mescid" could not be examined. Therefore all information abou the foundations are to be given in restitution scheme in Chapter VII basing upon the results of the excavations carried out by Vakıflar indicated on their drawings.

a. Walls: What is meant by walls is, the entire vertical surfaces of the building, rising above the ground level up to the edge of the roof at the exterior. And in the interior, from the ground level till the starting level of the superstructure in which the transition zones of Turkish triangle take place. The walls show some different characteristics like order and material on their exteriors as well as interiors. For this reason they will be analyzed under two headings, as exterior and interior.

Exterior: The walls are articulated into two parts by the timber tie beams (consist of six or seven rows corresponding to the thickness of the walls that they pass through) that are running throughout the exterior and most parts of the interior at the average level of 1.40m (Figures 9, 13 and 14). The lower parts of the exterior is of two kinds of stone; random rubble of andesite on the west and south facades and finely cut blocks of travertine on the east and north facades. Some cut stones are also used on the west and south facades but limited only to their corners. Some of those cut stones are travertine, especially on the north-west and south-east corners, but mostly andesite. The thickness of the timber tie beams varies between 0.12m and 0.18m. The material of all other parts above the timber tie beams is brick. The level of this division into stone and brick is strictly persisted on the east and north facades. On the west and south facades, however, the rubble masonry extends 0.90m above the continuous tie beam. Therefore the brick layers on these facades rest directly upon the rubble masonry instead of tie beams. A second tie beam 0.74m below the continuous one is placed at the north of the west facade. The length of this tie beam which is not running throughout the facade is 5.00m (Figure 6). Four or five random layers of rubble stones on the upper levels of the north and west facades which remain within the brick zone of the upper structure should also be mentioned here. They give the impression of belonging to the replacements of a later intervention in the past.

Interior: The articulation into stone and brick by tie beams is more diversified in the interior comparing with the exterior. The lower half of the upper structure (below the continuous tie beam) is entirely rubble of andesite. There is no cut stone face except a few on the inner faces (south and north) of the east wall of the entrance hall that are the mere extensions of the exterior masonry of the same wall. The repetition of the tie beams even on the same walls in addition to the continuous one are frequently met in all spaces. The continuous tie beam does not exist only on the east and west sides of the transverse wall of the prayer hall that separates the prayer hall from the entrance hall and the "türbe". Three other beams are placed at the levels of 0.65m, 0.95m and 2.42m instead of the continuous beam on both sides of this wall. The two of them divide the two windows and the entrance opening to the prayer hall which are placed on this wall. The third beam is placed above the two remaining within the brick zone of the upper parts. There are some other additional tie beams, in the prayer hall; at the east of the north wall 0.40m below the continuous one passing over the recess with the length of 1.10m and on the west wall 0.75m below the continuous tie beam, in the entrance hall; at the west of the south wall 0.65m below the continuous beam with the length of 1.00m and on the east wall dividing the entrance opening at the level of 2.00m where the brick infill ends, and in the "türbe"; at the north wall 0.65m below the continuous beam and on the east wall 0.75m below the continuous beam.

The use of brick has a special importance for Tahir ile Zühre. More than half of the building is comprised of brick with varying arrangements. Whole brick (21.5x21.5x4cm), half brick (11x21.5x4cm) and quarter brick (4x4x4cm) are the brick units of unglazed type utilized throughout the all surveyed parts of the structure.

Horizontal brickbond is the technique employed throughout the layout of the upper half of the upper structure. In this bond the whole bricks are set horizontally staggered half a brick length in successive courses with the 3cm of bed joints a nd 2cm of rising joints that are recessed by 0.5-1cm. Only Turkish triangles are the exceptions to this staggering process. The staggering length is varying due to the limitation by the triangular frame of the faces. Half brick however, is utilized as headers at the corners and as stretcher only at the spandrils of the exterior face of the main entrance arch which is placed in a rectangular recess (Figure 4).

The arches in this part are also made of brick. The thickness of the largest arches, such as the main entrance arch, the arches of the niches of the "türbe" are composed of one and a half brick units staggered half a brick length within their frames with varying width of joints from 1cm (at the intrados) to 4cm (at the extrados). The rest employed in the other openings are all smaller arches the thickness of which are one unit brick.

c. Superstructure: The superstructure of the building is analyzed according to the spaces they span, that is due to the diversities in its interior comparing with its exterior similar to the upper parts of the walls.

Exterior: The original technique, construction and insulation materials of the flat parts of the roof could not be detected since the entire surfaces of those parts were leveled with concrete. The dome of the "türbe" is also plastered but still enabling us to define the technique through locally flaked parts of the plaster around its skirt. But the technique employed in this dome is not the original one referring the dimensions of the bricks (9x19x6cm) which form the external layers as well as internal ones. Therefore, the main emphasis had to be focused on the main dome of the prayer hall which is still possessing its original properties. Since there is no plaster on this dome the technique of brick laying is clearly visible in spite of the severe damage on the courses (Figure 8). The units of whole bricks of the surface courses are horizontally laid but in the vertical section inclined towards the center of the dome like the voussoirs of any arch having the same angle with the spurs placed around. A permanent half a brick staggering process could not be established in the courses because of the reduction of the diameter from the edge towards the center in the successive courses as the nature of the geometry of the dome. In some parts however half bricks are also utilized but as mere balancing units.

Interior: The interior of the superstructure of the "mescid" can be examined under three part each of which are surmounting three different spaces.

The geometrical outline of the interior of the superstructure of the prayer hall is given previously. The surface of the dome is perfectly organized employing horizontal and vertical brickbonds placed diagonally with slight curves, by obtaining a zigzag pattern which is composed of eleven courses of half bricks of eight pointed, star-shaped leaves and horizontal courses of whole, half, quarter bricks and the bricks of three quarters length in between (Figure 17). Those star-shaped leaves are getting larger from the roundel towards the skirts although the number of half bricks forming the leaves increases, however, the general process does not change. One quarter brick staggering technique is applied throughout the entire layout of the brick pattern of the interior face of this dome. The roundel of the dome is surrounded by two courses of half a brick and a band of glazed ceramic tiles in turquoise with the same dimensions in between and glazed ceramic tiles in purple with the dimensions of a quarter brick are placed diagonally between each units of the ceramic tiles of this middle band. Following this border a course of glazed ceramic tiles in purple with the dimensions of half bricks again surrounds the remaining portion of the roundel in which the names of four Khalifs of Islam, Ebubekir, Ömer, Osman and Ali together with Mohammed are written in "Kufic" style (the inscription technique of the Seljuks) by the use of glazed ceramic tiles in turquoise (Konyalı, 1964: 517).

The surface of the vault of is the entrance hall composed of rhombuses enlargening from the center towards the edges. Each of those rhombuses are obtained by the application of vertical and horizontal brickbonds in successive courses of whole bricks. The first two rhombuses of at the center are made of glazed ceramic tiles in turquoise and purple with the dimensions of whole, half and quarter bricks. The entire pattern of the composition is obtained by the process of a quarter brick staggering.

The interior of the superstructure of the dome of the "türbe" has no specific pattern on the contrary of the dome of the prayer hall and the vault of the entrance hall. The horizontal brickbonds made of whole bricks have been applied at this dome. The upper parts towards the center are of obviously different type of bricks probably the production of the 1950's referring their dimensions.

3.4 Condition of the Structure

The building has no visible structural problem except for a few minor cracks at the east and west parts of the interior of the main dome and the upper part of the exterior of the entrance arch (near by the apex). They are mere mortar discharges due to the water penetration from the roof other than being structural cracks since they are not continuous (Eldrige, 1976). But, the material loss observed as missing bricks and wide range of mortar discharges on the main dome and the upper parts of the exterior faces of the walls, mortar discharges at the lower levels of the rubble parts of exterior and interior of the walls are the existing problems. Since the building has intensive rising damp and rain penetration problems as well as salt decay and decay due to growth of plants, the material loss will continue and result in serious structural problems in the future.

3.5 Condition of the Fabric

In this part, missing materials together with weathering forms of the existing materials are described defining the scope and content of the intervention criteria for the actual restoration work and for the long term observation of the weathering state of the building.

The main problems of the building appear to be dampness and interrelated salt decay.

The dampness problem is visually observed as rising damp affecting all the walls up too approximately two meters height and rain penetration which is affected the domes ant the vault and the upper parts of the wall at the entrance hall. All the damp areas suffer from salt decay which is seen as a severe problem of historic brickwork in the domes and vault as well as in the walls.

Detailed description of the decay in fabric which is the result of visual observations, can be done as follows;

Soiling which is dirt deposits on the surfaces as soot and dust are observed throughout the surfaces of all travertines and particularly on the interior brick surfaces at the dome and vault and on all exterior brick surfaces. Soiling is also observed at the lower parts of the exterior surfaces of andesites, more intense at the south and west facades. Loss of material is observed on interior parts of andesites especially intense on the south wall of the "türbe", eastern part of the south wall of the prayer hall and the north wall of the entrance hall. In addition to these, mortar discharges are observed in the lower parts of andesite zone especially intense where loss of material and salt deposit are found.

Weathering forms of loss of material and soiling are common to all exterior surfaces of bricks especially intense on the south and west facades. On the roof, however, colonization of plants on the layers of bricks are observed in addition to loss of material and soiling. Salt deposits are intensely spread over the brick surfaces of the main dome and the entrance vault. Besides those places they are also observed in the areas where loss of material has been detected.

Loss of material and soiling are observed on the glazed ceramic tiles of the "mihrap", the vault of the entrance hall, roundel of the main dome, the portal, "hacet" window of the "türbe" and exterior face of the "türbe" window. Loss of material is especially dense on the entrance vault and "türbe" window.

3.6 Evaluation of the Present State

The existing traces show that the "mescid" has not undergone wide range of alterations in terms of spatial layout but a few minor changes. Those changes can be grouped as replacements, substitutions, additions and extractions.

Replacements: They are seen on the upper parts of the exterior faces of walls giving the impression of being later repairs with the original bricks and noticed by their irregular joints on the contrary of the lower courses of the brick masonry.

Substitutions: They are different materials in their kinds and substituted with the original materials for the purpose of completion of the missing parts. They are seen on the upper parts of the north and west facades as a few courses of random rubble, the courses of new bricks (differed from the others by their different dimensions) on the upper parts of the east facade (together with the original bricks), on the upper parts of the dome of the "türbe" and leveling concrete on the flat parts of the roof and "türbe" floor.

Additions: They are new bricks of 1958, used together with the original bricks but as latter additions like infill in the rectangular continuation of the arched "türbe" window and southern part of the portal protrusion.

Extractions: The traces of windows that are recognized by the remains of mud plaster on the edges and rubble infill in them gives the impression of being opened in a latter period and filled with rubble with cement mortar, in another period. Their deformed rectangular shapes and the application of mud plaster (thinking that gypsum was the only rendering material used in the building).

1. Tahir ile Zühre
2. Hoca Hasan
3. Beyhekim
4. Zevle Sultan
5. Abdülmümin
6. Abdülaziz
7. Sakahane
8. Başarabey
9. Terceman
10. İçkaraaslan
11. Sırçalı
12. Zenburi
13. Bulgurdede
14. Erdemşah
15. Hacı Ferruh
17. Karatay
18. Hoca Fakih
19. Halkabegüş

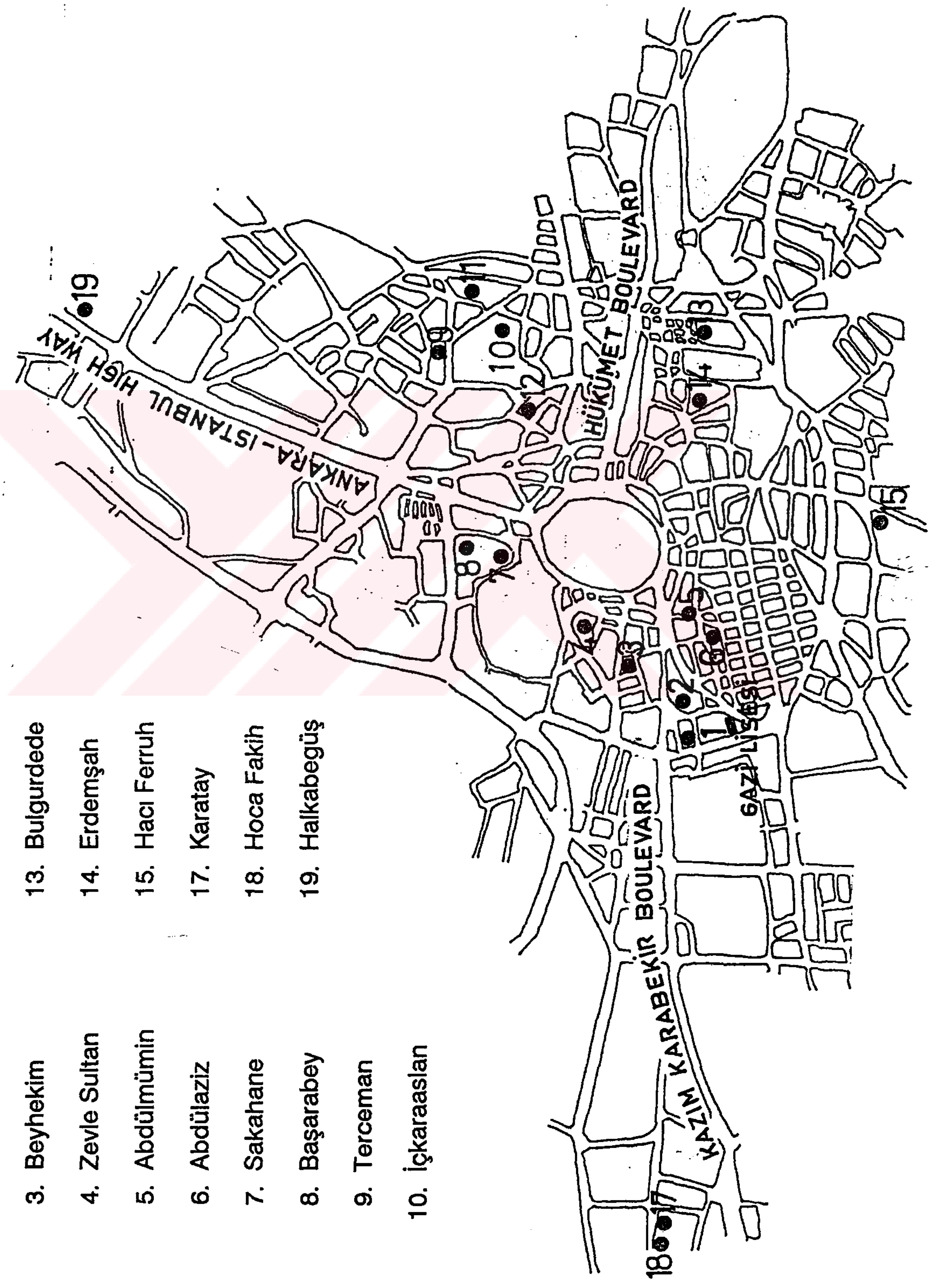

Figure 1. Konya Map

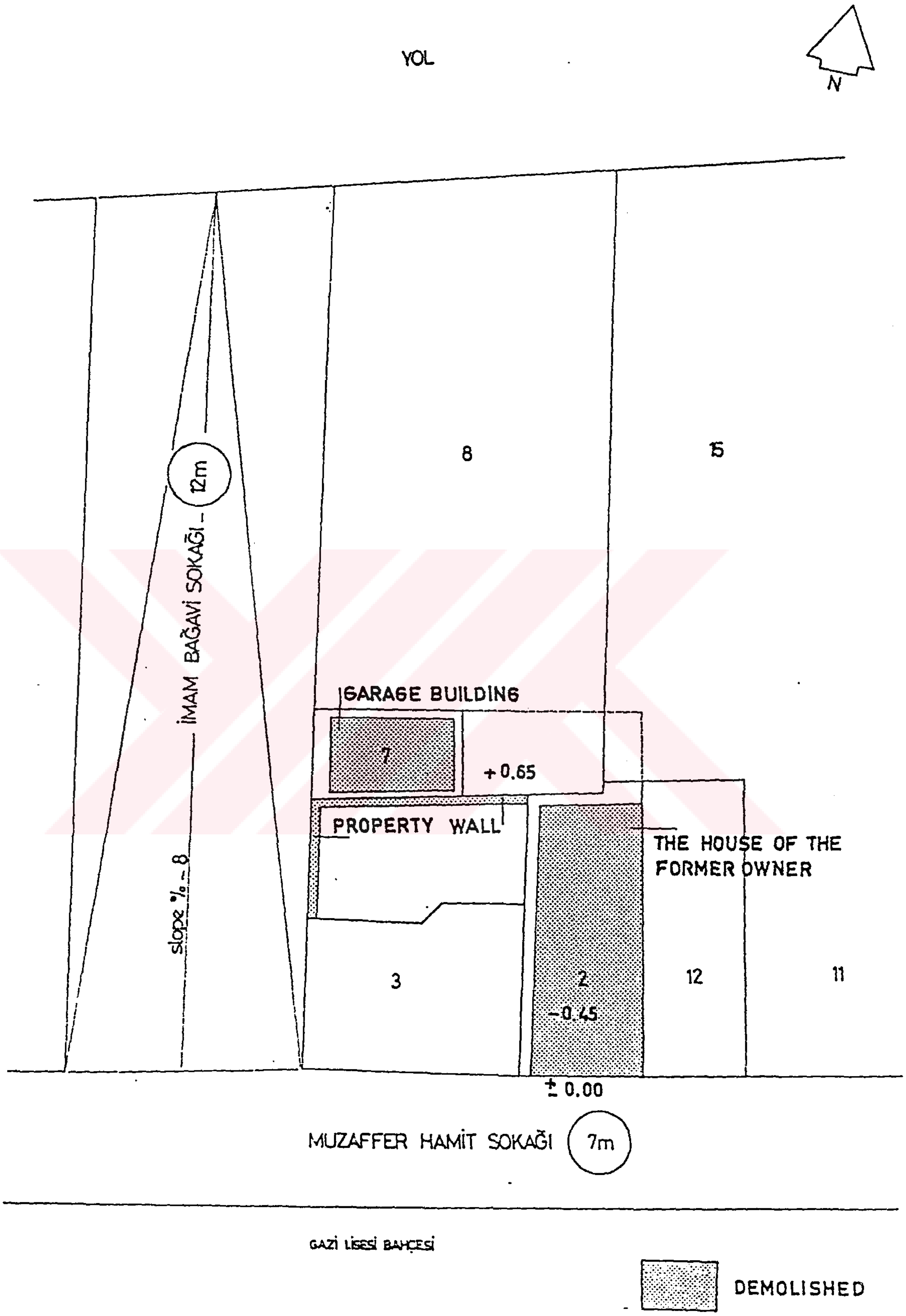

Figure 2. Site Plan

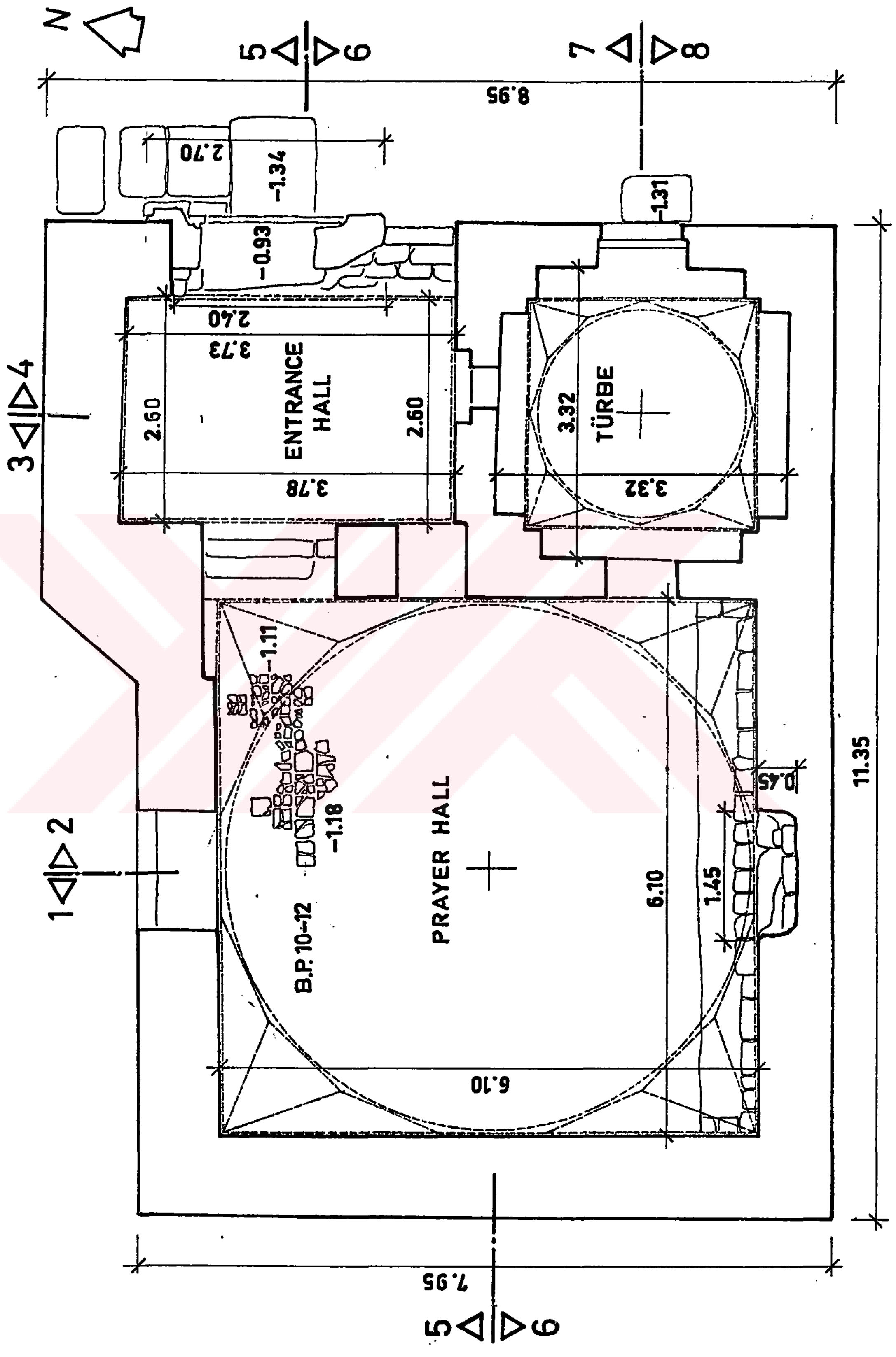

Figure 3. Plan

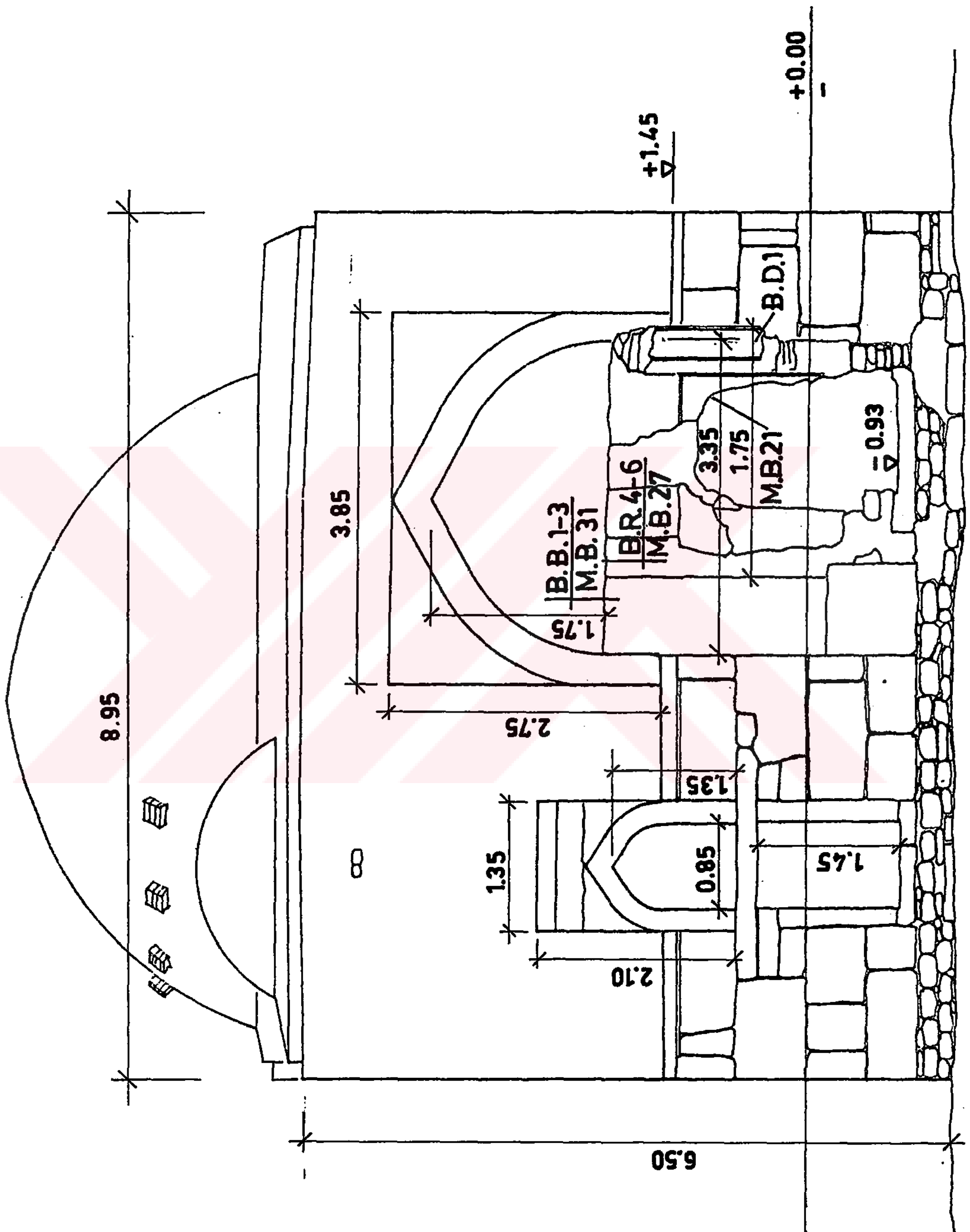

Figure 4. East Facade

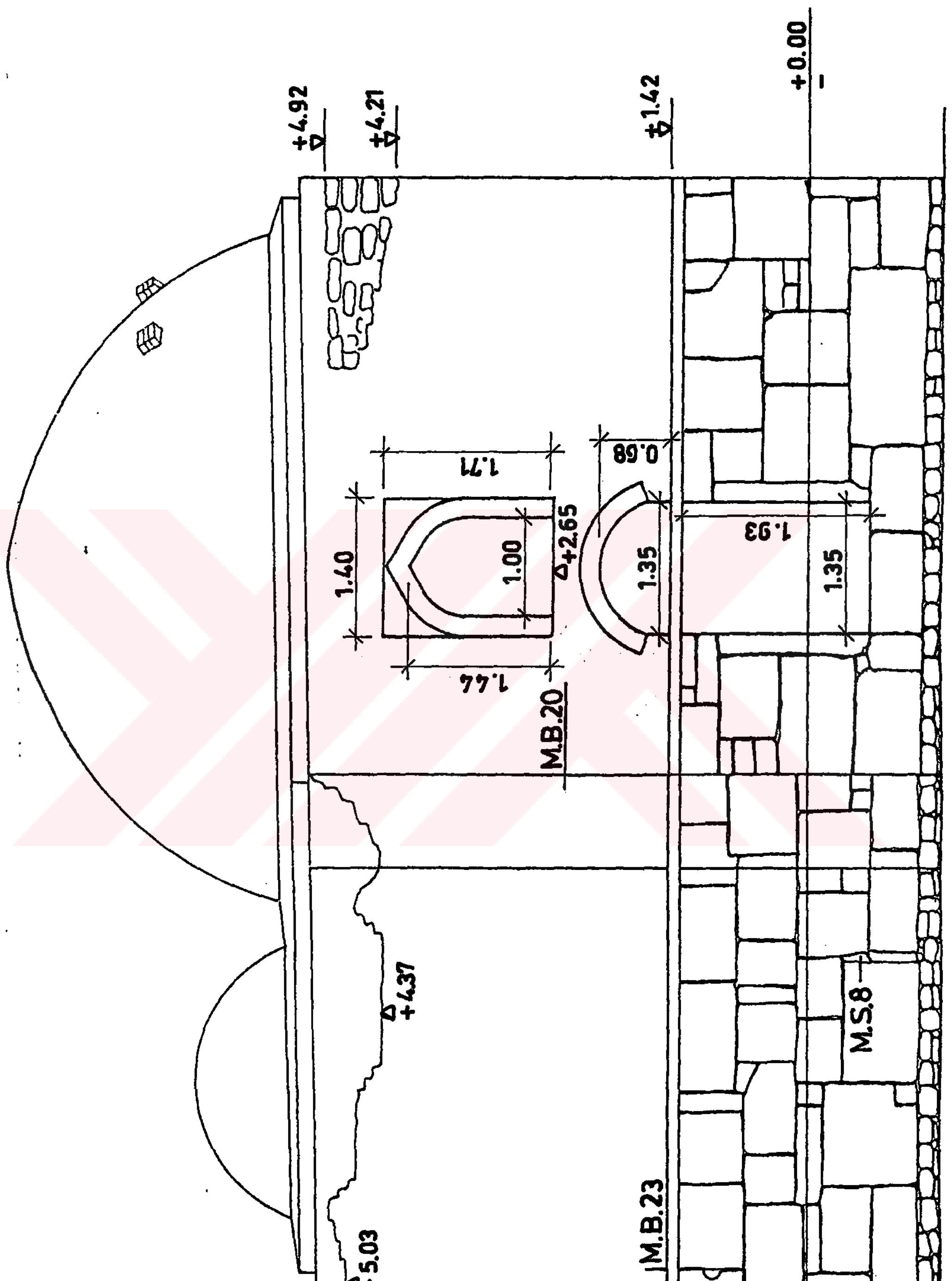

Figure 5. North Facade

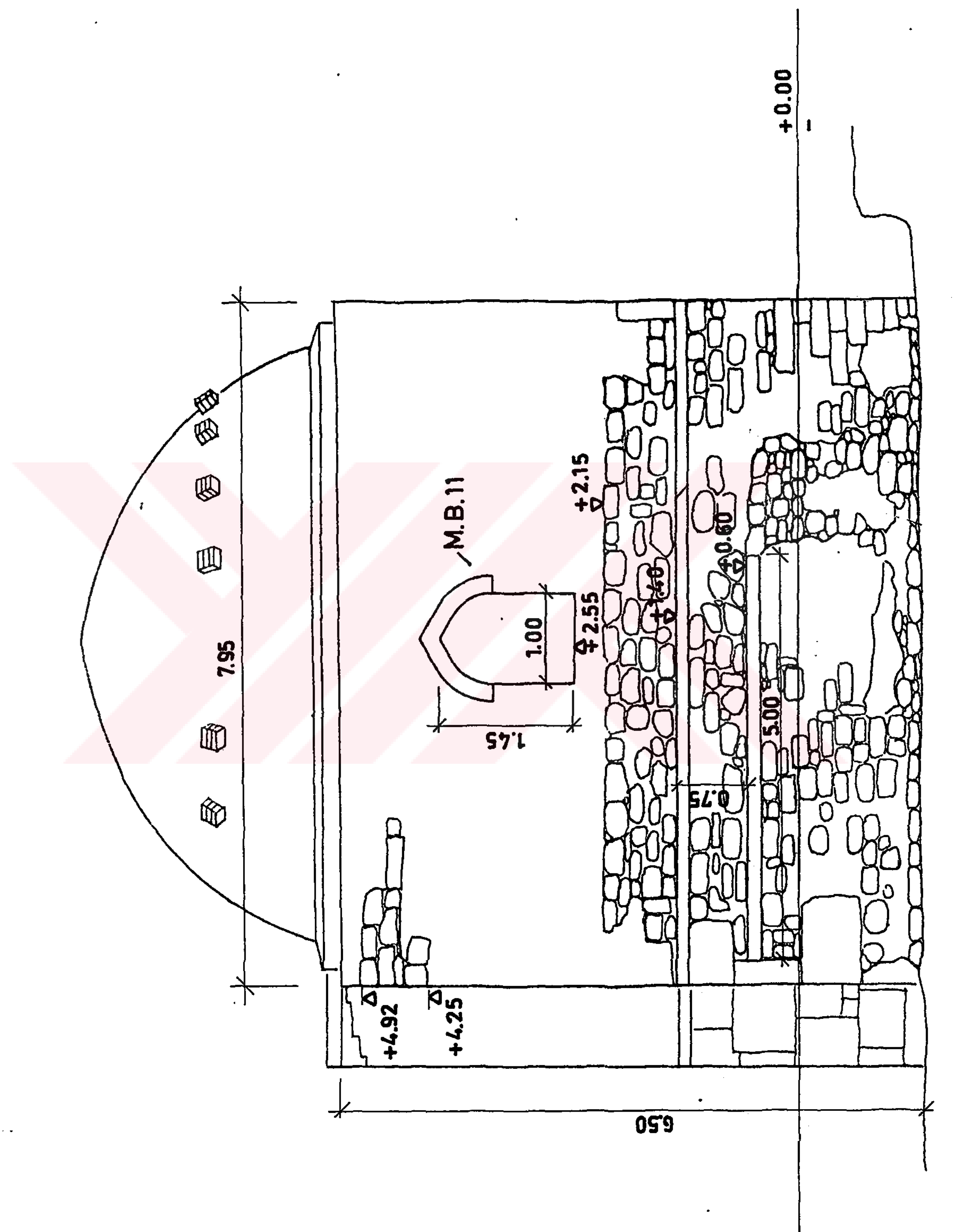

Figure 6. West Facade

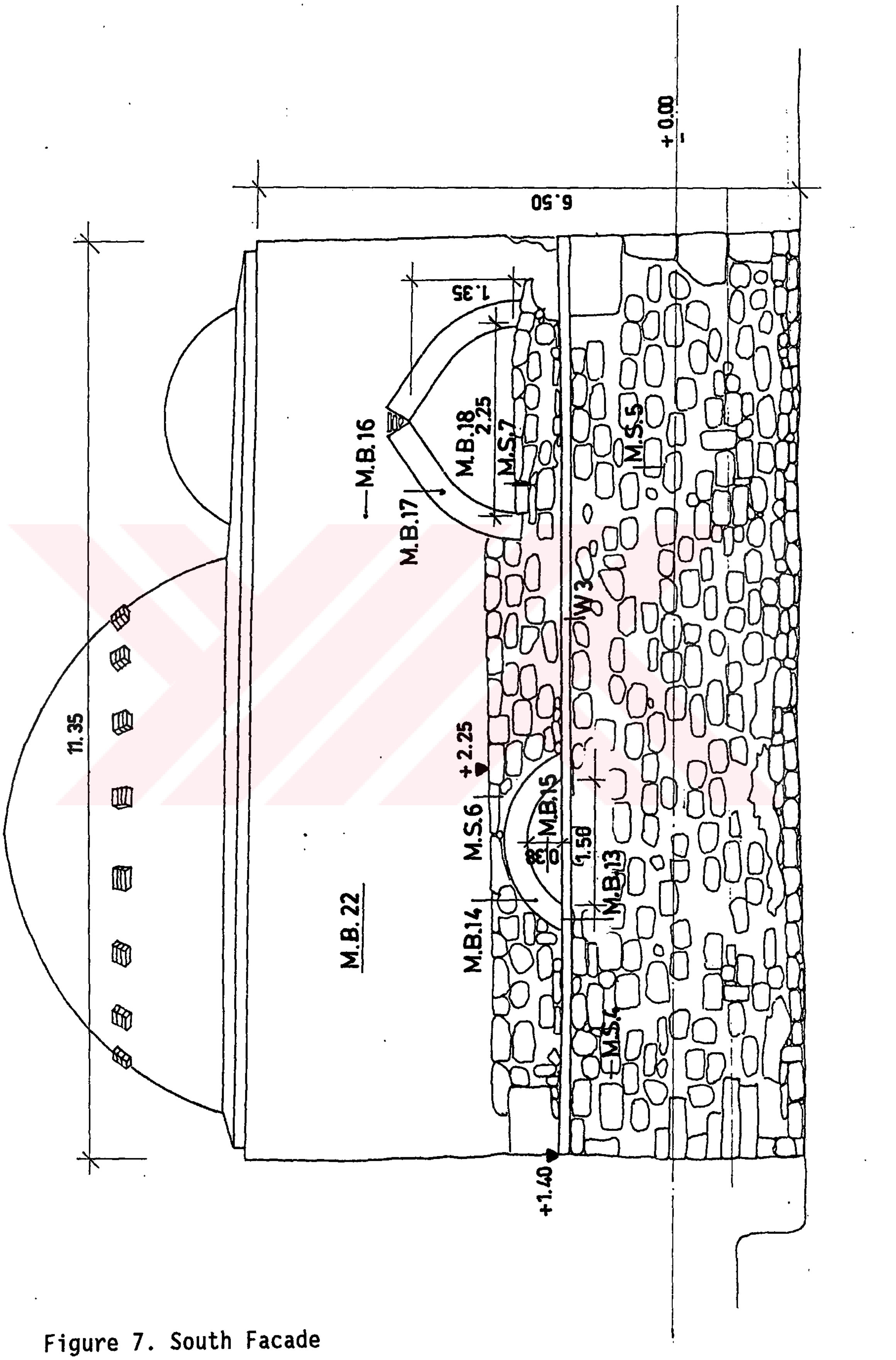

Figure 7. South Facade

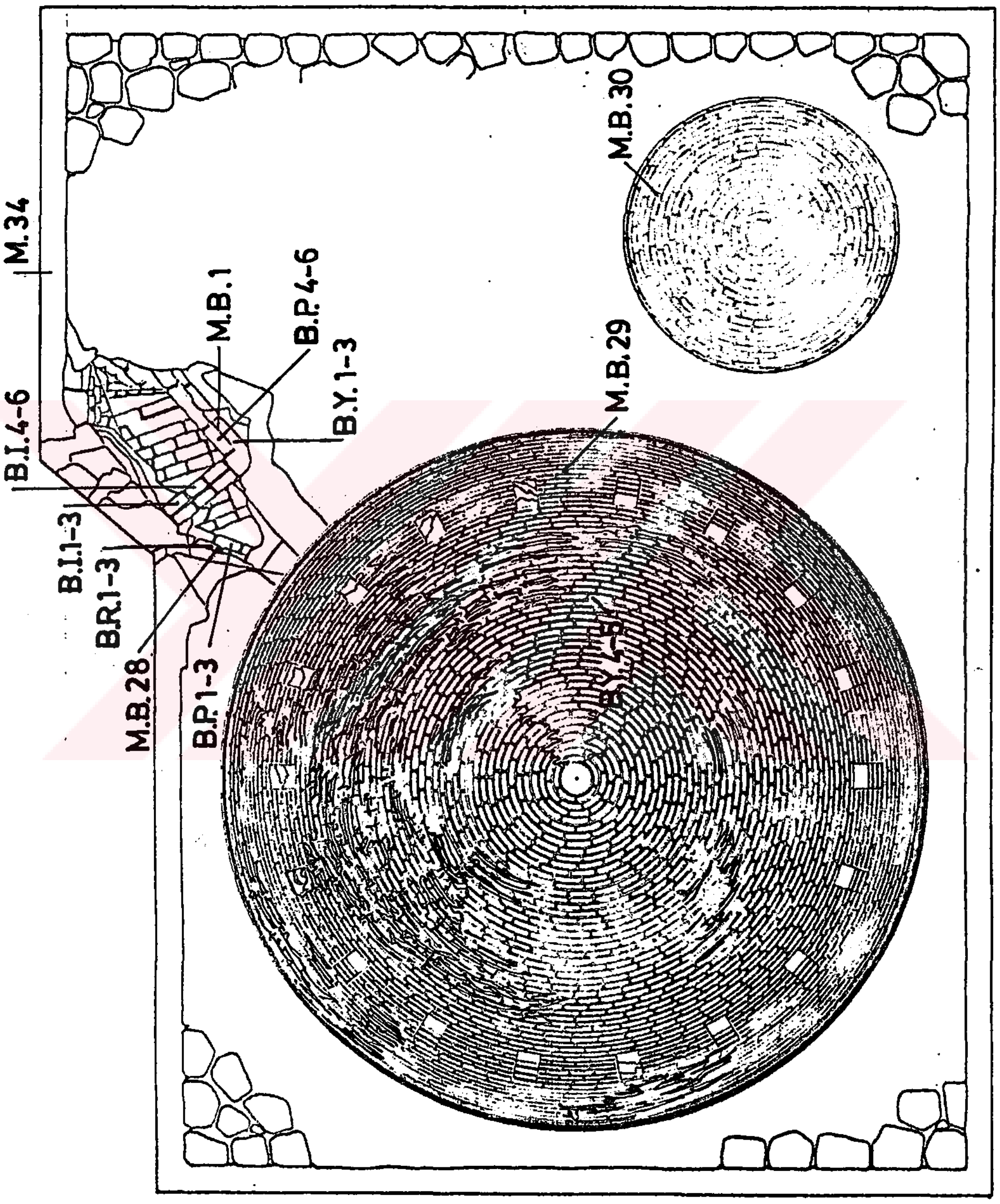

Figure 8. Roof Plan

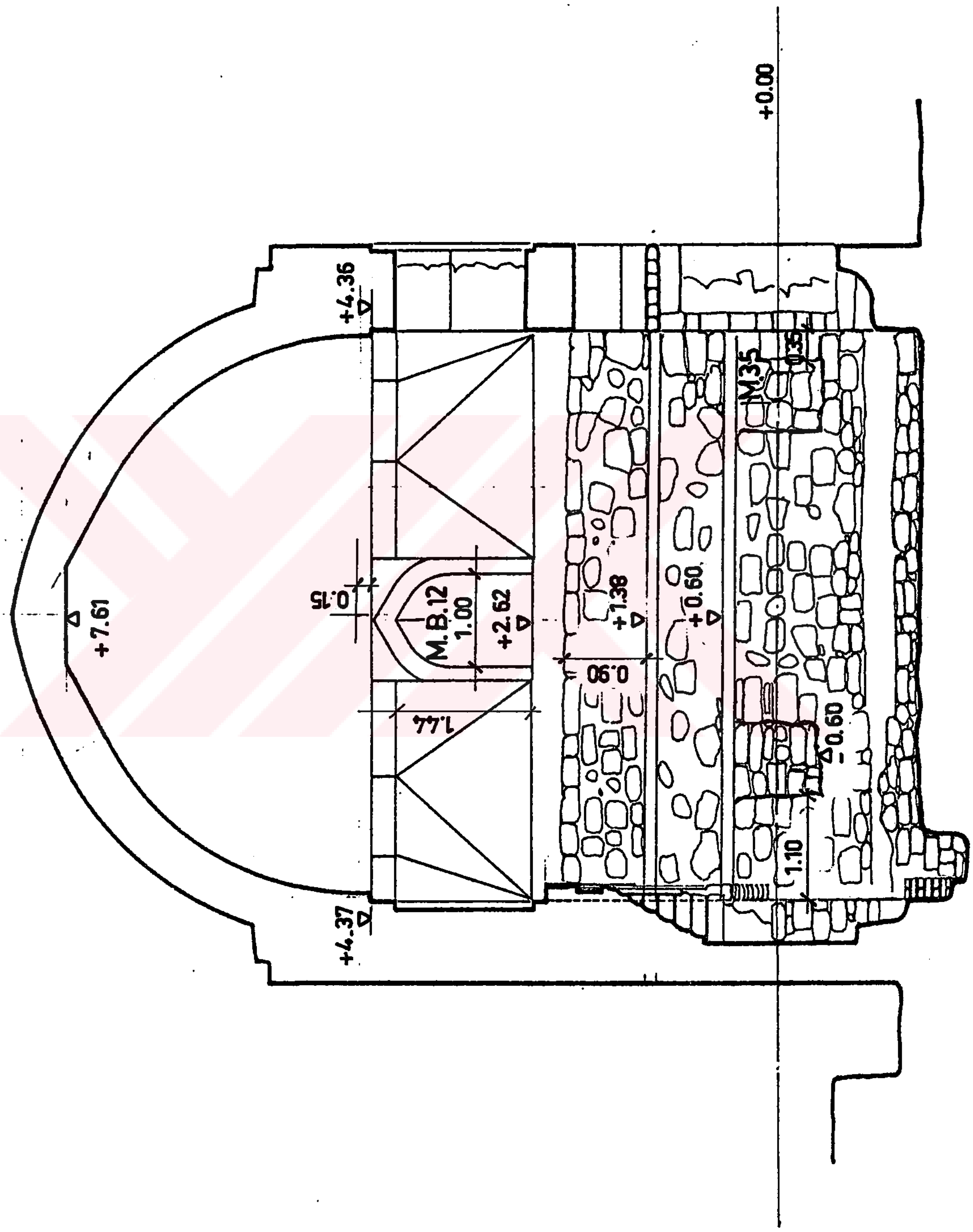

Figure 9. Section 1-1

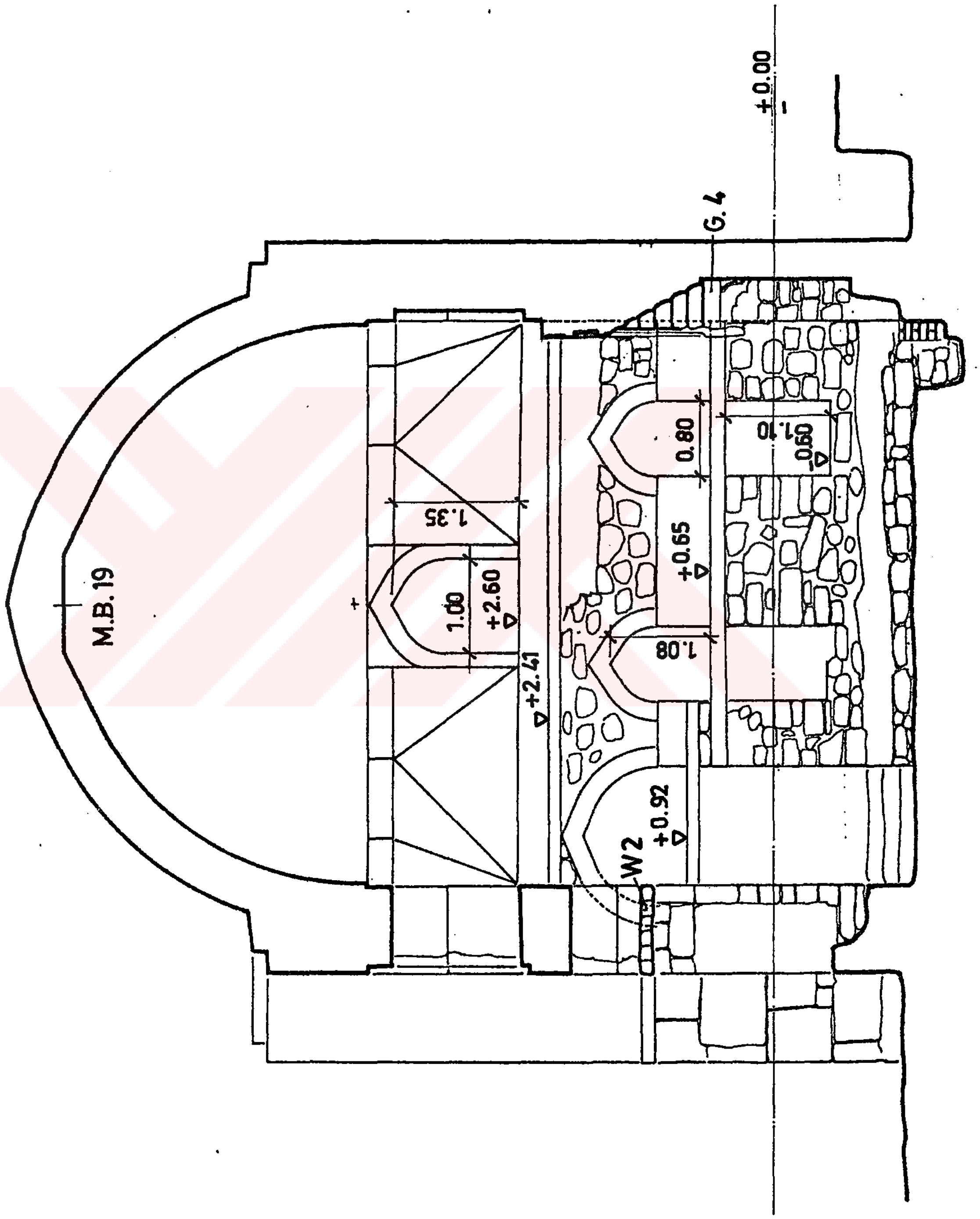

Figure 10. Section 2-2

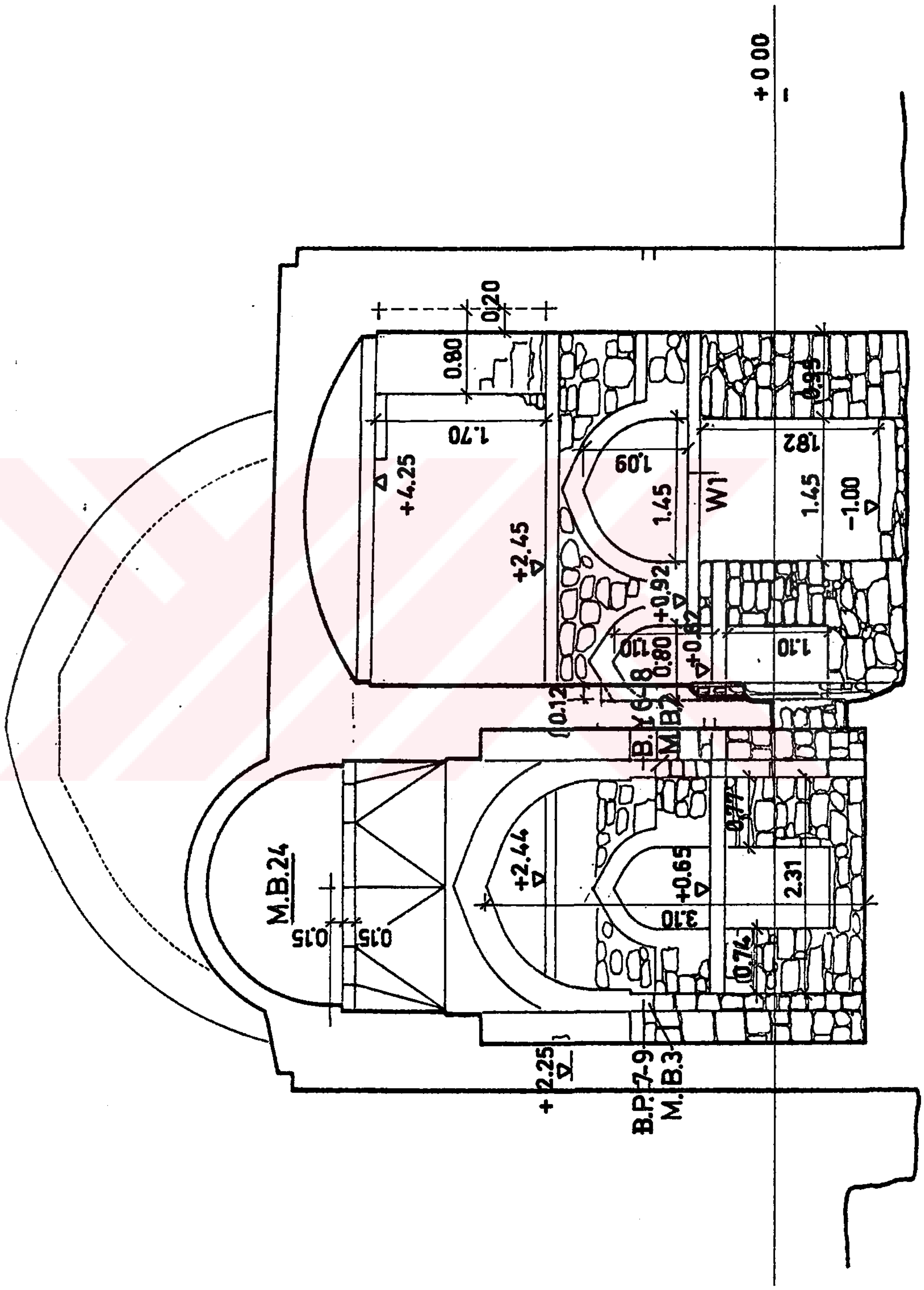

Figure 11. Section 3-3

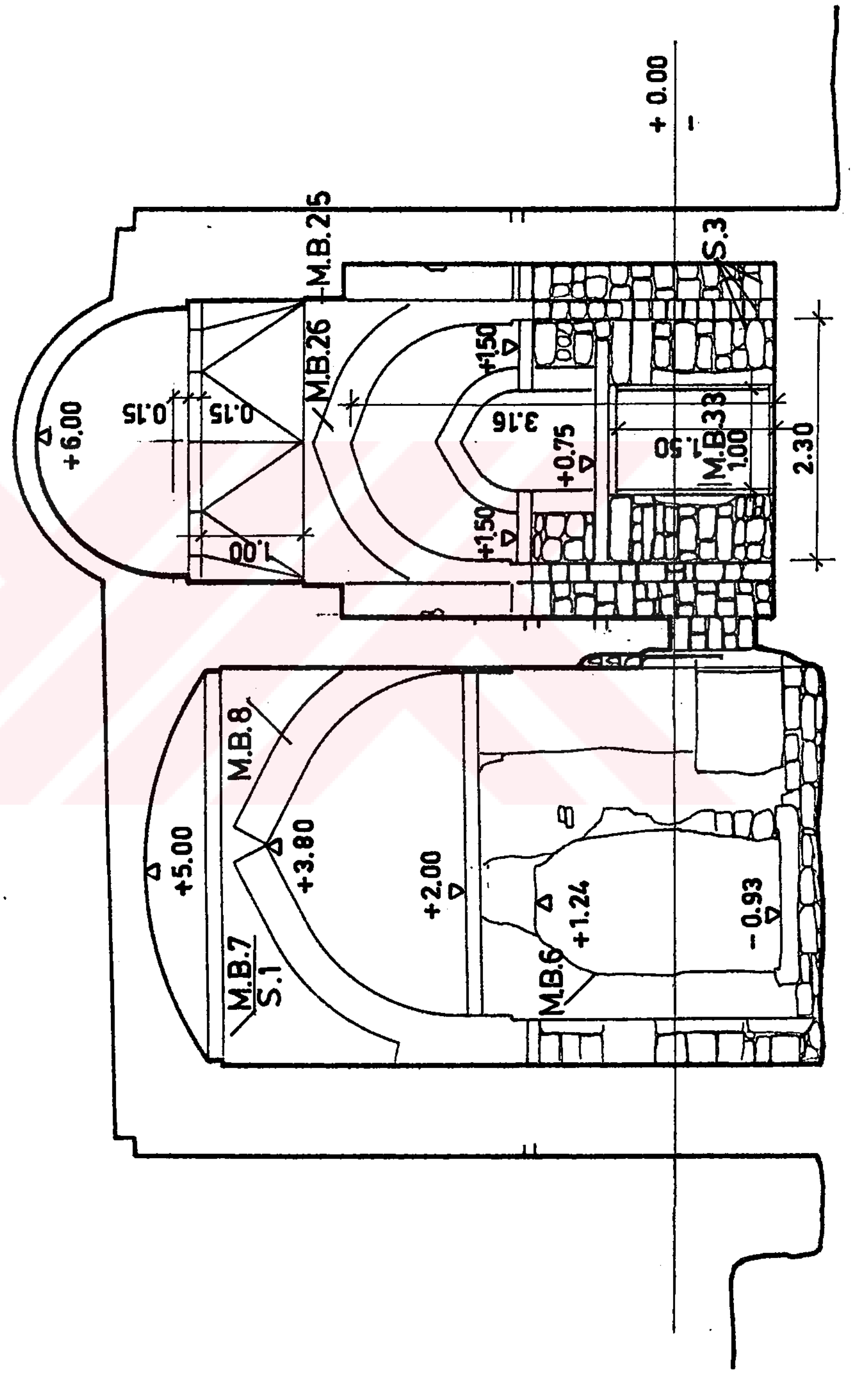

Figure 12. Section 4-4

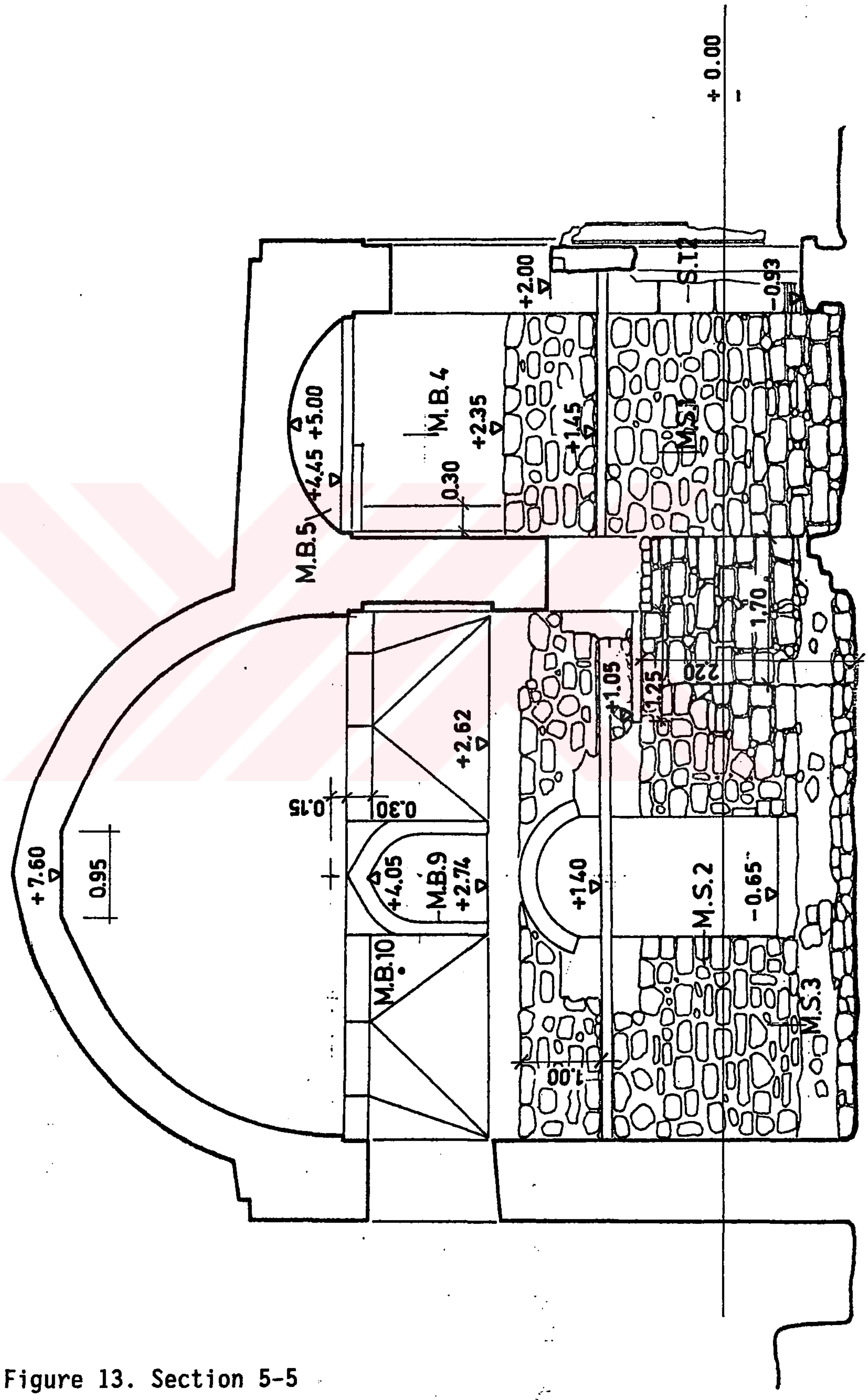

Figure 13. Section 5-5

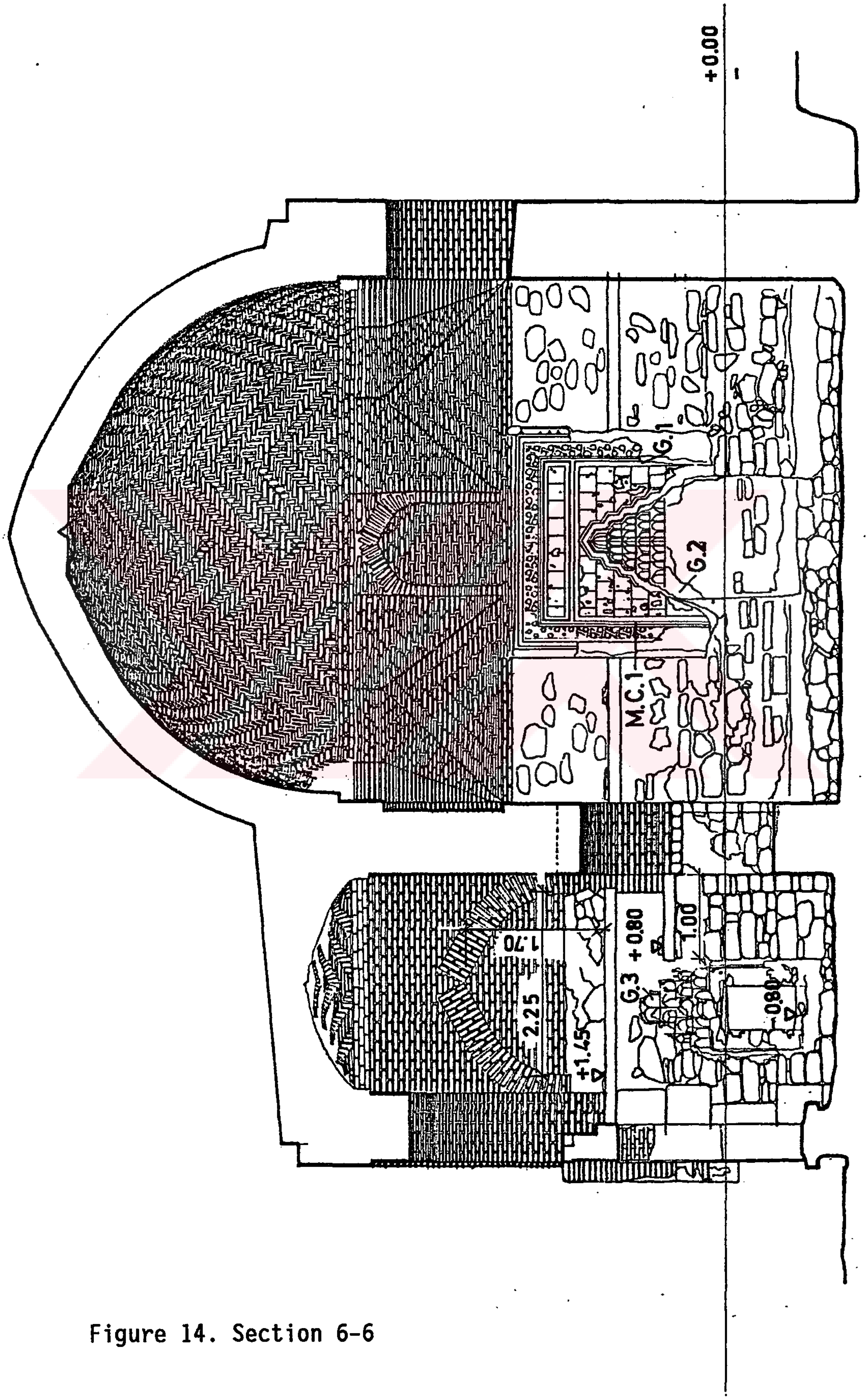

Figure 14. Section 6-6

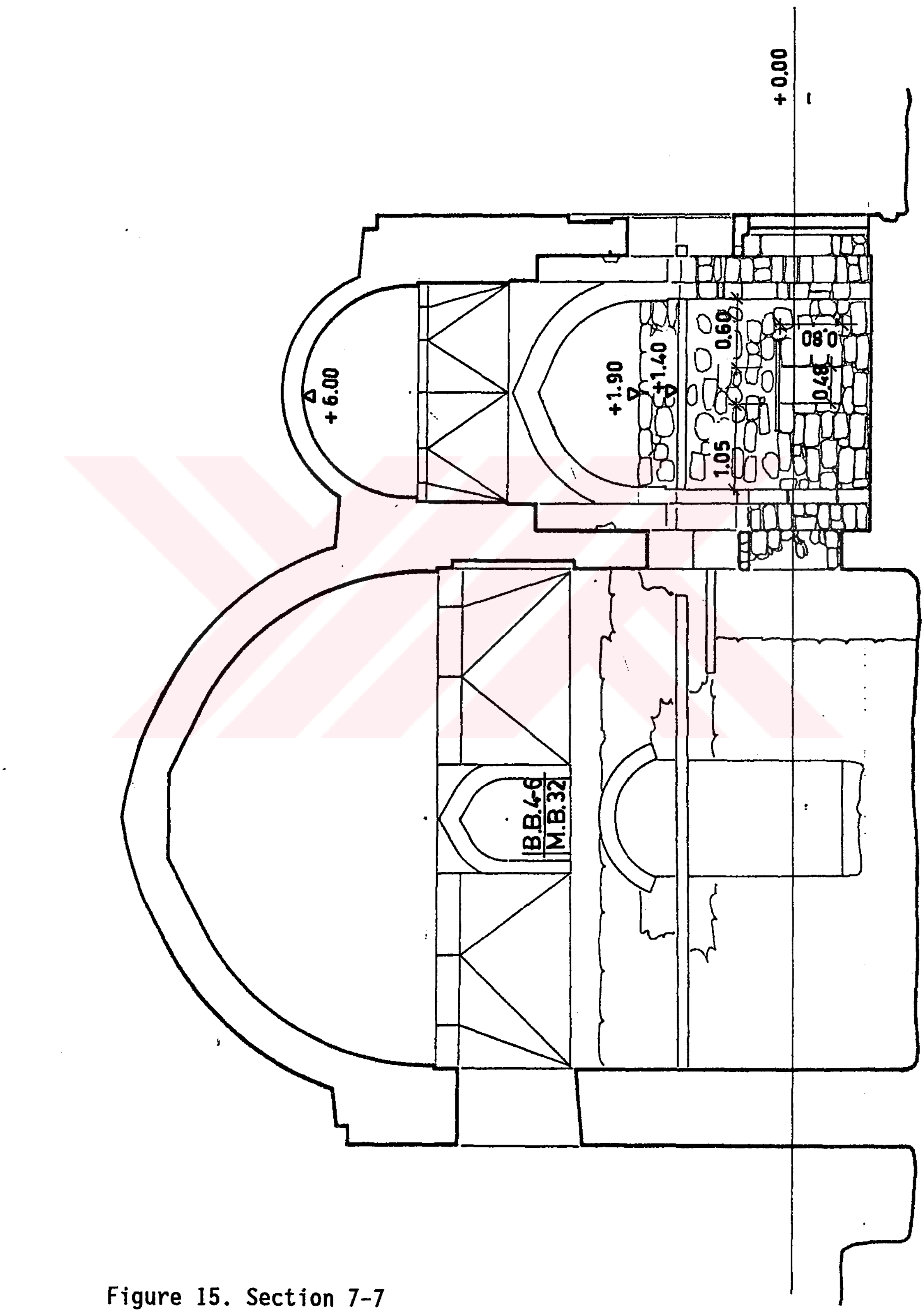

Figure 15. Section 7-7

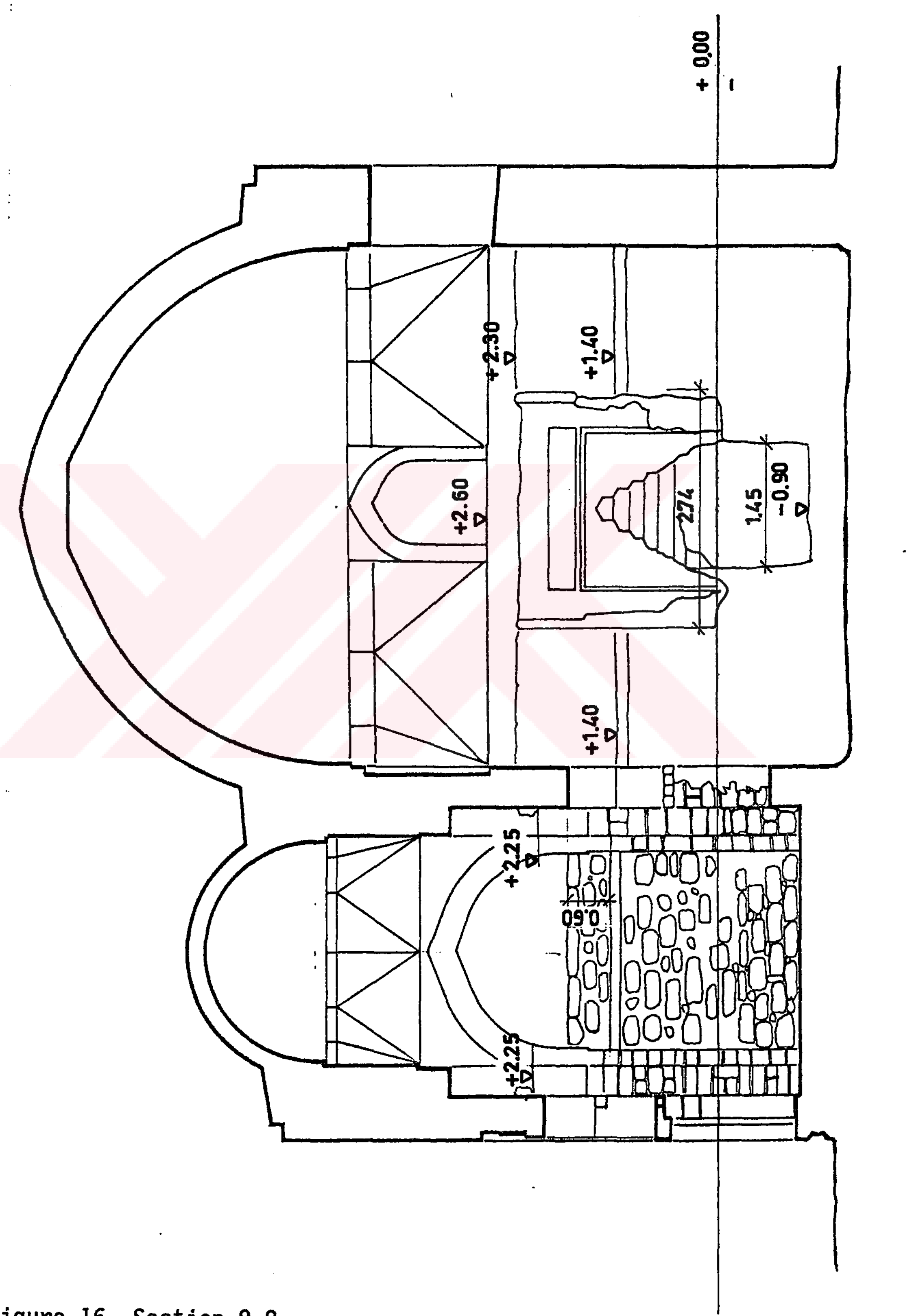

Figure 16. Section 8-8

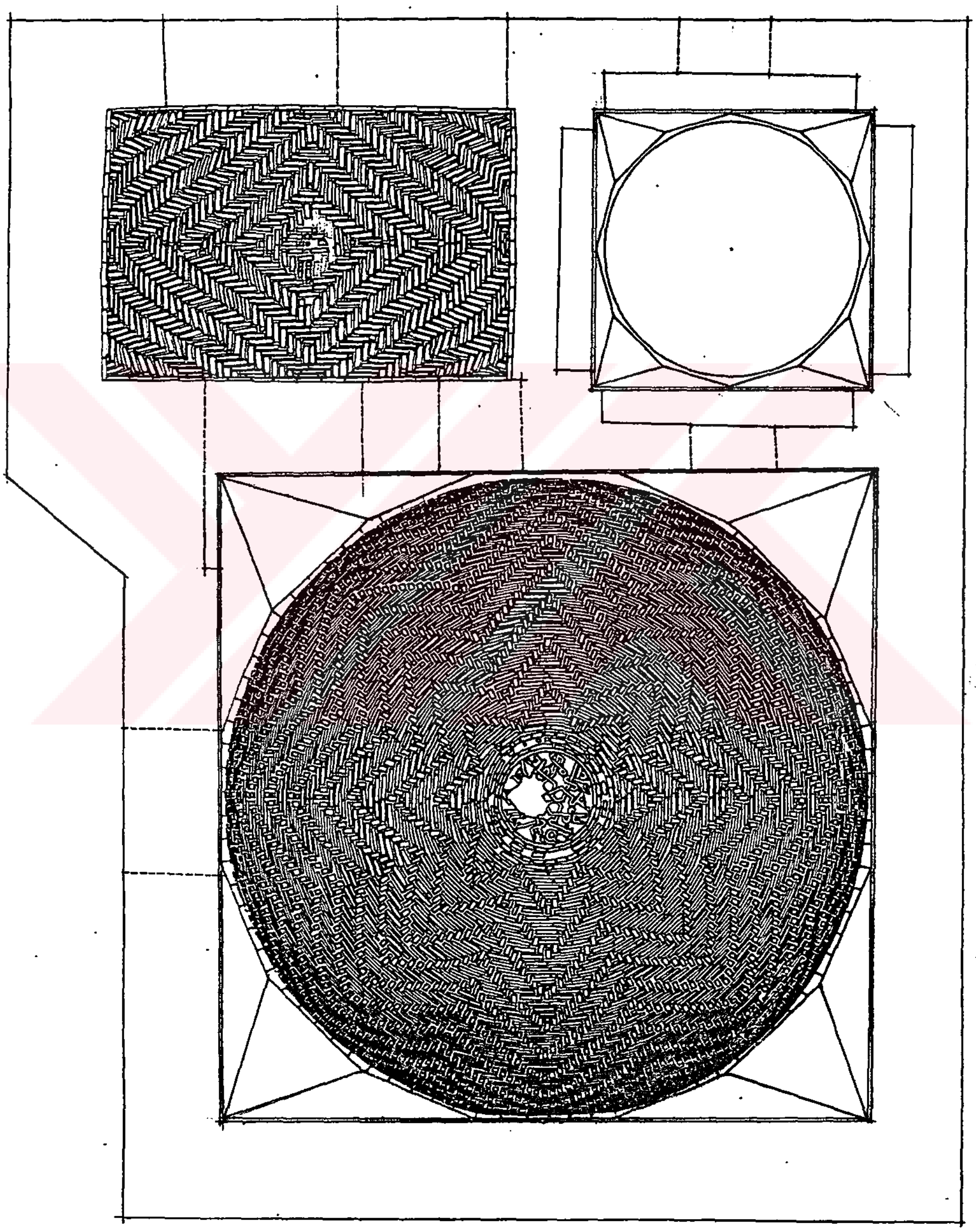

Figure 17. Superstructure

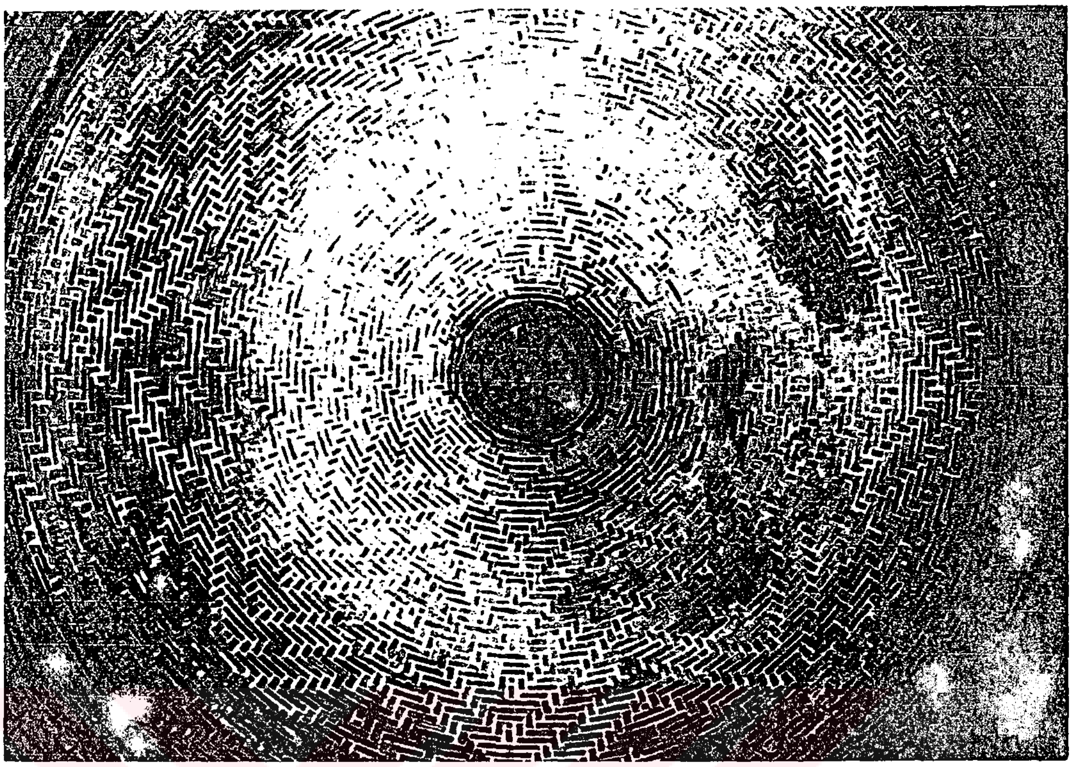

Figure 17a. The Dome of the Prayer Hall

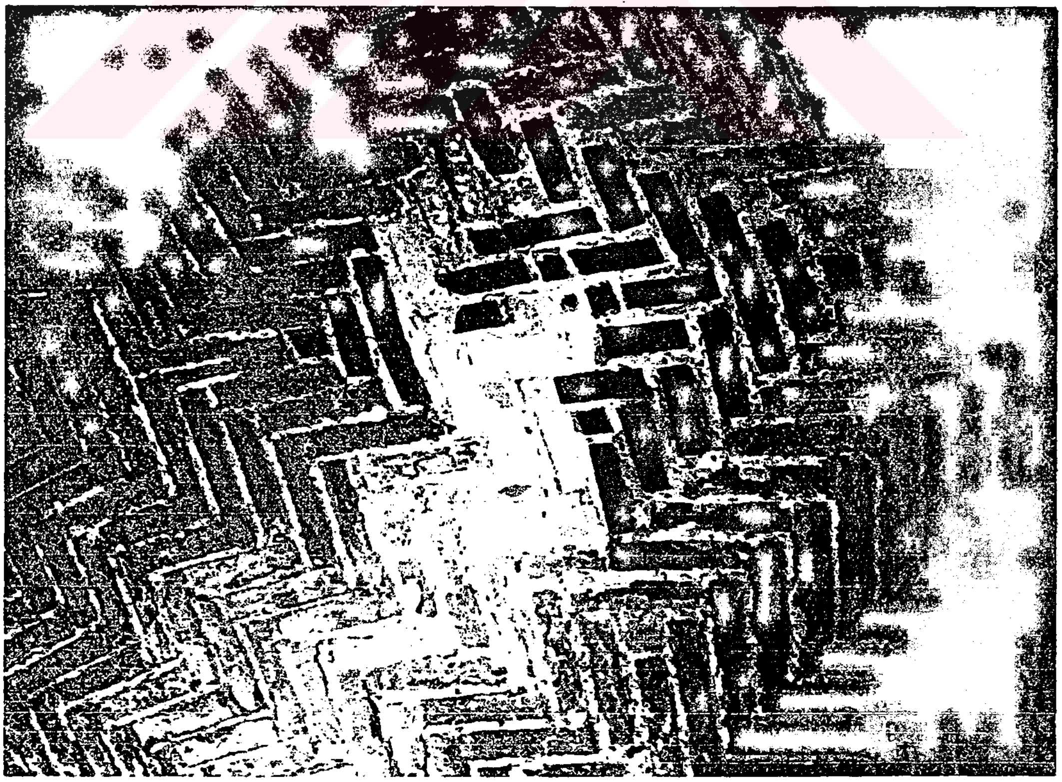

Figure 17b. The Vault of the Entrance Hall

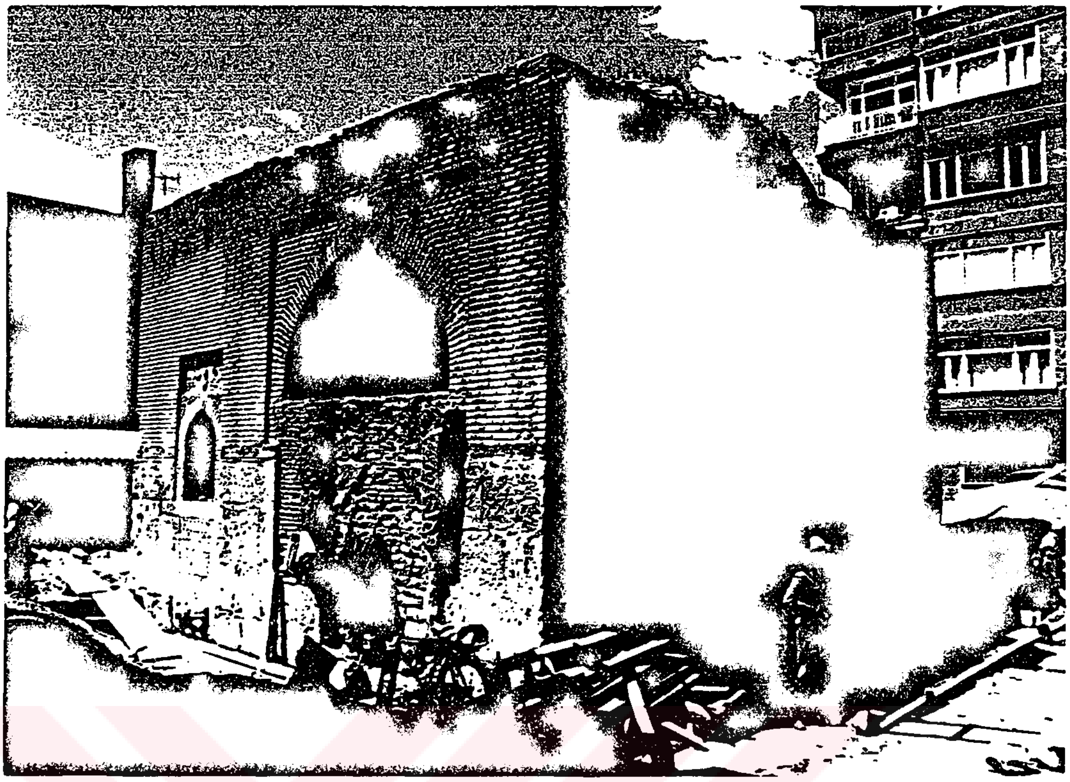

Figure 17c. View from the North-East Corner

Figure 17d. View from the North-West Corner

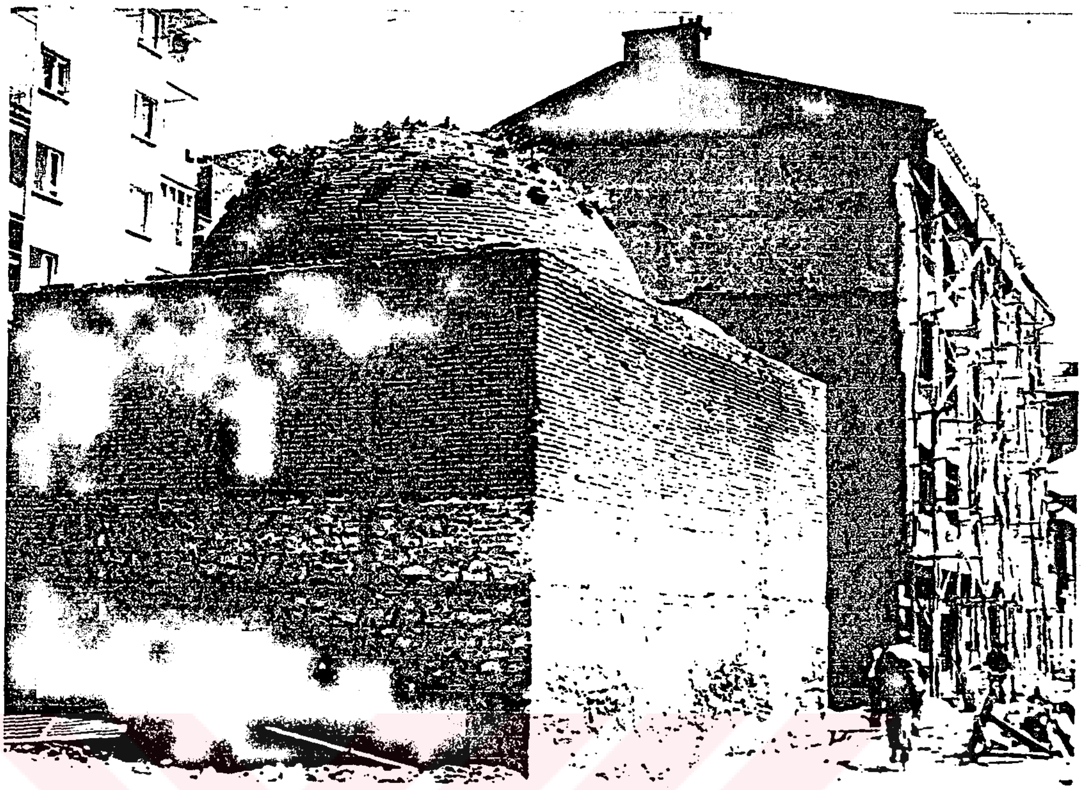

Figure 17e. View from the South-West Corner

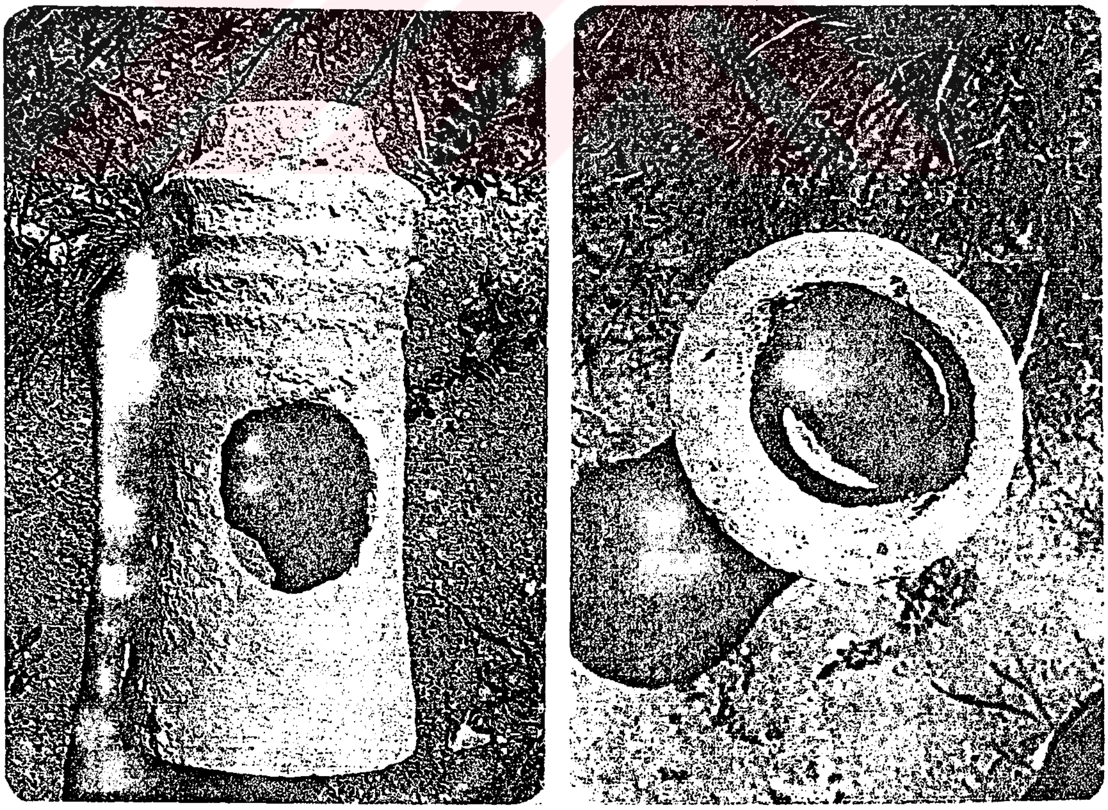

Figure 17f. Original Drainage Pipe of the "Mescid"

CHAPTER IV

LABORATORY STUDIES

The aim of the laboratory studies is to determine the basic physical properties and components of the deteriorated and sound parts of the original materials and to have a sound knowledge of the sources and causes of decay which will lead us to find remedies and to choose materials as compatible as possible with the original ones in terms of durability. Therefore, they are based on the determination of the basic physical properties of the structural and ornamental materials collected from the building and investigations of the sources and causes of the decay of the materials respectively.

Determination of the colors and mineralogical composition of bricks, determination of the water absorption capacity, porosity, bulk densities of the materials, determination of the binder and aggregate ratios with their sand type and shapes by microscopic examination of the mortars and gypsum renderings, determination of wetting and drying rates of the bricks and analysis of the soluble salts were the experimental part of this study.

4.1 Identification of the Samples

The materials collected from the building are stone, brick, wood and mortars as structural materials, glazed ceramic tiles and gypsum renderings as ornamentation materials, soluble salts from the efflorescences and from the decayed bricks stones and mortars. The kinds and positions of the samples are indicated on the related drawings (Figure 4 and 16). They are coded indicating their type (letters at the beginning) and number of samples (digits at the end). They are as follows;

a. Stones: One sample of andesite and two samples of travertines were collected.

S.A.1 : Andesite (1 sample)

S.T.1 - 2 : Travertine (2 samples)

b. Bricks: Totally 38 samples of all groups referring their colors and bricks of 1958 intervention were collected.

B.R.1 - 6: Red brick (6 samples)

B.Y.1 - 8: Yellow brick (8 samples)

B.P.1 - 12: Pink brick (12 samples)

B.B.1 - 6: Brown brick (6 samples)

B.D.1 : Decorative brick (1 sample)

B.I.1 - 6: Brick of 1958 intervention (6 samples)

c. Wood: Three samples of wood were collected.

W.1 - 3 : Wood (3 samples)

d. Mortars: Totally 43 samples of mortar used in the brick and stone masonries were collected.

M.B.1 - 33: Mortars used in the brick masonry (33 samples)

M.S.1 - 8: Mortars used in the stone masonry (8 samples)

M.I.1 - 2: Cement mortars of 1958 intervention

e. Glazed ceramic tile: 1 sample of glazed ceramic tile was collected.

G.C.T. 1: Glazed ceramic tile (1 sample)

f. Gypsum renderings: 5 samples of gypsum renderings were collected.

G.R.1 - 5 : Gypsum rendering (5 samples)

g. Soluble Salts : 5 samples were collected.

S.1 - 5 : soluble salt (5 samples)

4.2 Determination of the Colors of Bricks

Four main different colors (hue) of brick have been determined according to the lightness (value) and color saturation (chrome) by using Munsell Soil Color Charts (MUNSELL, 1971). Those colorimetric characteristics are;

B.R.1 - 3 : (5YR - 7/6 Reddish Yellow)
B.R.4 - 6 : (2.5YR - 6/6 Light Red)
B.Y.1 - 3 : (10YR - 8/3 Very Pale Brown)
B.Y.4 - 8 : (2.5 Y -8/4 Pale Yellow)
B.P.1 - 12: (5YR - 8/4 Pink)
B.B.1 - 3 : (7.5YR - 6/4 Light Brown)
B.B.4 - 6 : (5YR -6/4 Light Reddish Brown)
B.D.1 : (2.5YR - 6/6 Light Red)
B.I.1 - 3 : (7.5YR - 6/4 Light Brown)
B.I.4 - 6 : (5YR -7/4 Pink)

4.3 Mineralogical Composition of the Original Bricks

The mineralogical compositions of the original bricks were determined by using X-ray powder diffraction technique. X-ray diffraction patterns of the original bricks show that they consist of feldspar (albite), iron oxides and quartz (Figure 19).

Q:Quartz A:Albite I:Iron Oxides

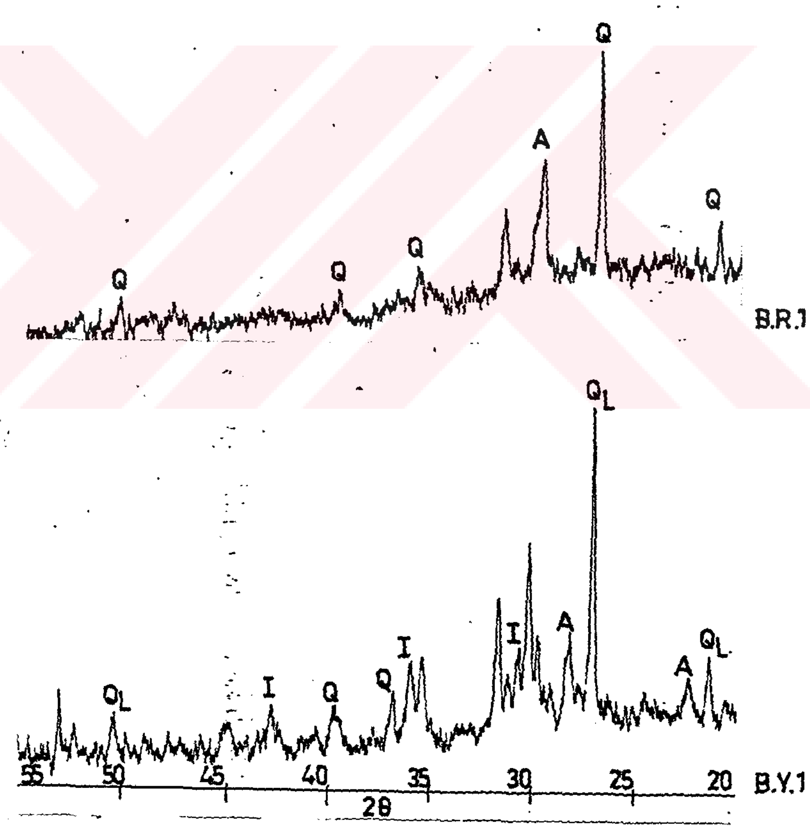

Figure 19. X-ray Diffraction Patterns of Bricks

However, the absence of clay minerals peaks is also noticed. It is assumed that the bricks must have been fired up to fairly high temperatures such that the crystal structure of clay minerals have been lost. However, the absence of high temperature minerals like crystobalite shows that the firing temperature never reached to 1000°C (Brindley et al., 1960).

4.4 Determination of the Water Absorption Capacity, Porosity and Bulk Densities of the Materials

Those basic physical properties of the bricks, stones of andesite and travertines, glazed ceramic tiles, mortars and gypsum renderings have been determined by the use of standard tests (RILEM, 1980; Knöfell et all, 1987; TS 2513, TS 699). The average mean values with standard deviations (Reddy, 1988) are given in Table 1.

Table 1. Water Absorption Capacity (WAC % weight), Porosity (P % volume), and Densities (D gr/cm3) of the Materials Used in the Monument

Samples	Number of Samples	WAC	P	D
Stones:				
Travertine	2	3.0±1.3	8.1±3.7	2.85±0.04
Andesite	1	7.7	16.6	2.17
Bricks:				
Red	6	30.4±1.0	44.9±1.0	1.47±0.01
Yellow	8	32.8±2.0	45.8±2.4	1.40±0.03
Pink	12	34.9±1.8	48.2±1.4	1.38±0.04
Brown	6	16.6±1.4	29.8±1.7	1.77±0.05

Continued.,

1958 In.	6	21.3±2.0	34.1±2.4	1.61±0.04
Original Mortars:				
Stone	16	21.2±3.7	34.3±4.7	1.63±0.07
Brick	54	25.9±2.7	39.4±3.0	1.53±0.06
Decorative Br.	1	30.8	46.5	1.50
Glazed Cer. T.	1	24.0	40.0	1.75
Cement(1958In)	2	14.3±5.2	26.5±7.7	1.90±0.15
Concr. Imit.*	3	9.4±0.6	19.1±1.2	2.02±0.00

*Concrete imitation bricks of recent restoration works

The stones of andesite and travertine used in the structure have lower water absorption capacity and porosity but higher densities than the other materials used in the building.

The original bricks show similar characteristics in their values of water absorption capacity, porosity and density except for the brown bricks which are very rarely used in the structure. The bricks of 1958 intervention work which differ in size, have lower water absorption capacity, porosity and higher density values.

The original mortars used in the brick and stone masonry have close similarities concerning their water absorption capacity, porosity and densities. The mortars of stone masonry, however, are slightly denser than the ones in brick masonry while their absorption capacity and porosity are less.

Six lime mortars (M.B. 28-33) which are used together with the bricks of 1958 intervention differ from the others in all their properties.

The cement mortars applied in 1958 intervention have considerable differences in their physical parameters compared to all lime mortars. Their water absorption capacity and porosity are much less than the lime mortars of stone and brick masonry and their densities are higher.

4.5 Raw Materials of Lime Mortars and Gypsum Renderings

Raw materials of the mortars and gypsum renderings have been determined by dissolving their binder in dilute hydrochloric acid (Middendorf et al., 1990; Jedrjzevska, 1981; Teutonico, 1986). Two series of each sample of all mortars and gypsum renderings have been analyzed. The properties of the raw materials of mortars of stone masonry show similar characteristics in binder to aggregate ratio, distribution of aggregates and sand type. In the case of the mortars of brick masonry, however, six of them (M.B.28-33) differ from the others in all their properties as mentioned above (Appendix A).

In the following tables (Table 2 and 3) the average mean values of the percentages of acid soluble, aggregate portions and aggregate distributions of the mortars of stone and brick masonries (six of those different ones are not included) and gypsum renderings with their standard deviations from the mean are given.

Table 2. The Percentages of Acid Soluble, Aggregates and Aggregate Densities of Original Mortars and Gypsum Renderings

Samples	Number of Samples	%Ac.Sol.	%Agg.	Agg. Dens.
Stone Mor.	16	59.2±6.3	40.7±6.3	2.44±0.07
Brick Mor.	54	65.4±5.5	34.6±5.5	2.44±0.07
Renderings	5	96.2±0.7	3.8±0.7	——

Table 3. Percent Aggregate Distribution of the Original Mortars of Stone and Brick Masonries

Sieve (Micron)	Stone Mortar	Brick Mortar
1000≤x	4.1 ± 1.4	3.2 ± 0.8
500	7.9 ± 1.4	6.8 ± 1.9
250	16.4 ± 2.5	13.3 ± 2.6
125	8.5 ± 2.0	7.7 ± 2.0
125≥x	4.0 ± 0.6	3.9 ± 1.1

As the Table 2 shows, the percentage of binder is more than the percentage of aggregate in mortars of stone and brick masonries. This difference is higher in the mortars of brick masonry. Aggregate percent of mortars in stone masonry is higher than the ones in brick masonry, average densities of sand particles being equal (2.44gr/cm3). As a result of that stone masonry mortars are denser than the brick masonry mortars. Gypsum renderings however have the least amount of aggregates.

The size distributions of sand in the original mortars of stone and brick masonries are similar and proper (ASTM, 1980). 250 microns size particles are in high amounts, the smallest and largest size particles are in minimum amounts (Figure 20). On the other hand size distributions of sand in the lime mortars of 1958 intervention are variable and out of standards.

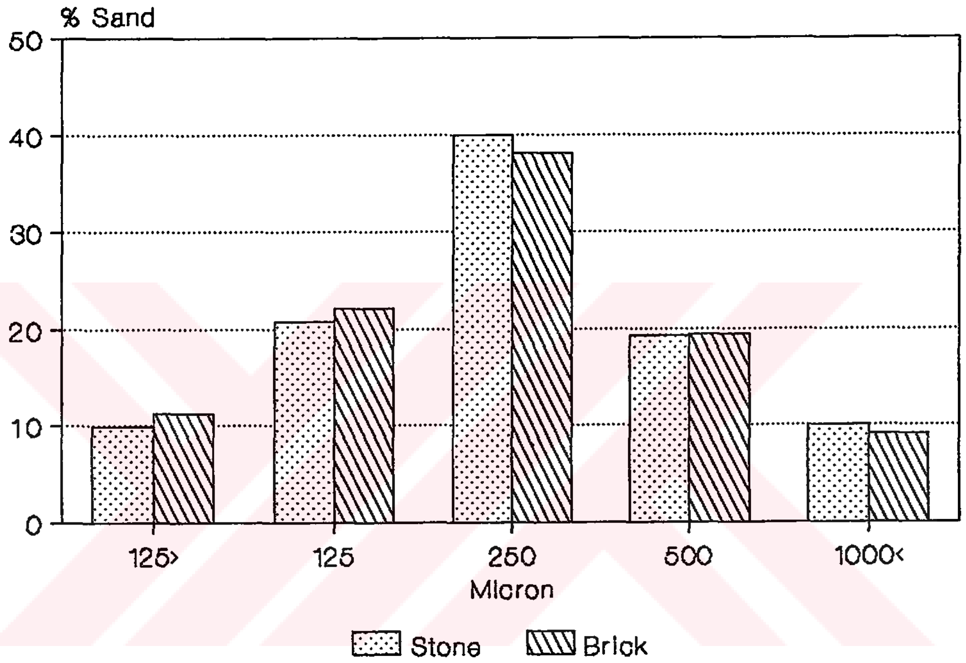

Figure 20. Percent Size Distribution in Original Mortars (Average of 16 samples of stone and 54 samples of brick mortars)

The sands have been examined according to their type and shape under the microscope. In the original mortars feldspars, quartz and rock fragments are the main components of the aggregates. Regarding their shapes, the angular ones form the major group that consist of feldspar. Rounded aggregates however, consist of quartz and rock fragments which are in minor quantities. In the lime mortars of 1958 intervention, rock fragments are the main components of the aggregates with rounded shapes.

4.6 Determination of Wetting and Drying Rates

Water absorption rates of bricks were determined by total immersion (Teutonico, 1986). The weight increase of the samples are measured at certain time intervals in ten days. The results are given in the Appendix B. The highest amount of water was absorbed within the first 15 minutes corresponding to more than 70 percent of the total absorption. The original red, yellow and pink bricks showed the same trends except for the brown bricks which have the least absorption rates. The bricks of the 1958 intervention differed from the original bricks with less amount of absorption rates but more than the original brown bricks. The absorption rates of all bricks are graphed (Figure 21).

The determination of the drying rates of the bricks were carried out at 20°C and approximately 40% relative humidity (Appendix C). The weight decreases are measured within certain time intervals in ten days. The all bricks dried within ten days. The obtained results are graphed in Figure 22.

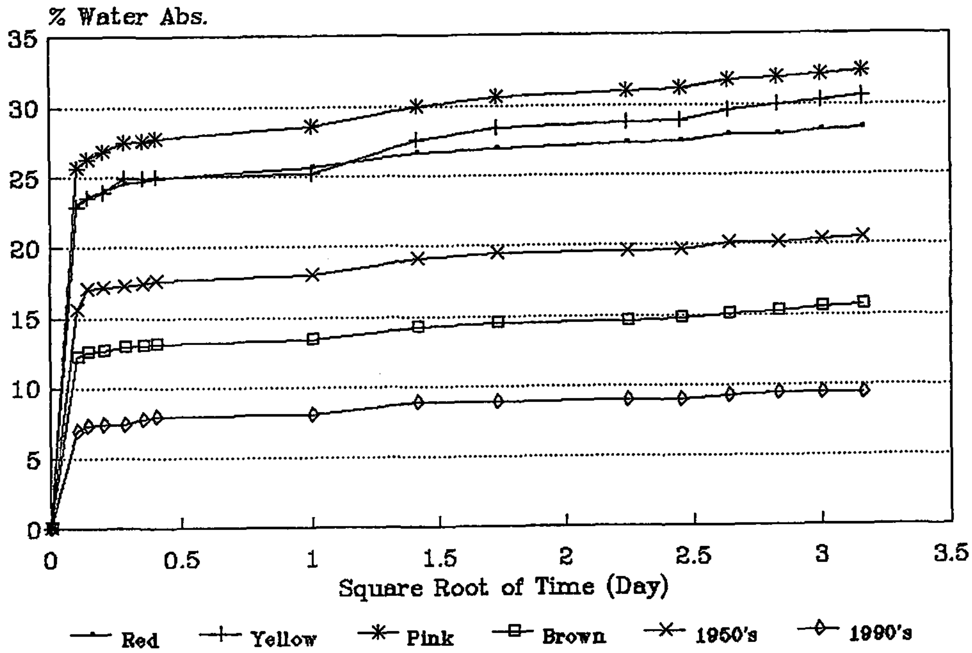

Figure 21. Water Absorption Rates of Bricks

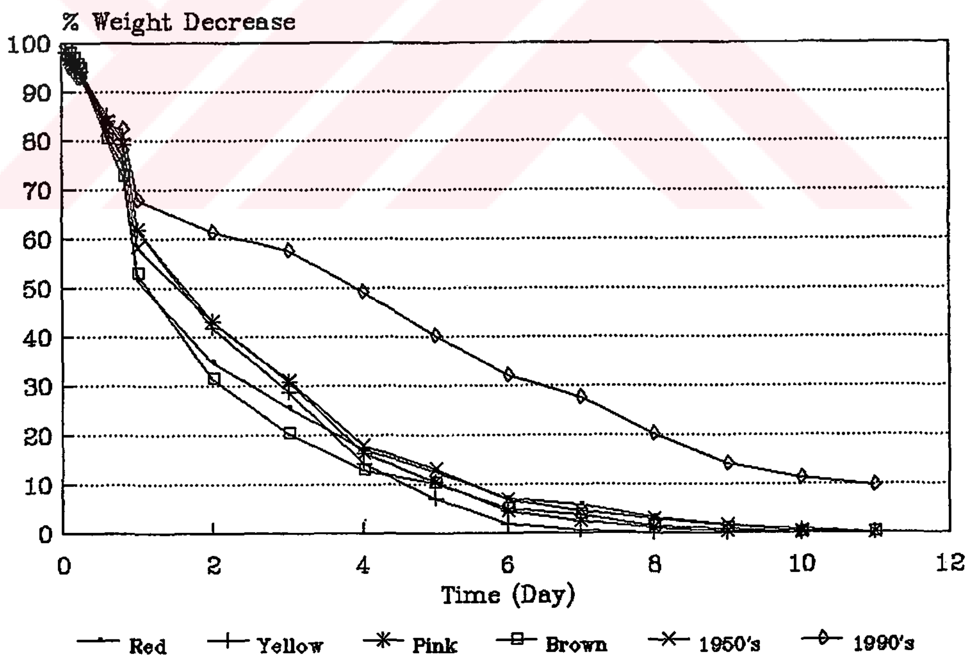

Figure 22. Drying Rates of Bricks

4.7 Analysis of the Soluble Salts

Soluble salts collected from the efflorescences and from the decayed bricks, stones and mortars have been analyzed qualitatively (Arnold, 1983). Sulphate, nitrate and chloride ions were detected in all samples from the decayed parts.

The mineralogical compositions of the soluble salts were determined by using X-ray powder diffraction technique. Sodium sulfate (Na_2SO_4), potassium nitrate (KNO_3) and gypsum ($CaSO_4.2H_2O$) were observed in diffraction patterns (Figure 23).

K:KNO3 T:Na2SO4 G:CaSO4. 2H2O Q:SiO2

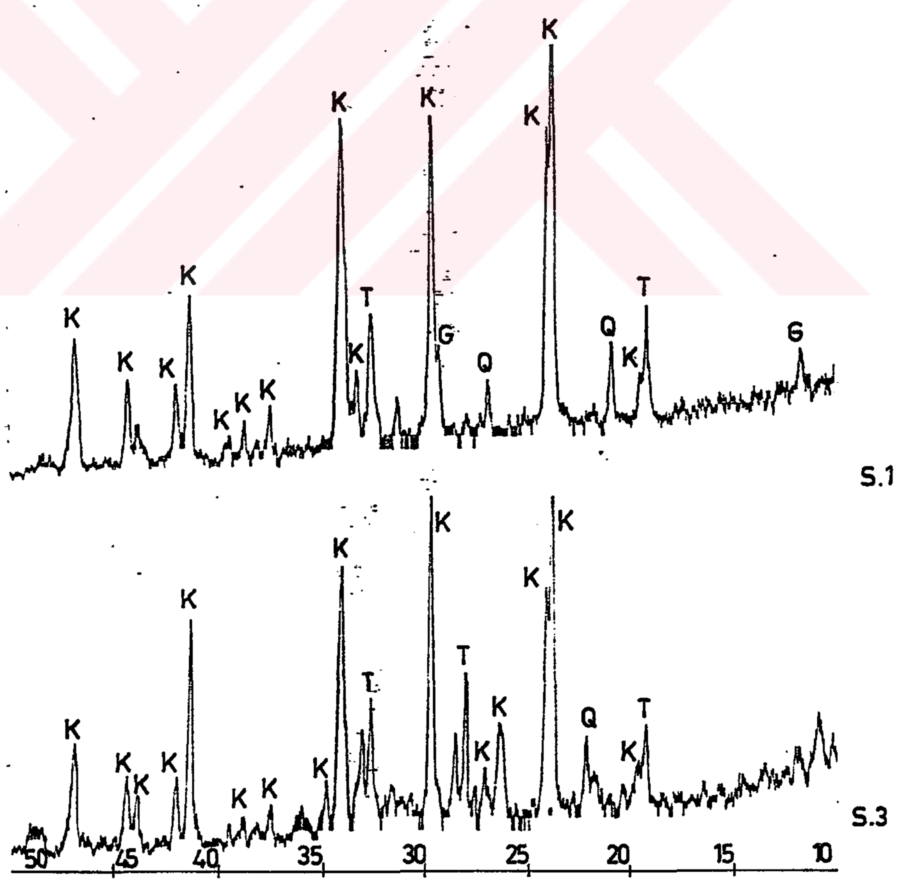

Figure 23. X-ray Diffraction Patterns of Soluble Salts

Alkaline sulphates detected by the analyses originate from portland cement and nitrates are most likely due to the soil.

4.8 Discussion and Evaluation of the Laboratory Studies for the New Interventions

The laboratory studies were purposely focused on those analyses which can be carried out in our laboratory, and which will reveal the important characteristics of the materials in the monument, explain the nature and content of the existing problems and give us clues on their solutions. Therefore the analyses were done to define the important physical properties of original and intervention materials such as water absorption capacity, porosity and wetting and drying rates, to determine the characteristics of some raw materials in the composition of brick and mortars, and to understand the sources and distribution of salts in the monument.

This section is devoted to the discussion of those results and their interpretation on the choice of new materials for repairs, such as brick and mortar and on the description of salt and dampness problem and the ways of dealing with it.

4.8.1 Discussion of the Basic Physical Properties of Original and Intervention Materials

The physical properties determined are important parameters which explain the response of the material to environmental changes like temperature and humidity, describe the relationship of materials with each other finally help us to define the behavior and characteristics of the monument.

a. Discussion of the Basic Physical Properties of Original Materials

Original bricks: The similar water absorption capacity (≈30 - 35%), porosity (≈45 - 48%) and densities (≈1.38 -1.47gr/cm3) (Table 1) and uniform wetting and drying rate (Figure 1 and 2) of original bricks except for rarely used brown bricks, prove a careful selection of raw material and a well controlled manufacturing process (mixing, moulding and firing). Those basic physical properties of bricks are also very close to the properties of mortars in the brick masonry (Table 1). This closeness in the basic physical properties gives the superstructure a shell-like property.

Original mortars: The slight differences in the basic physical properties of the mortars of stone and brick masonries are due to their dependent use in two different kinds of masonry (Table 1). For example, the mortars used in the stone masonry are denser (1.63gr/cm3) than that of brick masonry (1.53gr/cm3) with less percent of binder, less water absorption capacity and less porosity in harmony with denser stone compared with brick (Table 1).

Timber tie beams: Those two different kinds of masonry are combined by the use of timber tie beams. These beams must have acted as buffers reducing different mechanical stresses that are generated by external causes in the stone and brick masonry.

Similarities in the basic physical properties of the materials prove that the durability has been established in the structure by the use of compatible materials which have kept the monument sound since more than seven hundred years.

b. Discussion of the Basic Physical Properties of Intervention Materials

The bricks of 1958 intervention: Comparing with the original bricks, the bricks of 1958 are different in their water absorption capacity, porosity and density values. They are denser than the original ones with less water absorption capacity and porosity (Table 1) and drying rates are slower than the original bricks. However, these differences are still within acceptable limits if compared with the concrete imitation bricks which are often used in recent restorations without considering their harmful effects (Table 1., Figure 22). Cement imitation bricks are much denser, much less porous than traditional building materials and much slower in drying rates. Their presence will inevitable cause dampness problems in the localities where they are used. They are also the sources of soluble salts and transfer them easily to the more porous original building materials like stone, brick and mortars. All these points explain why they should never be used in the restorations.

The lime mortars of 1958 intervention show inconsistent trends (Appendix A) in all their physical properties as well as the proportion, type and shape of sand particles as raw material. They show no similarity neither with the original mortars nor with each other.

The cement mortar in the rubble infill applied as binder in two windows of the west wall of the prayer hall, in the joints of cut stones of the east and north facades and concrete on the roof and on the "türbe" floor applied as damp proofing material stand as destructive inhomogenities with their different physical properties (Table 1). Besides being active sources of soluble salts (See Section 4.7) their very slow drying rates are effective on the dampness problem as they prevent water from evaporating due to their high density and less porosity (Table 1). Therefore all cement mortars should be removed from the structure. But if it proves impossible, they should be neutralized by the use of proper techniques to stop their inevitable damage in the structure. This can only be achieved by keeping those parts completely dry and away from high thermal fluctuations. However, it is not possible to provide those conditions in an old structure in Konya's climate without knowing the microclimatic characteristics of the monument which can be studied by special computer calculations (Gibbs, et al., 1989) and periodical measurements on the structure (Boztepe, 1987).

4.8.2 Discussion of Mineralogical Composition of Bricks and Raw Materials of Mortars and Plasters

Mineralogical compositions of bricks determined by X-ray diffraction spectroscopy (Figure 19) show that the original bricks were fired up to fairly high temperatures such that the crystal structure of clay have been lost as the absence of clay mineral peaks show. However, the absence of high temperature minerals like crystobalite proves that the firing temperature never reached to 1000°C (Brindley et al., 1960).

Raw materials of mortars and plasters: This study provided information about the characteristics of sand but not of binder which is lime or possible additives. The binder was dissolved in dilute acid and its proportion has been determined.

The microscopic examination of sands showed that durable original mortars were mainly composed of angular shaped feldspar particles for both brick and stone masonries. In spite of the slight changes in the physical properties of the mortars in brick and stone masonry, the size distribution of sands are similar (Figure 20) also complying with the existing standards of today (ASTM, C144, 1980). 250 micron size particles are in highest amounts, the smallest and largest size particles are in minimum amounts. Sand percent of mortars in stone masonry are more than the mortars in brick masonry (Table 2). The average densities of sand particles are equal in both masonry types (2.44gr/cm3) (Table 2).

Gypsum is also widely used in the building as plaster and ornamentation material together with glazed ceramic tiles in the reliefs of the portal, "mihrap", spandrils of the east window and "hacet" window of the "türbe". From the analysis of this study, we know that the main component of those renderings is gypsum, however, the physical properties and probable additives have are not known. Since they involve specific analytical techniques, gypsum renderings and glazed ceramic tiles should be the subjects of a separate studies.

4.8.3 Moisture and Soluble Salts in the Fabric

The moisture readings proved that the monument is under heavy dampness which reveals itself as rising damp on the walls up to two meters high from the existing ground. Rain water that is not driven away from the building by sufficient water collecting systems and ground water the level of which could not be investigated during the surveys, are the possible sources of rising damp which is effective on the lower parts of the structure. Rain penetration from the roof edges because of the missing cornice elements and loosened joints of brick courses is another source of dampness which is effective on the upper parts of the structure.

As it is well known, the existence of such excessive moisture in any fabric cause deterioration in two ways; the first one is in the form of freeze-thaw cycles due to the sudden changes in the temperature during a day, e.g. sudden temperature fall at night and due to long term seasonal changes. The second one is due to salt crystallization cycles causing loss of material, weakening the strength of the material and developing efflorescences on the exposed surfaces. Deterioration due to salt crystallization cycles proceeds not only by wetting and drying of the material but also by the fluctuations of relative humidity around the equilibrium vapour pressure of the particular salt in the material. Climatic data of Konya and microclimatic measurements in the monument may help to figure out salt crystallization stresses generated in the material by that phenomenon which will be discussed next.

4.8.4 Climatic Data of Konya in Relation to Condensation Risk and Salt Decay at the Monument

The climatic data of Konya, covering last few decades are shown in Figure 24, 25, 26 and 27. As the figure shows, the maximum risk of condensation is in winter months when the average relative humidity is 80 being at its maximum. By looking at the equilibrium relative humidities at which the salts get wet, one can figure out that the parts of the monument with heavy salt problem (the domes and the vault) will be thoroughly wet in winter (Table 4).

Table 4. Equilibrium Relative Humidities at which the Salts Get Wet at 25°C

Salt	Formula	Relative humidity
Nitrokalite	KNO_3	92.5
Nitronatrite	$NaNO_3$	73.9
Mirabilite	$Na_2SO_4.10H_2O$	87
Thenardite	Na_2SO_4	81
Gypsum	$CaSO_4.2H_2O$	98

Although the climatic data during the year indicate the times when the wetting of salts and condensation is most likely the actual conditions for the monument may be quite different and when the salts dry out. On the other hand, wetting and drying conditions may also be provided by daily fluctuations of relative humidity depending on temperature changes and rainfall. Daily changes may result in more rapid deterioration. In order to figure out the actual fluctuations of relative humidity and temperature inside and near the monument, a microclimatic survey should be done for the year (Baronio, et al., 1992; Arnold, 1989).

As a conclusion, salt problem of the monument may be better controlled by closing the monument with doors and windows so that climatic fluctuations are minimized at least at the inside of the monument. Salt cleaning should be done to decrease the salt content as much as possible.

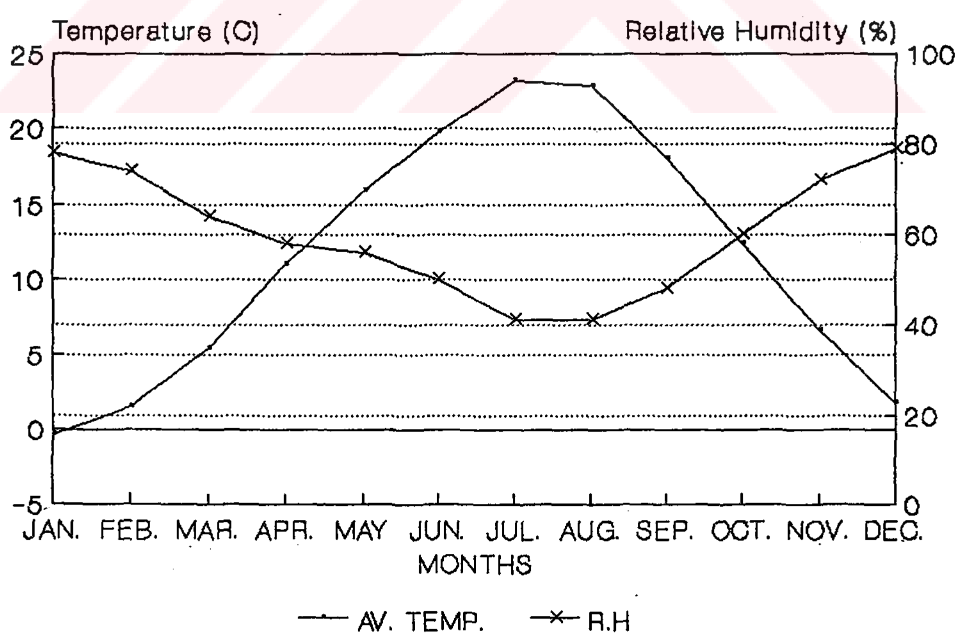

Figure 24. Average Relative Humidity and Temperatures in Konya.

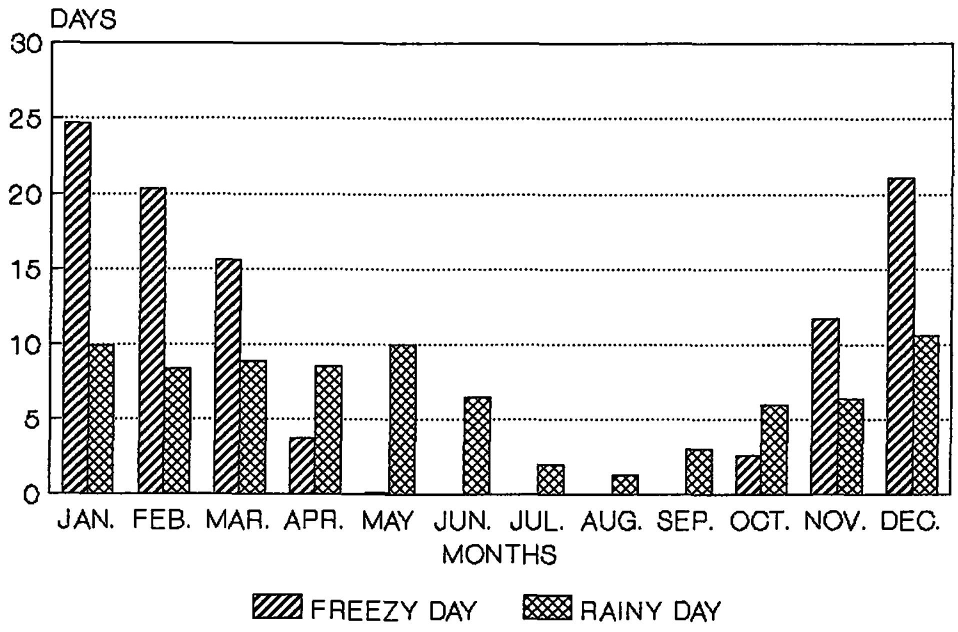

Figure 25. Freezy and Rainy days in Konya.

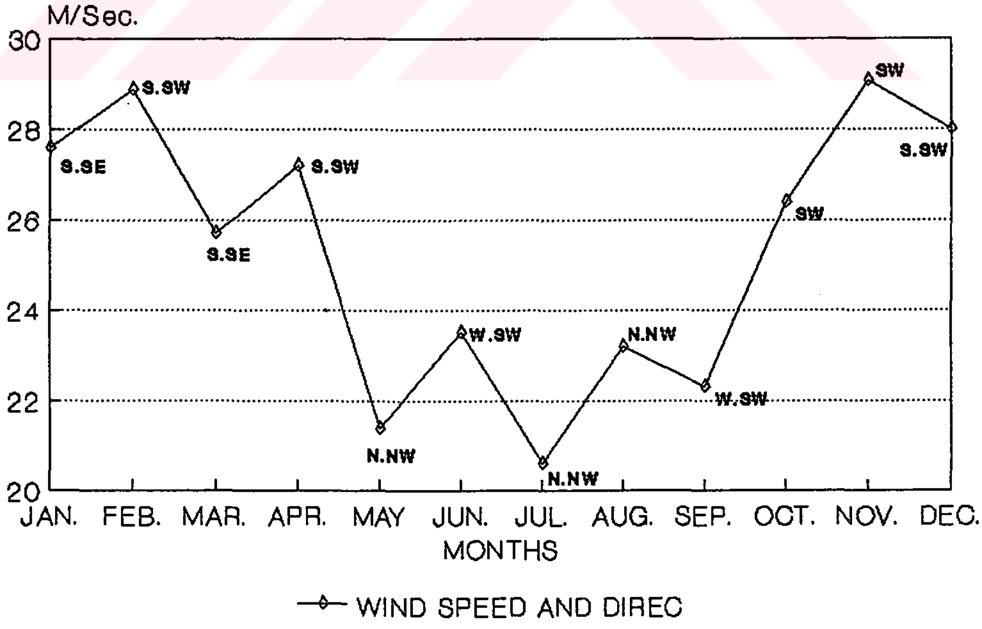

Figure 26. Wind Speed and Direction in Konya.

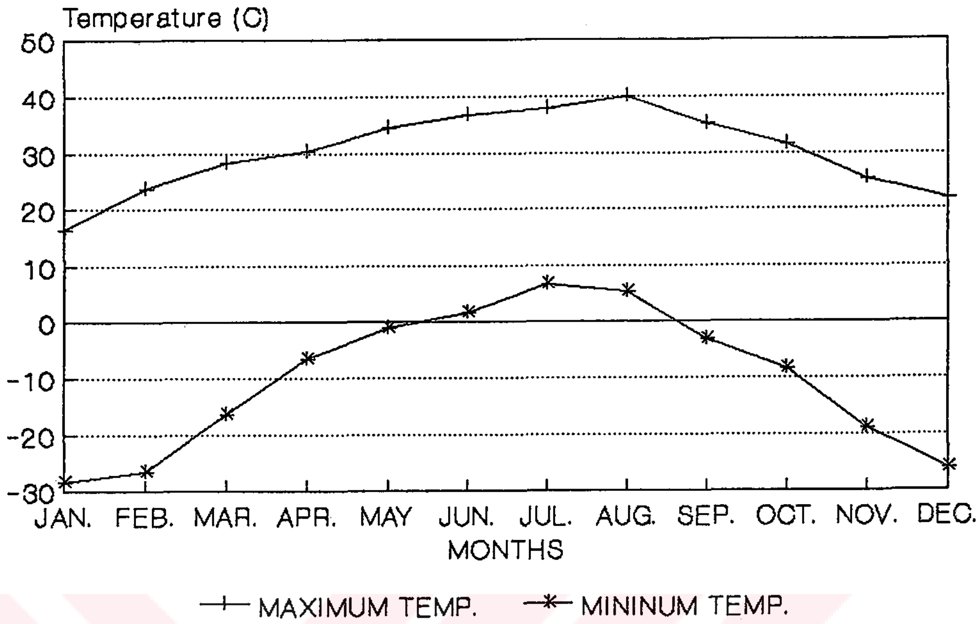

Figure 27. Maximum and Minimum Temperatures in Konya.

4.8.5 New Interventions

In the light of laboratory studies and discussion of their results, following proposals are given as new interventions for the restoration of the monument.

a. The Selection of New Bricks for Repairs

The new brick should have similar properties to the original ones to keep the structure sound and durable for a long time. This means that the new bricks will have around thirty to thirty-five percent water absorption capacity, around fourty-five percent porosity and around 1.40gr/cm3 density.

Considering the bricks used in the recent restorations, cement imitation bricks are totally discarded because of their harmful effects and far different physical properties which have already been stated.

Factory bricks available in the market are much denser and less porous as stated in Turkish Standards (TS 705) and not suitable to our purpose. However, specifications of solid hand made bricks in Turkish Standards (TS 704) are quite near to the original bricks of Tahir ile Zühre and will be suitable to our purpose. Although the compressive strengths were not measured, high porosity indicates low strength (Winkler, 1986) and to a first approximation low compressive strength of solid hand made bricks (TS 704) should be near to the strength of original bricks of the monument. Therefore we propose the use of solid hand made bricks in the repairs.

b. Preparation of New Mortars for Repairs

Our goal is to prepare mortars with similar physical properties to original ones and be free from soluble salts. Results of our laboratory studies show that original stone masonry mortars have around twenty-one percent water absorption capacity, thirty-four percent porosity and 1.63gr/cm3 of density. On the other hand brick masonry mortars have around twenty-six percent water absorption capacity, forty percent porosity and 1.53gr/cm3 of density. Binder and aggregate ratios of mortars were roughly obtained through the weight percent of acid soluble and insoluble parts which is 60:40 for stone masonry and 65:35 for brick masonry. Both mortar types had fine sand of 2.44gr/cm3 of density. We figure out that stone masonry mortars were obtained by mixing one part of fine sand with one and a half parts of lime by volume. Brick masonry mortars were obtained by mixing one part of sand with 1.8 parts of lime. Although we know the approximate mixing proportions of related mortars and properties of sand in original mortars, hydraulic properties of lime are not known. Preparation of mortars of the similar physical properties will not be so easy and reproducible unless we know the quality of lime and possible additives in them. In addition to that, some additives and amount of water added to the mixture will influence the final physical properties. Trials with different hydraulic limes and fine sand may lead us to proper mixtures. However, we have a serious problem in the building materials market in Turkey. The limes in the market are not very well specified for their degree of hydraulic properties and they unfortunately contain cement and other harmful additives in them. This means that there is a need to specify quicklimes and slaked limes for their hydraulic properties. After such a survey and establishment of standards, some manufacturers may provide standard hydraulic limes in the market for the restoration practice.

c. Cleaning of Soluble Salts in the Structure

The salt in the structure should be extracted locally, preventing its migration to deeper parts and uncontaminated materials. The cleaning must start with brushing of the efflorescences with soft hair brushes and wetting should be limited during the cleaning process.

The areas of rising damp where the structure is quite wet can be cleaned by electrochemical techniques by mounting the electrodes at the surface of wet wall with an electrolytic connection to the wall (Friese, 1992). The variations in the procedure may be putting cellulose or paper wadding next to the electrodes with or without a solution cell next to it (Friese, 1992; Jedrzejevska 1970; Skibinski, 1985).

Relatively dry areas can be cleaned with wetted poultices (Faugere, et al., 1985, Subbaraman 1985) or vacuum fluid technique which involves inducing a water flow through the outer layers of masonry and washing out the soluble salts with the help of vacuum system connected to every brick (Friese, 1992). All cleaning processes should be controlled with spot tests and conductometric readings. The actual cleaning can be one or two of these processes depending on the first trials and discovering the efficiency of one or two of them in a particular location. The work should be done by trained and experienced people on the subject.

CHAPTER V

HISTORICAL RESEARCH

5.1 Historical Background of Konya

Konya had a great attraction for settlers in all epoches of the history of Anatolia because of being a very wide and a fertile plain.

Archaeological finds prove that the traces of forefathers of the ancient Anatolians extend back to the Neolithic Age (6800-6500 B.C.) in this central and the largest area of the Anatolian Peninsula. Starting from the Neolithic Age; the Calcolithic (5000-3000 B.C.), the Bronze (2000-1650 B.C.), Hittite (1650-712 B.C.), Phrygian (712-695 B.C.), Lydian (680-546 B.C.), Persian (546 B.C.-17 A.D.), Roman (17-395), Byzantine (395-1074) Ages were the periods that Konya has undergone. From 1074 until 1318 Konya was ruled by Anatolian Seljuk Turks experiencing its golden age. Thereafter it was ruled by Karamanids (1318-1466) and Ottomans (1466-1920) until Republican Period (Dülgerler, 1984: 9-12).

5.2 Historical Background of "Mescid"s of the XIIIth Century

XIIIth century is the time during which the art and architecture of the Anatolian Seljuk State reached its peak as well as its political power and economic prosperity. They flourished in the entire area, with numerous buildings in Konya, being their capital, Sivas and Alanya. Besides those well known edifices, there are some small buildings, built especially in Konya and Akşehir, called "mescid"s. They were constructed to serve limited number of people in their neighborhoods with the purpose of daily religious practice. Their donors were usually state officials or some well known people who actually lived in that area (Bakırer, 1967: 4). In spite of their small scales they reflect the stylistic and architectural trends of that period in their construction techniques, geometrical patterns of ornamentations and details. Unfortunately many of these "mescid"s have been entirely destroyed like Akıncı Mescidi (1210), Alevi Sultan Mescidi (XIIIth Century ?) due to the lack of care or for the sake of so called new development plans for the city (Dülgerler, 1984: 14). Some of them rebuilt following their demolitions like; Hatuniye Mescidi (rebuilt in 1873) and the "mescid"s like Aksinne Dibekli (XIIIth Century ?), Demirci Hoca (XIIIth Century ?), Eflatun (XIIIth Century?) and Hoca Ali (XIIIth Century ?) have been completely destroyed and rebuilt or altered to a degree of loosing their original features. But the other "mescid"s are still capable of giving reliable informations of their original plans, materials of construction and decorative elements.

There is a recent effort to determine the roots of these "mescid"s trying to link them with the earliest "türbe"s and "mescid"s built independently or included within some other edifices like mosques and "medrese"s (theological schools) of Central Asia and Iran (Dilaver, 1970: 17), (Katoğlu, 1966: 81).

Another issue in discussion is questioning the presence of the "son cemaat mahalli" (a colonnaded portico, to receive the late comers for prayer), if it was pre-determined within those additional units mentioned above or provided as a mere transition space leading people into the main prayer hall which probably gave way to the development of a more precisely defined "son cemaat mahalli" in succeeding years, as accomplished in Milas Hacı İlyas Bey Mosque (1330) being the earliest example of the "Beylik"s (principalities) Period. It is postulated that the layout of this mosque, accepted as a prototype, generated well known Ottoman Mosques thereafter. No matter what the origin could be, it should be admitted that the concept of the "mescid"s of the XIIIth Century the all variations of which emerged and evolved simultaneously in Seljuk Period either consisted of a single prayer hall or combined with "türbe" and other additional units besides prayer hall.

5.3 Historical Background of Tahir ile Zühre

The first detailed examination of the "mescid" was carried out by İ. H. Konyalı, an art historian, in 1962. According to his interview with the owner, named Sütçü Mehmet, the "mescid" was inherited from his father-in-law, by that time sixty years ago. The owner, Sütçü Mehmet, also stated that the "mescid" was not in use since that time.

According to the archive investigations by Konyalı, the "mescid" is mentioned as the "mescid" and "Dar'ül Hüffaz (school for special studies on the Koran) in the foundation charts of Konya, recorded in the name of Fatih Sultan Mehmed and Bayezid II. According to those records the "mescid" was belonging to Sahip Ata Fahrettin Ali who was the famous vizier of Alaaddin Keykubat, the well known Sultan of the Anatolian Seljuk Turks. Regarding the construction date of Sahip Ata Mosque (Larende Camii) which was built in 1258, the construction date might be falling to sometime around that date (Bakırer, 1967: 75). The "mescid" has other names like Arzu ile Kanber, Dönbaba etc. (Konyalı, 1964: 517).

İ. H. Konyalı also states that the "mescid" was repaired in 1958. Although there is no detailed documentation but it can be estimated that all openings to the exterior were closed by windows, the lower parts of the south and west facades and interior were plastered, the floor of the "türbe" and the flat parts of the roof were grouted and the cornice stones at the roof edges were replaced.

Today the "mescid" is registered as pious deed in the ledger of Konya Vakıflar Müdürlüğü" (The General Directory of Pious Endowments of Konya), with the reference number of 93.

CHAPTER VI

COMPARATIVE ANALYSIS OF "MESCID"S

6.1 Plan Layouts

The "mescid"s of this period can be examined under two groups;

Group 1. The "mescid"s composed of a single prayer hall,

Group 2. The "mescid"s having additional spaces besides the prayer hall.

Group 1. The prayer hall of this group is always square planned and surmounted by a dome. Their facades are not pierced by large openings like portals with monumental proportions or large windows. The dome sits directly on the walls without any transition zone at the exterior. At the interior however, transition from the square plan of the prayer hall to the circular plan of the dome is provided by the use of Turkish triangles or pendentives.

Among those "mescid"s only Güdük Minare (in Akşehir) has a minaret. The "mescid"s that can be included within this group are; İçkaraaslan (1219 or 1236), Şekerfuruş (1220), Terceman (first half of the XIIIth Century), Abdülaziz (first half of the XIIIth Century), Halkabegüş (first half of the XIIIth Century), Abdülmümin (second half of the XIIIth Century), Sakahane (second half of the XIIIth

Century) in Konya and, Altınkalem (1223), Ferruh Şah (1224), Güdük Minare (1227), Küçük Ayasofya (1235) in Akşehir (Figure 18).

Group 2. The additional parts of this group are provided by extending the side walls of their prayer halls, in Başarabey, Erdemşah and Karatay on the North, in Hacı Ferruh, Beyhekim, Tahir ile Zühre and Akşebe Sultan on the East where their entrances take place. The North sides of Tahir ile Zühre and Beyhekim protrude from the side walls of their prayer halls. Regarding their plans these additions to their prayer halls are formed in two ways;

a. By means of an entirely closed space,

The additional parts of this group show some differences in their interiors comparing with each other. In some cases those additional parts may be consisted of a single space, as in Basarabey (1213), Hacı Ferruh (1215), Erdemşah (1220) and Karatay (1248) "mescid"s in Konya. In other cases they can be divided into several spaces within one of which a "türbe" is housed as in Beyhekim (second half of the XIIIth Century), Tahir ile Zühre (second half of the XIIIth Century) "mescid"s in Konya and Akşebe Sultan (1230) in Alanya. The exterior of these "mescid"s do not reveal their inner articulation. Among these "mescid"s only Akşebe Sultan has a minaret but built separately from the building. For this "mescid" it should also be noted that the additional part was built later. But the construction date of this addition is not known (Figure 18).

b. By means of a colonnaded portico,

The additional parts of the "mescid"s of the former group are converted to be colonnaded porticoes in the "mescid"s of this group. The entrance facades of these buildings are pierced by large openings spanned by arches. Hoca Hasan (first half of the XIIIth Century), Zenburi (first half of the XIIIth century) and Sırçalı (1258) in Konya are the "mescid"s with minarets in this group. The shafts of those minarets of Hoca Hasan and Sırçalı form one side of their porticoes. Hoca Hasan of this Group has a "türbe" and Bulgur Dede (second half of the XIIIth Century, in Konya) has a convent room both adjacent to the West side walls of their prayer halls. Bulgur Dede has also a basement placed below its convent room (Figure 18).

6.2 Materials and Construction

Cut stone, rubble stone and brick were the basic construction materials for all the "mescid"s of the XIIIth Century.

Cut stone is used either for the lower halfs of the walls as in Beyhekim, Sakahane, Abdülmümin and Tahir ile Zühre or for the entire facades as in Karatay, Hacı Ferruh and Halkabegüş "mescid"s. Re-used cut stones are also used in these "mescid"s as in Zevle Sultan, Şekerfuruş, Abdülmümin and Sırçalı in Konya and Ferruh Şah and Güdük Minare in Akşehir (Konyalı, 1945: 312) like patchworks.

Rubble stone is used for the side or rear walls having secondary importance other than the entrance facades or for the walls that are to be plastered. In some cases rubble or cut stones are also used as flooring or pavings as in Tahir ile Zühre. Mostly used stones are "Giçi Muhsine" and "Sille Taşı" (volcanic tuff) and "Gödene Taşı" (calcereous stone) (Oral, 1961: 356).

In spite of the rich sources of stone in Anatolia the Seljuks were apt to use brick in varying shapes, dimensions and colors, until the end of the XIIIth Century eventhough limited to small "mescid"s, tomb towers and minarets (Bakırer, 1980: 144). The bricks used in this century are manufactured from red fired clay. The unglazed brick units are the basic material for the brickbonds employed throughout this century.

1st Group;

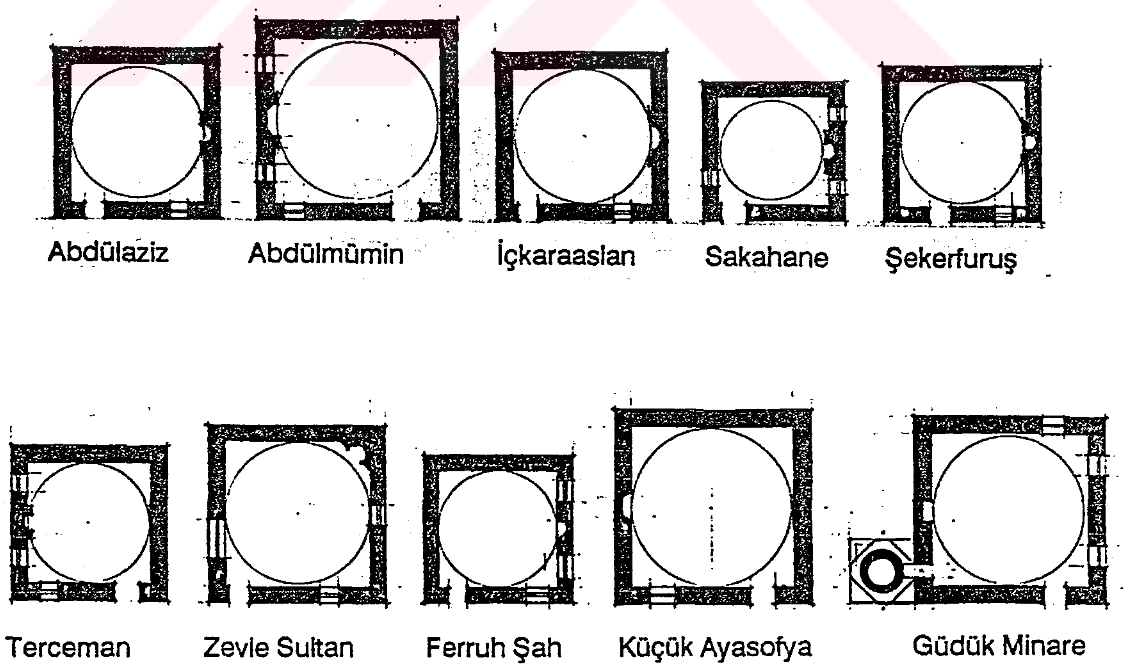

Figure 18. Comparative Analysis of "Mescid"s

2nd Group;

Type a. Type b.

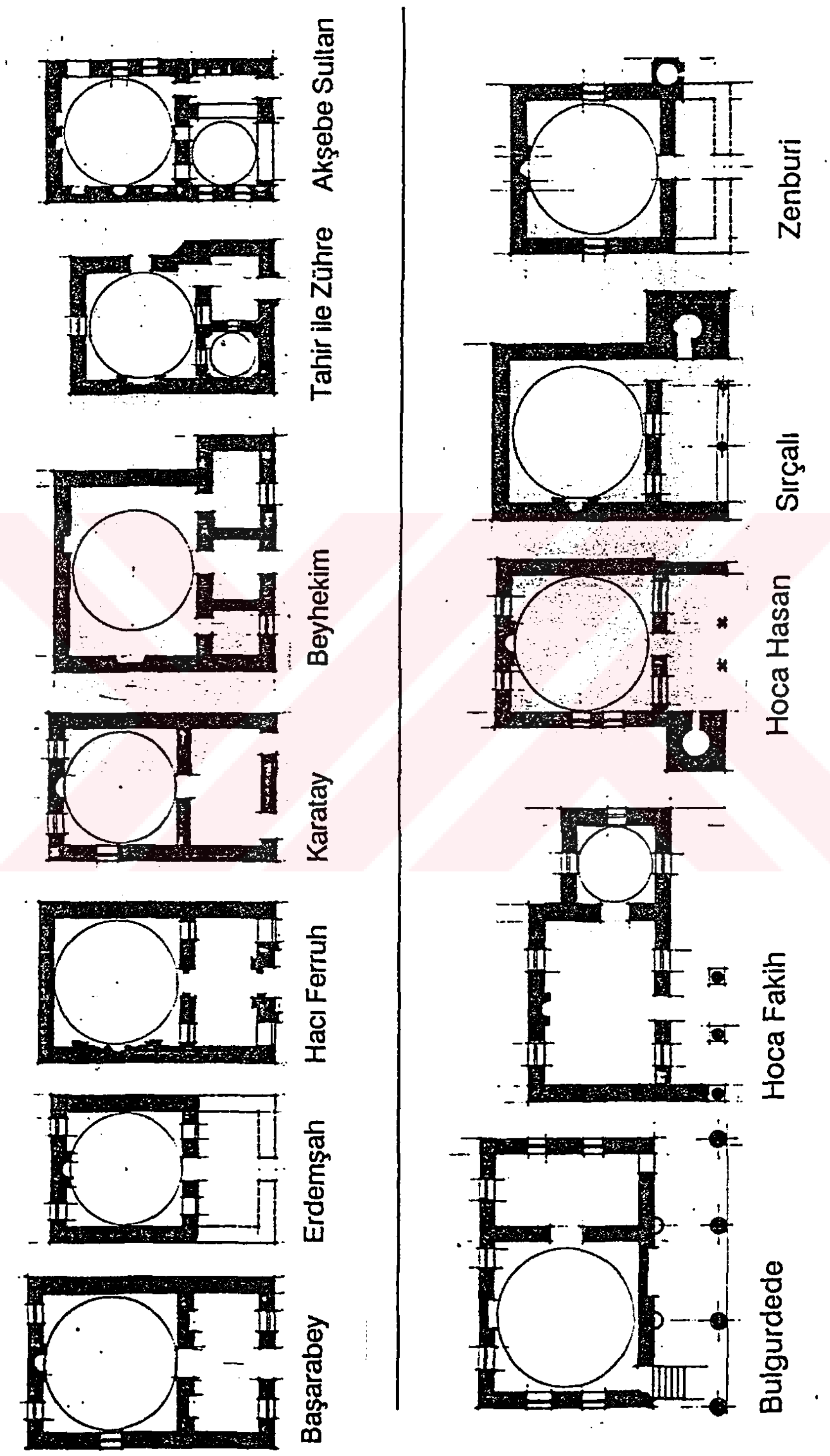

Figure 18. Continued.,

CHAPTER VII

RESTITUTION SCHEME

The evaluation of the building and comparative study show that the "mescid" has been preserved its integrity in terms of its spacial layout. Therefore the restitution work mainly concentrates on the partially or completely missing architectural elements, finishing materials and renderings. Unfortunately the other "mescid"s of the same period does not give a direct information since they have the similar problems with Tahir ile Zühre. The scarcity of the sources to illuminate the restitution problems of Tahir ile Zühre was another problem. The relevant sources are far from giving detailed information.

Then, those completely missing elements and the elements which have been subjected to partial losses are defined with their locations, forms, dimensions and materials that are supplemented by the laboratory studies. The reliability of each of these properties have been tried to be determined by the use of sources as an old photograph (Konyalı, 1964: 516) of the "mescid", finds that are obtained during the latest excavation, existing situation of the elements in concern, existing traces in the building, comparative studies and in most cases architectural necessities.

7.1 The Restitution of the Site

Elaborate workmanship and architectural organization of the east and north facades comparing with the others show that they were both open to public as if they were treated as main facades. Such qualities are not seen on the west and south facades. With respect to random rubble faces of the lower parts and the extension of these rubble parts above the tie beam gives the impression of having secondary importance. İ.H.Konyalı notes that there was another building (Dar'ül Hüffaz) adjacent to the "mescid" or very close to it. He also states that it was demolished in the period of Karamanids leaving no trace (Konyalı, 1964: 518). In the light of these information it can be assumed that Dar'ül Hüffaz was supposed to be placed adjacent to the south facade of the "mescid" since this facade has no opening.

7.2 The Restitution of the Elements

7.2.1 Mihrap

As the general features of the "mihrap" was given in Chapter III the unknown part of the "mihrap" is the lower parts. A few remains of stalactites beneath the existing five rooms are sufficient enough to complete them into seven which is the complete number of rows. The main problem of the "mihrap" is the missing lower parts of the either sides of the rectangular framework. Comparisons with the other "mihrap"s of the "mescid"s or mosques of the same century show that those parts reveals mainly two types of variations. In some cases they rest upon the floor in other cases however, engaged columns, in varying numbers, are placed on either sides of the niche. The dimensions and the format of the "mihrap" of Tahir ile Zühre is equally applicable for both variations. Therefore those parts can not be completed without further reliable data.

A few courses of brick found during the last excavation in front of the "mihrap" proved that the skeleton of the rectangular framework of the "mihrap" is of brick resting on the footings of the foundations. These finds give way to complete the missing parts of the rectangular framework with its original material other ornamentations of gypsum reliefs and glazed ceramic tiles covering this brick skeleton can be extended to the original floor level copying the existing upper parts since their form, dimensions and materials are known.

7.2.2 Portal

It is placed in the entrance arch which is the largest opening in the building deviated from the central axis from this arch. It makes 0.20m protrusion from the wall where its suspended. The skeleton of the portal is brick. Glazed ceramic tiles and gypsum is used together in the ornamentations. Geometric interlaces and the use of glazed ceramic tiles are very similar with the ornamentations of the "mihrap". The raw materials of the mortar (M.B.21) used in the brick skeleton of the portal is found to be similar with the other mortars used in the brick masonry of the building (Appendix-A).

The 0.20m protrusion from the wall, deviation from the central axis of the entrance arch and finely cut stone surfaces of the lower south and north sides of it, the use of gypsum (it is easily dissolved in water) in unsheltered place from the rain, its placement within the largest opening which gives the impression that it is especially designed an open "eyvan" brings about some certain questions if the portal is in its original place or not. In this respect for different scenario can be produced.

a. It was constructed at the same time with the building without considering those questions.

b. Initially there was no portal, it was constructed in a later period in its existing place by using the same techniques regarding ornamentations and materials.

c. Initially it was placed at the west wall of the entrance hall providing entrance to the prayer hall and it was transferred to the existing place. The external dimension, the width of the threshold stone at the bottom and decorated exterior borders are fit to the existing opening which gives way into the prayer hall.

d. Initially there was no portal, it was transferred from another building may be from Dar'ül Hüffaz which was demolished in a later period.

The comparison with the other portals of the "mescid"s of the same period do not give information. The age determination of the mortars used in the "mescid" and portal may give their construction dates, but this data can not be used if such a transfer took place in the past.

7.2.3 The Flooring and Paving Materials

The original flooring materials could not be detected in our surveys on the site during which the exterior and interior surfaces of the ground had already been leveled with concrete. Therefore all informations to be given in this section are based upon the excavations carried out by Vakıflar that are indicated on their measured drawings.

Three large travertine plates in front of the main entrance found during the first excavation (Figure 3.) enable us to know the original level of paving that is 0.40m down from the already existing threshold stone. Another stone plate found in front of the "türbe" by the same excavation at the same level of the ones found in front of the main entrance verifies this data (Figure 3). Nine pieces of drainage pipes made of fired clay found in the same excavation along the east and north facades at the depth of 1.5m referring to the statement of the contractor should also be noted here proving the existence of a drainage system around even if we may not be able to trace out the layout of the entire network.

Twelve or fifteen units of brick most of which are crumbled but remained in their original order found in the second excavation carried out in front of the entrance of the prayer hall with two pieces of stone plate 0.07m above the level of the bricks give us the original levels of flooring and its material (Figure 3.). No information could be obtained about the original flooring material of the entrance hall.

The upper level of the footings extends 0.63m down from the original floor level of the praying hall according to the third excavation in front of the "mihrap" in the prayer hall. The footings in this section protrude 0.20m from the inner face and probably from the outer face of the wall, even though the situation of the exterior is not indicated on these drawings. Therefore the total width of the footings can be estimated as 1.30m including 0.90m thickness of the wall. But the total depth of the footings, that is to say, the lowest level of the building under the ground is not known. The basic material of the footings is andesite with its local name Sille Taşı. Nevertheless, no more reliable data can be obtained without further excavations and investigations to have a sound knowledge of the infrastructure of the building.

7.2.4 Renderings

The remains of gypsum plaster found in different parts prove that gypsum was the main material as rendering as well as ornamentation material. The small projection (2cm) of the bottom edges of Turkish triangles prove that the interior faces of the walls were plastered with gypsum at least till the starting level of

Turkish triangles including the either sides of the openings.

7.2.5 Cornice Elements of the Roof

They are known by the old photograph of the "mescid" taken before 1958 intervention (Konyalı, 1964: 516). However, it does not give enough detail about the form and dimensions. Only the location and the material can be perceived by a careful examination. If we think that those stones were replaced in 1958 as a continuation of a tradition, by the new ones, of andesites, they can be considered that they were original. The widely used andesite cornice stones of many other "mescid"s in Konya also verify this data.

7.2.6 Windows and Doors

The material and details of original windows and doors of the "mescid" are not known since there is no remain. The other "mescid"s of the same period have the same problem due to the destructions by several reasons or alterations. But the remains of some gypsum window frame found during a recent excavation carried out in Hoca Hasan (of the same period) in Konya leads to think that this could also be applied for Tahir ile Zühre. But if the glazed ceramic frames of the windows of the "türbe" and "hankah" of Sahip Ata (he was also the donor of Tahir ile Zühre) is considered this could also be applied for Tahir ile Zühre. Even their exact locations within the openings are not known since there is no trace. Therefore it must be admitted that the windows of Tahir ile Zühre are still not known.

7.3 Conclusion

Summing up these evaluations;

a. The "mihrap", the floors of the prayer hall and pavings of the external grounds can be completed since their locations, forms, dimensions and materials are known.

b. Cornice elements of the roof are known only by their location and material. They can also be replaced by the same material at the same level but the unknown dimensions and form should be taken into consideration.

c. The location of the portal is open to debate as well as its existence, if it is originally built at the same time together with the "mescid", latterly added or transported. The existing state does not give sufficient information about the entire form and dimensions for any case.

d. The doors and windows are unknown elements with respect to their properties as, form, dimension and material, except for their locations (as niche and openings).

CHAPTER VIII
EVALUATION OF TAHİR İLE ZÜHRE

Historical research and comparative analyses of this study has shown that Tahir ile Zühre is one of the buildings of a unique type of an important period in the history of Anotolia. It is also placed in a unique group if compared with the other "mescid"s of the same period because they house a "türbe" in their layouts like Beyhekim and Akşebe Sultan "mescid"s. This gives them funerary characteristics as well as being religious buildings. The studies also proved that Tahir ile Zühre is a representative example of the buildings in which two different traditions in terms of material use, are skilfully combined; brick tradition of the Seljuks that they brought it from Asia and local tradition of stone use in Anatolia.

The scarcity of information, as for the architectural elements some parts of which are missing like the "mihrap" and portal, and completely missing elements like windows, doors and cornice elements of the roof were the main problems in order to make a complete restitution scheme. Therefore, most of our evaluations for those missing elements had to be based on the evaluation of their existing situation and architectural necessities which they may not give detailed information to be applied for their completions in the restoration stage. If the same detailed analysis which has been carried out for Tahir ile Zühre could be expanded to all the "mescid"s of the same period, it would be helpful not only to obtain supplementary information for each "mescid" but also to develop restoration techniques for "mescid"s and most likely for many other buildings of the same period.

The site surveys and the laboratory studies indicate that besides its historic, stylistic and architectural values Tahir ile Zühre also possesses some technological features that might be common to its period. The shell-like properties of its superstructure that are obtained by the use of carefully selected and prepared compatible materials, the astonishing homogeneities in the basic properties of stone and brick masonries prove how the "mescid" was able to reach our times. Two different kinds of masonry that have different physical properties are combined by the use of timber tie beams counterbalancing different mechanical stresses, acted as buffer and at the same time preventing the upper parts of brick from rising damp which is likely a recent problem introduced to the building somehow acting as damp-proof course. Although the actual location of the original drainage system is not exactly known, a few pottery drainage pipes found during the latest excavations prove the presence of a well functioning drainage system in the past (Figure 17.f).

In spite of all these superb technological features the monument is suffering heavy dampness problems combined with salt crystallization phenomenon due to the wrong interventions, as concrete applications in 1958, lack of proper water collecting systems and lack of maintenance for years. Therefore it needs some interventions that are specified in this study some of which are to be carried out urgently and some necessitate further studies and long-term investigations.

CHAPTER IX

RESTORATION PROPOSAL

9.1 Restoration Approach

Due to its religious and funerary characteristics Tahir ile Zühre is considered to continue its original function.

The evaluation of the building and comparative studies have shown that the monument have preserved its architectural integrity except for a few missing elements like doors and windows and some other elements with missing parts like "mihrap" and the portal. The main change in the building is 1958 intervention. This intervention did not cause much disturbance to the architectural integrity but it introduced some problems to the building. That is why it is evaluated in terms of physical inhomogenities in the structure. On the other hand, surveys and laboratory studies proved that the monument is in heavy dampness problem and salt decay and also suffering from harmful incompatible cement and concrete materials of 1958 intervention.

Therefore, our restoration will consist of mere physical interventions which aims to control and eliminate the existing problems, and some interventions which will be helpful for the use of the monument to sustain its function. The new interventions have high concern on architectural features, technological characteristics and historic values of the monument and aims to preserve them.

All the evaluations summarized here determined the scope of the new interventions. They are as follows;

a. The monument will be preserved with all its architectural features that were able to reach today.

b. Some of the applications of 1958 intervention that caused serious damage to the structure (cement and concrete applications) will be removed. If the removal is impossible the adequate techniques must be developed to neutralize their harmful effects to the structure.

c. The interventions are mainly done for the sake of physical stability of the structure and for the control of the existing problems which will be called protective interventions. Some interventions are for the use of the monument. Both types of interventions have been decided in the light of the restitution scheme.

d. The interventions will be visually distinguished from the original parts where they take place.

e. Specifications of new intervention materials are obtained from laboratory studies to be compatible with the original fabric in terms of durability as well as architectural integrity of the monument.

Before the description of the interventions, the following sections have been introduced to help to explain the aims, content and scope of the interventions. These are the explanation of the decision on 1958 intervention and selection and preparation of the new repair materials.

9.2 Explanation of the Decisions on 1958 Intervention

1958 intervention did not cause wide range of alterations as far as the overall architectural context is concerned. They are in the form of limited replacements of original bricks, substitutions and additions of the 1958 bricks to the upper parts of the east and north facades and infills to the south of the portal, in the rectangular continuation of the "türbe" window on the east facade, around the staircase opening to the roof and the dome of the "türbe" (See Section 3.6). Besides brick, the other materials involved in 1958 intervention are lime mortar, cement mortar and concrete.

The physical properties of 1958 bricks are within the limits of tolerance to be kept in the original fabric where the binder is also lime mortar. However, cement mortars and concrete give serious damage to the original fabric (See Section 4.8.1.b). Since the removal of materials in touch with original fabric will cause inevitable damage to the structure, 1958 bricks will be left in their position, but the cement and concrete applications will be removed as much as possible.

9.3 Selection and Preparation of the New Repair Materials

Selection and preparation of the repair materials are done according to the results of laboratory studies which are discussed in detail in Section 4.8. Here are the decisions based upon those discussions.

a. The selection of the new intervention bricks: As it was discussed previously (See Section 4.8.5.a) the bricks to be used as repair material will be solid hand made brick which is available in the market. But before giving the final decision for the use of a particular manufacturers product it must be subjected to some tests to determine their properties that are given in the standards (TS 704), and the physical properties measured in this study. Materials which fulfill the requirements of Turkish Standards should have the basic physical properties within the range of tolerance. However, it is always better to check those properties in representative number of samples, to ensure long term durability of our interventions.

The dimensions of those standard solid hand made bricks (19x9x5cm) are not similar with the bricks of Tahir ile Zühre. This will cause some problems. Therefore, the new intervention bricks will have the same dimensions with the original (21.5x21.5x4cm and 11 x21.5x4cm). On the other hand, a special sign should also be placed on one side to be exposed to distinguish them from the original bricks of the monument. These directions must be given to the manufacturer before the production of the orders.

b. Preparation of the new mortars: The mortars to be used in the new interventions are of two kinds as specified in Section 4.8.5.b being for stone and brick masonry. The type of the sand, and their particle size distribution, the sand and lime proportions will be the same as specified in the same section. In addition to this they should be free from cement and soluble salts. As it was stated, another important factor which will affect the final product mortar is the quality of lime. Therefore the lime should be properly slaked, conforming with the lime standard and its hydraulic property should be examined before selection, in order to have reproducible mortars of the specified properties.

Hydraulic mortar, is supposed to be originally used on the flat parts of the roof and in the joints of the brick courses of the exterior faces of the domes. The new hydraulic mortar to be applied to those parts, should be permeable enough to allow rapid evaporation but it should not absorb much water. If two or more layers of hydraulic mortar and plaster are applied to the roof, which have the same physical properties to original brick masonry and being less porous at the outer layer (Table 1) the superstructure will have uniform behavior to outside conditions and it will be an advantage for long term durability of the monument.

9.4 Interventions

The interventions may follow the sequence below except the removal of macroplants which should be done before the interventions on the roof.

9.4.1 Protective Interventions

a. New drainage systems for the site and the roof: The first drainage system proposed is to prevent the building from rain water attacks in the ground. A few original pottery drainage pipes found during the excavations (See Section 7.2.3) proved that the "mescid" originally had a drainage system. But, that did not give us enough information to draw out the entire network. Therefore a new drainage system with the standard concrete drainage pipes of today is proposed to be connected with the collecting pit already exists at the south-west corner of the site, belonging to the existing disposal system of the city. The original pipes will be exhibited in a glass case in the entrance hall including a written information which is supplemented by some simple drawings on which the locations where they were found are indicated.

The second one is simply a ditch system, in addition to the first one, to be placed along the south and north facades to collect the surface waters of Muzaffer Hamit and İmam Bağavi streets that are both asphalted. This system will also be connected to the same pit.

The third one is the drainage system to collect rain water of the roof.

If the concrete layer can be removed, new andesite stones (it was the material of the original cornice element, known from the restitution scheme) will be replaced on the edges, but they will be simplified and shaped in the form of gutter. The surface waters will be discharged by the use of metal downpipes connected to those gutters of andesite. The inner surface of the gutters and all the flat parts of the roof will be insulated by the application of hydraulic mortar which is specified in Section 9.2.b.

Construction of a new roof: If the concrete layer can not be removed the possibility of letting it to live together with the original fabric must be concerned. In this case, the task will be keeping it dry to prevent penetration of soluble salts to the porous fabric as well as controlling other damages like local condensation, high thermal expansion and contraction problems. A new protective roof is proposed to minimize some of those problems which is built of steel frame, and covered with corrugated translucent fiber sheets. The steel frame should have no direct contact with the monument. That is to say the supports of this construction will directly be resting upon to the ground giving no excessive loads to the monument. The surface waters of this roof will be collected by means of gutters with downpipes to be connected to the newly built drainage system.

b. Removal of concrete applications and cement mortars: Concrete was applied on the roof and "türbe" floor. The thickness of the concrete layer on the roof (approximately 15-20cm) indicates that its removal may not be an easy task due to the probability of giving harm to the original fabric. In case concrete can not be removed a new protective roof will be introduced as above. If it can be removed it will be replaced with hydraulic lime mortar (See Section 4.8.5 and 9.2.b).

The removal of leveling concrete on the "türbe" floor, however, does not seem much risky since it is placed directly on the ground. Such a removal may also give chance to detect the original floor cover which will be already decayed, if it remained beneath the concrete layer. If there is no clue about the original floor, following its removal, it will be substituted with gravel fill. This will indicate the lack of information about the original material.

The other application of cement mortars (they have already lost their stability) in the joints of cut stone faces of the east and north facades will be removed. They must be replaced with the new lime mortar similar to the original stone masonry mortars (See Sections 4.8.5 and 9.2.b).

c. Renewal of discharged mortars: Starting from the main dome the all discharged joints of brick courses of the domes will be renewed with hydraulic mortar (See Section 9.2.b). The application area of the hydraulic mortar is the exterior faces of the domes of the prayer hall and the "türbe" and flat parts of the roof (in case of the removal of the concrete layer). All the rest of the discharged joints in the building will be renewed with the lime mortar. The composition of the repair mortars will be varying according to the masonries where it is applied. The specifications for each case is given in Section 4.8.5.

d. Renewals of missing bricks: The missing bricks of the dome and the spurs around, the missing bricks of the upper levels of the exterior walls and of the floor of the prayer hall will be renewed by solid hand made bricks (See Sections 4.8.5.a and 9.2.a) with the new mortars similar to the original brick masonry mortars (See Sections 4.8.5.b and 9.2.b).

e. Cleaning of Soluble Salts: Existing soluble salts in the superstructure and in the walls must be cleaned by a proper method. As it was discussed in Section 4.8.5.c, there are few cleaning techniques and their use depend not only on the building but also on different parts of the same building such as wet and dry zones. Therefore the final technique or techniques are to be decided after several trials of each one for each case, if it will be electrochemical, wetted poultices or vacuum fluid technique.

f. Protections to prevent the building from drastic climatic conditions: The evaluation of the climatic data of Konya proved that the building is subjected to drastic fluctuations of the climatic conditions that may be effective on freeze-thaw and salt crystallization cycles generating many weathering forms. All these factors necessitate protection of inner parts of the monument by means of windows and doors. As it was discussed in the restitution scheme (See Section 7.2.6 and 7.3) the characteristics of the windows of Tahir ile Zühre is not known. This creates a difficulty in the choice of their material, form and dimensions in terms of restoration principles. Therefore it is deemed that they can be replaced by the wooden frames with glass for mere protective purpose and providing daylight. Including the largest arched opening on the east facade, only exterior openings will be closed.

The door of the prayer hall is known only by its location (See Section 3.2.2.b) but its form, exact dimensions and material are not known. Only material that can be supposed is wood. However, since it is inside the monument, this opening does not need a door.

The existing traces in the portal does not give any clue if there was a door in it. But because of the necessity of a thorough protection, a door is needed. It will be placed on the interior face of the portal frame due to the amorphous shape of the opening. Since we know that the original material of its skeleton was brick (See Section 7.2.2), the missing parts of the portal will be supported with the new repair brick (See Section 9.2.a) with new lime mortar (See Section 9.2.b).

g. Removal of macroplants: They will all be removed before the interventions of the roof. Using toxic agents is not necessary for this removal since they are relatively small plants.

h. The portal and "mihrap": Due to the scarcity of information the portal can not be completed. Even its location is also open to debate. Its existing posture gives the impression, as if it is suspended on the brick wall of 1958 intervention which is not stable and in a critical stage too. However, it still keeps an important place in the "mescid", as an architectural element. From the restitution scheme we know that the original material of its skeleton is brick with lime mortar. Here, it is decided to preserve it in its existing place by completing only the missing lower parts of the rectangular frame, using new brick masonry mortar, as an emergency mechanical support. It will also be protected from rain by means of protective eaves to be mounted immediately above, as a continuation of the window sill in the arched opening of the entrance hall. This protection is needed due to the presence of gypsum which is highly soluble in to water, and glazed ceramic tiles.

In case of "mihrap", the relevant data is sufficient enough (except for the existence of engaged columns) to complete the "mihrap". However, since the consolidation and/or completion techniques of gypsum work and glazed ceramic tiles need special conservation study and experts for their realization, the "mihrap" will also be intervened same as the portal.

Both portal and "mihrap" should be the subject of a special conservation work dealt with experts who have experience on conservation of glazed ceramic tiles and ornamental plasterwork. The research of this study on their restitution will be helpful during the conservation work.

9.4.2 Interventions that are Necessary for the Use of the Monument

The floor of the prayer hall will be of new intervention brick with the binder of lime mortar except the area in front of the entrance which is of andesite.

For the floor of the entrance hall, travertine plates with random shapes at the same level with the first stepping stone placed at the bottom of the entrance arch of the prayer hall will be used. Each stone should also have a sign carved on their exposed surfaces distinguishing them from the original ones as it was done for the new bricks.

The paving material of the external ground will also be of travertine plates with the same sign, at the same level with the original ones.

The renewal of the floor of "türbe" has been discussed and explained above (See Section 9.4.1.b).

9.4.3 Long Term and Periodical Observations

- A microclimatic survey of the monument including the measurements inside and outside of the building should be done for the year. The results will explain whether a climatic control is necessary or not and if a climatic control proves to be necessary, the conditions and periods of control that is its specifications. At that point, one has also to consider the results of salt cleaning process.

- Observations on the weathering material; if the loss of material continue, salt deposits develop etc.

- Observations whether the dampness dries out should be done at least once every year to check the efficiency of interventions and whether new problems come up.

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APPENDICES

APPENDIX A. Percent Acid Soluble, Aggregate and Sand Size Distribution in Mortars

SAMPLES	% AC.SOL.	% AGG.	% 1000 M.	% 500 M.	% 250 M.	% 125 M.	% 125
M.B.1	60.2 ± 0.5	39.8 ± 0.5	3.6 ± 0.9	4.3 ± 0.1	14.2 ± 0.2	12.0 ± 0.2	5.9 ± 0.4
M.B.2	65.8 ± 0.9	34.2 ± 0.9	3.0 ± 0.1	8.2 ± 0.2	14.4 ± 0.4	5.9 ± 0.1	2.8 ± 0.2
M.B.3	63.6 ± 0.2	36.4 ± 0.2	3.8 ± 0.2	9.3 ± 0.1	15.1 ± 0.2	6.0 ± 0.1	2.3 ± 0.0
M.B.4	60.2 ± 0.3	39.7 ± 0.3	3.0 ± 0.4	6.8 ± 0.5	14.6 ± 0.4	10.6 ± 0.1	4.8 ± 0.4
M.B.5	64.9 ± 0.7	35.1 ± 0.7	2.6 ± 0.4	5.4 ± 0.1	12.8 ± 0.2	9.8 ± 0.1	4.7 ± 0.2
M.B.6	70.0 ± 0.7	30.0 ± 0.7	2.5 ± 0.4	4.8 ± 0.1	10.1 ± 0.3	7.8 ± 0.2	4.7 ± 0.1
M.B.7	60.4 ± 1.3	39.6 ± 1.3	2.7 ± 0.3	6.2 ± 0.1	14.7 ± 0.0	11.1 ± 0.2	6.2 ± 1.1
M.B.8	66.3 ± 0.0	33.7 ± 0.0	3.3 ± 0.5	6.9 ± 0.1	13.2 ± 0.7	6.3 ± 0.1	4.2 ± 1.1
M.B.9	69.1 ± 12.8	30.9 ± 12.8	2.6 ± 0.6	6.2 ± 2.7	11.1 ± 4.7	7.7 ± 3.5	3.7 ± 1.6
M.B.10	76.0 ± 0.6	24.0 ± 0.6	2.6 ± 0.3	3.9 ± 0.2	8.8 ± 0.1	6.0 ± 0.2	3.9 ± 0.1
M.B.11	69.0 ± 0.7	31.0 ± 0.7	2.4 ± 0.3	5.2 ± 0.5	11.0 ± 0.5	7.4 ± 0.1	5.3 ± 0.2
M.B.12	74.5 ± 0.0	25.5 ± 0.0	2.6 ± 0.1	4.5 ± 0.2	9.6 ± 0.1	5.9 ± 0.0	3.1 ± 0.2
M.B.13	61.1 ± 1.2	38.9 ± 1.2	5.2 ± 1.1	8.9 ± 0.6	15.5 ± 1.3	6.7 ± 0.4	3.0 ± 0.1
M.B.14	60.8 ± 0.5	39.2 ± 0.5	4.7 ± 0.0	9.0 ± 0.4	16.3 ± 0.1	6.7 ± 0.0	2.7 ± 0.0
M.B.15	69.0 ± 7.2	31.0 ± 7.2	2.7 ± 0.5	6.1 ± 1.9	11.7 ± 3.4	5.5 ± 1.2	4.9 ± 0.1
M.B.16	68.3 ± 0.0	31.7 ± 0.0	2.6 ± 0.0	6.9 ± 0.1	13.1 ± 0.2	6.0 ± 0.1	3.5 ± 0.4
M.B.17	51.9 ± 11.5	48.2 ± 11.5	3.8 ± 0.0	11.5 ± 3.0	19.3 ± 5.4	8.8 ± 2.2	5.1 ± 1.0
M.B.18	65.2 ± 0.0	34.8 ± 0.0	3.8 ± 0.8	7.3 ± 0.1	13.2 ± 0.0	6.2 ± 0.00	4.4 ± 0.7
M.B.19	61.3 ± 5.1	38.7 ± 5.1	3.8 ± 0.1	9.3 ± 1.3	16.1 ± 2.0	6.9 ± 1.0	2.8 ± 0.6
M.B.20	72.9 ± 0.2	27.1 ± 0.2	2.6 ± 0.2	5.4 ± 0.2	9.6 ± 0.2	6.5 ± 0.2	3.2 ± 0.1
M.B.21	65.7 ± 0.3	34.3 ± 0.3	3.4 ± 0.0	5.8 ± 0.2	12.1 ± 0.4	8.9 ± 0.0	4.3 ± 0.1
M.B.22	73.7 ± 0.3	26.3 ± 0.3	1.7 ± 0.1	5.2 ± 0.2	10.2 ± 0.2	6.5 ± 0.1	3.4 ± 0.1
M.B.23	70.2 ± 0.8	29.4 ± 0.8	3.5 ± 0.3	7.5 ± 0.1	11.5 ± 0.8	4.6 ± 0.3	2.6 ± 0.1
M.B.24	63.3 ± 0.8	36.7 ± 0.8	2.8 ± 0.2	5.9 ± 0.2	14.3 ± 0.2	10.3 ± 0.1	3.4 ± 0.0
M.B.25	60.2 ± 0.3	39.8 ± 0.3	3.9 ± 0.9	6.4 ± 0.1	15.8 ± 0.8	10.9 ± 0.5	3.3 ± 0.4
M.B.26	60.1 ± 0.4	39.9 ± 0.4	4.1 ± 0.2	9.6 ± 0.1	17.1 ± 0.3	6.6 ± 0.1	2.8 ± 0.2
M.B.27	63.5 ± 0.6	36.5 ± 0.6	3.2 ± 1.0	6.2 ± 0.1	12.7 ± 0.2	9.7 ± 0.2	4.8 ± 0.1
M.B.(AV)	65.4 ± 5.5	34.6 ± 5.5	3.2 ± 0.8	6.8 ± 1.9	13.3 ± 2.6	7.7 ± 2.0	3.9 ± 1.1

SAMPLES	% AC.SOL.	% AGG.	% 1000% M.	% 500 M.	% 250 M.	% 125 M.	% 125_= M.
M.S.1	52.8 ± 0.1	47.2 ± 0.1	3.8 ± 0.1	7.6 ± 0.3	18.2 ± 0.2	12.5 ± 0.1	5.4 ± 0.0
M.S.2	54.2 ± 0.6	45.8 ± 0.6	3.8 ± 0.1	9.1 ± 0.1	19.4 ± 0.3	9.4 ± 0.2	4.1 ± 0.2
M.S.3	67.5 ± 0.1	32.5 ± 0.1	3.1 ± 0.5	6.6 ± 0.3	12.8 ± 0.4	6.4 ± 0.2	3.5 ± 0.1
M.S.4	61.3 ± 0.3	38.7 ± 0.3	4.2 ± 0.2	7.6 ± 0.4	15.5 ± 0.2	7.8 ± 0.1	3.9 ± 0.1
M.S.5	53.2 ± 1.2	46.8 ± 1.2	7.2 ± 0.9	9.4 ± 1.2	18.1 ± 0.7	8.8 ± 0.2	3.6 ± 0.0
M.S.6	69.7 ± 1.2	30.3 ± 1.2	2.6 ± 0.1	6.5 ± 0.2	12.4 ± 0.5	5.5 ± 0.2	3.4 ± 0.2
M.S.7	54.0 ± 0.9	46.0 ± 0.9	5.2 ± 0.6	10.0 ± 0.2	18.5 ± 0.4	8.5 ± 0.3	4.3 ± 0.4
M.S.8	61.3 ± 4.9	38.7 ± 4.9	2.8 ± 0.8	6.2 ± 0.8	16.2 ± 2.4	9.1 ± 0.8	4.3 ± 0.2
M.S.(AV)	59.2 ± 6.3	40.7 ± 6.3	4.1 ± 1.4	7.9 ± 1.4	16.4 ± 2.5	8.5 ± 2.0	4.0 ± 0.6

SAMPLES	% AC.SOL.	% AGG.	% 1000% M.	% 500 M.	% 250 M.	% 125 M.	% 125_= M.
M.B.28	67.8 ± 0.2	32.2 ± 0.2	2.9 ± 0.7	3.5 ± 0.3	9.4 ± 0.0	8.8 ± 0.3	7.4 ± 0.0
M.B.29	47.0 ± 0.6	53.0 ± 0.6	13.8 ± 1.4	5.4 ± 0.0	11.4 ± 0.1	16.6 ± 0.5	5.6 ± 0.3
M.B.30	65.4 ± 0.3	34.6 ± 0.3	6.7 ± 0.0	4.9 ± 0.6	8.5 ± 1.3	10.2 ± 2.0	4.4 ± 0.2
M.B.31	51.1 ± 0.6	48.9 ± 0.6	8.8 ± 0.3	6.4 ± 0.3	13.7 ± 0.0	14.1 ± 0.1	6.2 ± 0.1
M.B.32	50.2 ± 0.4	49.8 ± 0.4	8.6 ± 0.3	8.4 ± 0.1	13.3 ± 0.2	15.7 ± 0.0	4.1 ± 0.0
M.B.33	49.4 ± 0.6	50.6 ± 0.6	9.6 ± 0.5	6.4 ± 0.4	13.4 ± 0.3	15.3 ± 0.1	6.1 ± 0.0

APPENDIX B. Wetting Rates of Bricks

RED BRICKS				YELLOW BRICKS			
TIME	B.R.1-3	B.R.4-6	AVERAGE	B.Y.1-3	B.Y.4-5	B.Y.6-8	AVERAGE
0 Min	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
15 Min	21.7 ± 0.3	24.2 ± 0.7	22.9 ± 1.2	25.6 ± 0.6	20.5 ± 1.9	22.4 ± 3.5	22.8 ± 2.1
30 Min	22.5 ± 0.4	24.8 ± 0.7	23.6 ± 1.2	26.2 ± 0.4	21.8 ± 2.2	22.6 ± 3.5	23.5 ± 1.9
1 Hr	23.0 ± 0.4	25.0 ± 1.6	24.0 ± 1.0	26.7 ± 0.5	21.9 ± 2.1	23.1 ± 3.7	23.9 ± 2.0
2 Hrs	23.5 ± 0.2	25.6 ± 0.7	24.5 ± 1.1	27.3 ± 0.6	23.2 ± 2.0	24.2 ± 3.6	24.9 ± 1.7
3 Hrs	23.7 ± 0.3	25.7 ± 0.7	24.7 ± 1.0	27.3 ± 0.5	23.2 ± 2.0	24.4 ± 3.8	24.9 ± 1.7
4 Hrs	23.8 ± 0.4	26.0 ± 0.5	24.9 ± 1.1	27.4 ± 0.5	23.2 ± 2.0	24.4 ± 3.8	25.0 ± 1.8
1 Day	24.7 ± 0.4	26.5 ± 0.7	25.6 ± 0.9	28.2 ± 0.5	23.8 ± 2.1	25.3 ± 3.7	25.2 ± 2.2
2 Days	25.8 ± 0.4	27.5 ± 0.5	26.7 ± 0.8	29.9 ± 0.4	25.7 ± 2.0	27.1 ± 3.8	27.6 ± 1.7
3 Days	26.2 ± 0.4	27.7 ± 0.6	26.9 ± 0.7	30.3 ± 0.4	26.7 ± 2.5	28.0 ± 3.8	28.4 ± 1.5
5 Days	26.6 ± 0.4	28.1 ± 0.7	27.3 ± 0.8	30.9 ± 0.5	26.8 ± 2.4	28.4 ± 3.8	28.7 ± 1.7
6 Days	26.7 ± 0.3	28.1 ± 0.6	27.4 ± 0.7	31.1 ± 0.5	26.9 ± 2.4	28.5 ± 3.7	28.8 ± 1.8
7 Days	27.1 ± 0.3	28.6 ± 0.7	27.8 ± 0.8	31.6 ± 0.4	27.3 ± 2.1	30.0 ± 3.6	29.6 ± 1.8
8 Days	27.1 ± 0.4	28.9 ± 0.7	27.9 ± 0.8	31.7 ± 0.4	27.7 ± 2.0	30.6 ± 3.6	30.0 ± 1.7
9 Days	27.3 ± 0.4	28.9 ± 0.7	28.1 ± 0.8	32.0 ± 0.5	28.0 ± 2.2	30.6 ± 3.6	30.2 ± 1.7
10 Days	27.8 ± 0.3	28.9 ± 0.7	28.3 ± 0.6	32.6 ± 0.5	28.7 ± 2.4	30.6 ± 3.6	30.6 ± 1.6

PINK BRICKS					
TIME	B.P.1-3	B.P.4-6	B.P.7-9	B.P.10-12	AVERAGE
0 Min	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
15 Min	24.9 ± 0.2	23.0 ± 2.5	27.4 ± 0.7	27.4 ± 1.0	25.6 ± 1.8
30 Min	25.9 ± 0.1	23.6 ± 2.7	27.9 ± 0.7	27.8 ± 1.0	26.3 ± 1.8
1 Hr	26.7 ± 0.2	24.1 ± 2.4	28.2 ± 0.5	28.6 ± 1.0	26.9 ± 1.8
2 Hrs	27.4 ± 0.2	25.0 ± 2.4	28.8 ± 0.3	28.7 ± 1.0	27.5 ± 1.5
3 Hrs	27.4 ± 0.2	25.0 ± 2.4	28.9 ± 0.2	28.9 ± 1.1	27.6 ± 1.6
4 Hrs	27.5 ± 0.2	25.0 ± 2.4	29.2 ± 0.4	29.3 ± 1.1	27.8 ± 1.7
1 Day	28.4 ± 0.2	26.1 ± 2.2	30.4 ± 0.4	29.7 ± 1.0	28.6 ± 1.6
2 Day	29.5 ± 0.2	27.2 ± 2.3	32.0 ± 0.6	31.0 ± 1.1	29.9 ± 1.8
3 Day	30.0 ± 0.2	28.0 ± 2.4	33.1 ± 0.5	31.3 ± 1.3	30.6 ± 1.9
5 Day	30.3 ± 0.3	28.2 ± 2.5	33.7 ± 0.8	31.9 ± 1.2	31.0 ± 2.0
6 Day	30.4 ± 0.2	28.2 ± 2.5	34.0 ± 0.6	31.9 ± 1.2	31.2 ± 2.1
7 Day	30.9 ± 0.1	29.1 ± 2.4	34.6 ± 0.5	32.3 ± 1.3	31.7 ± 2.0
8 Day	30.9 ± 0.1	29.3 ± 2.4	34.8 ± 0.3	32.7 ± 1.4	31.9 ± 2.
9 Day	31.3 ± 0.4	29.3 ± 2.4	35.0 ± 0.6	32.8 ± 1.3	32.1 ± 2.1
10 Day	31.3 ± 0.4	29.3 ± 2.4	35.8 ± 0.6	33.2 ± 1.4	32.4 ± 2.4

BROWN BRICKS				BRICKS OF 1958		
TIME	B.B.1-3	B.B.4-6	AVERAGE	B.I.1-3	B.I.4-6	AVERAGE
0 Min	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
15 Min	13.8 ± 1.0	10.6 ± 1.1	12.2 ± 1.6	14.8 ± 2.4	16.4 ± 0.7	15.6 ± 0.8
30 Min	14.0 ± 0.9	11.2 ± 0.5	12.6 ± 1.4	14.8 ± 2.4	19.3 ± 0.6	17.0 ± 2.2
1 Hr	14.1 ± 0.9	11.3 ± 0.5	12.7 ± 1.4	14.8 ± 2.4	19.5 ± 0.5	17.2 ± 2.3
2 Hrs	14.3 ± 1.0	11.6 ± 0.5	12.9 ± 1.4	14.9 ± 2.5	19.7 ± 0.4	17.3 ± 2.4
3 Hrs	14.3 ± 1.0	11.7 ± 0.6	13.0 ± 1.3	15.2 ± 2.6	19.8 ± 0.5	17.5 ± 2.3
4 Hrs	14.4 ± 0.9	11.8 ± 0.6	13.1 ± 1.3	15.3 ± 2.5	20.0 ± 0.6	17.6 ± 2.3
1 Day	14.8 ± 1.0	12.0 ± 0.7	13.4 ± 1.4	15.6 ± 2.7	20.4 ± 0.6	18.0 ± 2.4
2 Days	15.6 ± 1.1	12.9 ± 0.9	14.2 ± 1.4	16.8 ± 2.7	21.5 ± 0.6	19.1 ± 2.4
3 Days	15.9 ± 1.0	13.2 ± 0.7	14.5 ± 1.4	17.2 ± 2.3	21.7 ± 0.5	19.5 ± 2.2
5 Days	16.0 ± 1.0	13.2 ± 0.7	14.6 ± 1.4	17.3 ± 2.0	21.8 ± 0.6	19.6 ± 2.2
6 Days	16.2 ± 1.0	13.3 ± 0.7	14.7 ± 1.5	17.5 ± 2.4	21.8 ± 0.6	19.6 ± 2.2
7 Days	16.5 ± 1.0	13.6 ± 0.7	15.0 ± 1.4	18.2 ± 2.7	22.0 ± 0.4	20.1 ± 1.9
8 Days	16.5 ± 1.1	14.0 ± 0.7	15.2 ± 1.3	18.2 ± 2.6	22.1 ± 0.5	20.2 ± 1.9
9 Days	16.7 ± 0.1	14.3 ± 0.6	15.5 ± 1.2	18.3 ± 2.5	22.4 ± 0.5	20.3 ± 2.0
10 Days	17.1 ± 1.1	14.4 ± 0.7	15.7 ± 1.4	18.4 ± 2.6	22.6 ± 0.5	20.5 ± 2.1

APPENDIX C. Drying Rates of Bricks

	RED BRICKS			YELLOW BRICKS			
Time(Day)	B.R.1-3	B.R.4-6	AVERAGE	B.Y.1-3	B.Y.4-5	B.Y.6-8	AVERAGE
0.00	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
0.05	99.5 ± 0.3	98.0 ± 0.5	98.8 ± 0.8	99.7 ± 0.1	97.7 ± 0.3	97.5 ± 0.7	98.3 ± 1.0
0.10	98.0 ± 0.8	96.3 ± 0.8	97.2 ± 0.8	99.2 ± 0.1	95.4 ± 0.2	95.7 ± 1.1	96.8 ± 1.7
0.15	96.7 ± 1.2	95.3 ± 1.0	96.0 ± 0.7	98.0 ± 0.4	94.8 ± 0.2	94.2 ± 1.2	95.7 ± 1.7
0.20	95.5 ± 1.4	94.0 ± 0.9	94.8 ± 0.8	97.5 ± 0.6	94.0 ± 0.6	93.5 ± 1.4	95.0 ± 1.8
0.25	95.0 ± 1.8	93.0 ± 1.3	94.0 ± 1.0	96.4 ± 0.8	93.3 ± 1.3	93.2 ± 1.3	94.3 ± 1.5
0.60	78.6 ± 6.1	82.8 ± 4.5	80.7 ± 2.1	83.6 ± 3.3	83.5 ± 4.4	88.1 ± 1.1	85.1 ± 2.2
0.80	72.3 ± 8.7	78.6 ± 6.0	75.4 ± 3.1	79.1 ± 4.4	76.9 ± 6.2	84.8 ± 1.1	80.3 ± 3.3
1.00	46.4 ± 11.1	57.2 ± 7.4	51.8 ± 5.4	58.6 ± 7.7	60.4 ± 13.9	66.9 ± 7.8	62.0 ± 3.5
2.00	30.8 ± 8.3	39.0 ± 12.2	34.9 ± 4.1	41.6 ± 10.0	39.4 ± 20.7	45.0 ± 12.7	42.0 ± 2.8
3.00	23.4 ± 6.5	28.0 ± 10.9	25.7 ± 2.3	27.5 ± 11.2	27.6 ± 20.0	31.4 ± 15.5	28.9 ± 1.8
4.00	16.8 ± 4.2	17.4 ± 7.2	17.1 ± 0.3	13.2 ± 7.2	14.4 ± 13.0	15.2 ± 10.0	14.2 ± 0.8
5.00	13.5 ± 3.5	11.9 ± 4.8	12.7 ± 0.8	8.3 ± 4.8	7.2 ± 6.3	6.2 ± 4.6	7.2 ± 0.9
6.00	8.8 ± 2.3	5.7 ± 2.2	7.3 ± 1.6	3.0 ± 2.1	1.3 ± 0.4	1.2 ± 0.7	1.8 ± 0.8
7.00	6.3 ± 0.9	3.0 ± 0.8	6.0 ± 2.1	0.9 ± 0.4	0.2 ± 0.2	0.5 ± 0.1	0.5 ± 0.3
8.00	4.7 ± 1.2	1.7 ± 0.5	3.2 ± 1.5	0.2 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1
9.00	3.2 ± 0.7	0.0 ± 0.0	1.6 ± 1.6	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
10.00	1.8 ± 1.2	0.0 ± 0.0	0.9 ± 0.9	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
11.00	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

PINK BRICKS					
TIME(Day)	B.P.1-3	B.P.4-6	B.P.7-9	B.P.10-12	AVERAGE
0.00	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
0.05	98.5 ± 0.8	98.1 ± 0.6	98.1 ± 0.6	98.2 ± 0.5	98.2 ± 0.2
0.10	97.1 ± 0.6	96.8 ± 0.3	97.3 ± 1.0	96.8 ± 0.2	97.0 ± 0.2
0.15	96.1 ± 1.0	96.2 ± 0.2	96.0 ± 0.5	95.8 ± 0.3	96.0 ± 0.2
0.20	95.5 ± 1.0	94.8 ± 0.4	95.5 ± 0.1	94.8 ± 0.2	95.1 ± 0.4
0.25	94.4 ± 1.1	94.0 ± 0.4	95.1 ± 0.2	93.8 ± 0.6	94.4 ± 0.5
0.60	85.2 ± 3.5	83.8 ± 3.2	85.3 ± 2.4	82.0 ± 3.8	84.1 ± 1.3
0.80	80.6 ± 5.0	79.6 ± 4.0	80.9 ± 0.8	76.0 ± 6.6	79.3 ± 2.0
1.00	64.4 ± 10.4	60.8 ± 9.6	64.1 ± 5.6	58.6 ± 5.1	62.0 ± 2.4
2.00	43.3 ± 13.6	43.0 ± 12.5	44.5 ± 7.5	41.8 ± 11.3	43.2 ± 1.0
3.00	31.7 ± 12.0	29.7 ± 11.9	31.6 ± 9.9	31.0 ± 12.1	31.0 ± 0.8
4.00	19.7 ± 7.3	14.7 ± 6.5	13.0 ± 6.2	18.4 ± 9.0	16.5 ± 2.7
5.00	15.5 ± 5.8	9.0 ± 4.5	5.9 ± 2.6	12.5 ± 6.3	10.7 ± 3.6
6.00	8.6 ± 3.6	2.7 ± 2.1	0.7 ± 0.8	6.1 ± 3.1	4.5 ± 3.0
7.00	5.8 ± 2.4	1.2 ± 1.2	0.3 ± 0.3	3.1 ± 1.9	2.6 ± 2.1
8.00	3.1 ± 1.8	0.3 ± 0.4	0.0 ± 0.0	1.1 ± 0.8	1.1 ± 1.2
9.00	1.1 ± 1.1	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.5
10.00	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
11.00	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

	BROWN BRICKS			BRICKS OF 1958		
TIME (Day)	B.B.1-3	B.B.4-6	AVERAGE	B.I.1-3	B.I.4-6	AVERAGE
0.00	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
0.05	98.8 ± 1.1	99.0 ± 0.7	98.9 ± 0.1	98.8 ± 0.4	98.0 ± 0.9	98.4 ± 0.4
0.10	97.7 ± 1.3	98.2 ± 1.6	98.0 ± 0.2	96.6 ± 1.0	96.6 ± 0.6	96.6 ± 0.0
0.15	96.8 ± 1.8	96.6 ± 2.2	97.0 ± 0.1	96.2 ± 1.1	95.0 ± 0.6	95.6 ± 0.6
0.20	95.7 ± 1.7	95.8 ± 1.9	95.7 ± 0.1	96.0 ± 1.2	94.5 ± 0.6	95.2 ± 0.7
0.25	94.8 ± 1.3	95.0 ± 1.0	94.9 ± 0.1	95.6 ± 1.3	93.8 ± 0.5	94.6 ± 0.7
0.60	79.2 ± 4.8	81.3 ± 0.8	80.2 ± 1.0	84.0 ± 3.5	80.2 ± 4.4	82.1 ± 1.9
0.80	71.2 ± 2.2	74.1 ± 2.1	72.6 ± 1.4	80.3 ± 2.1	73.6 ± 2.2	77.0 ± 3.4
1.00	56.3 ± 4.1	49.4 ± 7.8	52.9 ± 3.4	60.2 ± 9.0	56.4 ± 4.2	58.3 ± 1.9
2.00	32.0 ± 5.9	31.1 ± 8.0	31.6 ± 0.4	43.2 ± 15.3	43.9 ± 4.3	43.3 ± 0.3
3.00	20.9 ± 2.7	20.0 ± 3.2	20.4 ± 0.4	30.0 ± 14.7	32.2 ± 4.8	31.1 ± 1.1
4.00	14.1 ± 1.1	12.0 ± 1.6	13.0 ± 1.1	13.0 ± 8.8	23.0 ± 4.0	18.0 ± 5.0
5.00	11.2 ± 0.8	9.6 ± 1.1	10.4 ± 0.8	6.6 ± 5.2	19.9 ± 3.4	13.3 ± 6.6
6.00	6.3 ± 0.2	4.0 ± 1.8	5.1 ± 1.2	1.4 ± 1.3	12.8 ± 1.6	7.1 ± 5.7
7.00	5.0 ± 1.3	2.5 ± 2.6	3.7 ± 1.2	0.3 ± 0.2	8.7 ± 1.7	4.5 ± 4.2
8.00	1.9 ± 1.3	1.2 ± 1.3	1.6 ± 0.3	0.0 ± 0.0	6.1 ± 0.4	3.0 ± 3.0
9.00	1.0 ± 0.8	0.0 ± 0.0	1.0 ± 0.7	0.0 ± 0.0	3.4 ± 0.5	1.7 ± 1.7
10.00	0.2 ± 0.3	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.6 ± 0.5	0.3 ± 0.3
11.00	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0