

Discovery and documentation of the underground structures of Hagia Sophia (Istanbul, Turkey)

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Abstract

Hagia Sophia, an iconic world known monument of Late Roman-Early Byzantine architecture, is located at the heart of Istanbul and holds great importance in world architectural history. To fully comprehend its significance, it is crucial to examine the structure from all angles. The underground structures of Hagia Sophia have been investigated many times before. The first exploration and documentation attempt took place by cavers in 1986. Later, extensive studies were carried out by different caving groups and a total of 548 m of underground passages were mapped and documented. In February-July 2020, our project began with the aim of creating a 3D documentation of Hagia Sophia's underground structures. The project was led by the faculty members of the Department of Architecture at Fatih Sultan Mehmet University and Galeri Cave Research Group. Laser scanners such as Leica Blk 360 and Faro Focus 150 S were used to carry out the documentation process. Mapping of the newly discovered tunnels and the ones with level differences from the existing tunnel system was done using traditional methods due to the very narrow passages. The project led also to the discovery, mapping, and photography of new tunnels and underground structures. Consisting of 388 meters. Thus, total length of underground structures of Hagia Sophia reached to 936 meters.

Keywords: Hagia Sophia, underground structures, Byzantine.

Introduction

The underground structures of Hagia Sophia have been researched, mapped, and drawn many times until today. However, each research covers different places as the entrances that could be used varied depending on the time. At the request of the Hagia Sophia museum administration, cavers entered the underground structures for the first time in 1985, 86 and 87. However, they did not publish their research in the form of drawings. We can see the photographs in the Hagia Sophia archives, and we also have the opportunity to observe several sketches works from Mehmet Altun's archive.

Another study was conducted by a team from AS-PEG Cave Research Group, led by Dr. Çiğdem Özkan Aygün. Most of the underground structures of Hagia Sophia were investigated and extensively documented by this team. However, the drawings also had missing tunnels and spaces. Subsequent studies were conducted in the following years by the Boğaziçi University Cave Research Club, but this map only covered a smaller portion (Kurt B., 2013). As it can be seen, the underground structures of Hagia Sophia have been re-

peatedly measured and mapped by cavers. With each study, new discoveries regarding the structures were made. Indeed, this monument holds great significance in architectural history, making it a valuable learning ground for everyone.

Our project was carried out under the supervision of the General Directorate of Cultural Heritage and Museums of the Republic of Turkey, with the leadership of academics from the Department of Architecture at Fatih Sultan Mehmet University, namely Prof. Hasan Fırat Diker, Assoc. Prof. Mine Esmer, Dr. Alidost Ertuğrul, and Ali Hakan Eğilmez from the Department of Fine Arts at Istanbul Technical University.

The fieldwork of the project was conducted with a large team of cave explorers consisting of members from Galeri Cave Research Group, Istanbul Technical University Cave Research Club and Uludağ University Cave Research Sports Club. Survey and photography teams entered the structure multiple times. The project started on January 27th, 2019. In February-March, explorations were conducted to determine the methodology. Measurements of previously unmapped and unexplored tunnels were taken using traditional methods. Due to the global impact of COVID-19, the

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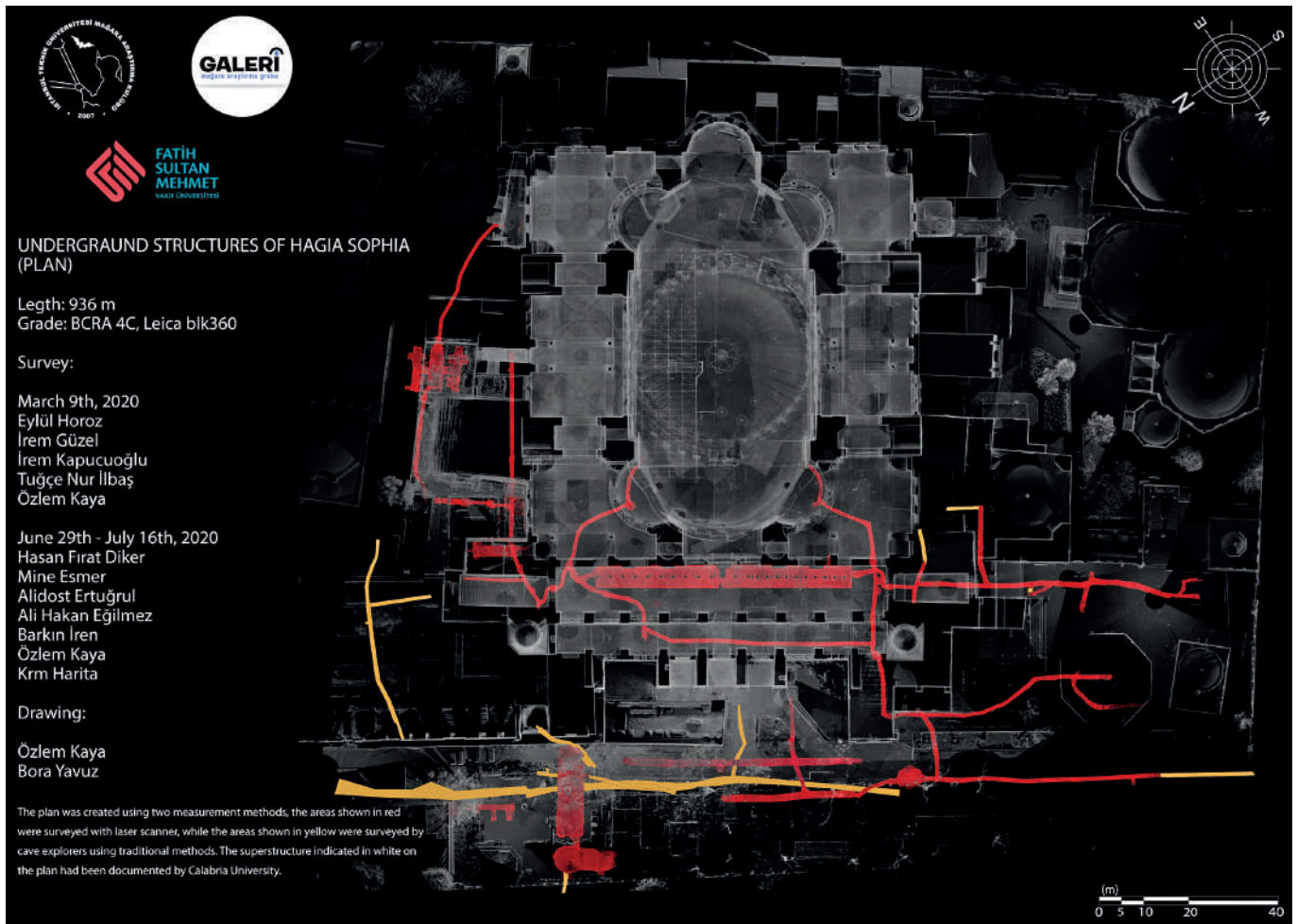


Fig. 1 – Underground Structures of Hagia Sophia. The plan was created using two measurement methods, the areas shown in red were surveyed with laser scanner, while the areas shown in yellow were surveyed by cave explorers using traditional methods. The superstructure indicated in white on the plan had been documented by Calabria University.

work was postponed until June-July of the same year. Throughout the month of July, both scanning and traditional measurement techniques were employed. The data collected was then compiled and drawn in November 2019.

Purpose of the Research

The aim of the research was to explore, examine, and document the underground structures of Hagia Sophia. Through surveying, drawing and taking photographs, the goal was to create a detailed inventory and enhance the understanding of the architectural and archaeological significance of this historical site. Additionally, the investigation of previously unknown or poorly documented tunnels aims to contribute to new discoveries and scientific studies.

Method of the Research

During the phase to determine the methodology of the documentation study, several trials were con-

ducted. Photogrammetry modeling was attempted, but due to the narrowness of the tunnels and the time-consuming nature of the modeling process, it was decided to use laser scanning.

The Faro Focus S 150 Terrestrial Laser Scanner and Leica BLK360 Camera Laser Scanner were utilized in the project. Due to its size, the Faro Focus S 150 was not suitable for scanning narrow tunnels, so most of the tunnels were documented using the BLK360. The BLK360 is capable of scanning in narrow, wet, and muddy areas. With its small and lightweight design, it proves to be quite useful for scanning underground structures and tunnels. However, there were tunnels where neither scanner could be used, and measurements in such parts were conducted solely using traditional methods.

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The wide underground spaces of Hagia Sophia were scanned using the Faro Focus by academics Assoc Prof. Mine Esmer and Prof. Hasan Fırat Diker. The



Fig. 2 – Leica BLK360 Camera Laser Scanner scanning in the tunnel (photo Özlem Kaya).

narrower tunnels, where cave explorers could navigate, were scanned by KRM Cartography employees and cave explorers (fig. 2). Throughout the project, a total of 936 meters of underground structures were surveyed and documented. Out of this, 668 meters were surveyed using the laser scanner, while 268 meters were surveyed using traditional methods (fig. 1).

The large space under the inner narthex, the tunnels leading to the northwest and southwest piers, the tunnels in the east and west directions with the Hipoje and the tunnel progressing under the “*Güzel Kapı*” in the south had been previously measured and drawn by the ASPEG team (Ali Yamaç, Murat Eğrikavuk) as part of Dr. Çiğdem Özkan Aygün’s project. (Aygün,

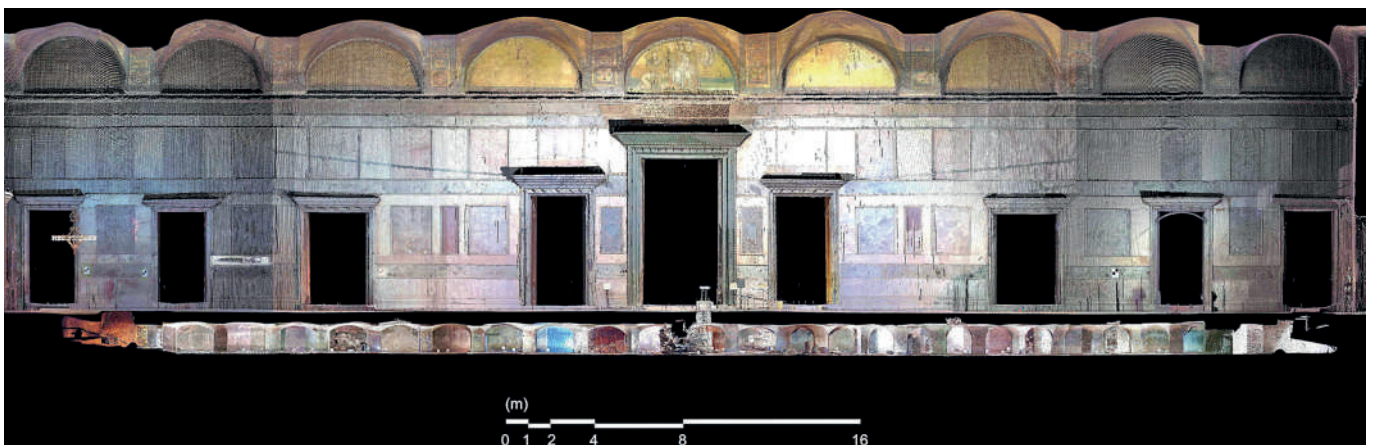


Fig. 3 – Section 1-1: North-south cross-section of the passage under the exonarthex (graphics Prof. Hasan Fırat Diker and Assoc. Prof. Mine Esmer).



Fig. 4 – Spoliated column at the western entrance of the channel under the northwestern buttress (photo Özlem Kaya).



Fig. 5 – Roots of chestnut tree and the underground structure (photo Özlem Kaya).

2010) When we compare their measurements with our scanning data, it becomes apparent how high-quality and accurate their work was. The careful and meticulous traditional measurement method aligns closely with the scanning data.

Scanning of the previously drawn tunnels allowed us to obtain significant number of cross-sections from the

model, providing us with the opportunity to establish the relationship between the underground structures and the superstructure (fig. 3).

This enabled us to create a more comprehensive understanding of the interplay between the underground tunnels and the overall architectural design. There is a comprehensive study by Prof. Hasan Fırat Diker



Fig. 6 – Brick arrangement in the tunnel (photo Özlem Kaya).

and Assoc. Prof. Mine Esmer on this subject (Diker *et al.*, 2021).

In the previous studies, a preliminary investigation had been conducted on a tunnel (previously unexplored) located beneath the garden of Hagia Sophia, oriented along the northeast-southwest axis at a lower level of other known tunnels. In our study, traditional measurement methods were used in this tunnel because the tunnel had been filled with in centuries filling material. Measuring of this narrow and occasionally widening sections of this tunnel proved to be quite challenging. In fact, during this measurement process, a measuring tape (tape measure) was used.

During our research, a new narrow tunnel extending from the inner narthex towards the northwest pier was discovered to open into a space filled with archaeological fill and rubble. To ensure the continuity, cavers had to widen the passage by pushing the sedimented mud to some extent, thus connecting these two tunnels. This passage, which was quite narrow, was approximately one and a half times the length of a human body.

The tunnel that progresses just below the northwest

buttress of Hagia Sophia was blocked by a reused column made of Marmara marble (fig. 4). However, afterwards it was determined that the tunnel was continuing beyond that point. In the following days, the survey and mapping studies showed out that it was connecting to the area identified through the entrance from the stone artifact storage.

The access to large underground spaces, previously known by the employees of Hagia Sophia Museum, was made possible due to the landscaping work carried out in the area. The chestnut tree located above the underground structures had penetrated the solid vaulted structure, causing damage to the underground structure.

This spacious area was filled with archaeological fill material and contained connections to previously tunnels (fig. 5). One of the tunnels was opening up to another large space at a higher level. Moreover, the arrangement of bricks in one of the tunnels was quite remarkable (fig. 6).

Another tunnel documented for the first time during our research was the one that was extending from beneath the madrasa building and was exhibiting features of the Ottoman era (fig. 7). The measurements of



Fig. 7 – A tunnel exhibiting Ottoman-era characteristics (photo Ali Hakan Eğılmez).

this tunnel were conducted using traditional methods. Access to the tunnel was discovered during the recent reconstruction of the madrasa building. In fact, there were open sections within the tunnel at various points.

Conclusions

The research conducted on the underground structures of Hagia Sophia involved a comprehensive documentation process using different scanners and traditional measurement methods. During the research process, previously undocumented tunnels were discovered, and their measurements were taken to establish their connections with the existing structures. Thus, total length of underground structures of Hagia Sophia reached to 936 meters.

These studies have provided an opportunity to gain a more detailed understanding of Hagia Sophia's underground structures and their relationships with the aboveground structure. Additionally, the influence of natural elements was observed in the discovered underground chambers, particularly the damage caused by the roots of a chestnut tree that penetrated the vaulted structure. Our findings emphasize the importance of considering impacts on the structures and implementing appropriate conservation measures.

In conclusion, this extensive research on Hagia Sophia's underground structures represents a significant step in documenting and correlating these structures with the overall site. The data obtained will contribute to a better understanding and preservation of these historically and archaeologically significant structures.

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