THREE DIMENSIONAL MODELING OF URLA, HERSEKZADE AHMET PAŞA BATH BASED ON TACHEOMETRIC MEASUREMENT

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ABSTRACT

THREE DIMENSIONAL MODELING OF URLA, HERSEKZADE AHMET PAŞA BATH BASED ON TACHEOMETRIC MEASUREMENT

Reliable documentation is a prerequisite for the conservation and restoration of historic monuments. Using the case study of Hersekzade Ahmet Paşa Bath in Urla, İzmir, three dimensional modeling as a conservation and restoration aimed documentation technique is considered. This study aims to manage the process of the production of easily viewed three dimensional representations of historic monuments with the aim of conservation and restoration. The method of the study comprehends gathering of measured data with tacheometric techniques and their evaluation with three dimensional modeling technique as an interpretation tool for the near-by surrounding, layout and structure of the case study.

A series of representation scales; namely 1/200, 1/100 and 1/50; are considered in order to make possible the discussion of various scales of a conservation and restoration design. The site model including the mass geometry, the neighboring masses, roads and the surrounding ground is drawn for printing in 1/200 scale; the caldarium of the women's section with its building elements such as dome, arch, wall and floor, and its architectural elements such as stone wash basins and marble floor covering, and decorative elements at the arches and domes is drawn for printing in 1/100 scale; and a dome on the caldarium of the women's section with its oculi, the structural deformations and the remains of plaster is drawn for printing in 1/50 scale.

This study states that the technique of three dimensional modeling has great potential for conservation and restoration aimed documentation of historic monuments. The data gathered is easy to interpret, once the principles of modeling are followed. Nevertheless, creating a three dimensional model is not a task to be underestimated since it will take considerable time and manual drafting effort. Thus, the technique should be applied to architectural heritage which necessitates through three dimensional evaluation.

ÖZET

URLA, HERSEKZADE AHMET PAŞA HAMAMININ TAKEOMETRİK ÖLÇÜME DAYALI ÜÇ BOYUTLU MODELLEMESİ

Tarihi yapıların korunması ve restorasyonu için öncelikli önemi olan, doğru belgelemedir. İzmir, Urla Hersekzade Ahmet Paşa Hamamı örneğinde gerçekleştirilen bu çalışmada koruma ve restorasyon amaçlı üç boyutlu belgeleme tekniği uygulanmıştır. Tarihi yapıların koruma ve restorasyon amaçlı üç boyutlu temsili süreci ayrıntılı olarak tartışılmıştır. Takeometrik teknikle alınan ölçüler ve betimleyici fotoğraflar, CAD programı kullanılarak değerlendirilmiştir.

Anıt yapıların korunması ve restorasyonu çalışmalarının gerekleri dikkate alınarak, 1/200, 1/100 ve 1/50 şeklinde bir dizi sunum ölçeği belirlenmiştir. Yapı geometrisini, komşu binaları, caddeleri ve yapıyı çevreleyen zemini içeren vaziyet modeli 1/200 ölçekte; kubbe, kemer, duvar ve döşeme gibi bina elemanları ile taş kurna, mermer döşeme kaplaması ve kemer ve kubbe süsleri gibi mimari elemanları içeren kadınlar bölümünün sıcaklık mekânı 1/100 ölçekte ve kadınlar bölümünün sıcaklık mekânının üst örtü elemanlarından olan kubbe ile üzerindeki fil gözleri, dış yüzeyindeki strüktürel deformasyonlar ve sıva kalıntıları 1/50 ölçekte çizilmiştir.

Bu çalışma, üç boyutlu modelleme tekniği ile tarihi yapıların koruma ve restorasyon amaçlı belgelenmesinde koruma sorununu algılamayı kolaylaştırıcı bir sonuç ürünün elde edildiğini göstermiştir. Toplanan verilerin yorumlanması, modelleme ilkeleri uygulandığı takdirde kolay olmaktadır. Diğer yandan, bir yapının üç boyutlu modellemesi, iki boyutlu çizimlere oranla daha fazla zaman ve çaba gerektirir. Buna göre, üç boyutlu modelleme tekniğinin, çok zaman almasına rağmen, üç boyutlu algılanması önemli olan tarihi yapılarda uygulanması yararlı olacaktır.

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CHAPTER 1

INTRODUCTION

The need for reliable information sources of heritage conservation is underlined in the Nara Document on Authenticity dated 1994 (ICOMOS 1994). Reliable data is to be collected in accordance with the character of the heritage object. So, the first step in the conservation and restoration of a monument is reliable documentation. Measured drawings, photographs, and analytical and critical reports are important both for conservation and restoration projects, and also for archives (ICOMOS 1964: Article 16). All forms of documentation should consider the site of the monument of interest (ICOMOS 1964: Article 14), as well as the spatial and technical characteristics of the monument (ICOMOS 1964: Article 16). In turn, every stage of the work of conservation and restoration interventions can be guided.

Since the period of Enlightenment, different kinds of methods for data collecting, processing and presenting have been developed. After the digital revolution; data collecting, processing and presenting methods are re-examined and interdisciplinary investigations are carried out (Warden and Woodcock 2005). Nowadays, documentation of historical monuments can be carried out with a variety of tools. The choice depends on the nature of the subject as well as the purpose of the survey (Andres and Pozuelo 2009). Tacheometric data collection and processing methods and presentation methods with three dimensional modeling in CAD are some of the contemporary investigation subjects (Remondino and El-Hakim 2006). Tacheometry is the process of measuring distance indirectly (Wikipedia 2010 a). A theodolite is a precision instrument for measuring angles in the horizontal and vertical planes (Wikipedia 2010 b). The theodolite was first made in the early 16th century (Swallow, et al. 2004). Astronomers in the 17th century understood that a beam of light could be used to measure the distance from one point to another, but it was the rapid development of electronics during and after World War II that made the practical implementation of this idea possible. Infrared electronic distant measurements became fairly widely available in the late 1960s, and it is this technology which is in common use today. Electronic distant measurements are considerably more expensive than the tools employed for more traditional measurement techniques, but also offer considerably more precision and flexibility, they have displaced traditional distance measuring tools for many survey tasks (Blake and Bedford 2010).

The electronic theodolite is a developed measuring tool which determines angles and distances from it to points to be surveyed. By combining the electronic theodolite with electronic distance measurement, the Total Station Theodolite, also known as an EDM, was developed. Swallow and his team (2004) realized that the benefits of using the total station as a measuring tool are its speed and reliability contrary to the manual measurement technique; it also means that readings can be made over longer distances. While using the total station, the surveyor should understand the subject to be mapped at the time of survey well. The interpretation and selection of data are made at the point of data capture (Blake and Bedford 2010). There is a very wide choice of these instruments available, offering a range of accuracies, facilities and speed of operation. This instrument has become the workhorse of modern surveying. Some units are equipped to measure without a prism known as REDM. On the other hand, CAD is a good tool for bridging the survey results together because it is capable of handling three dimensional vector data well (Blake and Bedford 2010). A realistic and accurate three dimensional model is important since it is a concrete product of interest to many information users (Remondino, et al. 2006). REDM generated wire frame forms, three dimensional edge only mapping of the objects, may be used as the armature for modeling. Development of surfaces and solids is necessary for good performance (Blake and Bedford 2010).

The history of architectural model making goes back to ancient times. The architectural model had been used as a design tool of many historical monuments. Designing on a small scale first, proved most cost effective. Designers could improve their ideas without losing valuable resources funding in ancient times also relied on architectural models. The architectural model has evolved with the availability of different materials when plastics became cheap, it was preferred as a model material. Today, softwares make it possible to construct digital architect models (Tripp 2010).

The three dimensional model obtained by laser scanning and digital photogrammetry allows storing both metric and qualitative information. The three dimensional model makes it possible to obtain many view points and sections at any point that is required. However, working the cloud of points of laser scanning is difficult because the lines which are critical for defining the object cannot be obtained in a direct way interpretation is necessary. Tacheometric survey however, makes it possible to obtain these lines with direct observations. Photogrammetric restitution also makes possible direct the observation of object lines however the process is more time consuming compared to tacheometric evolution (Andres and Pozuelo 2009).

1.1. Aim, Method and Content

The aim of this study is to present three dimensional modeling as a tool for communication of the measured survey content through the arrangement of information regarding various scales at a cultural heritage site. The measured survey content can be conveyed through a variety of technical means, including direct and indirect measuring techniques (Swallow, et al., 2004). In this study, the tacheometric techniques are used for gathering measured data. Using the case study of Hersekzade Ahmet Paşa Bath in Urla, İzmir, which is a first grade listed building (see Appendix A), the three dimensional modeling technique as an interpretation tool for the surrounding, layout and structure of a monument is discussed. So; the method of the study comprehends gathering of measured data with tacheometric techniques and their evaluation with three dimensional modeling technique. Pictorial photography and literature survey support this process. The tools used are a total station theodolite (Topcon 7003i), a digital camera (Canon EX-Z11), a measured data evaluation software (Topcon Link 7.2) and a drafting software (AutoCAD 2010).

The heritage characteristics are presented in 1/200, 1/100 and 1/50 scales. 1/200 scale refers to the site of the monument of interest. 1/100 scale refers to the spatial characteristics of the monument, where as 1/50 scale refers to its structural characteristics. The qualities to be documented at site scale are the neighbor buildings, open spaces and streets as defined by their scales, sizes, styles and functions (ICOMOS 1987). The qualities to be documented at the scale of the monument's spaces are the original lay-out and elements (ICOMOS 1964: Article 5, 8). The qualities to be documented at the scale of the monument's structure are its original structural elements and their damages (ICOMOS 2003).

It is claimed that the aim of a conservation and restoration project such as rehabilitation at urban scale and refunctioning decisions and structural interventions at architectural scale necessitate different types of documentary information that can be represented with a three dimensional model. In this study, three different documentation scales (1/200, 1/100, 1/50) are defined in accordance with three different types of probable conservation and restoration interventions. These interventions are defined as the site interventions, spatial interventions including rearrangement for adaptation or refunctioning, and structural interventions such as monitoring, preventive maintenance, reinforcement, dismantling and reassembly, etc. Within this frame, first, the three dimensional model of the selected monument and its surrounding are formed considering the necessities of 1/200 scale. The spatial model of the central section of the women's caldarium is formed considering the necessities of 1/100 scale. The structural model of one of the domes of the bath, which necessitates structural analysis, is formed considering the necessities of 1/50 scale. The list of measurement coordinates are provided in the Appendix E for further analysis to be carried out by civil engineers.

In chapter 1, the aim, method and content of the study are introduced. The recent investigation results related to the subject of interest are presented. In chapter 2, Hersekzade Ahmet Paşa Bath is introduced with its historical and architectural characteristics. In chapter 3, the organization of the documentation process is discussed. The critical points considered in the photographic documentation, measurements and drafting phases are highlighted. In chapter 4, the results of each phase mentioned in the above are evaluated. Guidelines for conservation and restoration aimed documentation of historic monuments are formulated.

1.2. Literature Review

For the scope of this thesis, the discussion of previous studies on measurement technique and on three dimensional modeling as a tool for conservation and restoration of monuments are important.

Fuji, et al. (2008) documented an archeological site in Ajina Tepa in Tajikistan with its historical walls which have the risk of collapse. They obtained a textured geometric model. Three dimensional mapping of the walls and the geomorphological mapping of the whole site are presented as the final work (Figure 1). This modeling technique makes it easy to discuss on the structural interventions, because the model gives information about the geometry of the walls and their surface morphology; and the geomorphological mapping of the whole site. For decisions of the structural interventions, some structural analysis should be carried out.

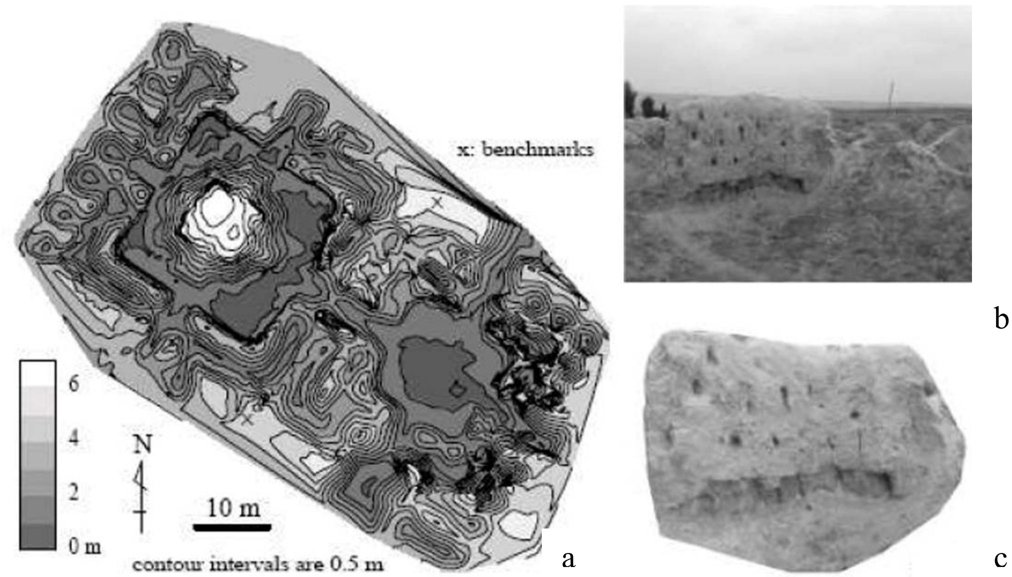


Figure 1. The map of the site (a), the wall modeled (b) and the texture mapping model of the wall (c) in an archeological site in Ajina Tepa in Tajikistan (Source: Fuji, et al. 2008)

Gomez-Lahoz, et al. (2008) made three dimensional models of two archeological settlements located in Spain (the Roman city of Clunia and the Celtic settlement of “Las Cogotas”) and textured them. The final results enabled the access to the geometry (shape, size and dimensions) and radiometry (texture and material) of the object, even if the settlements are inaccessible (Figure 2). However, the deformations such as cracks and hollows on the objects or partial demolishments are not shown on the models. It is possible to extract dimensions from every aspect of the final three dimensional models. In addition, one can get views of any desired vista. The final results can not be used for the discussions of the structural interventions because of the details of the models considering the scales (1/5000 and 1/3500).

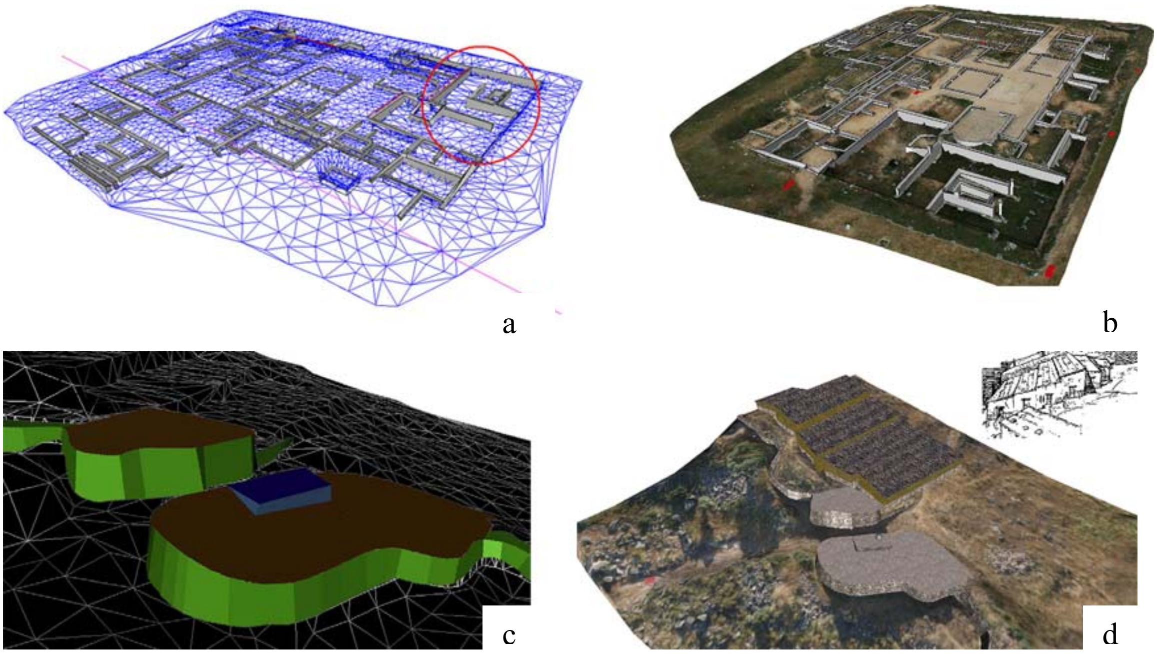
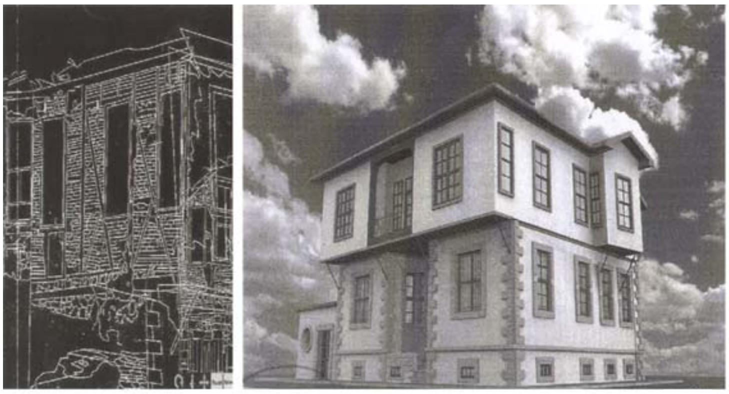


Figure 2. Three dimensional models of two archeological settlements located in Spain (the surface models of the Roman city (a) and the Celtic settlement(c); and their textured models (b and d) (Source: Gomez-Lahoz, et al. 2008)

Virtual archeology uses computer-assisted techniques, which allow getting the three dimensional data and evaluating them quickly contrary to the contemporary manual techniques, to develop realistic three-dimensional replicas of ancient objects and buildings. Normally these objects have disappeared or are preserved in a way that makes it difficult or impossible to interpret their original shape. Modern virtual reconstruction is quite realistic due to improved computer systems and visualization peripherals and a better understanding and implementation of geometric and visual modelling techniques. The process of digitizing the Muslim suburb in the city of Zaragoza began with its excavation. The suburb was documented with photographs and topographic studies. The final result is a three dimensional model and renders of different views of the Muslim suburb are taken (Figure 3). Every detail (the geometry of the buildings and their structural and architectural elements; the probable deformations of the elements) is presented on the renders. It is claimed in the article that this digital reconstruction will help to preserve the city's archaeological and cultural heritage by giving life to a distant past. Visitors can experience what life was like in the suburb, and it can provide a new perspective for historians (Guiterrez, et al. 2004). It is observed in the article that the plan geometry and the restitution works were used in order to model the suburb. This technique contributes to restitution discussions of the restoration and the conservation project.

Figure 3. Renders of different views of the Muslim suburb in the city of Zaragoza
(Source: Guiterrez, et al. 2004)

Yılmaz, et al. (2007) studied on a historical house which was damaged by fire in Konya. It is observed that every detail of the exterior surface of the building is drawn with its deformations and cracks. They state that a three dimensional model is useful for comparing the building's situation before and after its restoration. The wire frame model is a detailed model of the present state (Figure 4a). The textured model is a reconstruction model that presents restoration proposal (Figure 4b). In this model, it is observed that most of the deformations are removed. In order to decide structural interventions and before creating the reconstruction model, some structural analyses should be carried out and exhibited on the model.



a b

Figure 4. The wire frame model (a) and the rendered model (b) of a historical house in Konya (Source: Yılmaz, et al. 2007)

Armesto, et al. (2008) developed three dimensional models of a timber roof based on photogrammetric measurements. An accurate three dimensional geometric model of the girder truss including most of its irregularities such as out of plane distortions and damage to the girders' cross sections is prepared. In addition, a three dimensional mechanical finite element model was prepared (Figure 5). Static and dynamic analyses are made. Basically, the models are prepared only for defining the structural condition of the roof in detail. It is observed in the article that the technique contributes to the structural intervention discussions. The three dimensional model was made for defining the geometry of the timber roof. The finite element model of the truss was made for defining the loads and boundary conditions based on the real, irregular geometry. For the measurements, the photogrammetry data was transformed into finite element nodes.

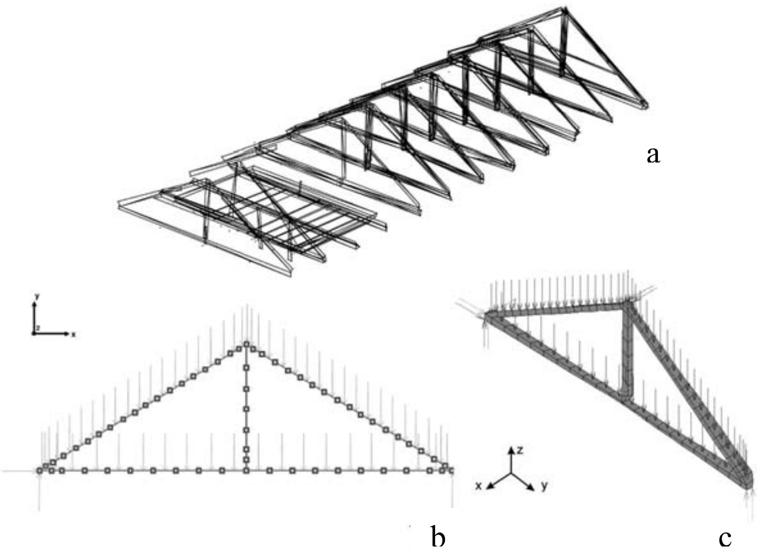


Figure 5. Three dimensional wire frame model (a), two dimensional finite element model(b) and three dimensional finite element model (c) of a timber roof of a historical house in Spain (Source: Armesto, et al. 2008)

CHAPTER 2

THE CASE STUDY

The monument selected as the case study is a 16th century Ottoman Bath located at the center of Urla. It is known as "Hersekzade Hamamı" or "Ahmet Paşa Hamamı". It is a 1st grade listed building (see Appendix A). Conservation of the monument is to be undertaken soon (Yarımada Newspaper 2010). The excavation of the changing hall and the near-by surrounding of the bath has been completed in November 2009. The pool traces, platforms and marble floor covering of the changing halls are observed after the excavation. Its conservation project is completed and presented to İzmir Number 1 Council of Conservation of Cultural and Natural Asset for approval.

The monument is a part of the Hersekzade Ahmet Paşa Complex which is composed of a mosque, a tomb, a fountain and a bath (Reyhan 2004). Only the bath (Hersekzade Ahmet Paşa Bath) and the mosque (Kapan Mosque) of this complex are there at present (Figure 6a). So, it may be dated to the end of the 15th century or beginning of the 16th century taking into consideration the foundation charter, the plan and the architectural characteristics.

The building is close to the center of Urla. The name of the street at the northeast side of the building is Kemal Paşa Street. The neighboring buildings are houses and a shop (Figure 6). The historic house at the east is a 2nd grade listed building. The other neighboring buildings are houses as well. The ground floor of one of them across the street is used as a shop. There is a 1st grade listed building (Kapan Mosque) at the north.

Figure 6. The satellite view and the neighboring buildings

2.1. Spatial Characteristics

The level of the entrance of the bath is 0.82 meters lower than the Kemal Paşa Street. The changing halls of the bath can be observed after the excavation but their superstructures are totally demolished. There is a courtyard at the southwest next to the water reservoir.

The building (638.8 m^2) is a double bath with a men's section (9.15 x 23.3 = 213.2 m^2) and a women's section (11.65 x 21.9 = 255.2 m^2). The men's section is located at the southeast; the women's section is located at the northwest. The bath has a water reservoir (3.47 x 19.5 = 67.7 m^2) and a courtyard (5.55 x 18.5 = 102.7 m^2) as well (Figure 7).

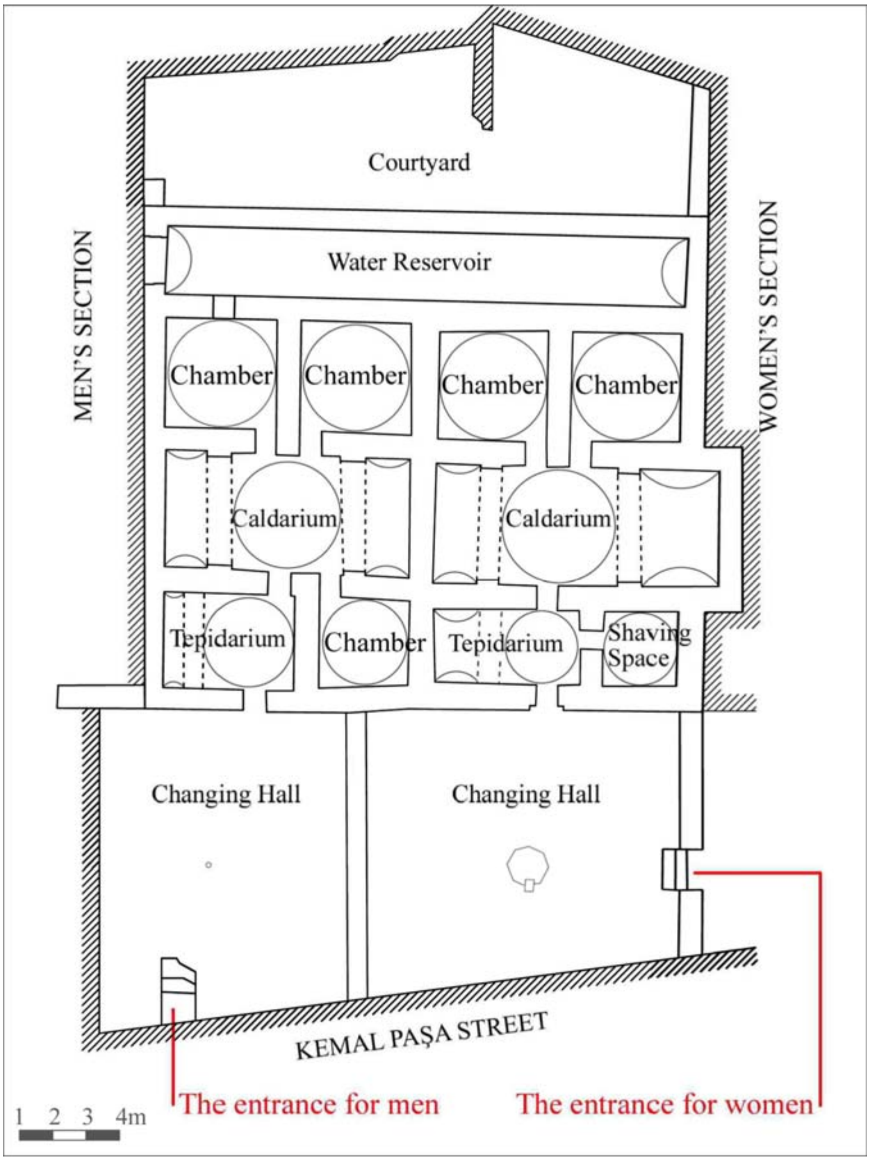


Figure 7. The plan of the bath

The men's section is separated from the women's section with a common wall. The entrance to the men's section is from the northeast side and directly from the street (Figure 8). The section includes a changing hall, a tepidarium, a rectangular caldarium with two iwans and three private chambers. All of these spaces juxtapose one another, respectively.

The entrance to the women's section is from the northwestern side and from a secondary street. The section includes a changing hall, a tepidarium, a shaving space, a rectangular caldarium with two iwans and two private chambers. These spaces are almost symmetrical in the men's section.

There is a rectangular planned water reservoir at the southwestern side of both sections (Figure 9). There is a window opening to the water reservoir from the southern private chamber of the men’s section. This opening is used to control the water level and to enter the reservoir for maintenance. Another opening to the water reservoir is on the southeastern wall of the building. It can not be seen from the outside because of the level of the surrounding ground.

a b

Figure 8. Entrances to the tepidariums (a), the changing halls and the steps of the entrances (b)

a b

Figure 9. The window openings to the water reservoir (a) and the water reservoir (b)

2.2. Architectural Elements

In the men’s section, no wash basin is observed. There are fountain traces on the walls in the caldarium and the private chambers; and the pool trace on the floor in the changing hall. Platforms are observed in the tepidarium and in the changing hall (Figure 10). The pendentives in the caldarium and the western private chamber are encircled by border and have floral pattern. In western private chamber of the men's section, there are muqarnas decorations on the pendentives (Figure 11).

a b

Figure 10. The fountain trace in the caldarium (a) and the platform in the tepidarium

a b

Figure 11. The muqarnas decorations (a) and the decorations of border and floral pattern on the pendentive (b) in the western private chamber of the men's section

In the women's section, there are marble wash basins; one in the caldarium, four in the southern private chamber and two in the southwestern private chamber. There are fountain traces on the walls in the caldarium and the private chambers. There is a pool trace on the floor in the changing hall. There are platforms in the caldarium, in front of the southeastern wall; and the tepidarium, in front of the northeastern and the southwestern walls (Figure 12). In the changing hall, there are remains of platform. The pendentives in the private chambers and the caldarium are encircled with borders. There are decorations at the beginnings of the panelled arches in the tepidarium (Figure 13).

a

b c

Figure 12. The wash basins in the private chambers (a), the wash basin and the platform in the caldarium (b) and the platforms in the tepidarium (c)

Figure 13. The pendentive encircled with border in the caldarium

2.3. Construction Technique and Material Usage

There is no trace regarding the superstructures of the changing halls of the women's and the men's section. The tepidariums of both sections are covered with domes. The iwan is covered with a vault in the women's section. The caldarium of the women's section is covered with a dome at the center and vaults on the iwans. The center oculus of this dome is projected through the exterior. The dome on the caldarium of the men's section is demolished. The iwans are covered with vaults. The northern private chamber of the men's section, the private chambers of the women's section and the shaving space are covered with domes. The domes of the southern and the western private chambers of the men's section have demolished. Their superstructure must be domes because the pendentives and the drum are still observed. The water reservoir is covered with a barrel vault.

The vaults and the domes of the superstructure were built with brick or brick and rubble stone with mortar as binding material and the surfaces were plastered (Figure 14).

The pendentives and drums are used as transition elements. The pendentives were built with brick, and the surfaces were plastered.

a

b c

Figure 14. A part of the superstructure from the southern view (a), the vault at the women’s section (b) and the dome at the men’s section (c)

The exterior and the interior walls were constructed with rubble stone and mortar as binding material. Generally, plaster is not observed on the exterior walls of the building at present. Lime plaster was used on the walls of the tepidarium, while brick-lime plaster was used in the caldarium spaces (Figure 15). The hollows of horizontal timber beams on the walls and in the transition levels show that timber beams were used for bonding (Reyhan 2004). The columns in the hypocaust were constructed with bricks.

a

b c

Figure 15. The southwestern exterior wall (a), the hollows on the walls in the caldarium of the men's section (b) and the wall and the brick-lime plaster on the wall in a private chamber of the men's section (c)

The floor covering, the stairs in the changing halls and the threshold materials of the bath are marble (Figure 16). Marble floor covering is observed in every space of the women's section and in the changing hall, in the tepidarium and in the northern private chamber of the men's section. In the caldariums, including hypocaust, the floors were built on masonry columns made of bricks or cut stones. The floors of the hypocausts of both sections can not be seen because of the debris layer.

Figure 16. The marble floor covering and the columns of the hypocaust

2.4. Evaluation

In order to evaluate the values and problems of Hersekzade Ahmet Paşa Bath as a cultural heritage, comparative information on the same type and period buildings may be provided. In addition, the conservation state of the monument may be highlighted. In turn, the significance of Hersekzade Ahmet Paşa Bath as a historic monument and its conservation problems can be made clear.

2.4.1. Characteristics of Ottoman Baths

In order to evaluate the Hersekzade Ahmet Paşa Bath, some information about the site characteristics and the architectural characteristics of the Ottoman bath buildings in its period should be given.

The Ottoman baths can be classified in two groups according to being private or public. The private baths are smaller in size. They serve a small group of people and were built independent or in a palace, khan, etc. However, the public baths serve more people and generally, they were built in a complex (Çakmak 2002). Some baths remained on the ground are a few meters lower than the present ground level, by the reason of false town planning and some unconscious applications made by municipalities (Büyükdigan 2003). The Ottoman baths are modest and simple buildings from exterior; however, the interior organizations and the architectural characteristics are attractive (Çakmak 2002). In each section the various spaces follow one another in accordance with the traditional layout. Some of them were built in the so-called double-bath type, with separate sections for men and women. The men's is always slightly bigger, and more elaborately decorated (Büyükdigan 2003). The entrances of these baths are from the changing halls and the men's section opens directly to a main street, however, the women's section opens to a secondary street. Generally, the two sections of these baths are separated with a common wall. The sections consist of changing halls, transition spaces, tepidariums, caldariums and private chambers; a water reservoir and a hypocaust. The transition spaces do not exist in the baths which were constructed after the 16th century (Önge 1995 cited in Çakmak 2002).

The architectural elements observed in the Ottoman Baths are platforms (in changing halls, tepidariums and caldariums), fountains (in changing halls and tepidariums), wash basins (in caldariums and private chambers) and belly platforms (in caldariums). There are small, arched niches for shoes under the platforms in changing halls (Önge 1995 cited in Çakmak 2002).

Most spaces have transition zones, domes and vaults, skillfully ornamented with muqarnas which is made of stucco on a brick structure and obviously an element of primary importance and an integral part of the overall harmony, especially in the 15th century baths. These baths were built of either stone or stone and bricks and their design was based on the technique that horizontal and sometimes vertical bricks framing individual stone blocks. The chief element of exterior dominance of the baths was domes built of brick (Büyükdigan 2003). There are circular or polygonal openings on the domes or vaults for lighting. These openings narrows through the exterior and are closed with glass named "oculi" from the exterior.

2.4.2. Conservation State of Hersekzade Ahmet Paşa Bath

The higher level of the present street and the building dates of most of the neighboring buildings (after 1950) show that there is not much remaining from the original site of the historic monument. In addition, the changing halls are not totally excavated since the present street and the ownership pattern make this investigation rather difficult (Figure 17).

Figure 17. The street-changing hall relationship

It is observed that the spatial organization of the bath is conserved in general. Some parts of the changing halls which can be observed after the excavation are under the present road and the surrounding open spaces. The changing halls have lost their superstructure and some parts of their walls. In other words, they have lost most of their third dimension. Thus, there are only the steps and some wall pieces of the entrances of the bath as remains.

The superstructure of the changing halls of the women's and the men's section are demolished. The superstructure on the iwan of the tepidarium, the central space of the caldarium and the southern and the western private chambers in the men's section are demolished totally. The superstructure on the southern private chamber of the women's section and the northern private chamber of the men's section are demolished partially.

Because of its partially demolished superstructure, the men's section has not been protected as much as the women's section whose superstructure is relatively in a better state. Another reason for being more protected is the level of the surrounding ground before the excavation in the women's section (Figure 18). It prevented people from entering the building.

Figure 18. The eastern view of the Bath before the excavation
(Source: Anka Architects 2009)

In the changing halls, all of the transition elements and some parts of the walls are demolished. Some parts of the exterior walls in the tepidarium of the men's section are demolished, as well. The rest of the walls are whole. The plasters on the interior walls and on the interior surfaces of the exterior walls are partially lost, while the plasters on the outer surfaces of the exterior walls are totally lost.

In the caldarium of the women's section, the marble floor covering is demolished partially. In the other spaces of the section, the floor covering can be observed but there are some deformations. The floor coverings of the caldarium and the private chambers of the men's section are totally demolished. The floors of the hypocausts in both sections can not be observed because of the debris layer.

The brick columns of the hypocausts in the men's section are not observed. In the women's section, the columns are partially demolished.

2.4.3. Results

The Hersekzade Ahmet Paşa Bath is a double bath with separate sections for men and women. The bath is simple from the outside; however, decorations on some building elements and some architectural elements such as wash basins and traces of fountains are observed inside. The entrances of the sections are from the changing halls; the men's opens to the street and the women's opens to a side of the street. The two sections are separated with a common wall. The architectural elements observed in the bath are platforms, wash basins and traces of fountains. All of the spaces observed in the bath have transition zones, domes and vaults, ornamented with muqarnas. The domes and the vaults were built with brick; the walls were built with rubble stone. The floor covering material is marble.

Its spatial organization composed of changing hall, tepidarium, caldarium, water reservoir and hypocaust juxtaposing one another in both men's and women's section is typical for the era. Similarly, structural elements such as domes on the tepidariums, the caldariums and the private chambers; the vaults on the iwans and the water reservoir; and the pendentives and the drums as transition elements to the domes are characteristics of the period.

It can be stated that the bath shows similarities with the Ottoman baths built in the 15th and the 16th centuries. It has historic and documentary values. Partially demolishment of the superstructure lets the climatic conditions speed the destruction. Being vacant is another reason that speeds the destruction.

CHAPTER 3

DOCUMENTATION WORK

The documentation of the Hersekzade Ahmet Paşa Bath has been carried out in three phases; photographic documentation phase, measurement phase and drafting phase. It has been pointed out that the conservation and restoration aimed documentation of a historical monument should consider the interpretation of the qualities regarding the relationships with the site, the spatial arrangement and the structural characteristics (see Section 1.1). The continuity of the original qualities and the related alterations or damages should be presented. Within this frame, the three dimensional modeling process of the Hersekzade Ahmet Paşa Bath was organized so that the critical points to be considered in the documentation of the above mentioned three qualities together with their changes can be clarified. These guidelines will help future work with similar aims.

3.1. Photographic Documentation Phase

Prior to the drafting of the historical bath, the investigation of the building itself and its near-by surrounding is a prerequisite. So; some photographs have been taken. The prints of these photographs are also used to note the numbers of the measured points and take some notes about the building and the site (Figure 19). It is important to use the station points of the total station theodolite while shooting the photographs. In conservation and restoration projects presented as two dimensional documents; sketches of elevations, sections and plans are prepared and the numbers of the points measured with the total station theodolite are noted on them. In this work, these two dimensional sketches are not used. The reason of using photographs instead of these two dimensional sketches is that the photographs provide information about the depths of the building elements. Hence, the three dimensional model can be more easily conceived. The measured points, marked on these photographs, which give perspective effect, make it easy to create the three dimensional model at the drafting phase.

For the case study, the total number of photographs taken is 217 whose of 51 are exterior photos and 166 are interior photos. 11 of them are used for taking notes at the site scale (Figure 19) and 80 of these are used for taking notes in the building scale.

Figure 19. Point names marked on the photograph

3.2. Measurement Phase

The measurements are primarily taken with the total station theodolite (Topcon 7003i). The conventional steel tape is rarely used for details such as ceramic pipes and wash basins. It is also used, if the total station theodolite can not be placed because of the unsuitability of the space or if the points can not be measured, because of shortness (less than 1m) of object-instrument distance.

3.2.1. Station Points and Traverses

It is desired to minimize the number of stations so that the amount of error and the consumption of time are minimized. In other words, a station point should cover the maximum number of measured points that define the building geometry. For this reason, the best places for the station points outside the building are defined as the points across its corners so that two façades can be observed at once (Figure 20). In addition, it is preferred to see the near-by surrounding at the same time. The best places for the station points inside the building are the centers of spaces and the points that see maximum details of the building elements and deformations.

Figure 20. The station points

3.2.2. Measuring with the Total Station Theodolite

The points on the case study building are measured with the Topcon 7003i total station theodolite. In order to situate it and make it ready to measure the points, the following points should be considered:

- The tripod is put on the station point and the screws on the legs are tightened when the tripod base is at the chest height.
- The instrument is put on to the tripod base and attached to it with the help of the screw under the instrument.
- In order to situate the instrument on the station point, two legs of the tripod may be moved at the same time, while keeping one leg stable. The instrument may be moved on the tripod base. After the situating, the instrument should be attached to the tripod base with the screw, again.
- The vertical and the horizontal motion clamps of the instrument are loosened.

- Every leg is extended or shortened by using the circular level on the tripod base to level the instrument.
- The instrument is leveled by using the plate level. The plate level should be made parallel to the abstract line between two screws by turning the two screws to the exterior or interior directions simultaneously, and the bubble should be brought to the center of the plate level. This procedure is repeated for each abstract line between screws. The instrument should be rotated 180° and the bubble should be checked if it is correctly centered.
- The instrument is turned on by pressing the “power” button.
- The “TopSURV” icon on the desktop is selected with the stylus pen (Figure 21).

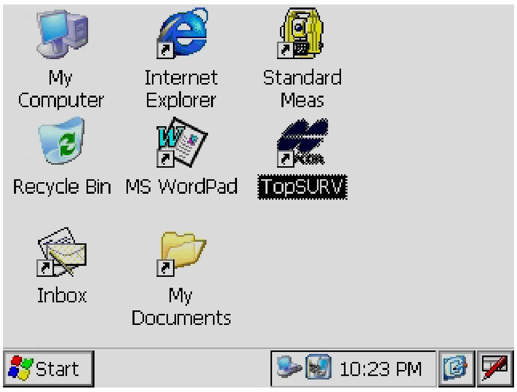


Figure 21. The “TopSURV” icon is selected

- “Job>New” selections are selected on the screen in order to create a new job.
- The name of the new job is typed to the “name” box and saved.
- “Edit>Points” selections are selected in order to type the coordinates manually.
- In order to add a new point, “Add” selection is selected. The name of the point is typed to the “point” box. The X, Y and Z coordinates of this point are typed to the related boxes. The “OK” is selected to save the point and close the window. This is the station point.
- Another new point is added. Different name and coordinates should be typed. This is the viewed point. It is saved and the window is closed again.
- “Data kayıt/Ölçüm> DN/BN Ayarı” selections are selected.

- The name of the first point which is the station point is typed to the “Dur nokta” box. The name of the second point which is the viewed point is typed to the “Bakl. Nokt.” box. If the measurement between the station point and the viewed point will be taken with the prism, “P” mode is selected; if not, “NP” is selected. If the reflector is used to take the measurement, the height of the reflector is typed to the “R.Yk” box in meters. If the reflector is not used, “0.00” is typed to the box. The distance between the zero mark on the instrument and the ground is measured and typed to the “A.Yk.” box.
- One looks at the viewed point from the optical telescope and chooses “SIFIR” selection on the screen in order to make the angle between the points zero. Enter is selected to save and close.
- “Data kayıt/Ölçüm>BN/ALIM Ölçümü” selections are selected.
- The name of the viewed point is typed to the “Nokta” box. NP is selected for the non prism measurement. The viewed point is measured and saved. Thus, the coordinates of the viewed point is saved. The window is closed.
- “Data kayıt/Ölçüm>Alım” is selected.
- The name of the first measured point is typed to the “Nokta” box and the measurements are taken. The first measured point may be the viewed point for checking. “Image” selection on the toolbar may be selected in order to take the measurements in an easier way. With this selection, there is no need to look from the optical telescope for taking the measurements; it is displayed on the screen.

3.2.3. Measurements Related to the Building

The total station theodolite is placed at the station points described in the above and the points, necessary for drawing the three dimensional model, are measured. The amount of measured points should be considered well with regard to the scale of the final draft. Before starting measuring, the drafting phase should be considered well because if there are errors in measurements or there are insufficient measured points, the geometry of the case study building can not be drawn and it is confusing and time consuming to compensate it in drafting phase. If more points are measured than it is necessary, it consumes time and confuses one while drawing.

In order to minimize the amount of errors while transporting the total station theodolite from one station point to another, some natural points on the building such as corner of a large stone or corner of a piece of a plaster remain or corner of a door opening are measured again. These points, measured twice from two different station points, are overlapped in the drafting phase for checking (Figure 22).

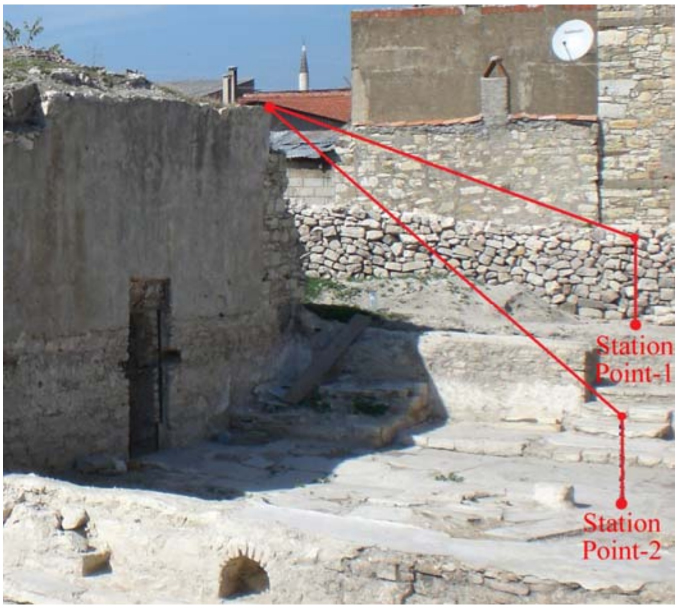


Figure 22. Double measurement of a corner point

3.2.3.1. Site Elements and Mass Layout

After situating the total station theodolite, the site elements such as the facades of the neighboring gardens and buildings, roofs of these buildings, changes in slopes of the roads and the surrounding ground are measured. For the mass layout, starting and ending points of every corner line of the case study building and its related elements are measured. The measurements for the site elements are not as detailed as the measurements for the mass layout. In other words, only starting and ending points of the walls, the roofs and the slopes of the roads and the surrounding ground are measured for the site elements, but every point that defines the building geometry: starting and ending points of every corner line, 3 measured points on curvilinear elements, 1 section (10-11 measured points on the section) on domes, 4 on oculi (4 for an oculus, 1 for the others on a dome) the slopes of the floor and the corner lines of the remains of walls and platform on floors of the changing halls are measured for the mass layout. These measurements are made to form the site model of the case study building in 1/200 scale. The deformations and the remains of plaster are not measured in this scale.

While the total station theodolite is outside the building to measure the site elements, some building parts which can be seen from that station point are measured, as well (Figure 23)

The dead points on recessed surfaces such as the planes behind cracked plastering necessitate extra station points.

a b

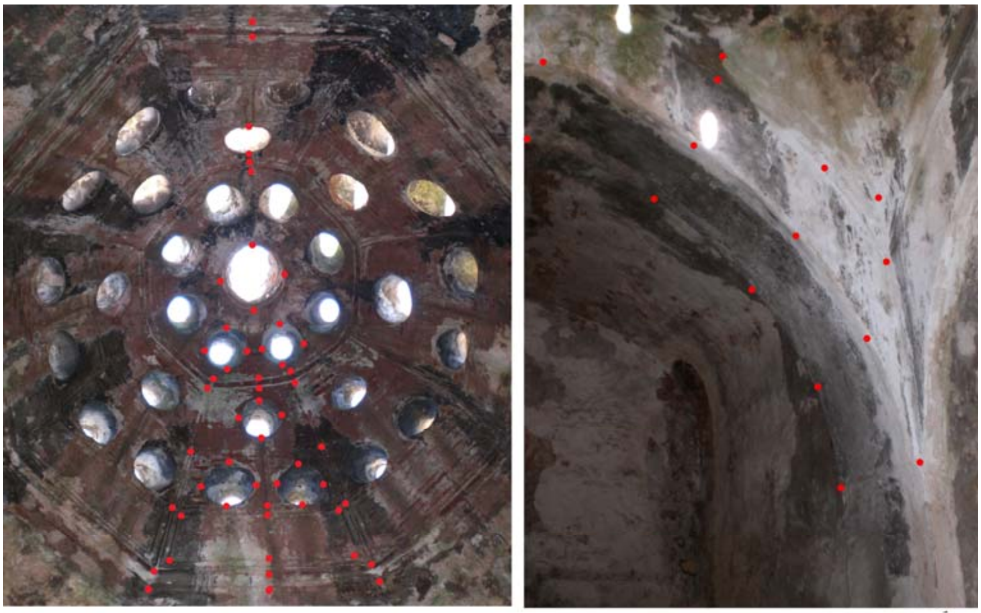
Figure 23. The measured points for the mass layout (a) and for the site elements (b)

3.2.3.2. Spatial Layout – Caldarium

The caldarium of the women's section is measured more detailed than the site model. Thus, 1/100 scale is aimed for printing. The building elements such as dome, arch, wall and floor are in the same detail as in 1/200: minimum 3, preferably 4 points for curvilinear elements; 4 corners for planar elements. However, the architectural elements such as wash basins, marble floor covering and decorative elements at the arches and domes are documented as well. The deformations and the remains of plaster are not measured in this scale.

The interior face of the dome of the caldarium of the women's section is sliced in eight pieces vertically and four pieces horizontally with borders around them. First, a section of the dome is measured. The measured points of this section are on the starting and ending points of the borders. Three or four points of every oculus in a repeating group of oculi and four points of the top oculus are measured to define the shape (Figure 24a).

Starting and ending points of every arch surface and at least three points of their round parts are measured in order to create the geometry (Figure 24b). The decorations are measured, too.



a b

Figure 24. The points measured on the dome (a) and on an arch (b)

Starting and ending points of every corner line of the walls in the caldarium are measured. Normally, the bottom corners of the interior walls define the floor level but the existence of debris on the floor especially at the corners necessitates extra measurements. In addition, the changes in the slopes of the floors and the remains of marble floor are measured. Corners of the remains of marble stone covering and thresholds are measured, too (Figure 25).

Figure 25. The points measured at the corners of the remains of marble stone covering

In the caldarium of the women's section, the pendentives are encircled by border without floral pattern at the end. The measured points are situated at starting and ending points and at least one measured point is situated at the round parts of every pendentive and its border (Figure 26).

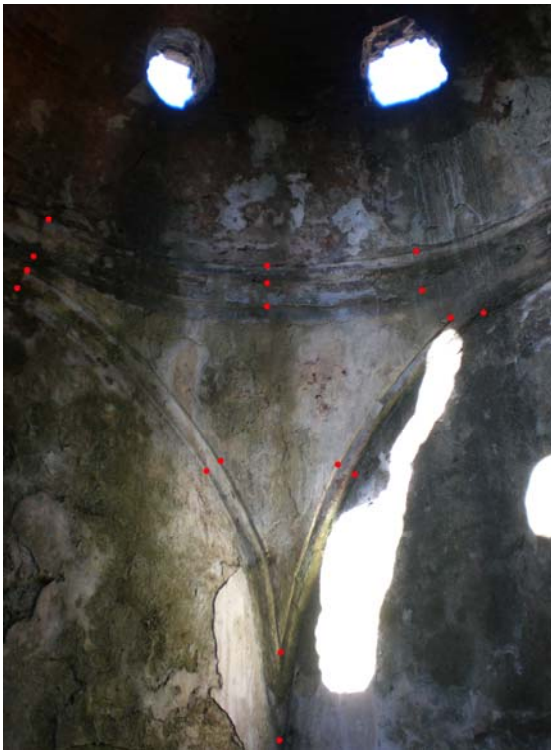


Figure 26. The points measured on a pendentive

3.2.3.3. Building Elements - Dome

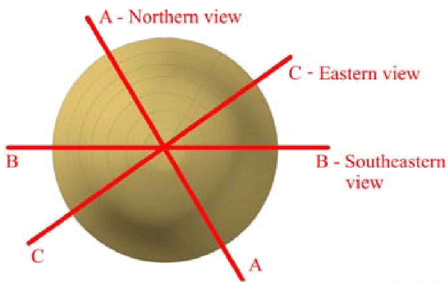
The only dome at the caldarium of the women's section is measured. The drum, the dome itself, the oculi and the deformations and the remains of plaster on them are measured. The number of sections is increased in order to well define the dome geometry. The amount and the positions of the measured points are decided with regard to the geometry of the building element and 1/50 scale for printing. The measured points are situated at most in every 35 cm. That means six points for half of the dome's section.

Three sections of the dome are measured in order to increase the accuracy (Figure 27). First the dome shape is defined (see Section 3.3.3); then, the oculi, the deformations and the remains of plaster on the dome are measured. Four points for each oculus are measured at the exterior. Some points which define the border of the deformations and the remains of plaster on the dome are measured considering 1/50 scale.

a-Northern View

b-Southeastern View

c-Eastern View



d-Plan View

Figure 27. The points measured on three different sections of the dome (a, b and c) and the plan view (d)

3.3. Drafting Phase

The measured points are transformed from the total station theodolite to the computer. In AutoCAD drawing format, the drafting phase starts with connecting the related points with lines to each other. This work makes it easy to perceive the points as a whole. As the first work of the drafting phase, the mass of the case study building should be modeled, and then the building elements, their details and deformations should be formed. Basically, "3dface" and "revolve" commands are used in formation of the documentary model.

3.3.1. Site Elements and Mass Layout

The mass geometry, the neighboring masses, roads and the surrounding ground are drawn to form the site model for printing in 1/200 scale. The measured points are listed in Table A.1 (see Appendix E). The site relations are aimed to be shown in these drawings. The remains of plaster on the building are not drawn (Figure 28, 29 and 30).

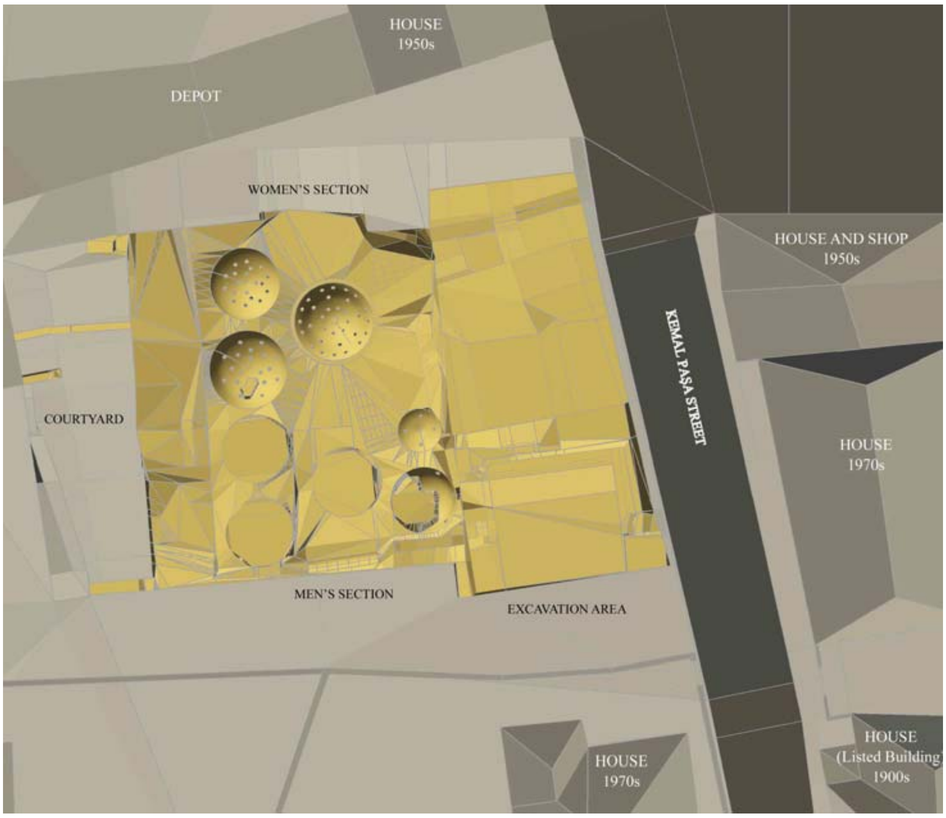


Figure 28. The site model

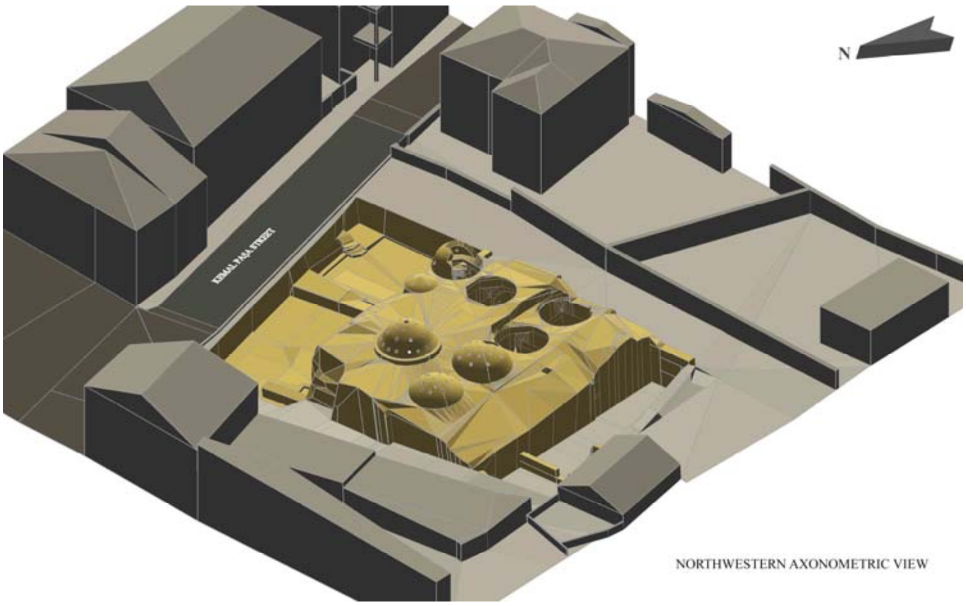


Figure 29. The Northwestern axonometric view

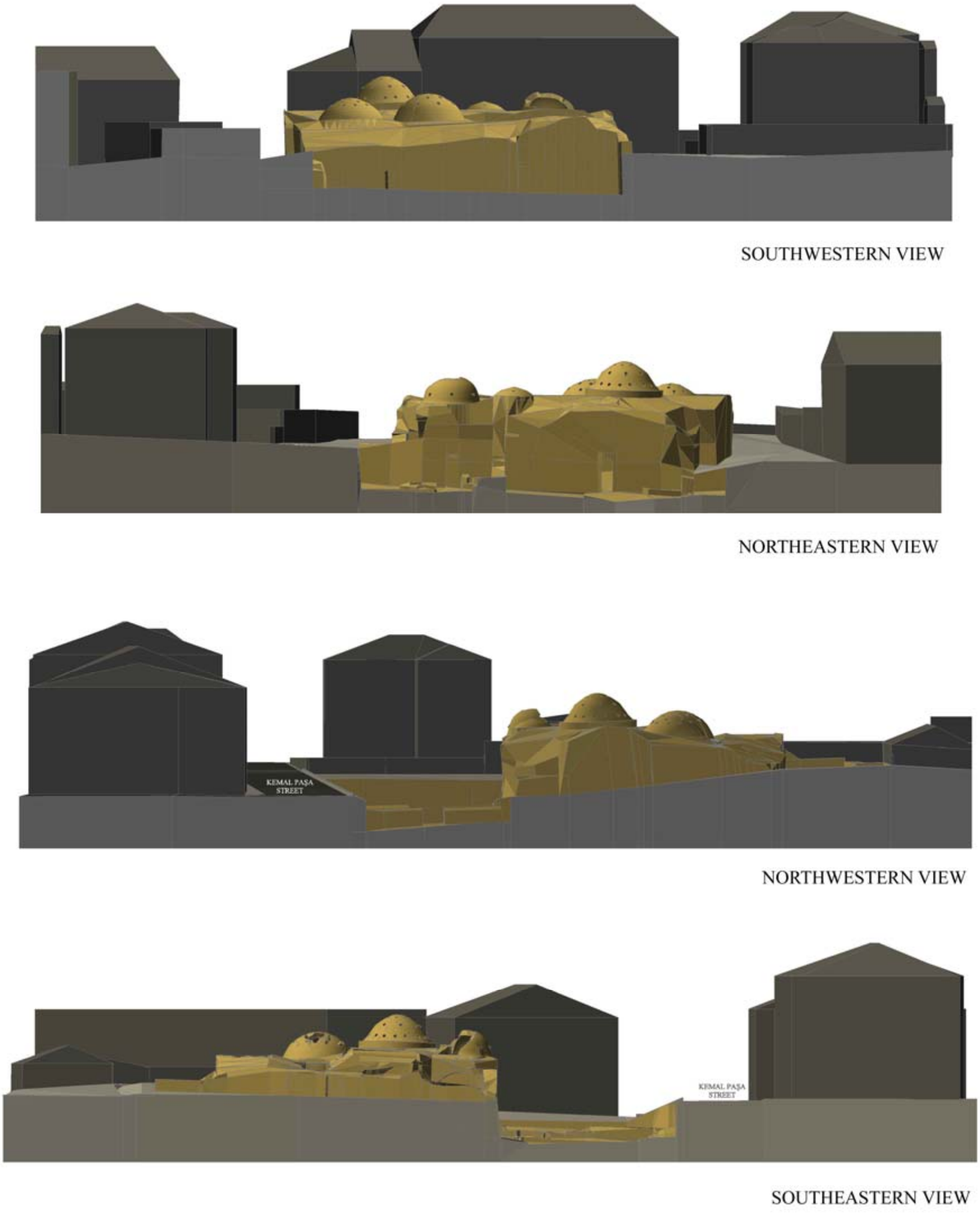


Figure 30. The silhouettes

Creating dome geometry starts with connecting the measured points on a section of the dome with lines to each other. "Z" coordinates of the lines are changed into the same value when viewed from elevation. The related points of these lines are connected to each other with "spline" command. "Revolve" command is used in order to create the dome geometry with the help of this spline (Figure 31). The dome on the tepidarium of the women's section can not be drawn because it is covered with earth.

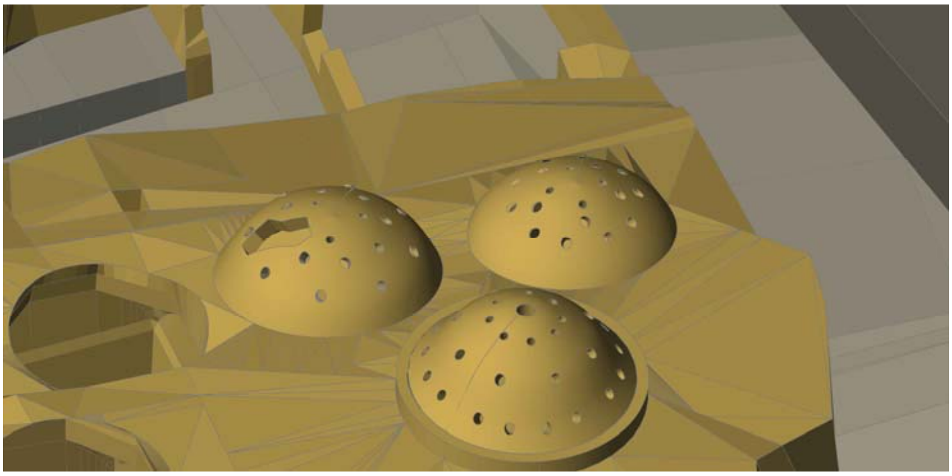


Figure 31. The domes created for the mass layout in the site model

The measured points that define the flat surfaces of the mass are connected to each other with three dimensional faces with the "3dface" command. Triangle and rectangle pieces of these three dimensional faces define the walls and the superstructure (Figure 32 and 33).

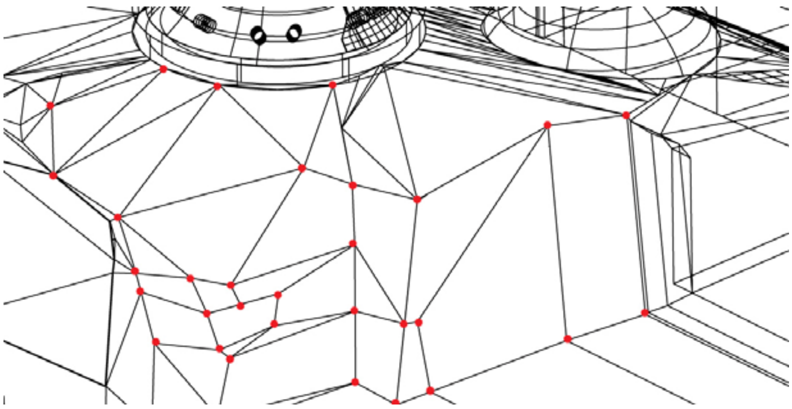


Figure 32. Three dimensional faces that define the walls and the superstructure

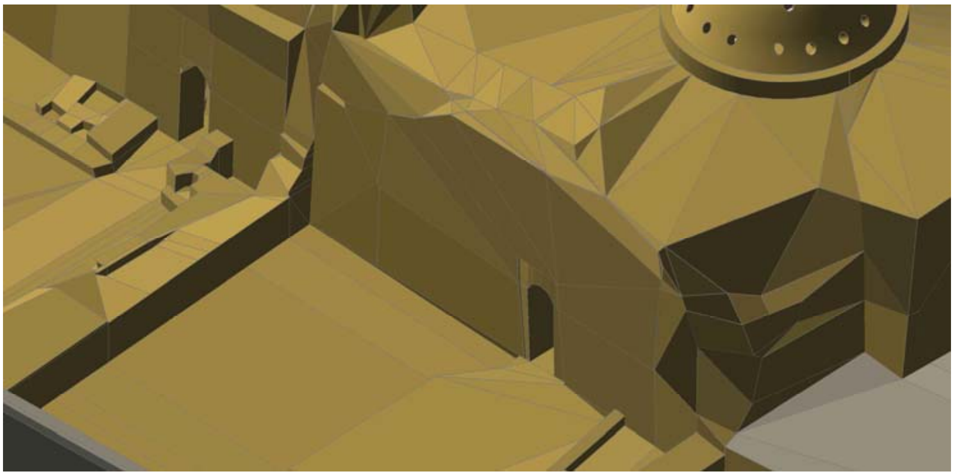


Figure 33. The flat surfaces of the mass layout in the site model

Every face of the walls and the roofs of the neighboring buildings are created with three dimensional faces with the help of the “3dface” command. The corner points of every face are enough to create the neighboring masses in the site model (Figure 34). Every three or four measured points defining the slopes of the roads, the geometry of the surrounding ground and the plan layout of the neighboring masses are connected to each other in order to form three dimensional faces.

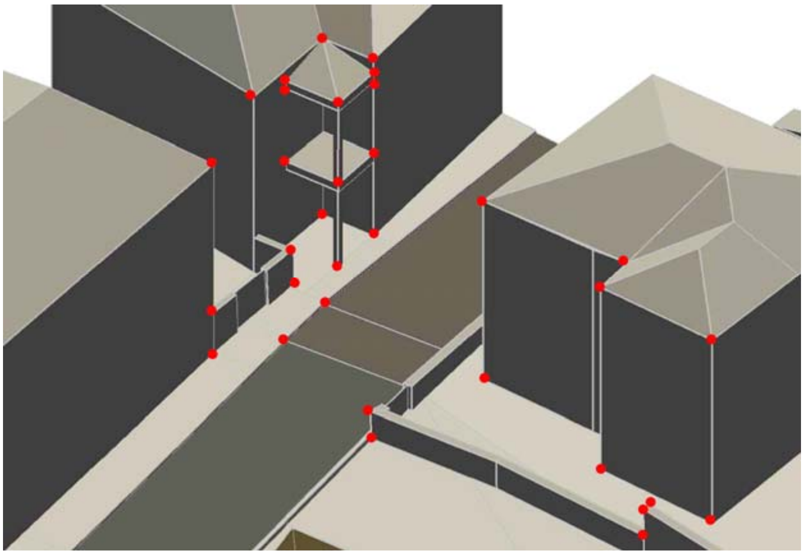


Figure 34. Some measured points for the site model

3.3.2. Spatial Layout – Caldarium

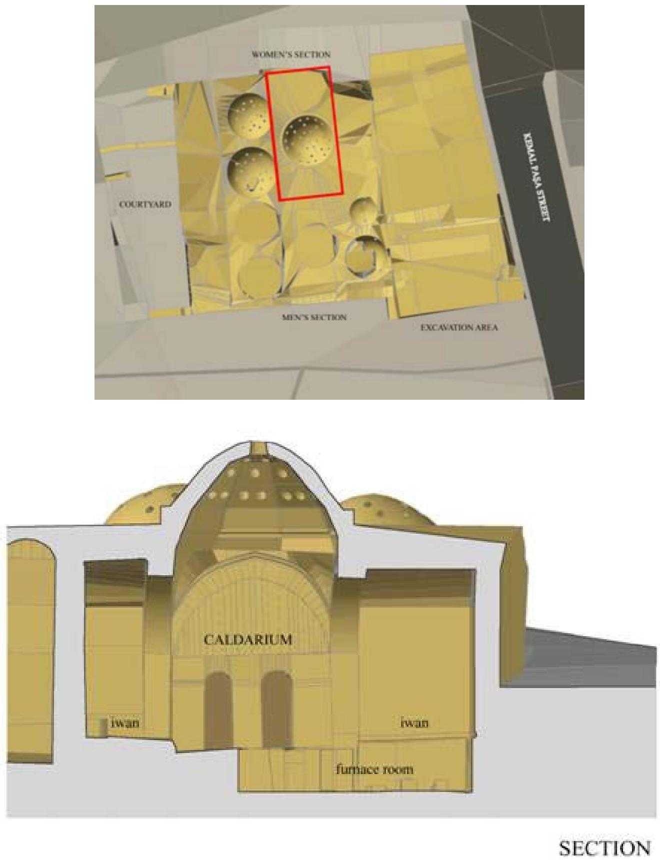


Figure 35. The caldarium of the women's section

The caldarium of the women's section (Figure 33) is drawn more detailed than the site model. Thus, 1/100 scale is used for printing. The measured points are listed in Table A.2 (see Appendix E). The building elements such as dome, arch, wall and floor are drawn in the same detail as in 1/200. However, the architectural elements such as wash basins, marble floor covering and decorative elements at the arches and domes are drawn as well. The deformations and the remains of plaster are not drawn in this scale. After forming the wire frame model, the renders of different views are taken in order to present the spatial arrangement and functional relations. It is thought that this model will make it easy to organize the spaces in the restoration phase (Figure 36).

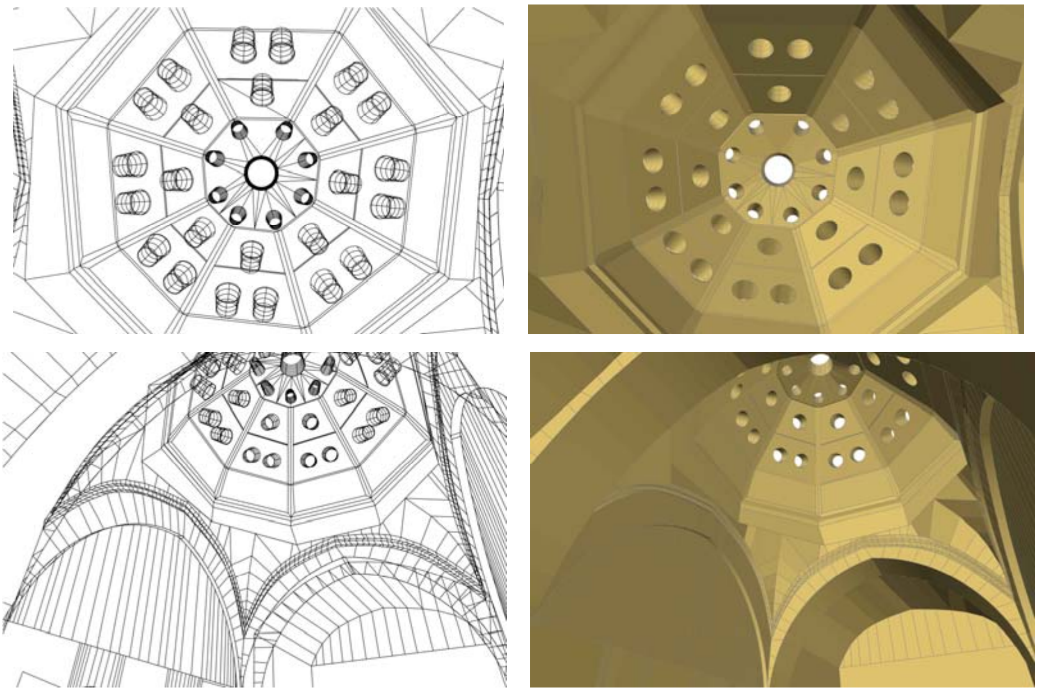


Figure 36. The perspective views of the caldarium of the women's section

The measured points on a vertical piece on the dome are connected with using the "3dface" command. The piece of the dome is copied seven times with using the "array" command. The oculi are created by using the "revolve" command and subtracted from the surface of the dome (Figure 37). Because the objects can not be subtracted from a three dimensional solid, the surface of the dome should be changed into "surface" from "three dimensional face" by selecting "Modify>Mesh Editing>Convert to Faceted Surface" selections.

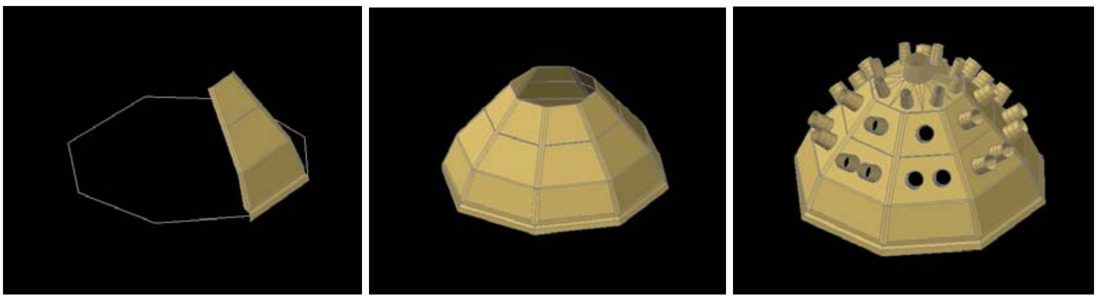


Figure 37. Creating the interior surface of the dome on the caldarium of the women's section

The Z coordinates of the lines that tie the measured points on two corners of the arch are not on the same line when observed in plan view. In order to make them on a line, Z coordinates of these lines are changed into the same value from "properties" selection when observed in the elevation. The lines are connected with using the "arc" command from the starting points to the top points of two corner lines of the arch. The lines that start the arch at the bottom and two arcs at the corner of the arch are used with "revolve" command in order to create the arch model (Figure 38). The angles of these arcs must be known in order to revolve the lines.

The thickness of the southeastern arch is 65 cm. The angle of the two arcs of the arch is 75°. The radius of the northeastern arc of the arch is 221 cm; the southwestern arc is 225 cm. The horizontal distance between the centers of the arch is 72 cm; the vertical distance is 6 cm.

The thickness of the northwestern arch is 68 cm. The angle of the northeastern arc of the arch is 72°; the southwestern arc is 74°. The radius of the northeastern arc of the arch is 226 cm; the southwestern arc is 222 cm. The horizontal distance between the centers of the arch is 75 cm; the vertical distance is 2 cm.

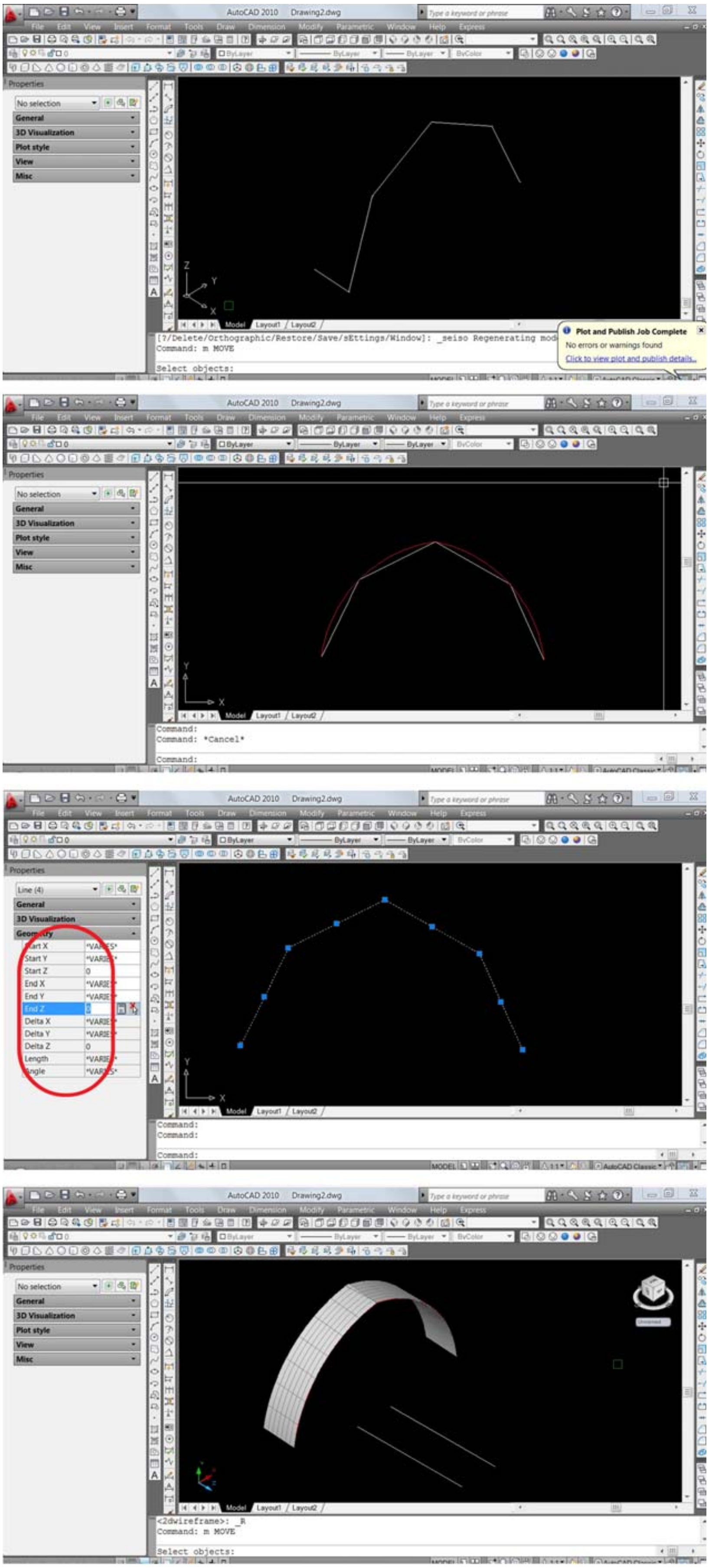


Figure 38. Creating the arch geometry with “revolve” command

The walls are drawn with three dimensional faces with the help of the “3dface” command. The measured points on every starting and ending points of the corner lines of the walls are considered (Figure 39). If a wall surface is related with a curvilinear building element such as an arch, small trapezoidal surfaces, maximum 20cm in width are created in order to provide an integral view of the wall and the related arch (Figure 40).

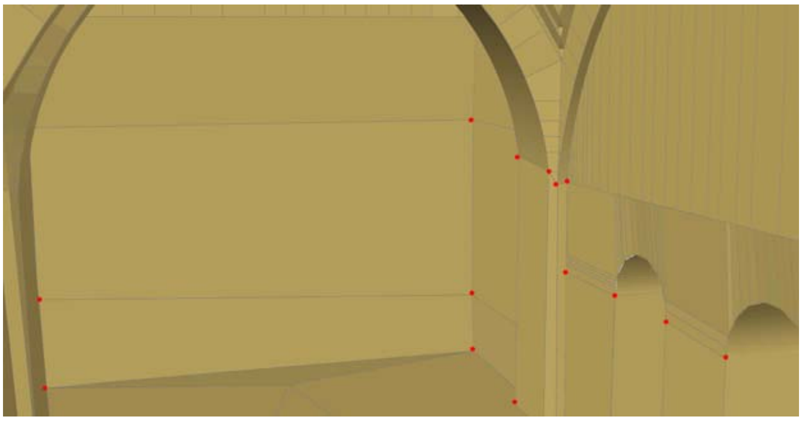


Figure 39. Three dimensional surfaces creating the walls

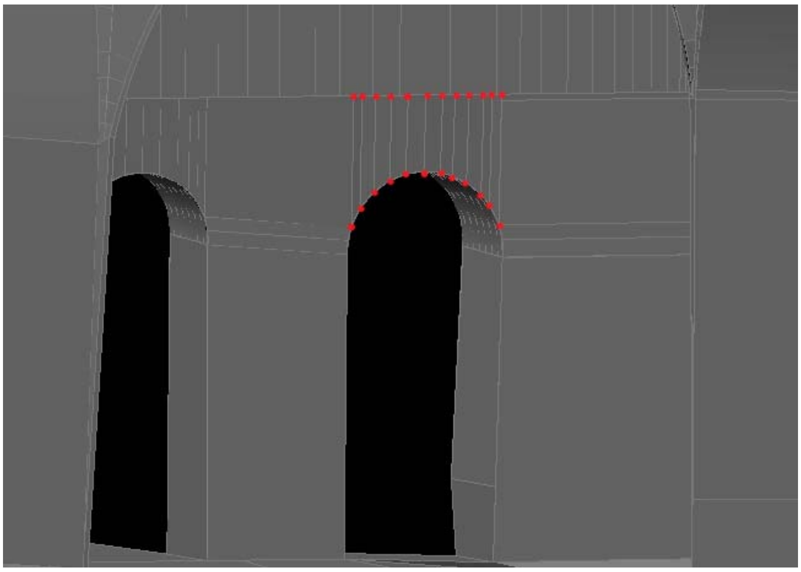


Figure 40. Narrow three dimensional faces above arches

The measured points at the changes in the slopes of the floors and at the corners of the remains of marble and stone floor are connected with three dimensional faces with the help of the “3dface” command (Figure 41). The thresholds are created with three dimensional faces, as well.

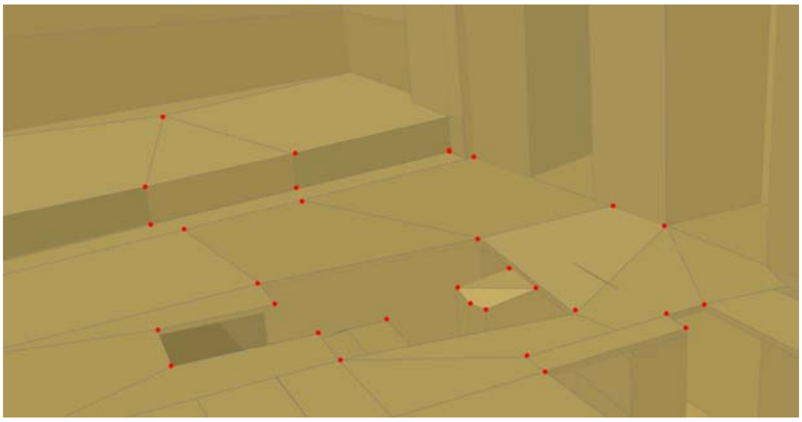


Figure 41. Three dimensional surfaces creating the floor

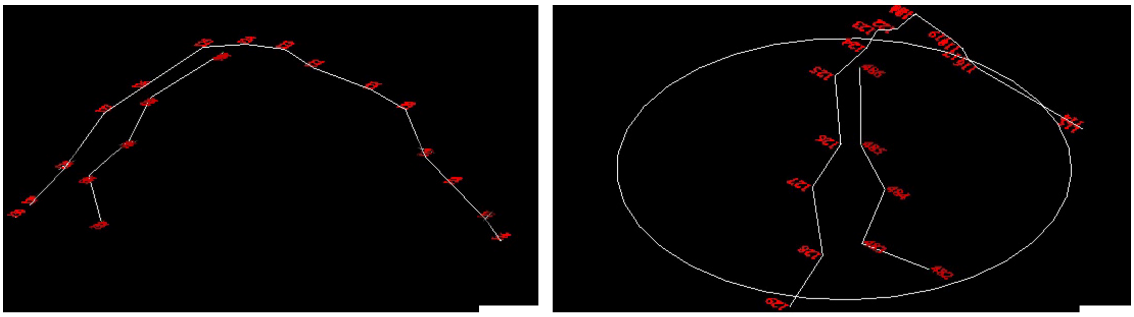
3.3.3. Building Elements – Dome

Figure 42. The dome on the caldarium of the women’s section

The dome on the caldarium of the women’s section (Figure 42) is modeled in accordance with the necessities of 1/50 scale. The measured points are listed in Table A.3 (see Appendix E). In other words, its geometry, the oculi and the deformations and the remains of plaster are all illustrated. In fact, the dome is octagonal but it is not observed from the exterior because of the deformations of the dome and its plaster.

Thus, the drawings from the exterior are not made considering the octagonal shape while the drawings from the interior are made so. The illustrations in 1/50 scale will guide structural intervention decisions in the restoration phase. The process of creating the dome consists of determining the dome geometry and the deformations and the remains of plaster on it and then constructing all these data. For creating the dome geometry, the following points should be considered:

- The measured points on the sections of the dome are connected with lines to each other by using “line” command (Figure 43).



a b

Figure 43. Measured points connected (a) and the base circle of the dome (b)

- The starting points of the section of the dome are connected with line. A circle whose center is on the midpoint of the line is drawn when looked from plan view.
- In order to situate the line pieces on a line, the Z coordinates of these lines are changed into the same value with the value of Z coordinates of the center of the base circle when looked from elevation view. “Modify>Properties” selections are used for this changing (Figure 44). This is done for the other section lines. This work may be done in another page of the software in order to prevent confusion.

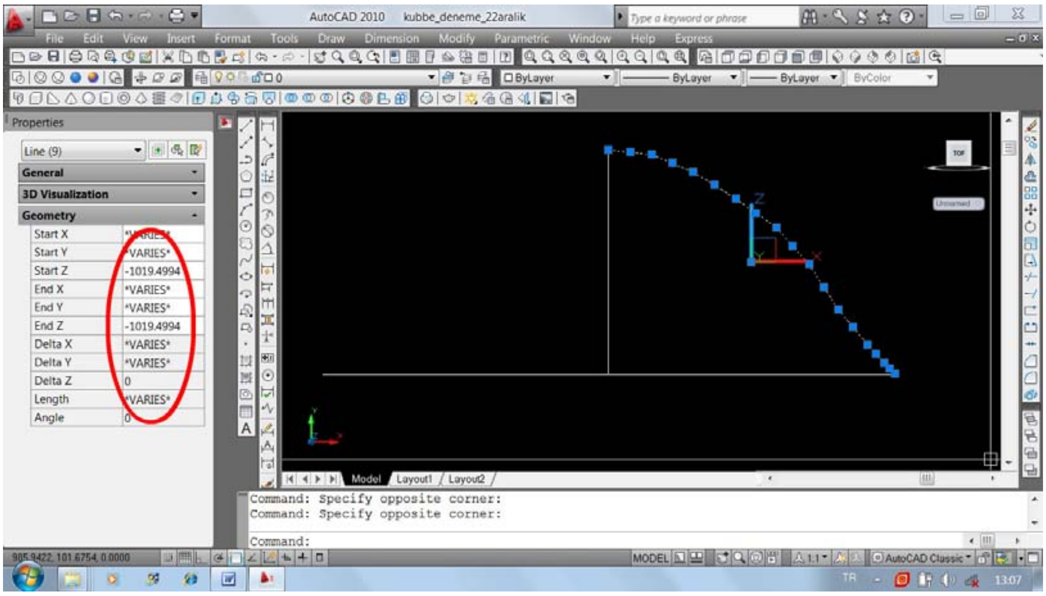


Figure 44. Situating the line pieces on a line

- These line pieces are connected with two splines by using “spline” command. The splines are the section frames of the dome.
- The section frame at one side and the center of the base circle are used to create the exterior surface of the dome by using “revolve” command (Figure 45).

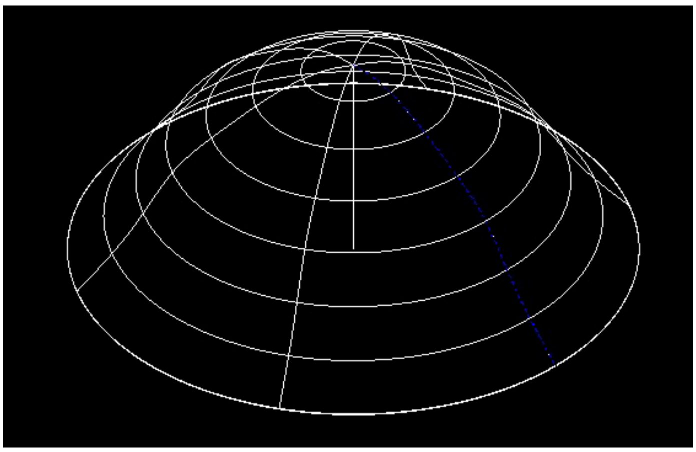


Figure 45. Revolved section frame for creating the exterior surface of the dome

- The section frame is copied and moved 40 cm through the center of the base circle. This copied section frame is of the interior surface of the dome.

- The copied frame and the center of the base circle are used to create the interior surface of the dome by using “revolve” command (Figure 46).

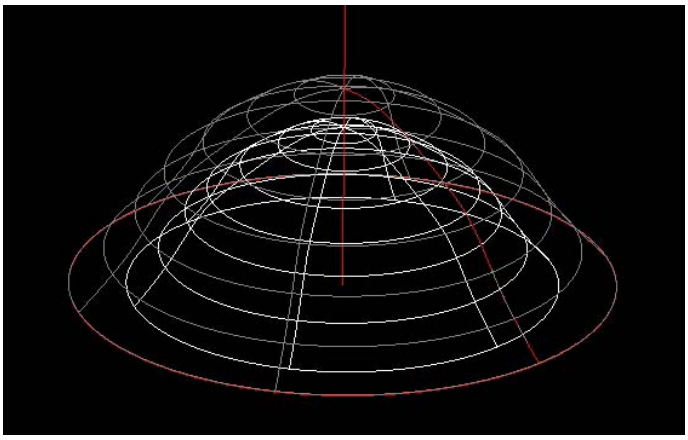


Figure 46. Revolved section frame for creating the interior surface of the dome

- The measured points that are taken from the oculi are connected to each other by using “spline” command (Figure 47).

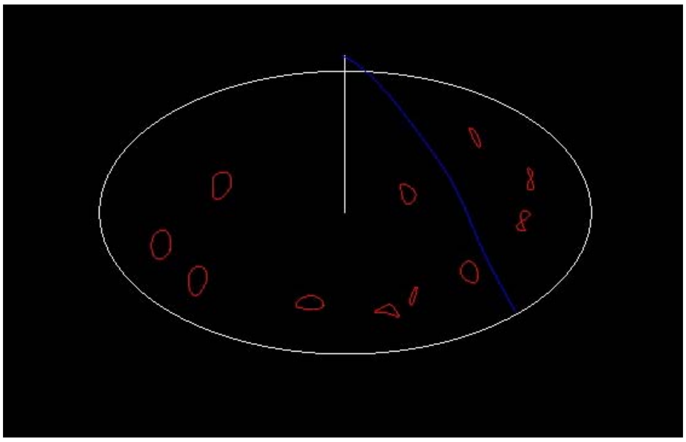


Figure 47. The splines created with the measured points on oculi

- The exterior and the interior section frames are rotated through the oculus. These two frames are for two sides of the oculus on the interior and the exterior of the surface of the dome. The frames are copied and moved through the other two sides of the oculus. Finally, there are 6 splines; 3 splines are for exterior and 3 splines are for interior surface of the dome (Figure 48).

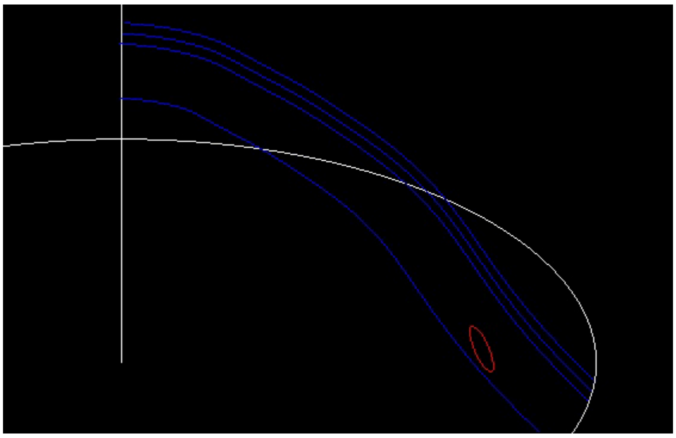


Figure 48. Copied and moved section frames for creating the oculus

- Perpendicular lines are drawn from the sides of the oculus spline to the related interior and exterior section frames (Figure 49). The same procedure is done from the other two sides of the oculus spline to the related interior and exterior section frames. Finally, there are 8 points; 4 at the interior section frames and 4 at the exterior section frames. The points are not on a line when looked from elevation because of the dome geometry.

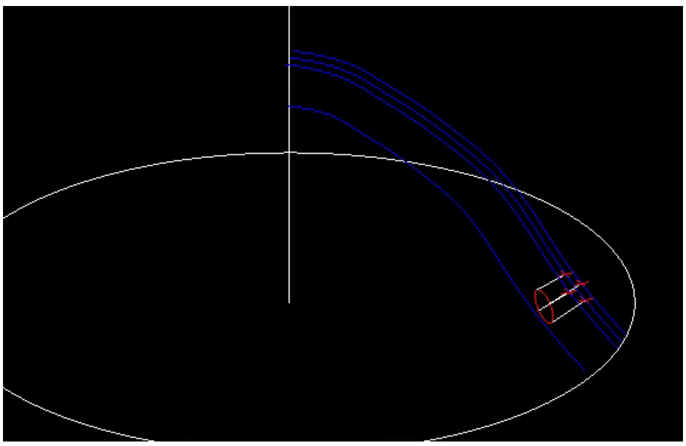


Figure 49. The perpendicular lines drawn from the oculus to the exterior section frames

- In order to situate them on a line, the Z coordinates of the points are changed into the same value with each other. A circle can be drawn instead of spline. This circle is for the exterior surface of the dome.
- A perpendicular line from the circle is drawn in 40 cm in height. The circle is copied.
- Because the region of the oculus on the interior surface is wider than the region of the oculus on the exterior surface, the perpendicular line is rotated through opposite to the center of the circle (Figure 50). A new circle is drawn for the interior surface of the dome.

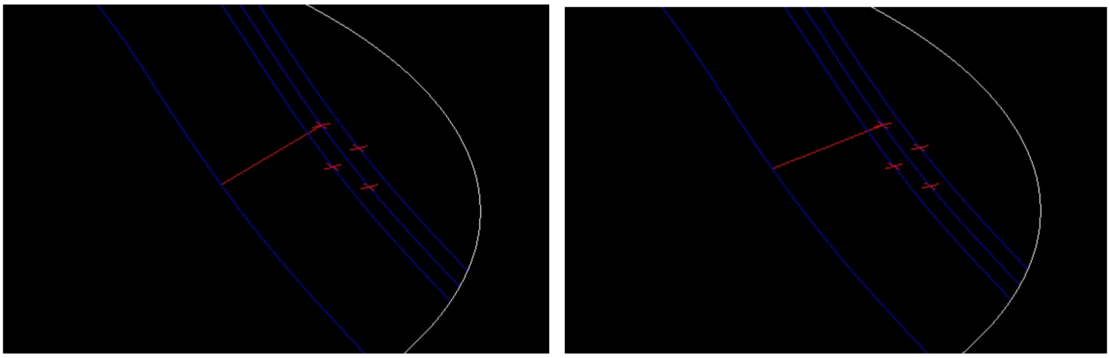


Figure 50. The rotated perpendicular line of the oculus

- Both of the circles are extruded more than 40 cm in order to cut the interior and the exterior surfaces of the dome. They are three dimensional solids (Figure 51).

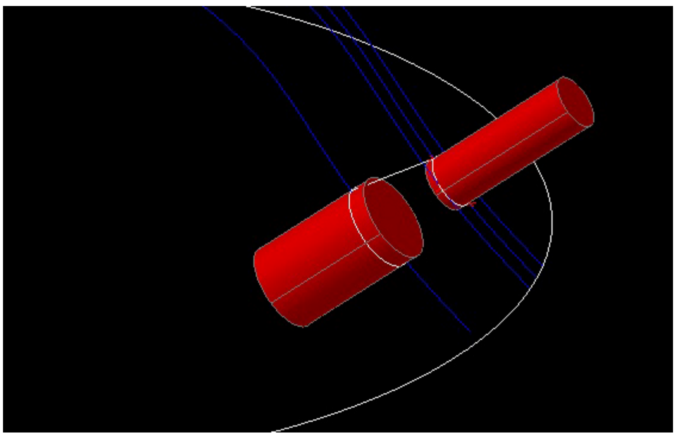


Figure 51. The extruded circles

- The rotated line is revolved around the center of one of the circles. This revolved surface is the interior surface of the oculus (Figure 52). The revolved surface and the three dimensional solid are moved to their own places on the dome.

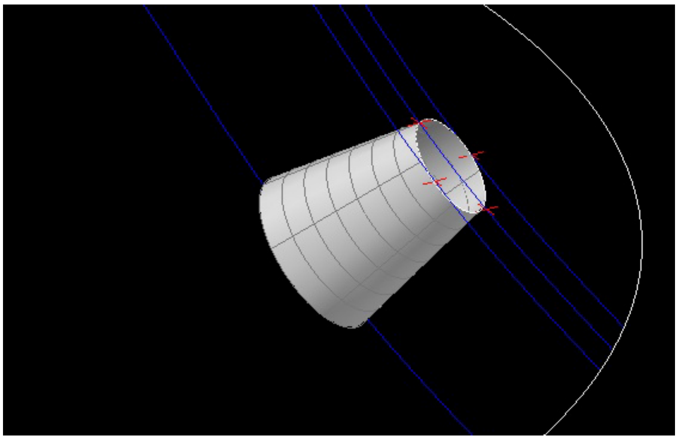


Figure 52. The interior surface of the oculus

- The three dimensional solids are subtracted from the related surfaces of the dome by using “subtract” command (Figure 53).

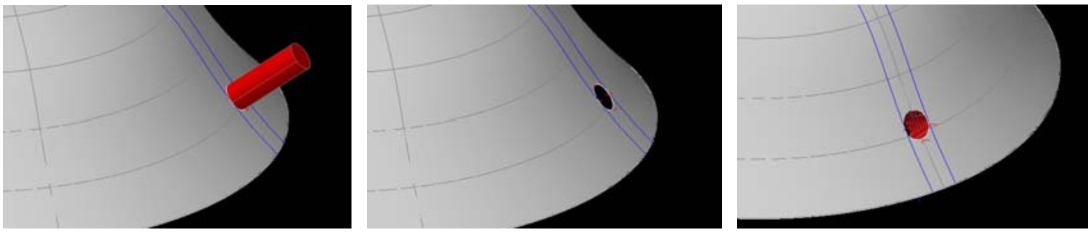


Figure 53. Creating the oculus and its interior surface

- Finally, there are subtracted dome surfaces and a surface of the oculus. This procedure is repeated for every oculus on the dome. If some oculi are similar to each other, they may be copied and replaced to the related places on the dome by using “copy”, “rotate” and “align” commands. The created dome with oculi on it is the geometry of the dome without deformations and remains of plaster (Figure 54).

Figure 54. The dome and the oculi on it

In addition to the measurements for creating the dome geometry, the measurements for the deformations and the remains of plaster on it are taken, as well. Two kinds of deformations are taken into consideration; partially demolishing and having hollows on the surface.

When the dome is demolished partially, the following points should be considered:

- Firstly, the interior and the exterior surfaces and the oculi on it are created.
- The measured points that define the demolished parts of the dome are connected with lines by using “line” command.
- The Z coordinates of these lines are changed into the same value with each other when looked from plan view. The lines are closed with other two lines to be able to extrude them.
- In order to subtract the surfaces of the dome, two three dimensional solids are needed; one from the interior, one from the exterior surfaces. The three dimensional solids are subtracted from the dome surfaces by using the “subtract” command (Figure 55).

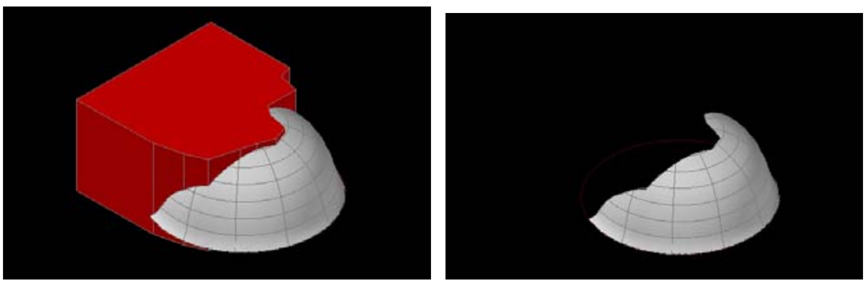


Figure 55. The three dimensional solid is subtracted from the exterior surface of the dome

- Between the cracked points on the exterior and the interior surfaces of the dome are closed with three dimensional faces by using “3dface” command (Figure 56).

Figure 56. A partially demolished dome

When the dome has hollows on its surface, the following points should be considered:

- The measured points on the deformation are connected with lines by using “line” command. Thus, a trace of lines is created on the surface of the dome.
- Some extra surfaces with the help of these line traces and the photographs are created by using “3dface” command.
- The space between the surface of the dome and the extra surfaces is closed with three dimensional faces. The related parts of the surface of the dome are subtracted with the help of the shape of the hollows by using “subtract” command (Figure 57).

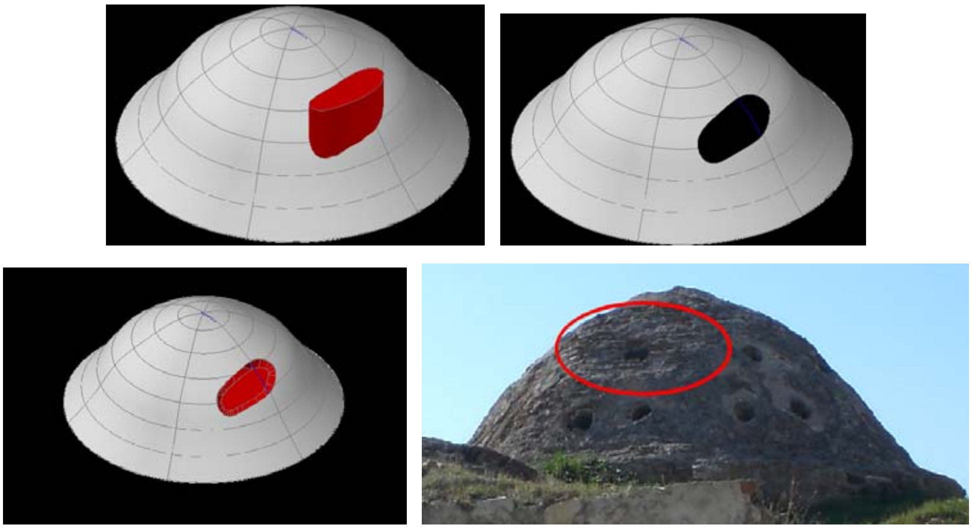


Figure 57. Creating the hollow and its surface on the dome

- If there is an oculus on the related part of the surface, the height of the surface of the oculus should be changed into the true dimension.
- If it is not a hollow but a projecting part (for example remain of plaster), the same procedure is followed through the opposite direction. But it is not needed to subtract the related part of the surface of the dome, because, the extra surface situates over the surface of the dome (Figure 58)

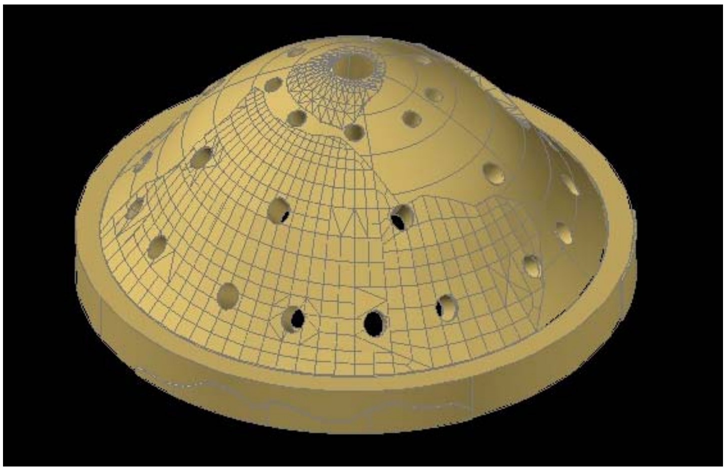


Figure 58. The dome with hollows and remains of plaster on it

CHAPTER 4

RESULTS AND DISCUSSION

The three dimensional modeling as a conservation and restoration aimed documentation technique of a historical monument based on tacheometric measurement was considered. The contemporary total station theodolite technology used in site surveys made possible the gathering of three dimensional data. This precise three dimensional data gave way to the generation of three dimensional representations. Since buildings are three dimensional entities, their three dimensional representations are explicative. In addition, the use of CAD allows viewing and printing in three dimensional in any case. Nevertheless, creating a three dimensional model is a time consuming task according to two dimensional drawings, especially with the irregularities of a historical monument. All vertical elements and rounded surfaces are to be constructed with their deformations. Then, the initial view of the three dimensional wire frame model is to be edited to produce easily understood views in relation with the content of the conservation and restoration problem.

This study is an attempt to manage the process of production of easily viewed three dimensional representations of historical monuments with the aim of conservation and restoration. A series of representation scales; namely 1/200, 1/100 and 1/50; were considered in order to make possible the discussion of various scales of a conservation and restoration design.

These scales are in accordance with the possible interventions at the close-by surrounding of the monument, the spatial interventions in relation with the adaptation or refunctioning of the monument, and the structural interventions that will help for the continuity of the monument's life. Using the case of Hersekzade Ahmet Paşa Bath in Urla, which is a disused and extensively ruined historical monument requiring intensive conservation and restoration interventions, the principles to be followed in the production of three dimensional representations of historical monuments are formulated.

4.1. Remarks for Photographic Documentation

- The photographs should not be taken in sunny days because the details of the building are not observed clearly. So, cloudy days should be preferred.
- The general photographs should be taken from the same points with the station points of the total station theodolite.
- The detail photographs should be taken so that the related building element (dome, wash basin, floor covering, etc.) makes up the majority of the photograph plane.

4.2. Remarks for Measurements

- Before starting measuring, the drafting phase should be planned. The limits of the urban pattern and the site qualities to be documented, the content of documentation of spatial characteristics and architectural elements regarding the monument, and the structural elements that require interventions should be all decided.
- When selecting a station point, the coverage of maximum number of points that define the building geometry is important. In addition, it is preferred to view the near-by surrounding at the same time to prevent time consuming.
- The amount of measured points should be sufficient and the positions of these points on the object should be considered well to create the geometry of each element. The amount of measured points on the object should be decided according to the viewing or printing scale of the drawings.
    - For the scale of 1/200; starting and ending points of every corner line for the planar surfaces, 3 points on curvilinear surfaces and 1 section (10-11 points on a section) on domes should be measured.
    - For the scale of 1/100; starting and ending points of every corner line for the planar surfaces, minimum 3, preferably 4 points on curvilinear surfaces, 1 section (10-11 points on a section) on domes and decorative elements should be measured.
    - For the scale of 1/50; three sections of the dome (the points that situated at most in every 35 cm for a section), four points for each oculus and the points

which define the border of the deformations and the remains of plaster on the dome should be measured.

- Site elements such as the facades of the neighboring gardens and buildings, roofs of these buildings, changes in slopes of the roads and the surrounding ground are not measured as detailed as the building elements.

4.3. Remarks for Drafting

- The mass of the case study building should be modeled first, and then the building elements, their details and deformations should be applied on to the three dimensional model.
- All of the plane surfaces such as roofs, walls, floor, roads and the surrounding ground should be modeled as three dimensional surfaces using "3dface" command in every scale of the drawings (1/200, 1/100, 1/50).
- Curvilinear elements should be modeled with the "revolve" command.
- The irregularities such as material loss in walls, etc. should be formed by subtracting the irregular geometries from the three dimensional surfaces.
- The irregularities such as remains of plasters should be added to the related three dimensional surfaces using the "union" command.

CHAPTER 5

CONCLUSION

The recent introduction of extensive usage of total station theodolite as the primary recording tool of the architect together with the typical AutoCAD software has given way to the complete utilization of digital three dimensional raw data in drafting. The thesis states that the three dimensional modeling has great potential for conservation and restoration aimed documentation of historic monuments, although it is time consuming (for the three dimensional drawings, 7 work days for the photographic documentation and measurement work, 40 work days for the drafting work; and for the two dimensional drawings, 3 work days for the photographic documentation and measurement work, 15 work days for the drafting work*). The data gathered is easy to interpret, once the principles of modeling are followed. These principles are to construct the model with independent three dimensional surfaces representing independent faces of the building elements, to use "revolve" command for the curvilinear elements and for the deformations, to create the element as a whole first, and then to use the "subtract" command to represent its irregularities, to use the "union" command for the remains such as plaster pieces of the domes, the walls or the arches or to use both for complex irregularities. Apart from the disadvantage of the time consumption, the necessity of manual drafting work should be considered. Thus, the technique should be applied to the architectural heritage which necessitates through three dimensional evaluation.

The analyses for the restitution, restoration and conservation works of the monument can be observed clearly and perceived as a whole on the three dimensional model, contrary to two dimensional drawings; and one can get views of any desired vista. The site model is a base for the discussions and analyses of the site relations. The spatial model is a base for the discussions and analyses of the building elements, their situations and material usage. The elementary model is a base for the discussions and analyses of the structural situation of the element and its material usage.

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*These are probable work days guessed on the basis of previous experiences. Two dimensional drawings have not been carried out.

REFERENCES

Anka Architects. 2009. *The Report for the Documentation Project of Hersekzade Ahmet Paşa Bath.* İzmir.

Andres, M. A. N., Pozuelo, F. B. 2009. *Evolution of the Architectural and Heritage Representation.* Landscape and Urban Planning. 91: 105-112.

Arias, P., Ordóñez, C., Lorenzo, H., Herraez, J., Armesto, J. 2007. *Low-cost documentation of traditional agro-industrial buildings by close-range photogrammetry.* Building and Environment. 42(4): 1817-1827.

Armesto, J., Lubowiecka, I., Ordonez, C., Rial, F. I. 2008. *FEM Modelling of Structures Based on Close Range Digital Photogrammetry.* Automation in Construction. 1-11.

Blake, B., Bedford, J. 2010. *Documentation for Conservation – A Manual for Teaching Metric Survey Skills.* RecorDIM Initative Teaching Guide. http://www.bill-blake.co.uk/files/Download/CIPA%20Recordim%20Teaching%20Guide.pdf (accessed July 30, 2010).

Büyükdigan, İ. 2003, *A critical look at the new functions of Ottoman baths.* Building and Environment. 38: 617-633.

Çakmak, C. 2002. *Tire Hamamları.* Ankara: Kültür Bakanlığı. 9-25.

Fuji, Y., Fodde, E., Watanabe, K., Murakami, K. 2008. *Digital Photogrammetry for the Documentation of Structural Damage in Earthen Archeological Sites: The Case of Ajina Tepa, Tajikistan.* Engineering Geology. 1-33.

Gomez-Lahoz, J., Gonzalez-Aguilera, D. 2008. *Recovering Traditions in the Digital Era: The Use of Blimps for Modelling the Archeological Cultural Heritage.* Journal of Archeological Science. 36: 100-109.

Guiterrez, D., Seron, F. J., Magallan, J. A., Sobreviela, E. J., Latorre, P. 2004. *Archaeological and cultural heritage: bringing life to an unearthed Muslim suburb in an immersive environment.* Journal of Cultural Heritage. 5: 63-74.

ICOMOS. 1964. *International Charter for the Conservation and Restoration of Monuments and Sites (The Venice Charter).* Venice. Article 14, 16. http: //www.international.icomos.org/charter/venice_e.pdf (accessed June 1, 2010).

ICOMOS. 1987, *Charter for the Conservation of Historic Towns and Urban Areas (Washington Charter 1987)*. Washington. Article 2. http://www.international.icomos.org/charters/towns_e.html (accessed April 20, 2010).

ICOMOS. 1994, *Nara Document on Authenticity.* Nara. http://www.international.icomos.org/charter/nara_e.htm (accessed June 1, 2010).

ICOMOS. 1999, Document of Nara. In: E Madran, N Ozgonul (Ed.). *International documents regarding the preservation of cultural and natural heritage.* Ankara: METU Faculty of Architecture Press. 503-504.

ICOMOS. 2003, *Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage*. Zimbabwe. Article 1.3, 1.6. http://www.international.icomos.org/charters/structures_e.html (accessed April 21, 2010).

Jokilehto, J., 2002*, A History of Architectural Conservation*. Oxford: Butterworth-Heinemann. 285.

Önge, Y., 1995, *Anadolu'da XII.-XIII. Yüzyıl Türk Hamamları.* Ankara. 22.

Remondino, F., El-Hakim, S. 2006. *Image-based three dimensional modeling: a review.* The Photogrammetric Record. 21: 115.

Reyhan, K. 2004. *Construction Techniques and Materialsof the Ottoman Period Baths in Seferihisar–Urla Region.* Unpublished Master Thesis. İzmir Institute of Technology. İzmir.

Swallow, P., Dallas, R., Jackson, S., Watt D. 2004, *Measurement and Recording of Historic Buildings*. 2, 4, 126.

Tripp, T. 2010. *A Brief History of Architectural Model Making.* http://www.articledashboard.com/Article/A-Brief-History-Of-Architectural-Model-Making/1595837 (accessed August 3, 2010).

Yarımada Newspaper. 2010. http://www.yarimada.org/news_detail.php?id=486 (accessed May 10, 2010).

Yılmaz, H. M., Yakar, M., Güleç, S. A., Dülgerler, O. N. 2007. *Importance of Digital Close-Range Photogrammetry in Documentation of Cultural Heritage.* Automation in Construction. 17: 489-498.

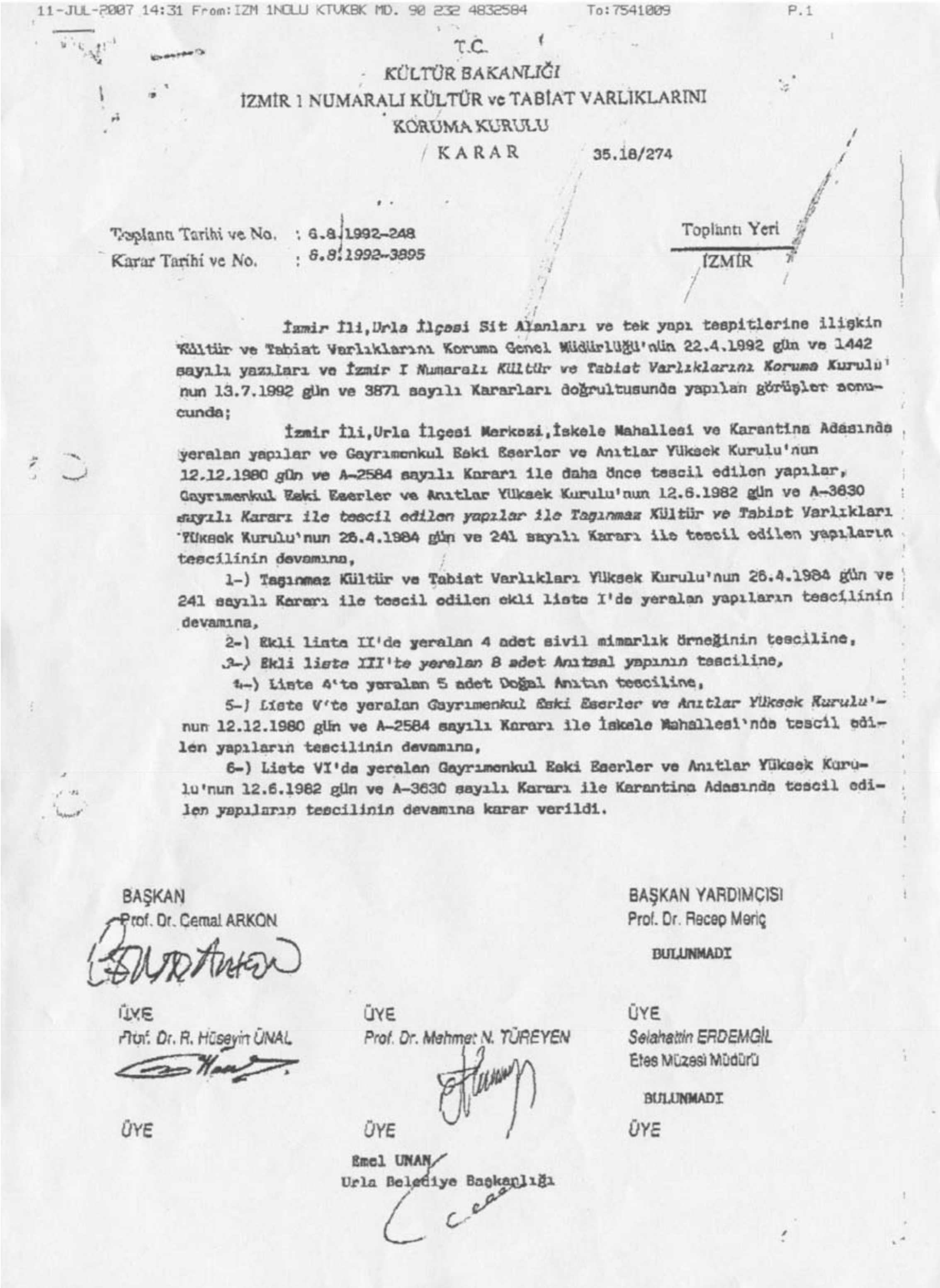
Warden, R., Woodcock, D. 2005. *Historic Documentation: A model of Project Based Learning for Architectural Education.* Landscape and Urban Planning. 73: 110-119.

Wikipedia. 2010 a. http://en. wikipedia.org/wiki/Tachymeter (accessed August 2, 2010).

Wikipedia. 2010 b. http://en. wikipedia.org/wiki/Theodolite (accessed August 2, 2010).

APPENDIX A

ARCHIVE DOCUMENTS



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T.C.
KÜLTÜR BAKANLIĞI
İZMİR 1 NUMARALI KÜLTÜR ve TABİAT VARLIKLARINI
KORUMA KURULU
KARAR 35.18/274

Toplantı Tarihi ve No. : 6.8.1992-248
Karar Tarihi ve No. : 6.8.1992-3895

Toplantı Yeri
İZMİR

İzmir İli, Urla İlçesi Sit Alanları ve tek yapı tespitlerine ilişkin Kültür ve Tabiat Varlıklarını Koruma Genel Müdürlüğü'nün 22.4.1992 gün ve 1442 sayılı yazıları ve İzmir I Numaralı Kültür ve Tabiat Varlıklarını Koruma Kurulu'nun 13.7.1992 gün ve 3871 sayılı Kararları doğrultusunda yapılan görüşler sonucunda;

İzmir İli, Urla İlçesi Merkezi, İskele Mahallesi ve Karantina Adasında yeralan yapılar ve Gayrımenkul Eski Eserler ve Anıtlar Yüksek Kurulu'nun 12.12.1980 gün ve A-2584 sayılı Kararı ile daha önce tescil edilen yapılar, Gayrımenkul Eski Eserler ve Anıtlar Yüksek Kurulu'nun 12.6.1982 gün ve A-3630 sayılı Kararı ile tescil edilen yapılar ile Taşınmaz Kültür ve Tabiat Varlıkları Yüksek Kurulu'nun 26.4.1984 gün ve 241 sayılı Kararı ile tescil edilen yapıların tescilinin devamına,

1-) Taşınmaz Kültür ve Tabiat Varlıkları Yüksek Kurulu'nun 26.4.1984 gün ve 241 sayılı Kararı ile tescil edilen ekli liste I'de yeralan yapıların tescilinin devamına,

2-) Ekli liste II'de yeralan 4 adet sivil mimarlık örneğinin tesciline,

3-) Ekli liste III'te yeralan 8 adet Anıtsal yapının tesciline,

4-) Liste 4'te yeralan 5 adet Doğal Anıtın tesciline,

5-) Liste V'te yeralan Gayrımenkul Eski Eserler ve Anıtlar Yüksek Kurulu'nun 12.12.1980 gün ve A-2584 sayılı Kararı ile İskele Mahallesi'nde tescil edilen yapıların tescilinin devamına,

6-) Liste VI'da yeralan Gayrımenkul Eski Eserler ve Anıtlar Yüksek Kurulu'nun 12.6.1982 gün ve A-3630 sayılı Kararı ile Karantina Adasında tescil edilen yapıların tescilinin devamına karar verildi.

BAŞKAN
Prof. Dr. Cemal ARKON

BAŞKAN YARDIMCISI
Prof. Dr. Recep Meriç
BULUNMADI

ÜYE
Prof. Dr. R. Hüseyin ÜNAL

ÜYE
Prof. Dr. Mehmet N. TÜREYEN

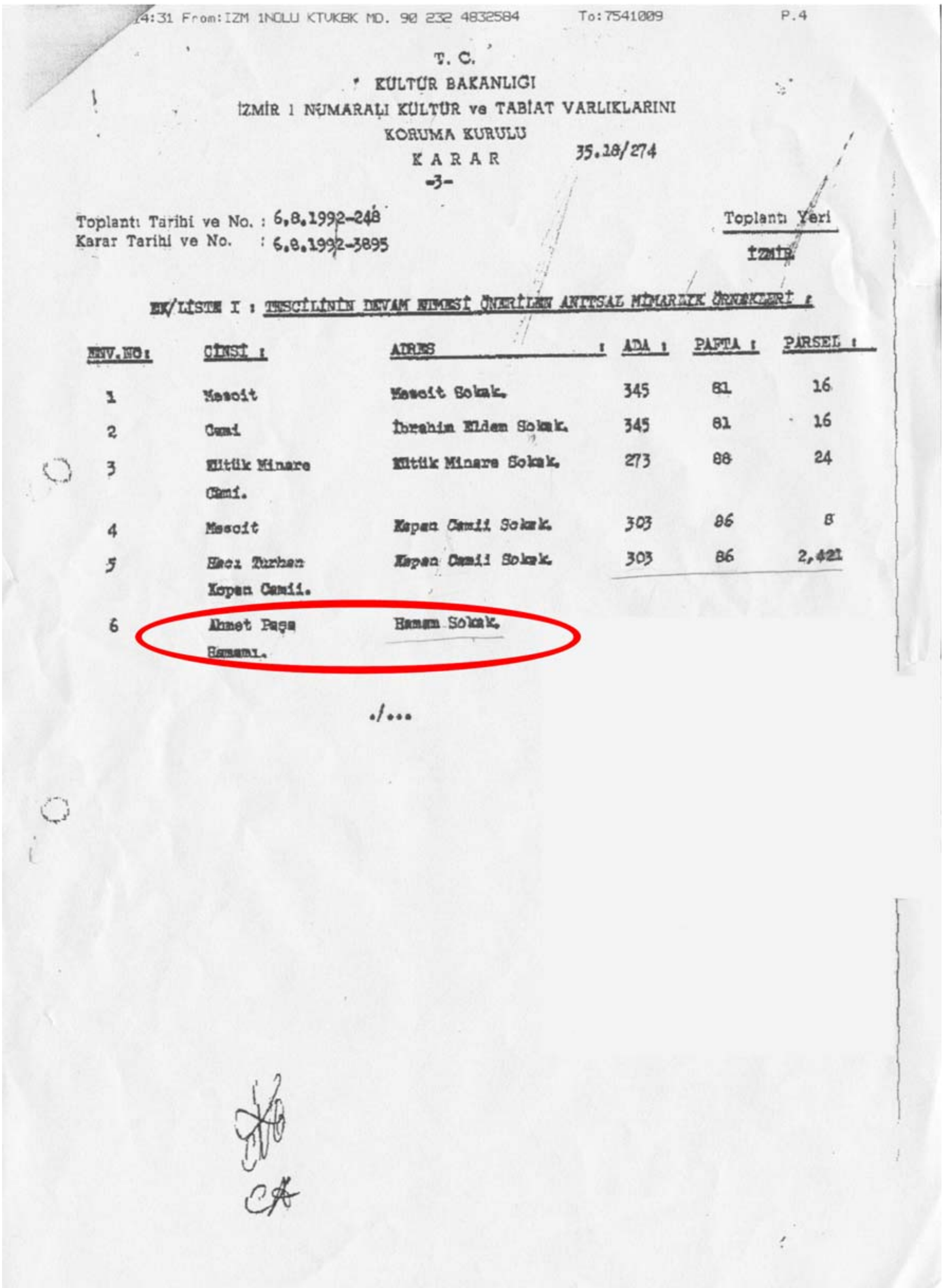
ÜYE
Selahattin ERDEMGİL
Efes Müzesi Müdürü
BULUNMADI

ÜYE

ÜYE
Emel UNAN
Urla Belediye Başkanlığı

ÜYE

Figure 59. Decision of İzmir Number 1 Council of Conservation of Cultural and Natural Asset



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T. C.
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KORUMA KURULU
K A R A R 35.18/274
-3-

Toplantı Tarihi ve No. : 6.8.1992-248
Karar Tarihi ve No. : 6.8.1992-3895

Toplantı Yeri
İZMİR

EK/LİSTE I : TESCİLİNİN DEVAM ETMESİ ÖNERİLEN ANITSAL MİMARLIK ÖRNEKLERİ :

ENV.NO:	CİNSİ :	ADRES :	ADA :	PAFTA :	PARSEL :
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2	Cami	İbrahim Eldem Sokak.	345	81	16
3	Kütük Minare Cami.	Kütük Minare Sokak.	273	88	24
4	Mescit	Kapan Camii Sokak.	303	86	8
5	Hacı Turhan Kapan Camii.	Kapan Camii Sokak.	303	86	2,421
6	Ahmet Paşa Hamamı.	Hamam Sokak.			

./...

Figure 60. Decision of İzmir Number 1 Council of Conservation of Cultural and Natural Asset

APPENDIX B

DRAWINGS OF THE BATH IN 1/200 SCALE

Figure 61. Site model - plan view

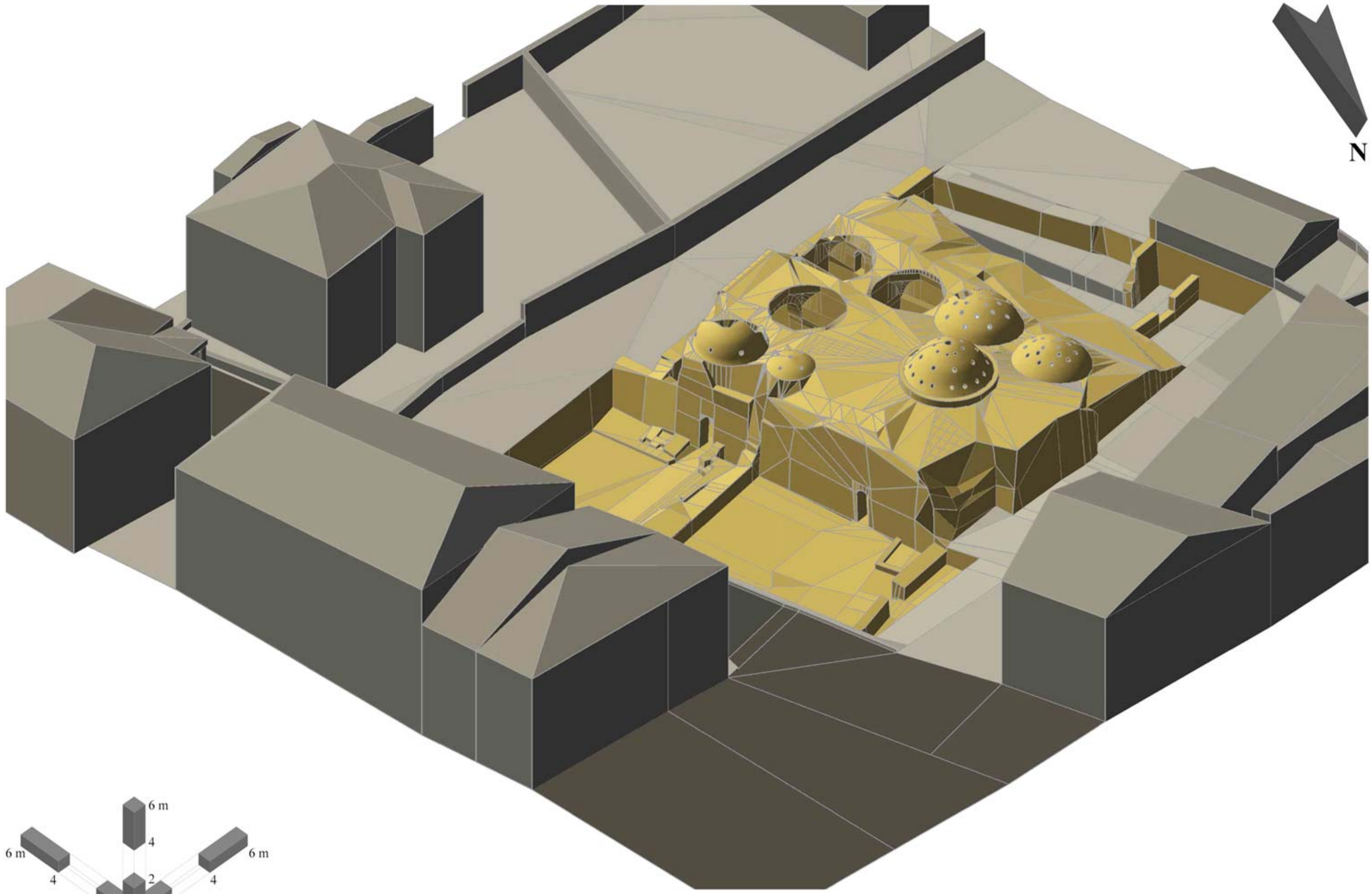


Figure 62. Northeastern axonometric view

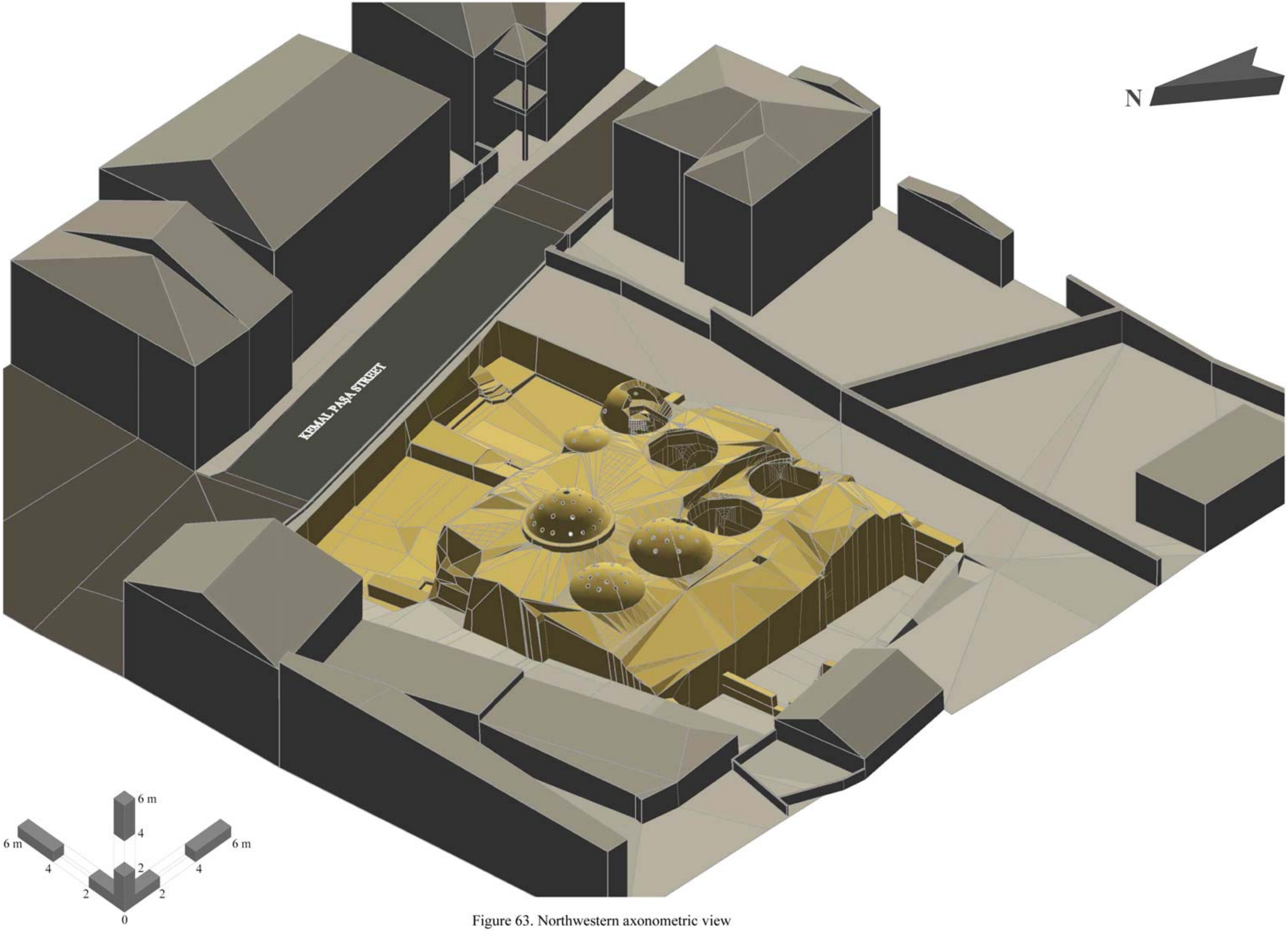


Figure 63. Northwestern axonometric view

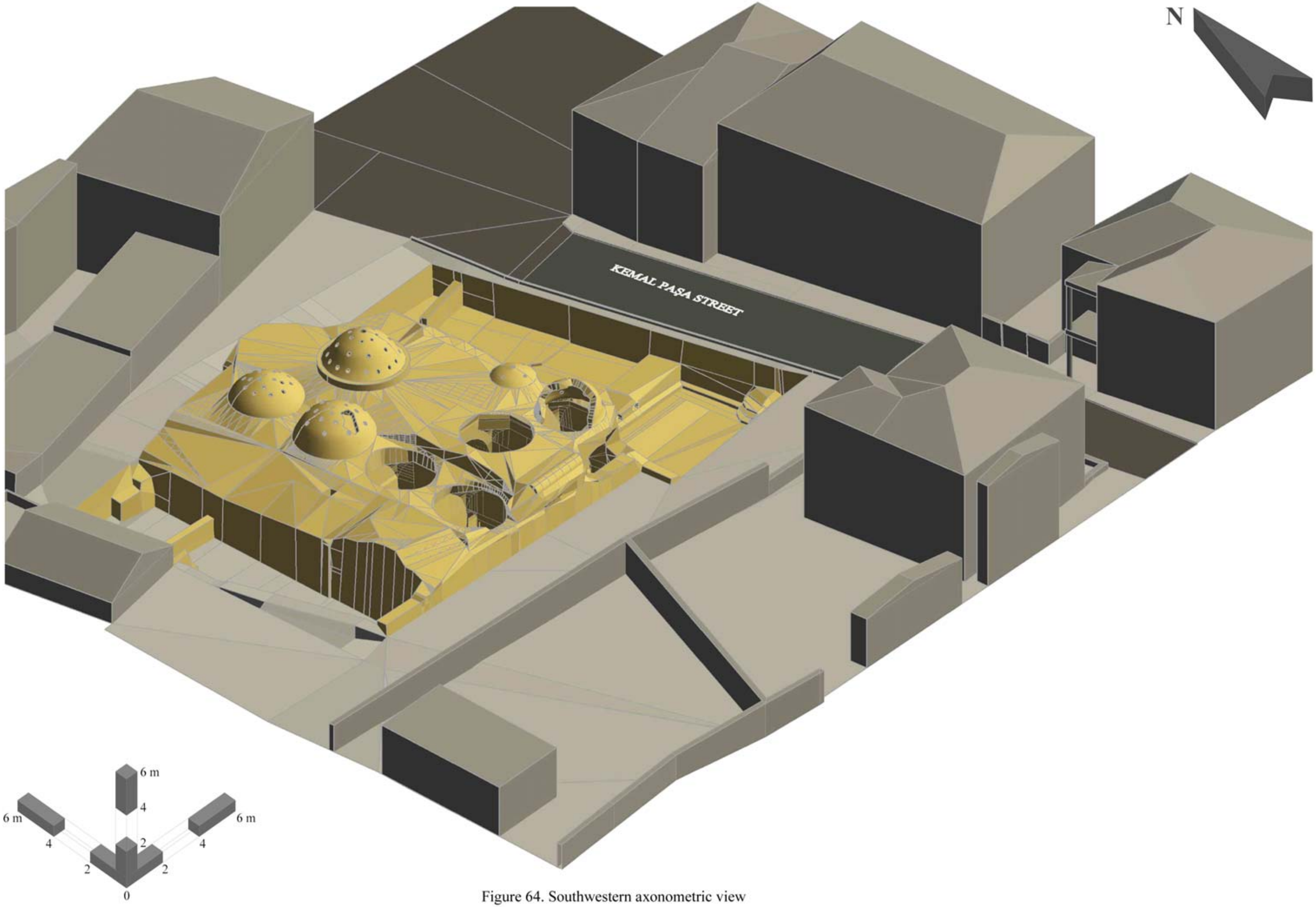


Figure 64. Southwestern axonometric view

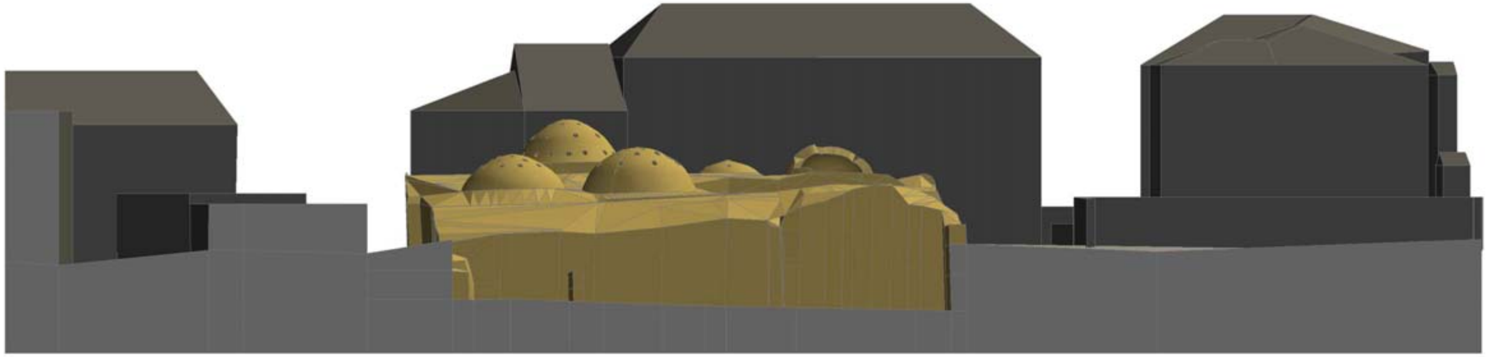


Figure 65. Southwestern view

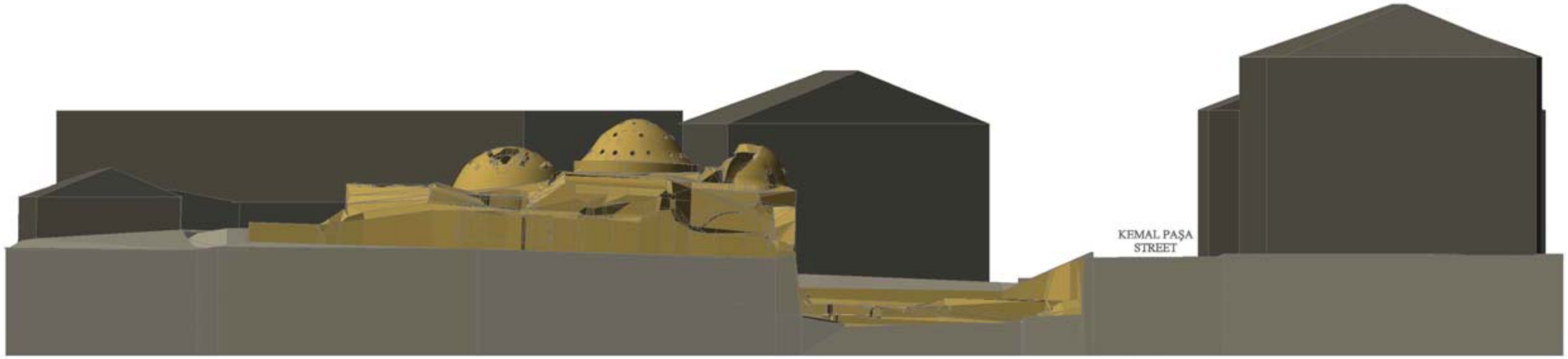


Figure 66. Southeastern view

0 0.5 1.0 1.5 m

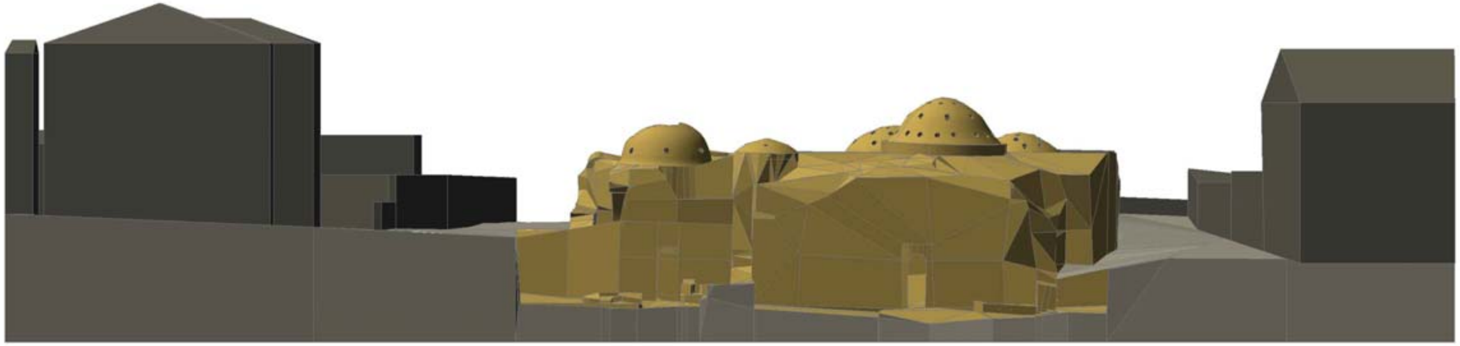


Figure 67. Northeastern view

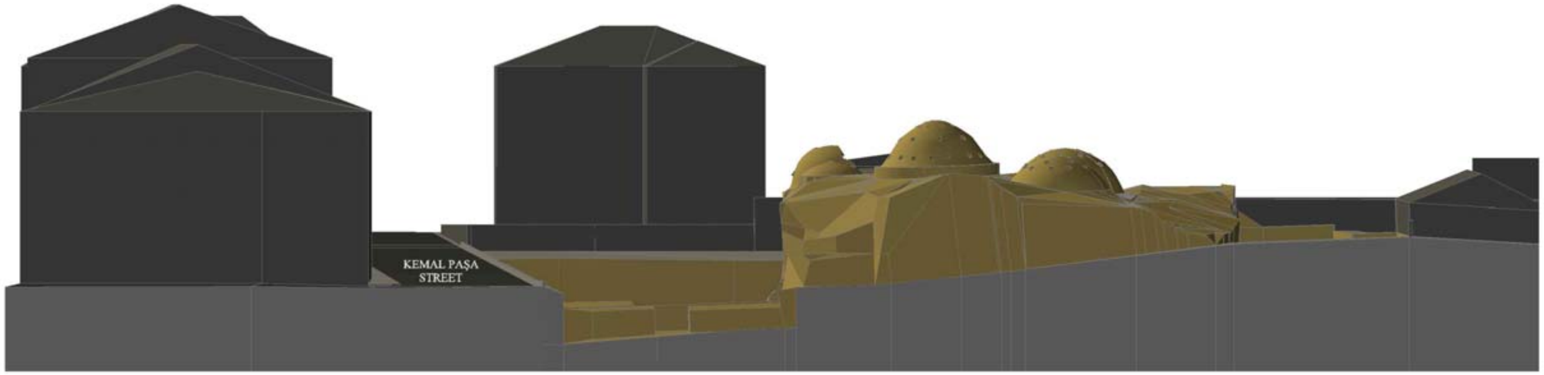
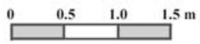


Figure 68. Northwestern view



APPENDIX C

DRAWINGS OF THE CALDARIUM IN 1/100 SCALE

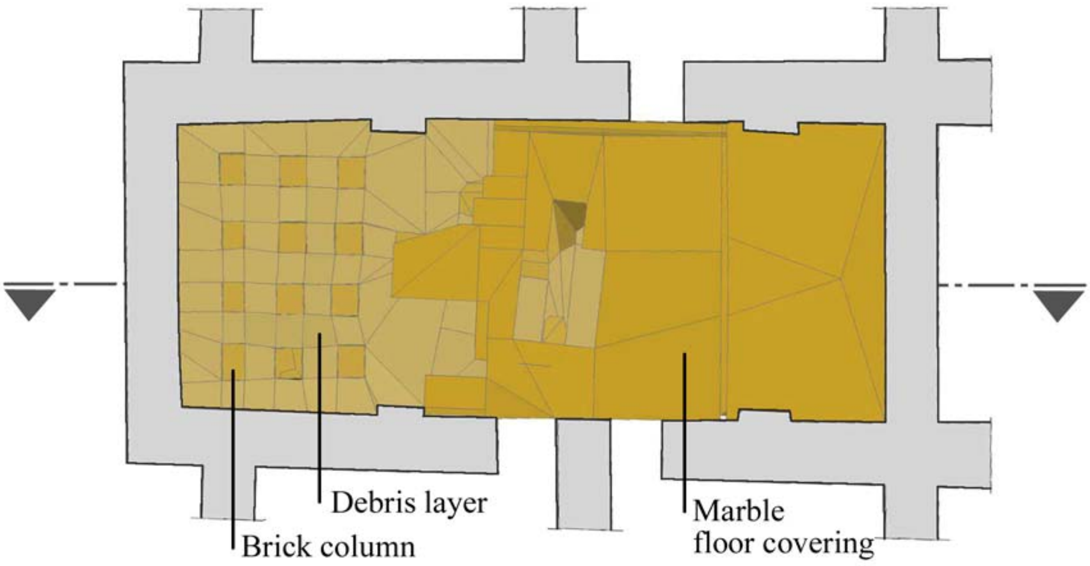


Figure 69. Floor model - plan view

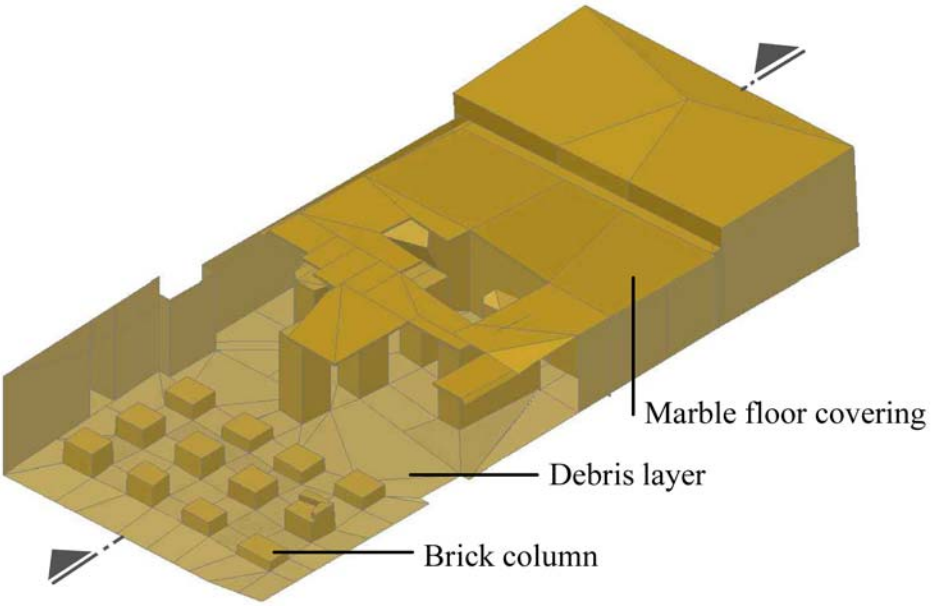
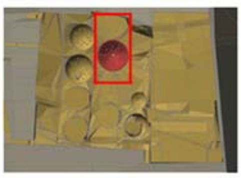


Figure 70. Floor model - axonometric view



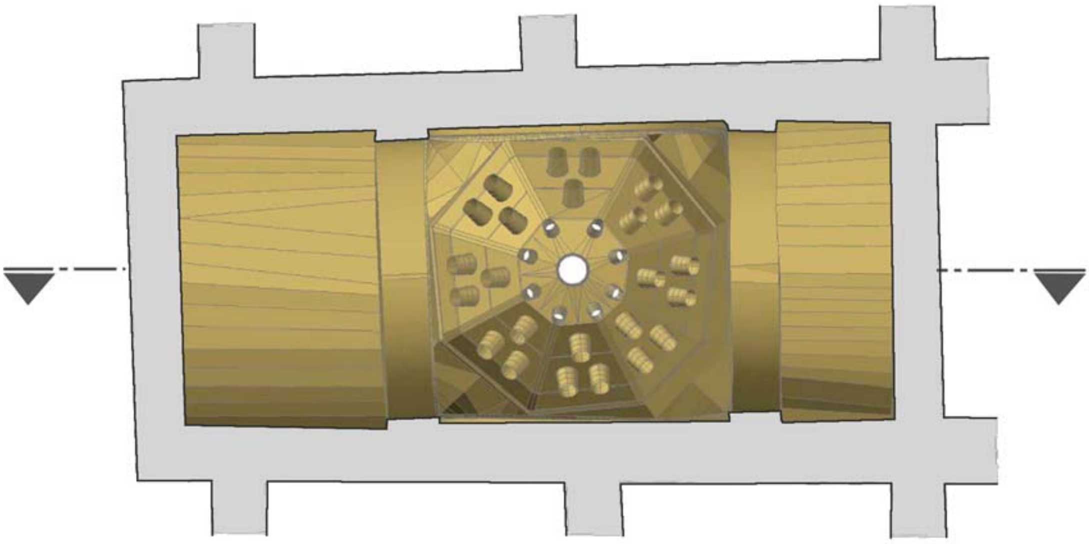


Figure 71. Ceiling plan

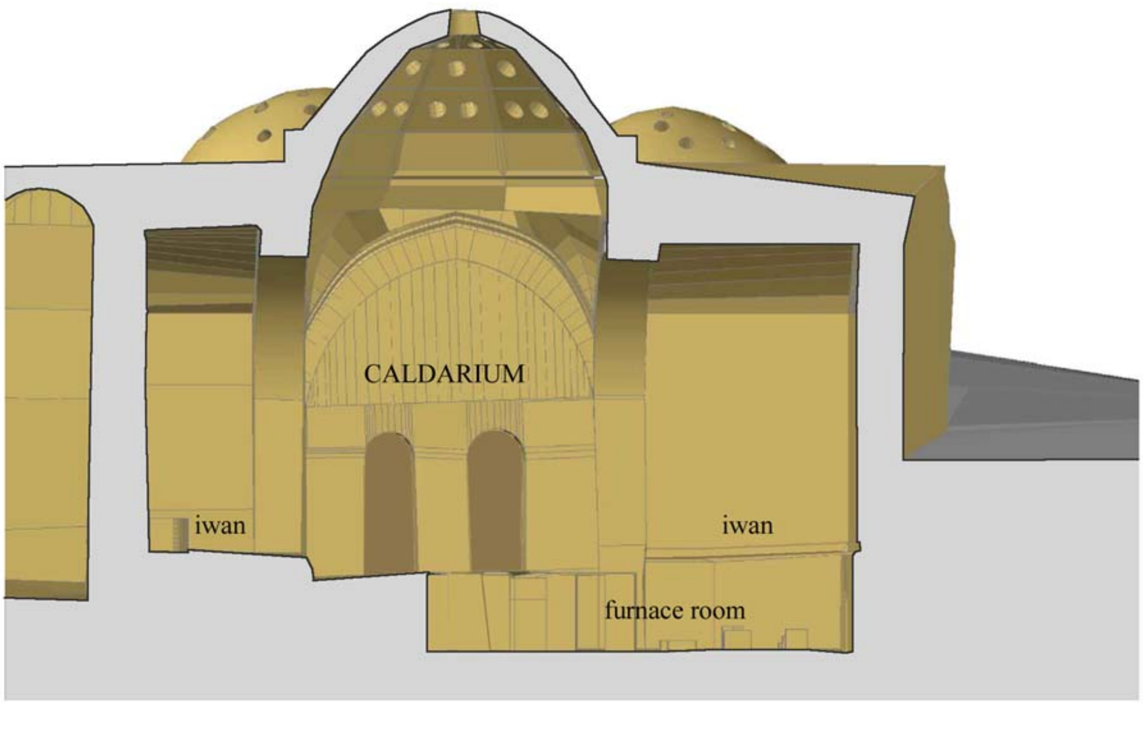
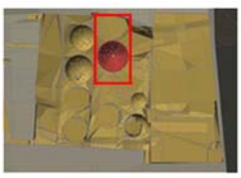


Figure 72. Section



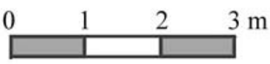
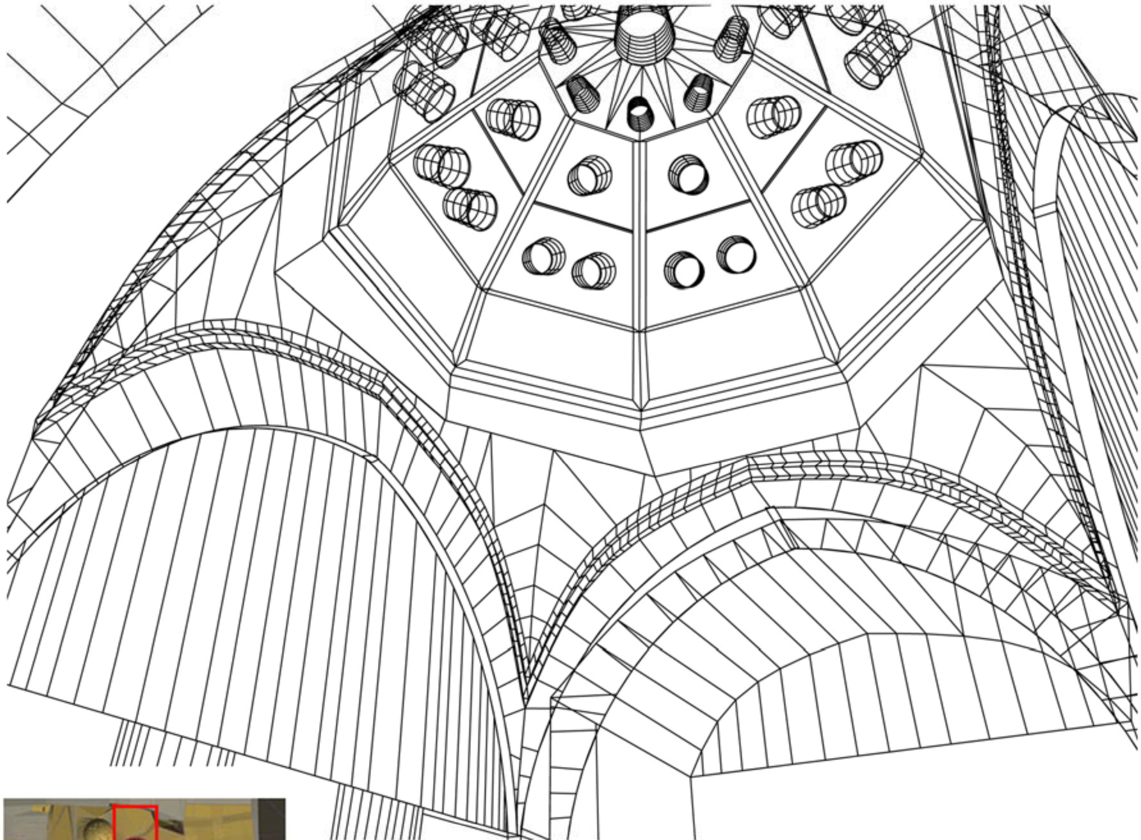


Figure 73. Perspective view - 1



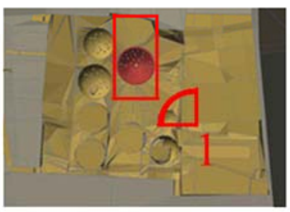
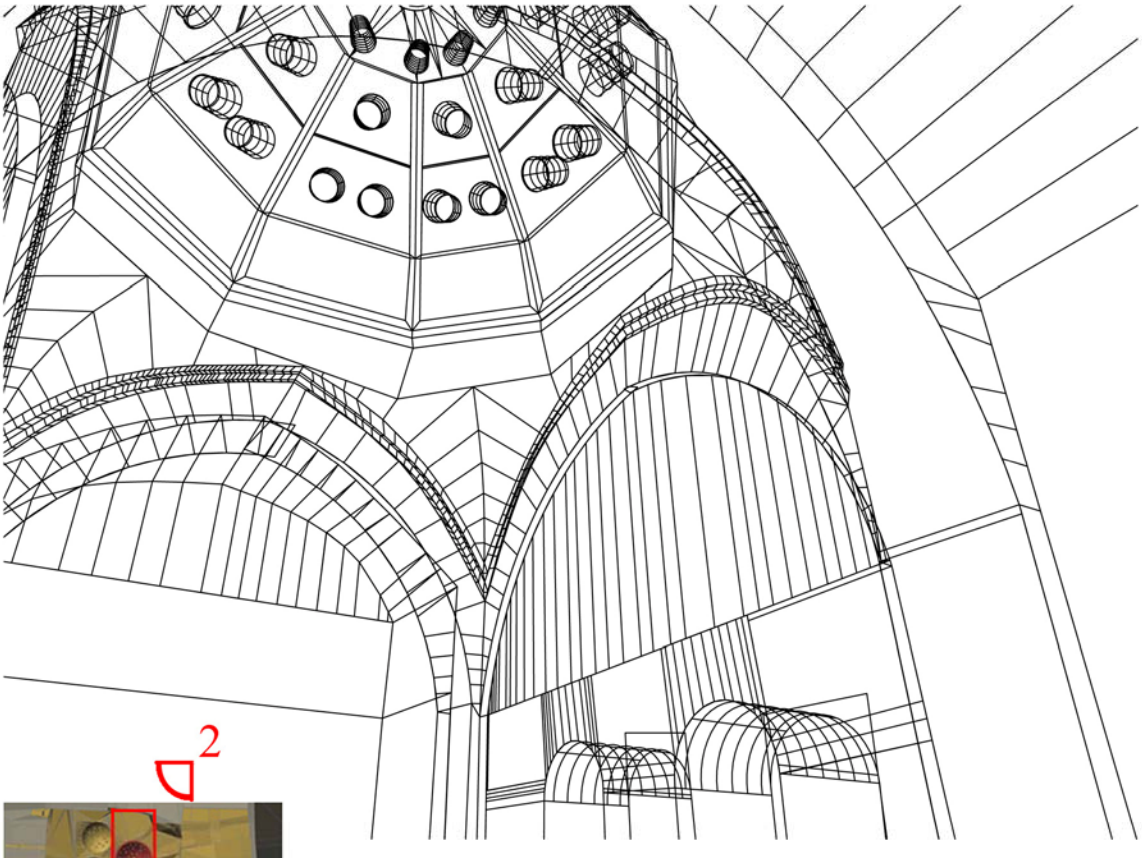


Figure 74. Perspective view - 1 - wireframe

Figure 75. Perspective view - 2



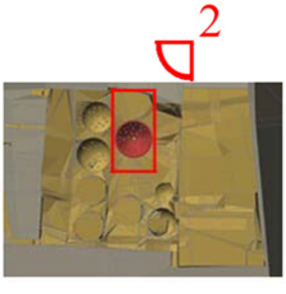


Figure 76. Perspective view - 2 - wireframe

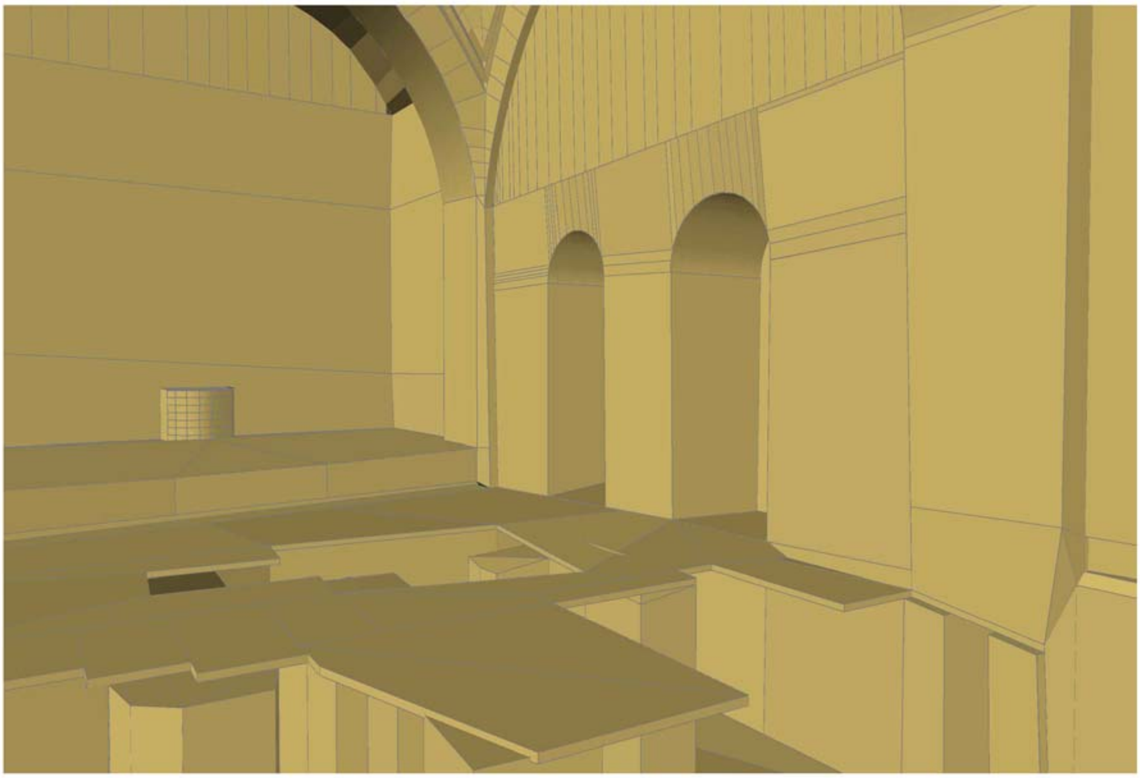
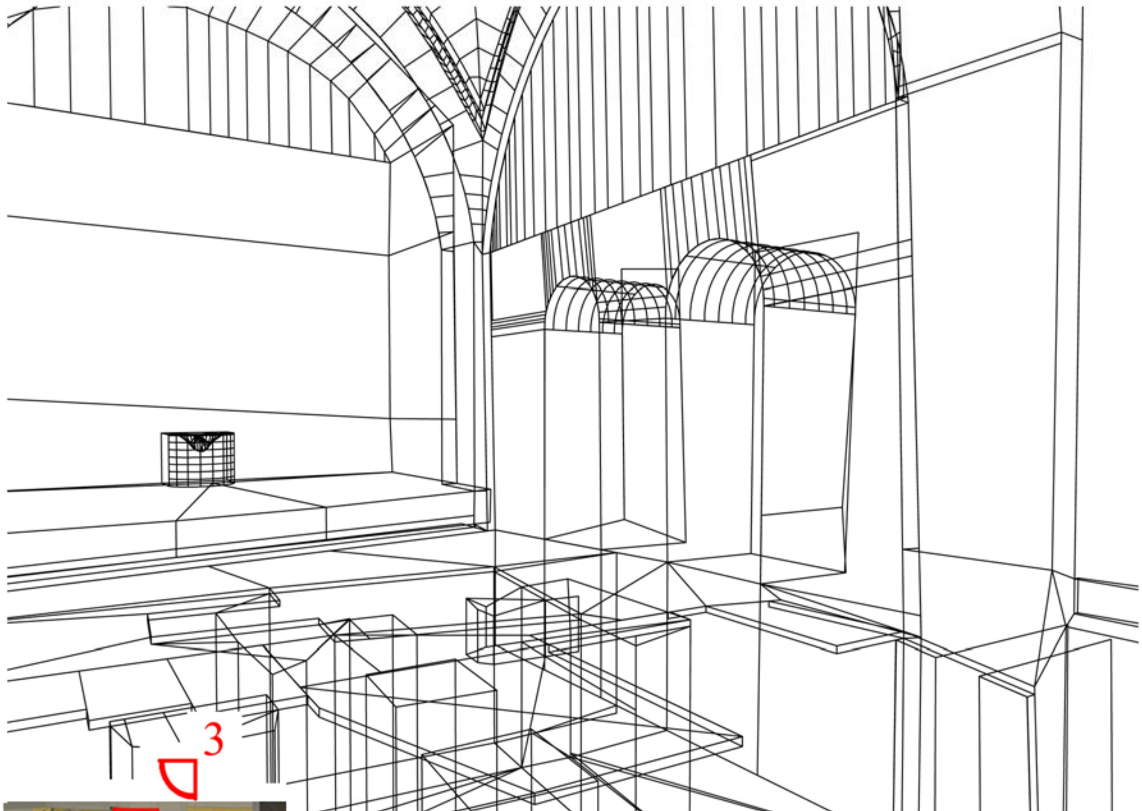


Figure 77. Perspective view - 3



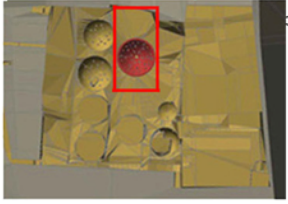


Figure 78. Perspective view - 3 - wireframe

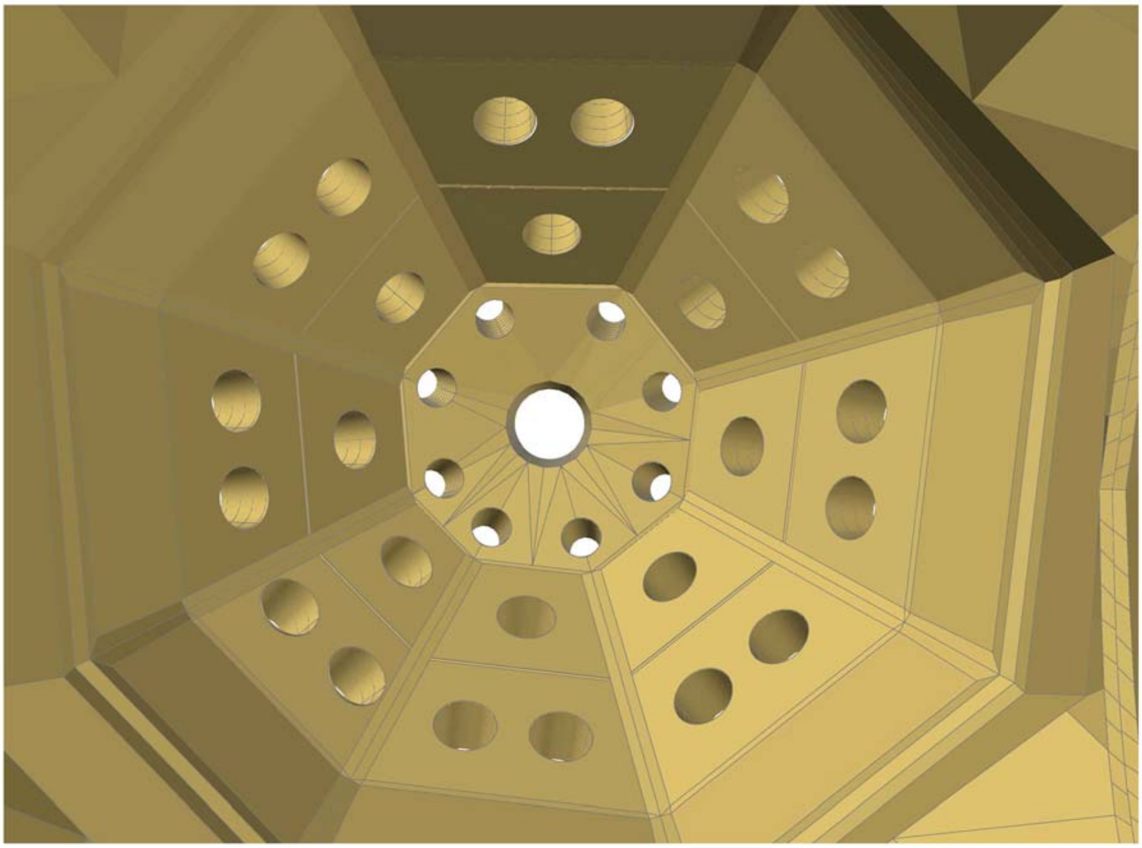
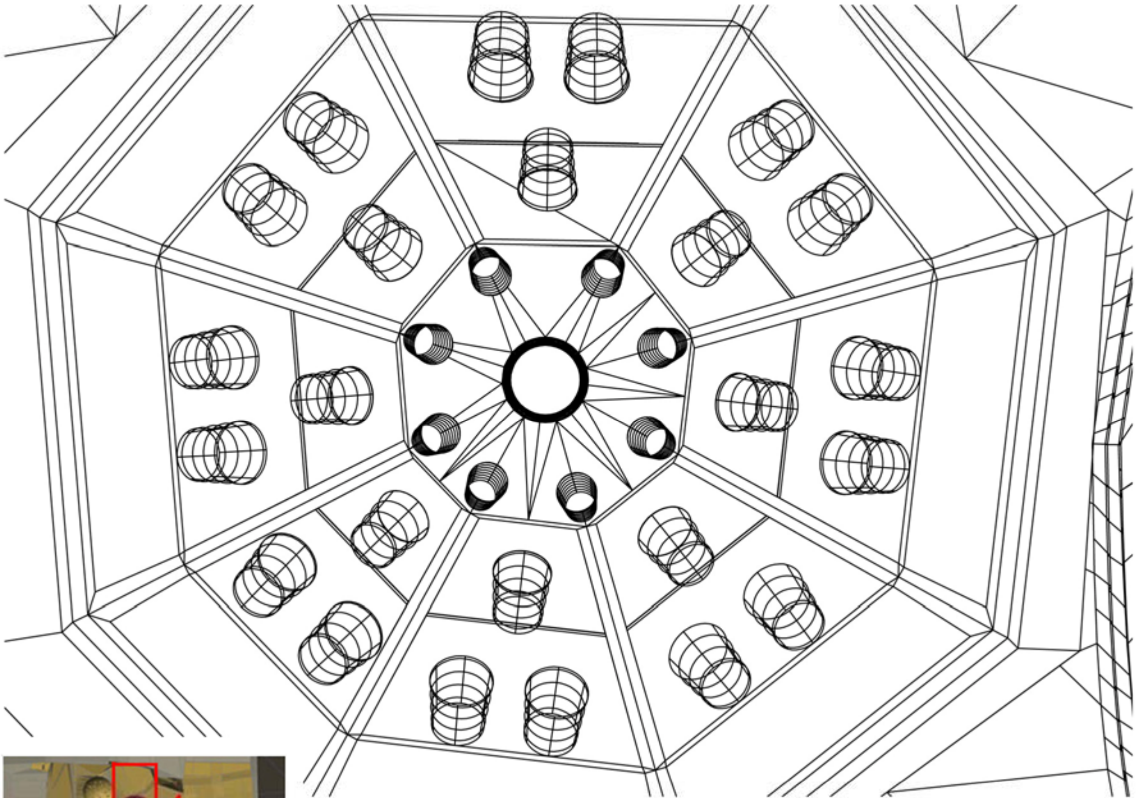


Figure 79. Perspective view - 4, dome



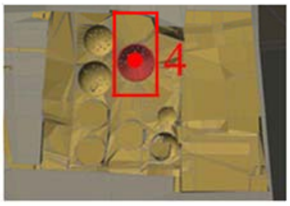


Figure 80. Perspective view - 4, dome - wireframe

APPENDIX D

DRAWINGS OF THE DOME IN 1/50 SCALE

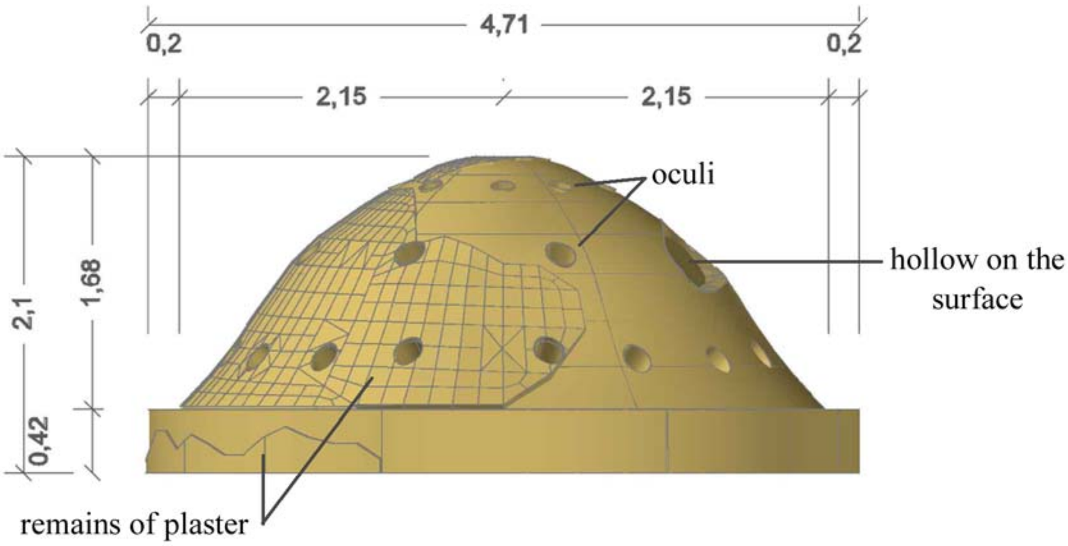
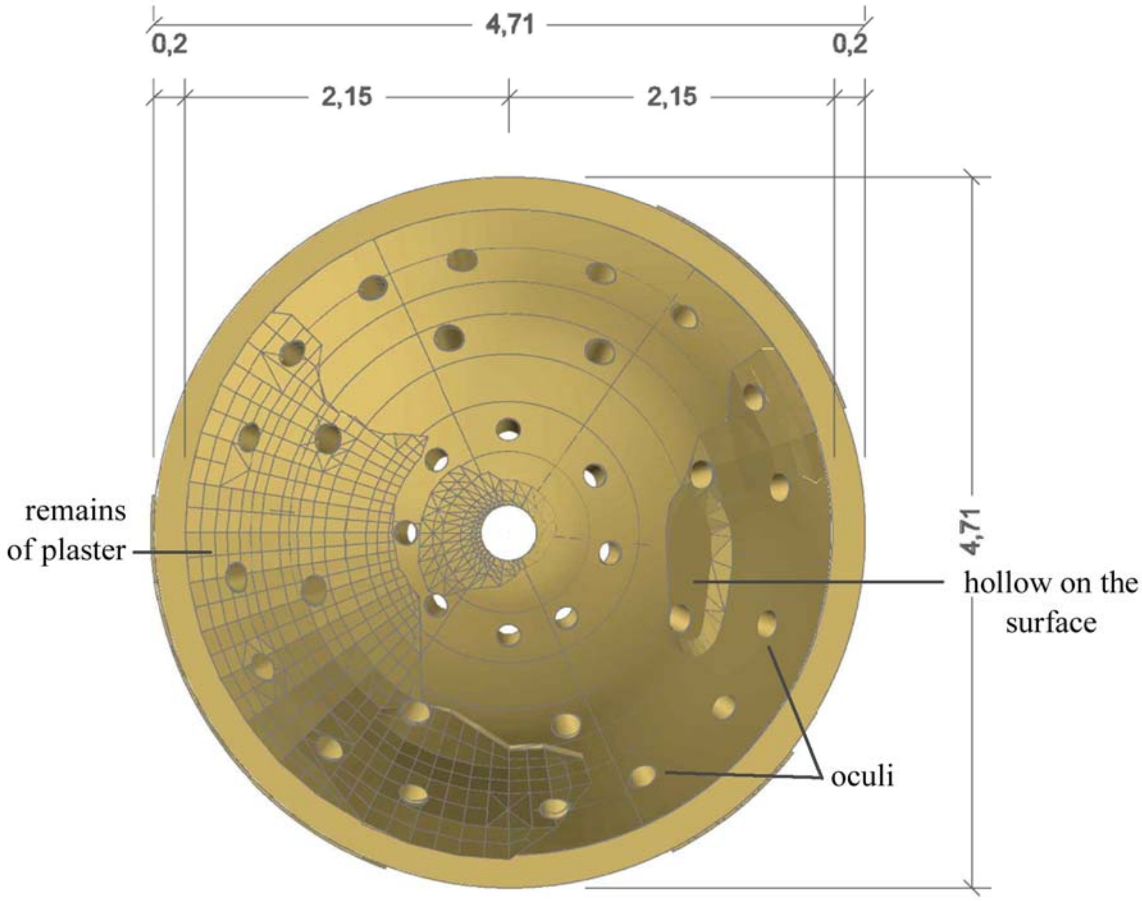


Figure 81. Dome model - southeastern view



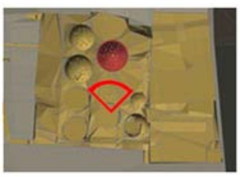
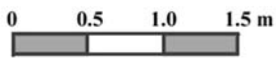


Figure 82. Dome model - plan view



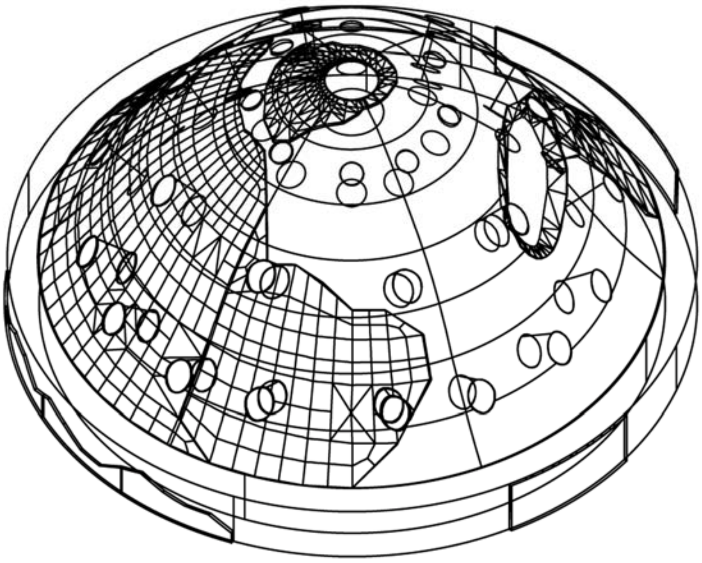


Figure 83. Dome model - axonometric view - wireframe

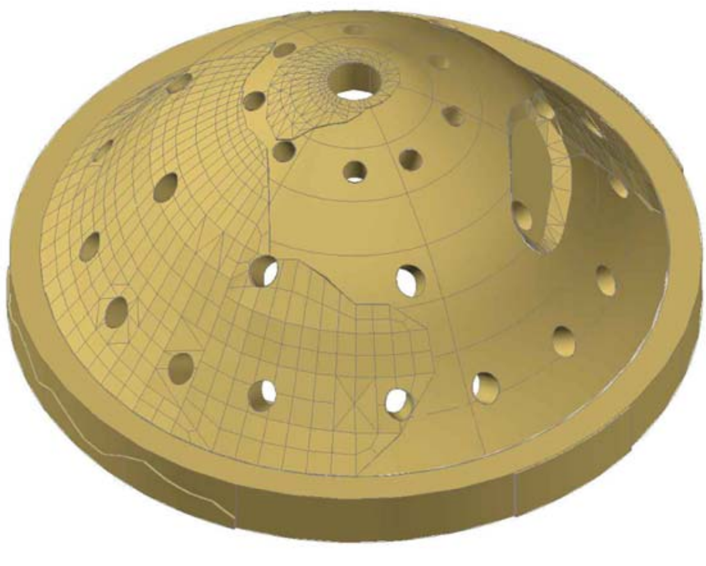
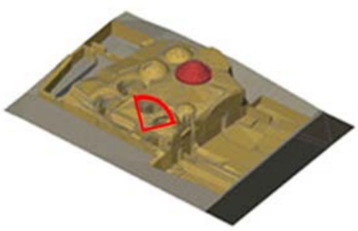
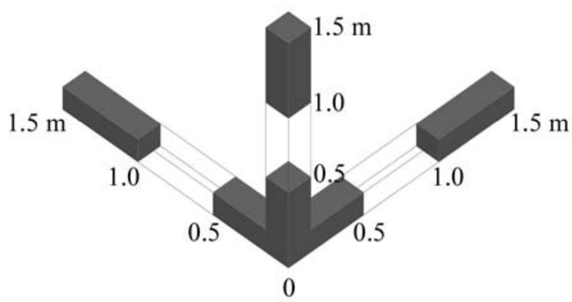


Figure 84. Dome model - axonometric view





APPENDIX E

COORDINATES OF THE MEASURED POINTS

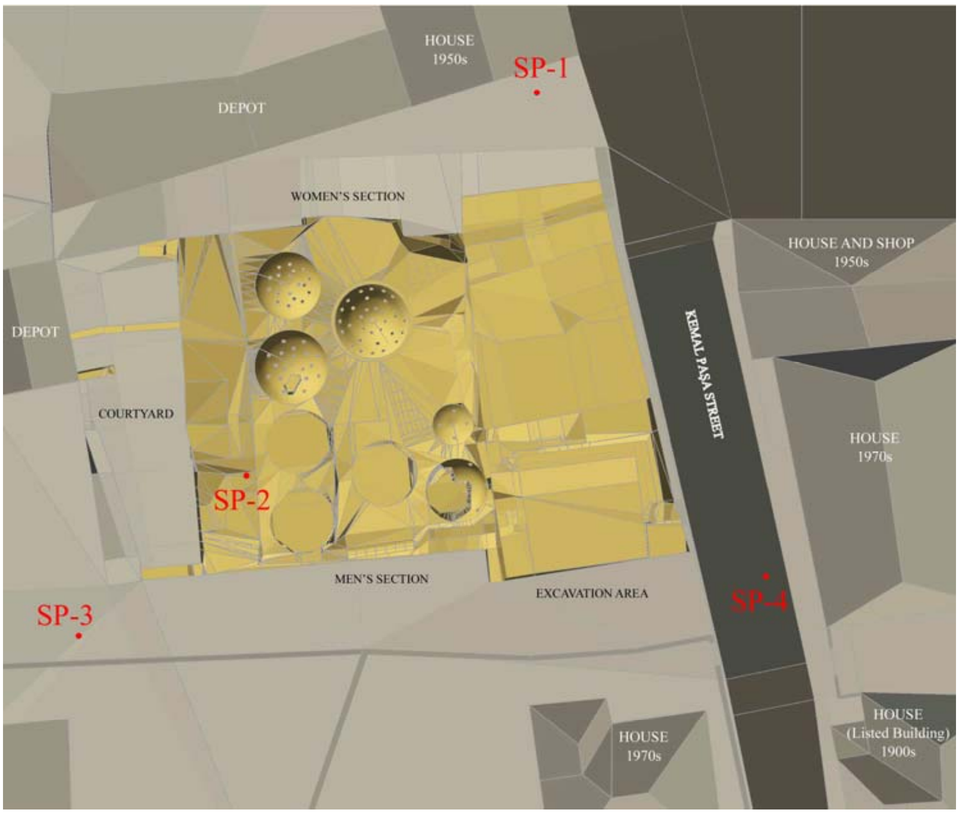


Figure 85. The station points outside the building

Figure 86. The station points inside the building

Table 1. The points measured from the SP-1 for the site model

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
R1	0	0	100
R2	100	100	0
1	6,951	6,951	102,48
2	10,612	7,235	99,919
3	6,631	6,84	102,378
4	6,047	6,626	101,646
5	5,889	6,583	100,701
6	4,864	6,685	99,517
7	4,827	7,142	100,414
8	4,73	8,187	100,421
9	4,587	8,255	101,062
10	4,465	9,69	101,25
11	5,217	7,852	101,273
12	4,475	9,81	100,011
13	3,231	9,785	100,014
14	3,219	9,818	101,742
15	3,509	9,7	102,191
16	5,205	9,967	102,267
17	3,104	10,104	102,011
18	2,841	12,738	102,37
19	2,631	14,134	101,89
20	2,643	14,185	101,739
21	2,581	14,499	101,345
22	2,594	14,99	100,861
23	2,512	15,097	100,562
24	3,142	19,236	101,583
25	3,108	19,689	101,089
26	3,033	19,987	100,817
27	4,031	6,559	98,931
28	2,451	4,69	98,943
29	2,639	0,823	98,685
30	15,976	7,878	98,334
31	15,504	7,645	97,776
32	17,045	-0,976	98,172
33	17,78	-0,057	98,483
34	17,502	2,197	98,477
35	18,153	2,279	98,499
36	10,189	1,662	97,446
37	13,971	-0,028	97,315
38	5,522	0,623	98,283
39	5,611	0,633	98,639
40	11,314	1,277	97,575

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
41	6,041	0,682	98,697
42	6,153	2,039	98,722
43	5,411	1,921	98,635
44	5,462	1,938	98,254
45	5,784	1,896	98,23
46	4,111	-1,715	98,671
47	3,598	0,921	98,698

Table 2. The points measured from the SP-2 and SP-3 for the site model

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
P1	50000	50000	100
1	50004,64	50003,75	99,947
2	50016,99	50000	101,123
3	50004,64	50003,76	99,945
4	50004,66	50003,81	99,689
5	50004,55	50003,93	99,599
6	50004,57	50004,13	100,123
7	50004,48	50004,97	100,278
8	50004,08	50008,63	100,78
9	50003,73	50010,97	99,524
10	50002,52	50020,56	100,148
11	50004,65	50012,36	101,642
12	50005,42	50012,66	102,171
13	50006,33	50012,92	102,282
14	50008,04	50013,34	102,353
15	50009,44	50013,44	102,127
16	50011,33	50013,76	102,232
17	50006,42	50006,94	101,814
18	50004,72	50011,7	101,43
19	50004,66	50011,58	101,241
20	50005,62	50012,54	101,425
21	50005,6	50012,5	101,23
22	50006,43	50012,7	101,423
23	50006,25	50012,67	101,229
24	50006,77	50012,66	101,414
25	50006,74	50012,67	101,214
26	50004,91	50012,41	101,655
27	50006,74	50012,91	101,541
28	50013,81	50012,03	102,732
29	50013,41	50011,7	102,069
30	50013,48	50011,36	101,921
31	50014,12	50011,3	102,612
32	50014,12	50011,3	102,612
33	50014,17	50011,62	102,834
34	50014,55	50011,82	103,098
35	50014,39	50012,32	103,116
36	50014,15	50012,29	102,945
37	50014,08	50012,33	102,943
38	50014,33	50011,95	102,583
39	50014,68	50012,32	102,659
40	50014,26	50012,02	102,426
41	50015,89	50013,44	102,313
42	50007,46	50006,31	101,737

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
43	50014,26	50011,78	102,343
44	50014,3	50011,45	102,243
45	50013,81	50013,73	102,161
46	50013,9	50013,68	102,301
47	50014,06	50013,61	102,508
48	50014,07	50013,31	102,735
49	50014,55	50013,25	103,05
50	50014,54	50013,01	103,157
51	50014,62	50012,8	103,243
52	50014,79	50012,49	103,337
53	50014,98	50012,41	103,395
54	50015,53	50011,75	103,289
55	50015,74	50011,57	103,177
56	50015,94	50011,4	103,032
57	50015,89	50011,19	102,933
58	50016,04	50011,05	102,775
59	50016,36	50011,04	102,598
60	50016,29	50010,73	102,323
61	50008,45	50005,47	101,773
62	50013,66	50012,63	102,674
63	50013,62	50012,77	102,521
64	50013,51	50012,66	102,358
65	50013,5	50012,49	102,488
66	50015,41	50011,39	103,084
67	50014,73	50011,47	103,042
68	50015,02	50010,72	102,538
69	50019,34	50013,4	103,13
70	50019,82	50012,92	103,266
71	50019,75	50013,31	103,243
72	50019,73	50013,01	103,265
73	50019,81	50012,45	103,157
74	50019,93	50012,04	102,961
75	50020,19	50011,7	102,694
76	50020,64	50011,57	102,377
77	50020,63	50011,31	102,056
78	50018,42	50010,03	101,905
79	50019,17	50011,55	102,51
80	50019,85	50012,09	102,977
81	50018,79	50012,87	102,971
82	50019,24	50003,28	98,539
83	50019,62	50003,32	98,584
84	50019,1	50004,22	98,745
85	50018,75	50005,79	98,659
86	50019,24	50003,24	97,903
87	50013,01	50004,41	97,969
88	50013,49	50004,44	97,992

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
89	50010,19	50005,44	97,061
90	50023,62	50005,13	98,703
P3	50009,88	50007,15	101,371
91	49999,98	49999,99	99,993
92	50004,49	50011,35	100,872
93	50004,5	50011,34	100,736
94	50005,49	50012,55	100,785
95	50005,55	50012,47	101,224
96	50005,54	50012,49	101,403
97	50005,45	50012,59	101,452
98	50006,8	50012,78	100,782
99	50007,47	50012,32	100,775
100	50005,18	50012,52	100,593
101	50004,88	50012,47	100,341
102	50004,44	50011,68	100,494
103	50004,44	50011,64	100,523
104	50006,08	50012,67	100,475
105	50008,22	50010,74	101,338
106	50007,77	50012,05	101,38
107	50006,22	50012,72	101,555
108	50004,6	50010,16	100,799
109	50003,97	50010,31	100,847
110	50011,57	50009,9	101,478
111	50012,65	50011,75	101,512
112	50010,44	50013,41	101,412
113	50009,87	50013,2	101,374
114	50008,98	50011,43	101,366
115	50010,06	50009,83	101,52
116	50012,49	50012,65	100,707
117	50012,43	50012,52	101,226
118	50011,34	50013,52	100,73
119	50009,86	50013,26	100,741
120	50009,29	50012,53	100,712
121	50009,62	50013,26	100,535
122	50009,38	50013,23	100,361
123	50012,44	50013,3	100,126
124	50012,44	50013,42	99,976
125	50012,05	50013,65	100,03
126	50011,65	50013,56	100,505
127	50011,22	50013,7	101,462
128	50009,14	50017,28	102,302
129	50008,41	50017,85	102,302
130	50007,71	50017,72	102,346
131	50006,52	50016,96	102,322
132	50011,23	50020,03	102,653
133	50011,04	50020,39	102,821

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
134	50010,66	50020,48	102,962
135	50009,91	50020,38	103,1
136	50009,54	50020,43	103,014
137	50008,97	50020,54	102,797
138	50008,67	50020,51	102,571
139	50008,73	50020,3	102,542
140	50009	50020,35	102,719
141	50009,45	50020,32	102,841
142	50010,01	50020,36	102,946
143	50010,38	50020,28	102,894
144	50010,84	50020,33	102,761
145	50011,01	50020,28	102,716
146	50010,22	50020,1	102,6
147	50009,99	50017,27	102,62
148	50005,8	50008,21	101,597
149	50007,03	50006,45	101,461
150	50007,1	50005,55	101,598
151	50008,48	50008,65	101,762
152	50009,14	50008,81	101,64
153	50009,06	50008,71	101,702
154	50010,52	50008,98	101,535
155	50016,84	50009,9	101,433
156	50017,15	50009,95	101,304
157	50015,33	50007,91	101,555
158	50012,64	50007,83	101,259
159	50013,22	50007,95	101,195
160	50012,59	50008,48	101,276
161	50008,62	50011,31	101,391
162	50007,31	50018,37	102,362
163	50007,91	50019,12	102,467
164	50010,9	50016,94	102,417
165	50018,32	50011,42	101,76
166	50016,56	50010,53	101,647
167	50013,12	50008,57	101,004
168	50019,4	50002,13	97,977
169	50011,92	50006,08	101,787
170	50019,43	50002,13	98,778
171	50020,07	50002,09	98,702
172	50012,32	50006,2	101,708
173	50022,82	50002,62	97,723
174	50016,18	50000,44	99,871
175	50014,53	50000,24	99,713
176	50011,42	50000,84	99,668
177	50006,38	50001,27	99,748
178	50003,47	50001,2	99,509
179	50006,8	50001,23	98,779

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
180	50014,82	50000,29	98,041
181	50014,01	50000,52	98,077
182	50016,99	50000	101,114

Table 3. The points measured from the SP-5 for the site model

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
H1	500	500	500
H2	5	5	5
1	507,336	500	502,469
2	502,021	499,685	502,403
3	502,126	499,551	502,285
4	502,198	499,461	502,129
5	502,193	499,829	502,41
6	507,129	499,963	503,577
7	501,814	500,02	500,316
8	502,133	499,396	500,234
9	502,751	499,819	500,277
10	502,795	499,83	501,874
11	502,159	499,436	502,518
12	501,969	499,284	503,135
13	501,207	498,731	503,932
14	501,943	499,754	503,387
15	501,492	500,394	504,05
16	501,346	500,406	504,51
17	501,396	500,285	504,416
18	501,387	500,323	504,414
19	501,375	500,354	504,406
20	501,456	500,411	504,178
21	500,062	502,416	502,475
22	500,405	501,937	503,644
23	500,728	501,484	504,073
24	499,148	501,855	503,987
25	499,796	502,256	503,342
26	499,507	501,816	504,419
27	499,502	501,783	504,001
28	499,162	501,861	503,963
29	497,964	501,113	503,912
30	497,776	500,322	504
31	497,749	500,199	504,312
32	497,76	499,953	504,43
33	497,849	499,403	504,484
34	499,338	498,185	504,425
35	499,674	501,752	504,632
36	497,034	500,477	502,529
37	497,452	500,768	503,508
38	497,296	500,034	503,438
39	497,596	499,595	503,909
40	499,114	497,39	502,311
41	498,741	497,898	503,585

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
42	498,47	498,302	503,857
43	498,474	498,307	503,987
44	500,157	498,051	503,921
45	499,312	497,494	503,133
46	500,115	502,354	500,817
47	499,822	502,298	500,783
48	500,375	502,061	500,778
49	500,489	501,843	500,388
50	500,418	501,951	500,292
51	500,418	501,951	500,269
52	500,026	502,371	500,384
53	497,384	500,71	500,405
54	497,343	500,019	500,4
55	497,138	500,426	500,471
56	497,119	500,387	500,199
57	498,692	501,552	501,198
58	498,409	501,357	501,04
59	498,555	501,426	501,561
60	498,505	501,489	501,183
61	498,287	501,295	500,451
62	498,29	501,309	500,901
63	498,759	501,615	500,906
64	497,874	499,143	502,232
65	498,237	498,641	502,201
66	498,24	498,641	503,2
67	498,144	498,72	503,623
68	498,043	498,883	503,729
69	497,881	499,15	503,303
70	497,201	498,716	502,533
71	497,297	498,767	502,676
72	496,347	498,208	503,533
73	496,978	498,246	503,391
74	497,065	497,97	503,385
75	496,451	497,898	503,532
76	496,064	497,669	503,457
77	498,044	498,834	502,254
78	497,607	498,616	503,706
79	497,951	499,117	501,619
80	498,063	498,948	501,626
81	498,113	498,883	501,461
82	498,221	498,711	501,293
83	498,185	498,71	500,915
84	497,931	499,117	500,933
85	501,13	499,571	500,108

Table 4 The points measured from the SP-6, SP-7 and SP-8 for the site model

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
P1	0	0	0
P2	100	100	100
1			
2	0,762	2,885	2,411
3	0,776	2,802	0,87
4	0,904	2,897	2,722
5	0,527	2,879	2,754
6	0,46	2,856	2,972
7	-0,231	2,762	3,01
8	-1,816	2,556	3,084
9	-2,339	2,46	3,374
10	-2,438	2,339	3,676
11	-2,444	2,43	3,199
12	-2,468	2,431	0,995
13	-2,255	2,438	0,955
14	-2,112	2,49	0,62
15	-2,406	2,15	0,538
16	-2,166	2,199	0,533
17	-2,144	2,333	0,701
18	-2,417	2,177	0,688
19	-1,209	2,419	0,454
20	-1,198	2,397	0,434
21	-2,156	1,556	0,446
22	-2,137	1,542	0,423
23	-0,62	2,387	0,45
24	-0,608	2,34	0,433
25	-0,988	1,12	0,316
26	0,58	1,342	0,384
27	0,588	1,315	0,41
28	0,696	0,606	0,382
29	0,901	0,467	0,381
30	1,099	0,41	0,404
31	1,107	0,247	0,034
32	1,798	0,348	0,046
33	1,913	-0,35	0,031
34	1,941	0,009	1,981
35	1,261	-0,109	2,005
36	1,253	0,115	1,862
37	1,234	0,27	1,648
38	1,158	0,267	1,557
39	1,157	0,276	1,129
40	1,267	-0,263	1,892
41	1,289	-0,371	1,785

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
42	1,282	-0,462	1,591
43	1,272	-0,459	0,962
44	1,254	-0,456	0,004
45	1,424	-1,435	-0,076
46	1,44	-1,445	0,066
47	1,378	-1,251	0,111
48	1,335	-1,204	-0,022
49	0,304	-1,496	-0,041
50	0,255	-1,404	-0,025
51	-0,69	-1,652	-0,07
52	-1,732	-1,7	-0,012
53	-1,774	-1,648	-0,002
54	-1,771	-1,703	0,204
55	-1,913	-1,824	0,293
56	-1,777	-1,717	1,172
57	-1,937	-1,832	1,392
58	-1,817	-1,697	1,745
59	-1,801	-1,628	1,859
60	-1,896	-1,357	2,026
61	-1,909	-1,189	1,988
62	-1,882	-0,98	1,755
63	-1,877	-0,946	1,499
64	-1,812	-0,916	0,001
65	-1,888	-1,055	0
66	-2,427	-1,732	0,002
67	-2,382	-1,588	-0,064
68	-2,417	-1,341	-0,074
69	-1,742	-1,869	0,1
70	-1,701	-1,863	2,959
71	-1,492	-1,832	3,604
72	-0,889	-1,768	4,217
73	-1,755	-1,566	3,744
74	-1,876	-0,952	4,257
75	-0,97	-1,711	4,288
76	-1,388	-1,352	4,63
77	1,379	-1,412	2,941
78	0,968	-1,487	3,883
79	0,653	-1,539	4,191
80	1,317	-0,979	3,973
81	1,245	-0,625	4,401
82	1,195	-0,589	4,73
83	0,626	-1,51	4,746
84	0,919	-1,001	4,833
85	-2,214	1,102	3,217
86	-1,896	1,151	3,834
87	-1,348	1,229	4,162

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
88	-2,093	0,278	4,231
89	-2,164	0,705	3,854
90	0,945	1,535	2,198
91	0,952	1,516	2,341
92	0,904	1,544	2,323
93	0,843	2,489	2,425
94	0,861	1,532	2,676
95	0,819	1,779	2,685
96	0,972	1,531	2,696
97	0,962	1,538	2,912
98	0,985	1,464	3,418
99	1	1,11	3,988
100	0,75	1,219	4,075
101	0,521	1,21	4,23
102	0,342	1,36	4,212
103	0,154	1,423	4,341
104	0,12	1,373	4,711
105	0,652	0,995	4,847
106	1,063	0,675	4,397
107	1,005	0,655	4,726
108	-0,12	1,391	3,973
109	-0,152	1,762	3,912
110	-0,299	1,803	3,896
111	-0,322	2,035	3,936
112	-1,013	1,971	3,93
113	-1,887	1,848	3,435
114	-0,624	1,313	4,071
115	-1,46	1,21	3,776
116	-2,326	1,873	2,333
117	-2,31	1,809	2,161
118	-2,346	1,8	1,881
119	-2,228	1,166	1,852
120	-2,184	1,147	2,111
121	-2,174	1,141	2,137
122	-2,172	1,138	2,175
123	-2,164	1,129	2,187
124	-2,147	1,123	2,224
125	-2,141	1,12	2,246
126	-2,144	1,121	2,27
127	1,137	0,126	4,865
128	1,075	0,119	5,616
129	0,884	0,22	5,531
130	0,918	0,01	5,56
131	0,541	-1,062	5,588
132	0,568	-1,255	5,516
133	0,707	-1,103	5,454

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
134	0,405	0,827	5,606
135	0,528	0,953	5,58
136	0,326	0,95	5,541
137	0,554	-0,511	5,928
138	0,64	-0,221	5,919
139	0,394	0,625	5,824
140	0,393	0,82	5,631
141	-0,042	1,14	5,482
142	-0,838	1,295	5,021
143	-1,836	0,067	5,174
144	-1,142	-1,298	5,374
145	-1,131	-1,344	5,298
146	-0,905	-1,461	5,396
147	-0,883	-1,379	5,495
148	-0,103	-1,294	5,734
149	-0,059	-0,979	5,96
150	-0,176	-0,796	6,101
151	-4,641	-3,135	-0,375
152	-0,014	-0,009	-0,01
153	-3,274	2,288	3,823
154	-3,545	2,271	3,825
155	-3,493	2,528	4,365
156	-3,249	2,213	4,004
157	-3,272	2,245	0,237
158	-3,246	2,2	-0,395
159	-3,084	1,202	0,199
160	-5,032	1,993	0,245
161	-5,006	2,032	0,204
162	-5,543	2,023	0,116
163	-7,096	1,735	0,291
164	-7,071	1,417	0,216
165	-7,121	1,731	3,32
166	-6,874	1,307	-0,254
167	-6,596	0,351	-0,374
168	-6,777	0,481	0,229
169	-6,75	0,415	2,055
170	-6,964	0,825	2,276
171	-6,624	-0,262	2,164
172	-6,621	-0,298	2,053
173	-6,428	-0,263	2,936
174	-5,894	-0,155	3,582
175	-4,917	-0,055	3,929
176	-3,847	0,059	3,587
177	-3,189	0,118	2,834
178	-3,045	0,125	2,135
179	-3,067	1,173	2,204

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
180	-3,065	1,14	2,099
181	-3,04	0,132	2,023
182	-3,041	0,149	0,212
183	-3,104	0,902	0,181
184	-3,227	2,104	3,947
185	-4,23	1,928	4,592
186	-4,23	1,925	4,594
187	-6,629	1,853	4,376
188	-6,72	0,653	2,939
189	-5,08	1,762	4,638
190	-5,105	2,042	4,376
191	-5,107	2,064	3,894
192	-5,177	2,065	0,642
193	-5,574	2,01	0,642
194	-5,589	1,957	1,064
195	-5,176	2,067	1,064
196	-5,429	2,165	0,86
197	-5,431	2,126	0,767
198	-5,413	2,006	0,692
199	-6,452	-0,385	-0,401
200	-6,646	-0,289	0,215
201	-6,646	-0,391	-0,373
202	-6,726	-0,377	3,149
203	-2,836	-0,438	-0,37
204	-2,797	-0,379	-0,249
205	-2,764	-0,475	-0,189
206	-2,745	-0,49	-0,155
207	-2,878	0,112	0,402
208	-2,892	0,111	2,911
209	-3,364	0,085	3,769
210	-4,003	0,006	4,152
211	-3,863	0,005	4,223
212	-2,809	-0,315	3,729
213	-2,698	-0,898	4,197
214	-2,707	-0,903	4,279
215	-2,704	-0,897	4,783
216	-3,906	0,024	4,773
217	-3,904	0,015	4,816
218	-3,895	-0,04	5,062
219	-2,735	-0,956	5,061
220	-2,726	-0,926	4,834
221	-6,141	-0,251	3,865
222	-5,662	-0,178	4,255
223	-5,372	-0,145	4,285
224	-5,035	-0,107	4,257
225	-5,022	-0,106	4,445

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
226	-5,101	-0,116	4,568
227	-4,922	-0,095	4,435
228	-5,571	-0,235	5,097
229	-5,6	-0,22	4,826
230	-5,612	-0,219	4,756
231	-6,506	-1,406	5,116
232	-6,531	-1,399	4,843
233	-6,554	-1,376	4,779
234	-6,564	-1,39	4,289
235	-6,669	-0,862	3,757
236	-6,088	-4	3,179
237	-6,162	-3,609	3,726
238	-6,263	-3,002	4,279
239	-6,247	-3,014	4,403
240	-5,094	-3,853	4,505
241	-5,541	-3,924	3,926
242	-5,072	-3,867	4,268
243	-5,032	-3,814	5,199
244	-5,041	-3,817	5,017
245	-5,003	-3,82	4,838
246	-6,238	-2,947	4,924
247	-6,262	-2,967	4,81
248	-2,3	-3,486	3,163
249	-2,734	-3,562	3,855
250	-3,411	-3,649	4,31
251	-3,343	-3,607	4,416
252	-3,357	-3,613	5,262
253	-3,417	-3,616	4,983
254	-3,423	-3,614	4,868
255	-2,468	-2,355	5,147
256	-2,475	-2,382	4,924
257	-2,45	-2,375	4,808
258	-2,435	-2,381	4,423
259	-2,452	-2,381	4,304
260	-2,363	-3,037	3,831
261	-2,457	-3,527	-0,021
262	-2,351	-3,568	0,208
263	-2,063	-4,349	0,182
264	-2,182	-4,236	0,13
265	-2,749	-3,977	0,145
266	-2,232	-4,279	2,082
267	-2,233	-4,281	1,955
268	-2,352	-3,549	2,067
269	-2,355	-3,553	1,966
270	-2,752	-3,579	3,218
271	-1,998	-5,015	4,666

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
272	-2,249	-3,485	0,738
273	-4,378	-3,775	4,01
274	-4,169	-4,465	3,873
275	-5,56	-3,954	3,313
276	-5,225	-4,612	3,458
277	-5,921	-4,839	2,219
278	-5,859	-4,743	2,046
279	-5,983	-4,017	2,143
280	-6,006	-3,95	2,04
281	-6,053	-3,989	2,157
282	-6,095	-3,944	2,07
283	-6,117	-3,919	0,402
284	-6,043	-3,96	0,196
285	-6,132	-3,959	0,133
286	-6,184	-3,968	-0,054
287	-6,045	-4,023	-0,102
288	-5,898	-4,76	0,257
289	-5,972	-5,026	0,251
290	-5,815	-5,49	-0,189
291	-5,813	-5,522	-0,433
292	-5,574	-6,08	-0,355
293	-5,749	-6,137	0,047
294	-5,751	-6,274	0,367
295	-5,729	-6,21	4,373
296	-1,887	-5,71	4,029
297	-1,867	-5,687	2,292
298	-1,836	-5,703	0,307
299	-1,832	-5,709	0,254
300	-1,93	-5,62	-0,049
301	-2,994	-6,045	-0,506
302	-2,925	-6,199	-0,266
303	-2,424	-5,934	-0,194
304	-2,368	-6,007	-0,456
305	-2,235	-5,764	-0,103
306	-4,192	-6,137	-0,126
307	-5,534	-6,363	-0,188
308	-1,922	-5,437	4,591
309	-1,978	-5,126	4,772
310	-2,668	-5,057	4,854
311	-2,773	-5,201	4,839
312	-2,875	-5,145	4,976
313	-5,783	-5,964	4,582
314	-5,81	-5,753	4,773
315	-5,181	-5,49	4,822
316	-4,993	-5,54	4,817
317	-4,934	-5,484	4,858

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
318	-4,111	-6,012	1,311
319	-3,453	-5,917	1,252
320	-4,147	-6,026	0,656
321	-3,759	-6,017	0,888
322	-3,757	-6,068	0,724
323	-2,07	-3,429	-0,088
324	-2,215	-3,421	1,671
325	-2,228	-3,246	1,87
326	-2,26	-3,073	1,994
327	-2,323	-2,836	1,815
328	-2,363	-2,726	1,553
329	-2,336	-2,717	0,401
330	-1,502	-3,356	-0,052
331	-1,58	-3,33	1,617
332	-1,558	-2,996	1,954
333	1,399	-2,227	0,053
334	-2,063	-3,397	-0,148
335	-1,083	-3,429	-0,794
336	-2,527	-1,811	-0,046
337	-2,544	-1,694	-0,06
338	-2,559	-1,693	-0,099
339	-2,632	-1,141	-0,089
340	-2,638	-1,13	1,727
341	-2,582	-1,265	1,896
342	-2,534	-1,432	2,019
343	-1,983	-1,311	2,035
344	-2,531	-1,814	1,529
345	-2,005	-1,047	-0,006
346	-1,936	-0,998	1,702
347	-2,724	-1,373	-0,422
348	-2,458	-1,374	-0,195
349	-2,591	-1,481	-0,229
350	-2,588	-1,414	-0,216
351	-2,5	-2,025	-0,134
352	-2,53	-1,91	-0,125
353	-2,315	-1,939	-0,103
354	-6,24	-2,7	-0,388
355	-6,268	-3,283	-0,107
356	-6,283	-3,272	-0,022
357	-6,387	-2,571	-0,017
358	-6,985	-2,701	0,027
359	-6,353	-2,496	0,055
360	-6,344	-2,526	1,625
361	-6,339	-2,744	1,908
362	-6,325	-2,896	2,015
363	-6,338	-3,106	1,917

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
364	-6,238	-3,246	1,692
365	-6,604	-1,119	-0,414
366	-6,672	-1,093	-0,107
367	-6,756	-1,193	-0,105
368	-7,278	-1,332	-0,035
369	-6,563	-1,82	-0,164
370	-6,545	-1,854	1,52
371	-6,537	-1,74	1,871
372	-6,54	-1,491	2,049
373	-6,586	-1,247	1,907
374	-6,604	-1,055	1,769
375	-6,655	-1,167	1,729
376	-7,366	-1,276	1,49
377	-10,787	-3,252	2,057
378	0,558	-3,355	-0,07
379	-1,442	-3,372	-0,043
380	-1,393	-3,339	-0,085
381	-1,345	-3,339	-0,101
382	-1,543	-3,035	-0,108
383	-2,08	-2,729	-0,107
384	-1,659	-2,622	1,647
385	-1,652	-2,985	1,973
386	-1,512	-3,345	1,567
387	-1,604	-2,645	2,418
388	-1,306	-2,582	3,099
389	-1,517	-3,15	3,253
390	-1,436	-3,494	3,583
391	-1,392	-3,49	3,911
392	-1,081	-3,008	3,95
393	-0,698	-2,563	3,891
394	-0,701	-2,51	3,634
395	-1,08	-5,558	2,477
396	-1,11	-5,376	2,947
397	-1,213	-4,75	3,505
398	-1,221	-4,672	3,881
399	-0,878	-5,018	3,963
400	-0,335	-5,418	3,885
401	-0,347	-5,487	3,521
402	-0,762	-5,517	3,175
403	-0,946	-5,353	0,228
404	-1,189	-4,948	0,145
405	-1,167	-4,915	0,04
406	-0,696	-5,477	0,068
407	-0,709	-5,517	0,234
408	-0,157	-4,751	-0,004
409	1,059	-4,492	-0,079

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
410	1,609	-5,123	0,078
411	1,734	-5,156	2,484
412	1,406	-5,25	3,115
413	1,038	-5,292	3,412
414	1,025	-5,251	3,797
415	1,287	-4,837	3,839
416	1,641	-4,304	3,467
417	1,693	-4,677	3,206
418	1,042	-4,425	-0,079
419	1,412	-2,243	0,054
420	1,343	-2,343	-0,065
421	1,403	-2,196	2,498
422	0,58	-2,34	3,714
423	1,484	-3,091	3,663
424	-0,096	-2,883	5,056
425	-0,415	-2,965	5,047
426	-0,554	-4,817	5,022
427	0,074	-4,544	5,342
428	0,726	-4,447	5,266
429	0,679	-4,717	5,291
430	0,891	-4,579	5,09
431	1,025	-3,246	5,504
432	-4,653	-3,127	-0,38

Table 5. The points measured from the SP-9 for the site model

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
E1	2000	2000	2000
E2	0	0	0
1	1998,029	1998,029	1999,458
2	1998,63	1998,284	1999,469
3	1994,659	1995,72	1999,382
4	1998,682	1998,301	2001,118
5	1998,605	1998,44	2001,379
6	1998,545	1998,565	2001,467
7	1994,727	1995,622	2001,137
8	1994,716	1995,627	2001,209
9	1998,399	1998,959	2000,888
10	1998,415	1998,97	1999,781
11	1998,657	1998,398	2001,607
12	1998,657	1998,396	2001,644
13	1998,795	1998,335	2001,651
14	1999,129	1998,478	2002,448
15	1999,724	1998,695	2002,901
16	1999,724	1998,723	2002,964
17	1998,311	1999,35	2003,018
18	1998,258	1999,371	2002,952
19	1998,488	1998,787	2002,499
20	1998,535	1998,739	2002,515
21	1998,321	1999,344	2003,466
22	1998,376	1999,366	2003,506
23	1998,348	1999,445	2003,639
24	1999,758	1998,724	2003,471
25	1997,41	2001,771	2001,928
26	1997,34	2001,621	2001,925
27	1997,841	2001,933	2002,675
28	1998,353	2002,154	2003,059
29	1998,335	2002,08	2003,059
30	1998,351	2002,149	2002,987
31	1997,943	2001,997	2002,71
32	1997,698	2000,738	2003,074
33	1997,711	2000,723	2002,974
34	1997,709	2000,784	2003
35	1997,57	2001,05	2002,728
36	1997,324	2001,622	2001,852
37	1997,407	2001,782	2001,854
38	1997,733	2000,616	2003,449
39	1997,834	2000,881	2003,462
40	1997,539	2000,817	2003,993
41	1997,474	2000,641	2004,581

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
42	1998,154	1999,301	2004,436
43	1997,419	2001,644	2000,171
44	2000,667	2003,032	2002,054
45	2000,368	2002,949	2002,458
46	1999,689	2002,7	2003,014
47	2000,493	2002,343	2003,068
48	2001,185	2001,961	2003,091
49	2001,226	2001,926	2003,05
50	2000,933	2002,623	2002,592
51	2000,854	2002,847	2002,255
52	2000,755	2003,006	2000,109
53	2000,004	2002,756	2000,15
54	1999,987	2002,772	2000,534
55	2001,191	2001,91	2003,485
56	2001,171	2001,876	2003,496
57	2001,16	2001,86	2003,781
58	1999,947	2002,61	2003,435
59	1999,949	2002,532	2003,494
60	1999,949	2002,506	2003,8
61	1998,497	2003,228	2004,853
62	1998,559	2003,094	2004,66
63	1998,617	2002,971	2004,423
64	2002,116	1999,678	2001,482
65	2002,118	1999,661	2000,082
66	2002,022	1999,625	2001,771
67	2002,084	1999,784	2001,777
68	2001,995	2000,05	2002,463
69	2001,728	2000,71	2003,055
70	2001,714	2000,669	2003,089
71	2001,544	1999,414	2002,656
72	2001,183	1999,274	2002,945
73	2001,176	1999,298	2002,988
74	2001,025	1999,212	2003,443
75	2001,213	1999,403	2003,481
76	2001,049	1999,355	2003,498
77	2001,61	2000,687	2003,519
78	2001,566	2000,668	2003,731
79	2001,301	2001,714	2000,561
80	2000,416	2001,457	1999,986

Table 6. The points measured from the SP-10 and SP-11 for the spatial model

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
P100	5000	5000	500
P101	5555	5555	0
1	5017,348	5000	503,471
2	5001,013	5003,754	500,348
3	5001,053	5003,902	503,081
4	5000,85	5003,916	503,82
5	5000,365	5003,962	504,135
6	4999,797	5003,992	504,241
7	4999,137	5004,043	504,1
8	4998,61	5004,088	503,389
9	4998,621	5004,061	500,391
10	5000,572	5001,968	500,281
11	5000,169	5002,012	500,275
12	5000,129	5002,649	500,286
13	4999,033	5002,697	500,287
14	4998,969	5002,128	500,266
15	4999,198	5002,099	500,184
16	4999,343	5002,073	500,059
17	4999,992	5001,956	500,168
18	4999,895	5002,095	500,211
19	4999,565	5002,176	500,118
20	4999,474	5002,765	500,051
21	4999,838	5003,798	499,493
22	4999,099	5001,639	500,29
23	5000,507	5001,731	500,182
24	4999,486	5001,971	500,031
25	4998,396	5000,732	500,466
26	4998,437	5000,824	500,464
27	4998,744	5000,883	500,449
28	4998,818	5002,028	500,529
29	4998,538	5002,316	500,616
30	4998,787	5000,881	499,988
31	5000,879	5002,03	500,638
32	5000,598	5001,923	500,598
33	5000,55	5000,742	500,548
34	5000,88	5000,611	500,572
35	5000,91	5000,533	500,792
36	5000,917	5000,525	501,705
37	5000,97	5000,358	502,03
38	5000,96	5000,145	502,101
39	5000,974	4999,957	502,042
40	5000,921	4999,846	501,832
41	5001,513	5000,462	500,071

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
42	5000,786	4999,059	499,838
43	5000,83	4999,048	500,1
44	5000,8	4999,266	500,163
45	5000,808	4999,103	503,255
46	4998,409	4999,267	503,408
47	4998,445	4999,275	503,468
48	4998,427	4999,298	503,477
49	4998,465	5001,588	503,635
50	4998,704	5001,645	504,28
51	5000,808	5001,542	504,022
52	5000,922	5001,508	503,574
53	5000,936	5001,524	503,484
54	5000,937	5001,489	502,61
55	5000,802	5001,605	503,183
56	5000,897	5002,365	503,385
57	5000,909	5001,544	502,743
58	5000,955	5001,741	502,83
59	5000,383	5001,605	503,957
60	4999,808	5001,656	504,12
61	4999,537	5001,614	504,139
62	4999,527	5001,647	504,121
63	4999,554	5002,406	504,229
64	4999,59	5002,247	504,111
65	4999,808	5002,402	504,239
66	4998,959	5001,669	503,916
67	4999,338	5002,402	504,198
68	4998,654	5002,257	503,34
69	4998,588	5001,67	503,271
70	4998,496	5002,378	502,598
71	4998,498	5002,314	502,58
72	4998,606	5002,106	503,295
73	4998,472	4999,279	503,54
74	4998,927	4999,236	504,254
75	4999,474	4999,185	504,398
76	4999,488	4999,196	504,513
77	4999,765	4999,181	504,524
78	4999,775	4999,158	504,415
79	4999,773	4999,152	504,312
80	5000,203	4999,138	504,238
81	4998,395	4999,233	499,936
82	4998,37	4999,236	501,957
83	4998,526	4999,393	499,959
84	4999,044	4999,369	500,009
85	4999,039	4999,219	499,891
86	4999,028	4999,137	499,953
87	4998,944	4998,45	500,027

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
88	4998,94	4998,421	501,65
89	4998,252	4997,184	502,079
90	4998,416	4996,534	502,473
91	4999,019	4999,133	501,446
92	4999,101	4999,123	501,822
93	4999,315	4999,092	501,975
94	4999,483	4998,932	501,898
95	4999,427	4998,813	501,923
96	4993,588	5000,601	499,919
97	4998,331	4999,989	500,063
98	4998,319	4999,989	501,616
99	4998,222	5000,095	501,883
100	4998,309	5000,279	501,972
101	4998,401	5000,624	501,839
102	4998,378	5000,693	501,315
103	4998,396	5000,683	499,99
104	4995,469	5000,935	499,983
105	4999,803	5000,769	505,446
106	4999,648	5000,552	505,481
107	5000,086	5000,529	505,417
108	5000,549	5000,261	505,078
109	5000,364	5000,465	505,362
110	4999,681	5000,805	505,405
111	4999,671	5001,152	505,256
112	4999,351	5001,016	505,281
113	4999,118	5000,466	505,364
114	4999,028	5000,087	505,279
115	4998,808	5000,381	505,327
116	4999,463	5000,3	505,478
117	4999,584	5000,454	505,482
118	4999,312	5000,533	505,555
119	4999,51	4999,669	505,339
120	4999,839	4999,559	505,165
121	4999,679	4999,511	505,116
122	5000,549	4999,369	504,297
123	4998,733	4999,516	504,459
124	4998,875	5001,251	504,733
125	5000,427	5001,131	504,794
P1			
126	4999,99	5000,002	500,002
127	4993,491	4994,95	498,953
128	4993,485	4994,934	500,205
129	4993,476	4994,907	500,246
130	4993,454	4994,84	500,377
131	4993,454	4994,838	503,429
132	4993,837	4994,792	504,005

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
133	4994,485	4994,771	504,364
134	4995,356	4994,725	504,555
135	4996,261	4994,685	504,356
136	4996,948	4994,662	504
137	4997,303	4994,671	500,396
138	4997,24	4994,674	500,25
139	4997,157	4994,964	499,065
140	4997,227	4994,719	500,198
141	4996,544	4994,651	499,036
142	4996,545	4994,648	499,531
143	4996,299	4994,755	499,573
144	4996,293	4994,799	498,888
145	4994,539	4995,135	498,872
146	4994,35	4994,366	499,641
147	4994,21	4994,741	499,734
148	4994,237	4994,875	498,967
149	4993,699	4996,78	498,878
150	4993,461	4996,22	499,803
151	4993,228	4996,231	499,621
152	4994,486	4998,812	499,989
153	4993,867	4997,508	499,681
154	4993,7	4997,651	499,946
155	4993,633	4997,364	500,021
156	4993,645	4997,526	500,344
157	4993,645	4998,408	500,003
158	4993,559	4998,383	499,97
159	4993,91	4998,334	499,581
160	4993,862	4997,795	499,671
161	4993,748	4997,765	499,836
162	4993,76	4997,803	499,526
163	4993,799	4997,827	499,737
164	4994,072	4998,958	499,97
165	4997,348	4998,917	499,971
166	4997,074	4997,322	499,078
167	4997,179	4997,204	499,849
168	4997,25	4997,424	499,913
169	4997,324	4998,008	500,747
170	4997,16	4998,02	499,551
171	4997,393	4996,755	500,307
172	4993,455	4996,801	500,289
173	4993,457	4996,808	500,154
174	4993,51	4996,615	500,111
175	4997,38	4996,352	499,672
176	4997,303	4996,538	498,989
177	4996,466	4995,316	499,234
178	4997,017	4994,948	499,049

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
179	4996,88	4995,528	499,151
180	4996,481	4995,645	499,201
181	4996,453	4995,79	498,931
182	4996,506	4996,451	499,153
183	4996,492	4996,512	498,901
184	4996,552	4995,763	499,038
185	4996,83	4996,309	499,237
186	4996,488	4996,935	499,099
187	4996,735	4997,084	499,204
188	4996,302	4998,657	500,001
189	4996,443	4997,028	498,975
190	4995,944	4996,165	499,206
191	4995,994	4995,664	499,142
192	4995,641	4995,675	499,1
193	4995,603	4995,39	499,213
194	4995,124	4995,449	499,119
195	4995,278	4997,755	499,963
196	4994,809	4995,713	498,998
197	4994,786	4995,538	499,111
198	4994,359	4995,473	499,066
199	4994,35	4995,748	499,03
200	4994,375	4995,861	498,891
201	4993,763	4994,974	498,871
202	4993,873	4995,462	498,911
203	4994,013	4996,36	499,244
204	4994,077	4996,561	499,17
205	4994,351	4996,5	499,144
206	4994,344	4996,558	498,897
207	4994,401	4997,029	499,161
208	4994,12	4997,131	499,23
209	4994,383	4997,334	499,119
210	4994,778	4998,479	499,812
211	4995,997	4996,254	499,199
212	4994,785	4996,273	499,155
213	4994,82	4996,513	499,119
214	4994,864	4996,868	499,146
215	4994,658	4999,291	499,929
216	4994,567	4999,578	499,725
217	4995,79	4999,37	499,973
218	4993,639	4998,228	502,344
219	4994,264	4998,071	503,613
220	4995,524	4998,005	504,244
221	4996,76	4997,978	503,537
222	4997,32	4997,981	502,29
223	4997,418	4996,993	502,42
224	4997,325	4996,47	503,685

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
225	4995,529	4996,919	504,599
226	4994,339	4996,825	504,275
227	4993,638	4997,544	502,394
228	4993,655	4998,218	502,299
229	4993,545	4998,237	502,327
230	4993,542	4998,682	503,369
231	4993,588	5000,066	504,162
232	4993,625	5001,58	503,324
233	4993,667	5002,087	502,195
234	4993,738	5002,086	502,174
235	4993,673	4998,225	503,429
236	4994,191	4998,151	504,12
237	4994,197	4998,163	504,27
238	4994,221	4998,215	504,364
239	4993,725	4998,245	503,675
240	4995,401	4998,085	504,704
241	4996,366	4998,014	504,412
242	4997,329	4997,994	503,423
243	4997,359	4998,511	503,955
244	4997,293	4998,543	504,203
245	4997,42	5000,135	504,71
246	4997,455	5000,068	504,262
247	4997,419	4999,027	503,863
248	4997,37	4998,016	502,292
249	4997,466	4998,021	502,292
250	4997,493	4998,414	503,239
251	4997,615	5001,559	503,219
252	4997,534	5001,608	503,17
253	4997,451	5001,912	503,614
254	4997,075	5001,982	504,098
255	4995,535	5001,998	504,788
256	4995,603	5002,019	504,357
257	4994,928	5002,033	504,583
258	4994,943	5002,046	504,098
259	4993,86	5002,066	503,582
260	4993,819	5002,119	502,275
261	4993,801	5002,764	502,309
262	4994,269	5002,717	503,419
263	4995,626	5002,641	504,247
264	4996,561	5002,628	503,892
265	4997,523	5002,631	502,284
266	4997,356	5000,475	504,837
267	4996,432	5001,811	504,86
268	4994,976	5001,957	504,752
269	4993,85	5000,809	504,824
270	4993,791	4999,295	504,803

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
271	4994,594	4998,239	504,744
272	4996,274	4998,084	504,725
273	4997,195	4998,931	504,769
274	4994,67	4998,258	505,265
275	4994,743	4998,26	505,345
276	4994,648	4998,216	505,221
277	4994,625	4998,205	505,129
278	4994,833	4998,456	505,854
279	4995,291	5000,047	507,162
280	4995,743	4999,751	507,167
281	4995,891	5000,019	507,17
282	4995,112	4999,373	506,991
283	4995,506	4999,471	507,11
284	4995,252	4999,551	507,221
285	4994,843	5001,294	506,309
286	4994,591	5001,317	506,217
287	4994,812	5001,54	506,205
288	4993,772	5002,107	500,856
289	4993,691	5002,908	501,081
290	4993,73	5004,255	500,801
291	4993,726	5004,282	502,485
292	4994,139	5004,27	503,395
293	4997,663	5004,152	502,507
294	4995,655	5004,223	504,299
295	4997,12	5004,168	503,52
296	4997,663	5004,083	501,031
297	4996,067	5002,064	500,162
298	4995,027	5002,11	500,183
299	4995,581	5003,58	500,272
300	4995,583	5003,649	500,686
301	4995,35	5003,854	500,693
302	4995,894	5003,832	500,689
303	4995,913	5004,132	500,817
304	4995,353	5004,122	500,799
305	4997,544	5000,708	499,979
306	4997,592	5000,715	501,382
307	4997,603	5000,71	501,62
308	4997,805	5000,311	501,966
309	4997,903	4999,893	501,683
310	4997,667	4999,994	501,52
311	4997,839	4999,87	500,27
312	4997,583	4999,986	500,202
313	4997,53	5000,009	499,972
314	4997,543	4999,804	500,231
315	4997,551	4999,827	500,402
316	4998,014	4999,991	500,18

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
317	4997,998	4999,973	500,367
318	4997,19	4999,799	499,968
319	4997,172	4999,919	499,992
320	4997,504	4999,396	499,908
321	4997,597	4999,344	500,114
322	4997,564	4999,563	500,191
323	4997,339	5000,367	499,985
324	4993,537	4999,13	499,989
325	4993,515	4999,137	501,514
326	4993,474	4999,246	501,787
327	4993,414	4999,44	501,892
328	4988,948	4997,105	502,249
329	4993,644	4999,923	501,419
330	4993,572	4999,883	499,988
331	4992,804	4999,187	500,002
332	4992,737	4999,16	501,492
333	4988,952	4996,997	502,253
334	4991,6	4998,598	499,953
335	4989,63	4997,407	499,968
336	4989,544	4997,433	500,11
337	4989,041	4997,135	500,188
338	4993,57	5000,627	499,972
339	4993,551	5000,624	501,378
340	4993,359	5000,955	501,865
341	4993,611	5001,297	501,613
342	4993,581	5001,303	499,989
343	4992,906	5001,355	500,016
344	4992,95	5001,347	501,485
345	4989,091	5001,091	502,417
346	4993,193	5000,647	501,409
347	4991,964	5001,159	500,032
348	4991,821	5001,168	500,155
349	4991,256	5001,202	500,226
350	4991,274	5000,746	500,223
351	4991,874	5000,713	500,165
352	4991,035	5001,193	500,45
353	4990,575	5001,191	500,482
354	4990,523	5000,759	500,471
355	4991,034	5000,739	500,432
356	4989,62	5000,759	500,349
P3	4991,872	5001,364	500,037
P4	4992,219	4999,021	499,967
P5	4992,186	4999,002	499,967

Table 7. The points measured from the SP-1, SP-2 and SP-4 for the structural model

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
1	-0,6355	0,6009	-0,1926
2	-0,6842	0,4511	-0,0271
3	-1,0241	0,2993	0,2539
4	-1,0573	0,0896	0,5718
5	-1,3003	-0,1539	0,8823
6	-1,5435	-0,6968	1,2368
7	-1,7078	-1,0376	1,3486
8	-1,9178	-1,4456	1,3262
9	-1,9125	-1,6440	1,3123
10	-1,8964	-2,0411	1,2045
11	-1,8907	-2,2576	1,1004
12	-2,1416	-2,6313	0,7346
13	-1,8847	-2,5915	0,8862
14	-1,8963	-2,6090	0,8897
15	-2,2490	-2,7507	0,5104
16	-2,3664	-2,9123	0,2411
17	-2,4972	-3,0924	-0,0436
18	-2,3904	-3,2336	-0,1111
19	-2,1265	-3,4397	-0,1787
20	-1,8043	-3,5444	-0,1787
21	-1,4697	-3,5974	-0,1787
22	-1,1459	-3,5027	-0,0767
23	-0,8765	-3,2491	0,1732
24	-0,8310	-2,9499	0,5705
25	-1,1868	-2,8837	0,7475
26	-1,5065	-2,7616	0,8669
27	-0,0142	-2,2442	0,5941
28	-0,2122	-2,2019	0,8217
29	-0,1089	-2,1643	0,6443
30	0,1298	-1,9354	0,5975
31	0,1716	-1,6109	0,6399
32	0,1037	-1,2775	0,7257
33	-0,0658	-1,1080	0,8656
34	-0,0458	-1,2646	0,7804
35	-0,2643	-1,5006	1,0529
36	-0,2419	-1,9431	0,9580
114	-1,1319	0,9483	-0,5242
115	-1,0510	0,8323	-0,4802
116	-2,0515	0,5556	-0,1992
117	-2,0360	0,4119	-0,0202
118	-1,8679	0,1680	0,3048
119	-1,7696	-0,0477	0,5538
120	-1,9404	-0,34	0,8938

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
121	-1,7337	-0,5719	1,0978
122	-1,4916	-1,0171	1,2938
123	-1,4649	-1,2895	1,4288
124	-1,2966	-1,5835	1,4728
125	-1,2755	-1,9951	1,3868
126	-0,83	-2,3722	1,0658
127	-0,8234	-2,7252	0,7878
128	-0,485	-2,9379	0,3298
129	-0,5342	-3,2962	-0,0652
130	-0,5495	-3,4457	-0,2112
131	-0,5191	-0,7011	-0,6938
132	-0,5303	-0,6123	0,6118
133	-0,4106	-0,7204	0,5958
134	-0,4598	-0,6296	0,5248
135	-0,2809	-0,2191	0,1318
136	-0,3207	-0,1870	-0,0492
137	-0,3376	-0,1094	0,0368
138	-0,18	-0,2556	0,0178
139	0,0595	-0,6378	0,0738
140	0,0169	-0,6559	-0,0962
141	0,1571	-0,7004	-0,0252
142	0,0530	-0,5339	-0,0192
143	-0,3449	-1,7211	-0,6918
144	-0,2846	-1,6126	0,6108
145	-0,2020	-1,7986	0,6108
146	-0,2175	-1,6969	0,5728
147	0,2456	-1,4915	0,0638
148	0,29	-1,4284	-0,0152
149	0,2702	-1,5959	0,0018
150	0,3610	-1,5056	-0,0892
345	-1,565	-2,6331	0,3728
346	-1,49	-2,6631	0,5808
347	-1,668	-2,7111	0,5908
348	-1,577	-2,7721	0,4568
350	-1,3280	-3,1551	0,0348
351	-1,2850	-3,3001	-0,1612
352	-1,4540	-3,1941	-0,0452
353	-1,2630	-3,1901	-0,0552
354	-1,9080	-3,0391	0,0828
355	-2,02	-3,0821	-0,0062
356	-1,785	-3,1181	-0,0212
357	-1,8740	-3,1791	-0,1242
481	-0,7870	-2,6631	-0,6892
482	-0,1230	-2,2341	0,1318
483	-0,3310	-2,6051	0,3668
484	-0,4070	-2,2471	0,7288

Point Name	X-Coordinate	Y-Coordinate	Z-Coordinate
485	-0,732	-2,2211	1,0328
486	-1,2050	-1,7571	1,3938