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GPR ANALYSIS OF SULTAN AHMED III LIBRARY (ENDERUN) IN TOPKAPI PALACE, ISTANBUL BEFORE RESTORATION

Keywords: project management, risk management, sustainable development, company

A b s t r a c t

Topkapı Palace was constructed between 1460 and 1478 by Sultan Mehmed the Conqueror. The Neo-classical Enderûn Library, also known as Library of Sultan Ahmed III, is situated directly behind the Audience Chamber in the centre of the Third Court of the Topkapi Palace in Istanbul. The Neo-classical Enderûn Library was built in 1718. To investigate the deformation conditions of this Library by non-destructive examination with the GPR-CX (Ground Penetrating Radar – Concrete Exploration) method was carried out. Mainly GPR-CX method was improved for investigate modern concrete walls and systems, as well as the high resolution and speed with non-destructivity made the system suitable for ancient buildings. In this study 2.3 GHz HF antenna was conducted with a 100×100 cm grid area to all the walls of Library, lead water pipes, vaulted base etc. were discovered. In addition the metal clamps of wall connections were also found and contributed to the static studies. By courtesy of non-destructive GPR-CX method, many unknown data were put forward about Library, which were constructed at 1718 AD.

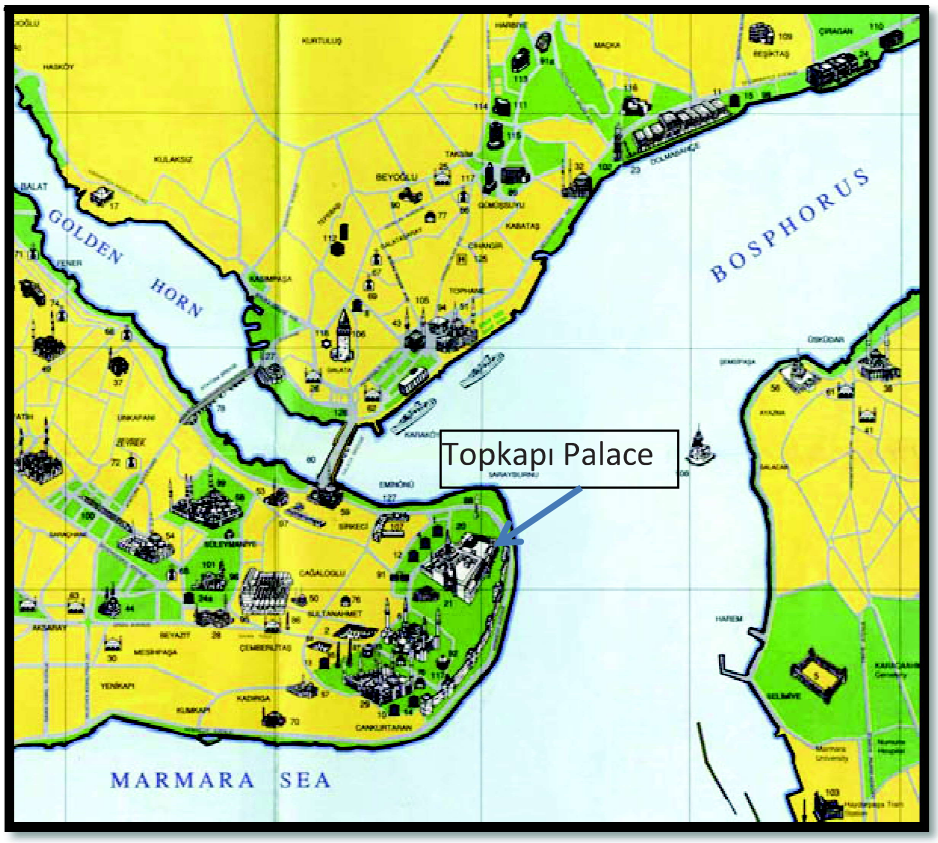
1. Introduction

After Fatih Sultan Mehmed's conquest of Istanbul in 1453, Topkapı Palace which was started to be built in 1460 and completed in 1478 (Fig. 1). It was built on an area of 700,000 square meters on the East Roman acropolis in Sarayburnu, at the tip of the historical Istanbul peninsula between the Bosphorus, Marmara Sea and the Golden Horn (Fig. 2). From the time of Sultan Mehmed the Conqueror to the thirty-first Sultan Abdülmecid, the empire has been used as an administrative, educational and artistic center for almost four hundred years. Although the dynasty was abandoned in the middle of the 19th century by the relocation of Dolmabahçe Palace, its importance was always preserved.

Fig. 1. Topkapı Palace

After the foundation of the Republic of Turkey, Topkapı Palace, which was transformed into a museum on April 3, 1924, is the first museum of the Republic and covers an area of approximately 400,000 square meters. Topkapi Palace is separated the city from the sea with its eastern Roman walls and Sur-i Sultani built by Fatih from land, is one of the biggest palace-museums of the world with its architectural structures, collections and approximately 300.000 archive documents. It is surrounded by gardens and squares around the palace, which consists of architectural structures around four courtyards which are entered through the gate of the Haghia Sophia and crossed by each other. The palace's external services such as the Hagia Irini Church, the Mint, the Bakery and the hospital, which were used as the first courtyard (Alay Square) Cebehane, the first courtyard of the palace and where the people could enter for admission, were available (Binark, 1974).

Fig. 2. Location of Topkapi Palace



Ahmed III. Library emphasizes the importance given to the education of Enderun. After Enderun Court, the pavilion houses and the hanging gardens are in the fourth pass to the courtyard. This room, which is also reached by Has Room's marble doors opening to Marble Sofa, includes the Circumcision Room, Baghdad and Revan Mansions and Iftariye Cameri, which are the most distinguished examples of the classical mosque architecture of Ottoman art. In the lower courtyard of the courtyard is a hanging flower garden, wooden Kara Mustafa Pasha Mansion, Physician's Head Tower and Sofa Mosque. Mecidiye Mansion and Esvab Chamber built during the reigon of Sultan Abdülmecid are the last buildings built in the Palace. It is known that there are many pavilions and huts in the Has Garden that surround the Topkapi Palace and do not reach to the day-to-day.

2. Building of Ahmet III Library

As a foundation library for boys studying at the Enderun Palace School, instead of Pool Villa was built by Sultan Ahmed III (1703-1730). This building is the first library of the Palace (Fig. 3). An Arabic poetry on the sentence gate gives the date of 1719 at the center of Enderun Court. In the book, Sultan III.

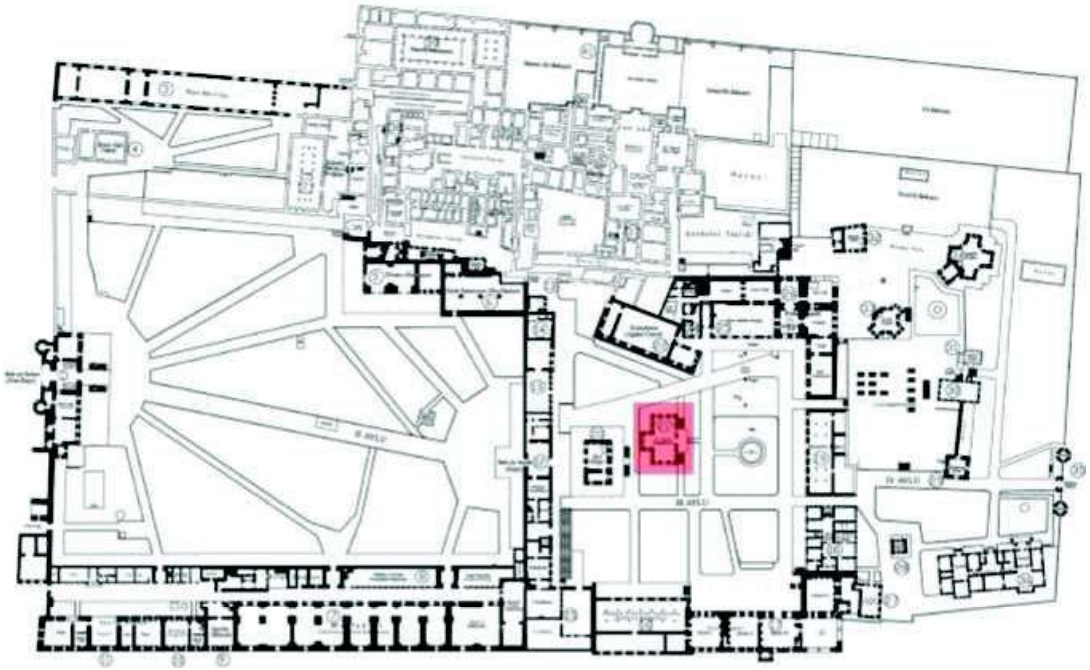
Ahmed tells us that this building, where books will be gathered, was built with his own money to encourage learning and gain rewards. This building, also called the Enderun Library, consists of a domed central space rising on a vaulted substructure. This space has been expanded on three sides by rivets. The outer pillars are covered with marble. At the entrance of the library there are two fountains on the side of the building and one on the side of the courtyard. The interior of Sultan Ahmed III Library is covered with 16th century Iznik tiles. The tiles were brought from the other palaces and mansions of the sultans in Istanbul. The domes and vaults were decorated with the floral motifs of the Tulip Age. Window and door wings are ivory inlaid classic geometric design. The windows and doors are covered with 17th century imperial tiles, and the ceilings are inlaid with geometric stone like Baghdad and Revan Pavilions. There are bookcases with silver wire cages between the windows. The collection of books in Sultan Ahmed III's own treasury and the books which were founded by Sultan Abdülhamid I and Sultan Selim III were preserved here until 1965 and later included in the collection of Saray Library. After Enderun Court, it passes to the fourth courtyard where the pavilions belong to the palaces and the hanging gardens (Binark, 1974).

Fig. 3. Building of Ahmet III Library

2.1. Restoration of Building

In the frame of general restoration works in Topkapi Palace, the building of Ahmet III Library started restoration works. Before restoration works, degradation zone, voids on the walls and domes should be detected. To detect structural problems and restoration budget ground penetrating radar (GPR) method were applied to red zone (Fig. 4).

Fig. 4. Plan view of Topkapi Palace. Red zone presents the building of Ahmet III Library



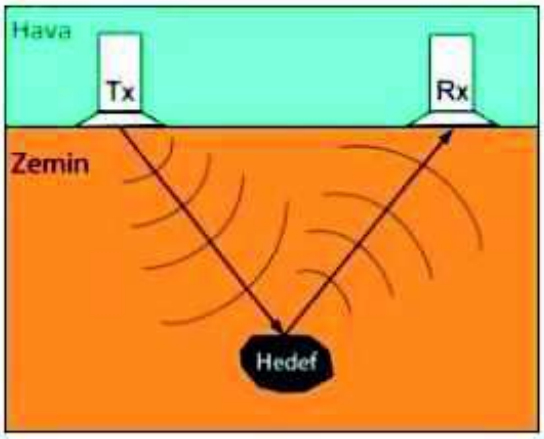
2.2. Method

Ground Penetrating Radar (GPR) is a geophysical method that is used to obtain an underground and inner wall image. GPR, a non-destructive method, uses electromagnetic waves in the microwave band (UHF / VHF frequencies) of the radio spectrum and uses the reflected signals from underground structures based on the information collected from underground. The design of the GPR system is defined in a wide range of applications and can be applied in a variety of environments including rock, earth, ice, fresh water, urban infrastructure and buildings. GPR is used to detect buried objects, changes in material properties, voids and cracks by properly forming the conditions. In the GPR method, high frequency radio waves are generally used in the range of 10 MHz to 2.6 GHz. The factors that determine the frequency to be selected are the effective depth of the target, the target size and the area to be surveyed. In general, GPR

measurement is carried out at specified intervals in the grounded areas. The method is generally concerned with the difference of the electromagnetic signals generated from the antennas from the original signals during the underground travel (Conyers, 2004). The GPR system consists of transmitter Tx and receiver Rx antennas (Fig. 5). During application, a transmitter emits an electromagnetic wave to the antenna. When energy meets a boundary between an embedded object or materials with a different dielectric value, it is reflected, broken or scattered on the surface. Another receiving antenna records changes in the turn signal. The GPR method is related to the electromagnetic wave, not to the acoustic. The underground electrical properties reflect the change of underground mechanical properties. It determines the speed of GPR signals according to the physical and chemical characteristics of the environment in which they move and collects information about the target.

GPR has many applications in many areas. Earth sciences are used to study the main rock, earth, groundwater and gypsum. Engineering applications include non-destructive inspection (NDT) of structures and pavements, detection of buried structures and electrical lines, and examination of lands and rocks. GPR used in environmental remediation, archaeological site archaeological features and mapping graveyards is used to define regular fill areas.

Fig. 5. Schematic representation of the antennas in the GPR system



The GPR is also used for criminal purposes to detect illegal tombs and buried evidence. Military uses include the identification of mines, unexploded ordnance, and tunnels. Underground mining applications use well surveillance radars to map structures from a well. Since GPR detects changes in dielectric properties underground, locating non-conductive plants can be extremely effective.

2.3. Application

In the building of Ahmet III Library, there is a basement with 11 columns (Fig. 6). All columns were investigated by GPR system and presented with 10 cm steps (Fig. 7). An example for a column showed in Fig. 8 (ECAY, 2014).

Fig. 6. Upper view of basement of the building

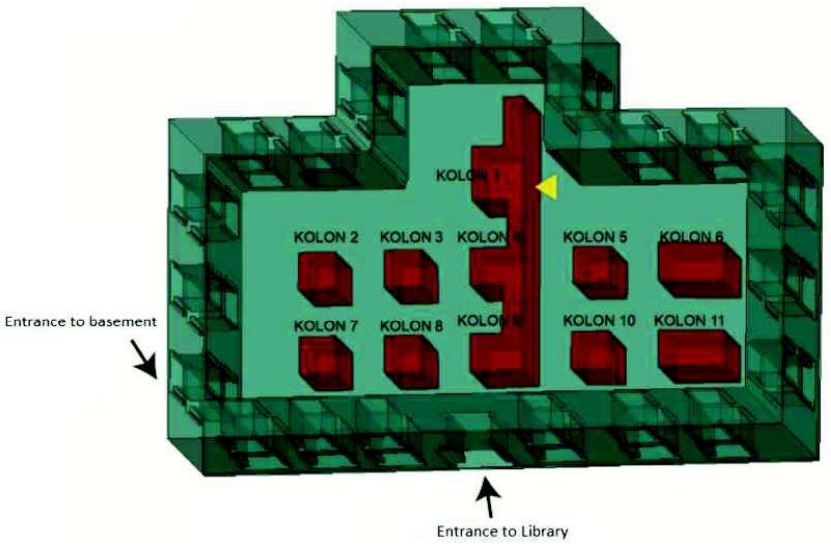
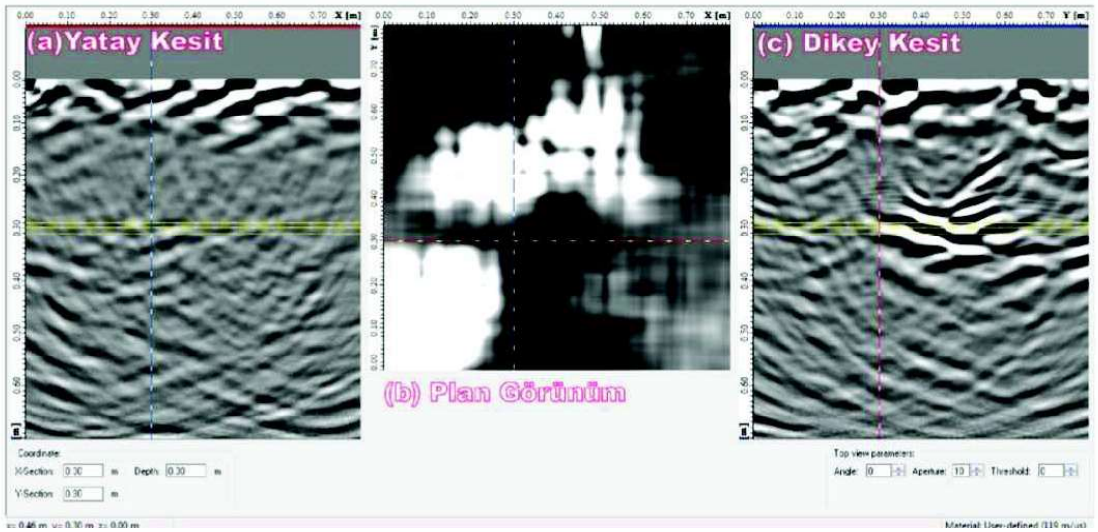


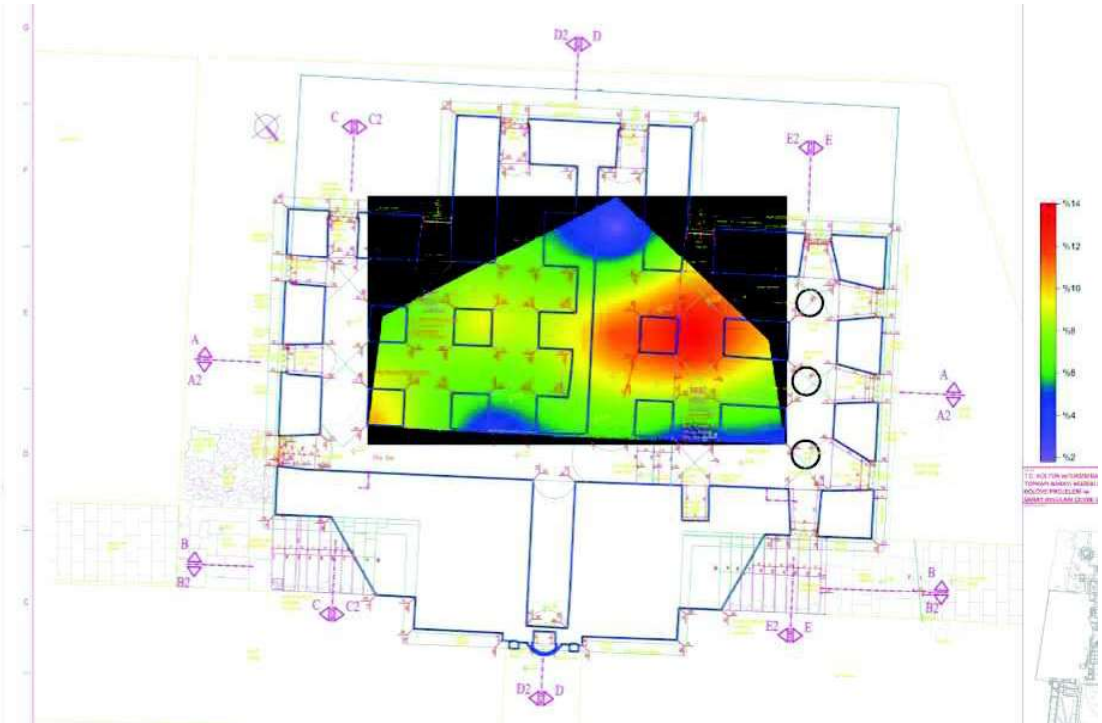
Fig. 7. GPR measurements on the walls of the Library

Fig. 8. GPR section for 30 cm penetrating depth. Failure rate is 22.94%



All measurements completed on the columns and were prepared horizontal failure risk distribution map in Fig. 9.

Fig. 9. Column failure risk distribution for basement



3.1. Façade Measurements

Façade of building were measured with 10 cm steps and all results presented on the plan (Fig. 10). All fronts of the Library building analyzed for 50 cm penetrating depth (Fig. 11).

Fig. 10. Risk maps for frontage of the building. **(a)** 10 cm penetrating depth, **(b)** 20 cm penetrating depth, **(c)** 30 cm penetrating depth, **(d)** 40 cm penetrating depth, **(e)** 50 cm penetrating depth, **(f)** 60 cm penetrating depth

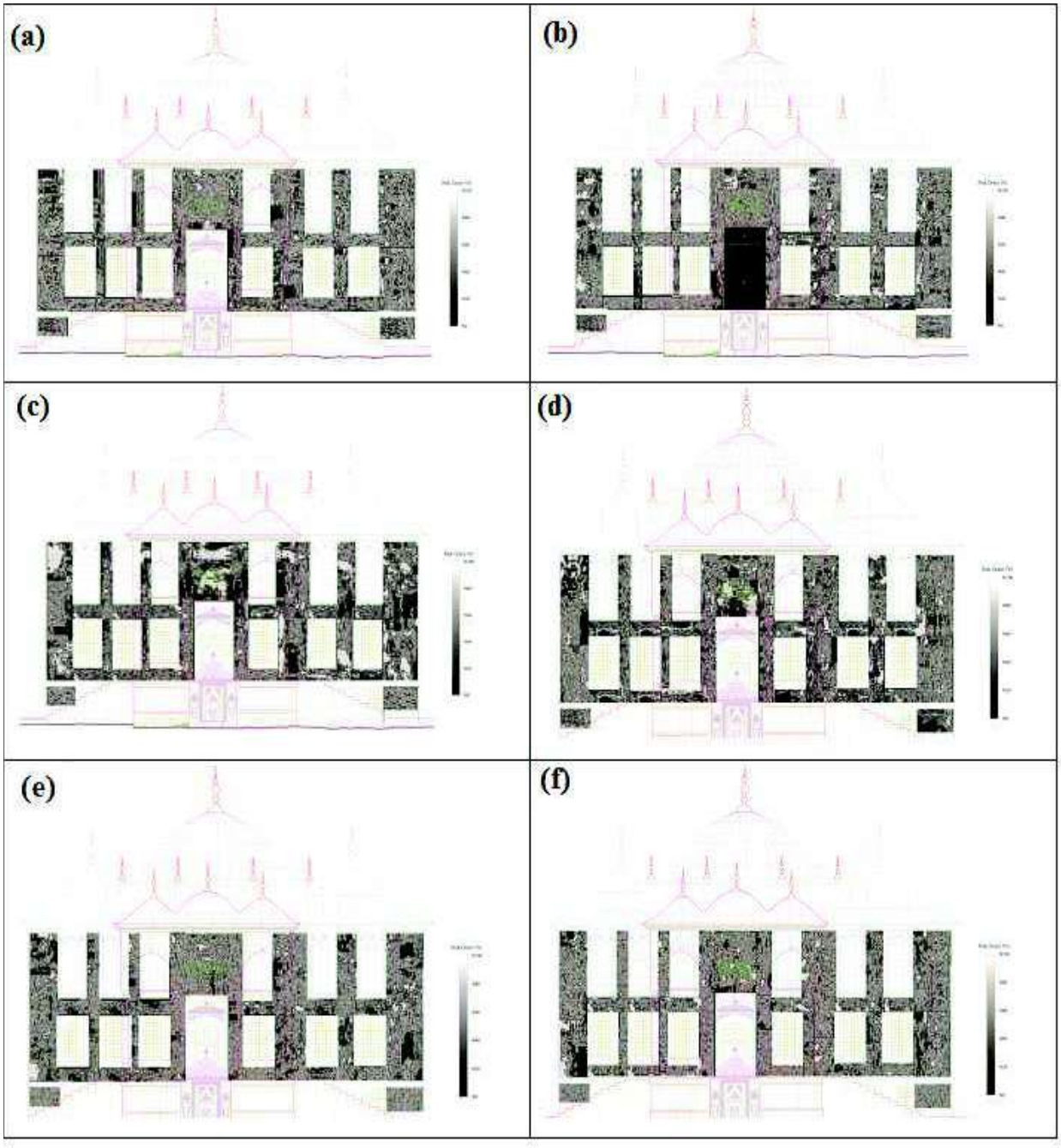
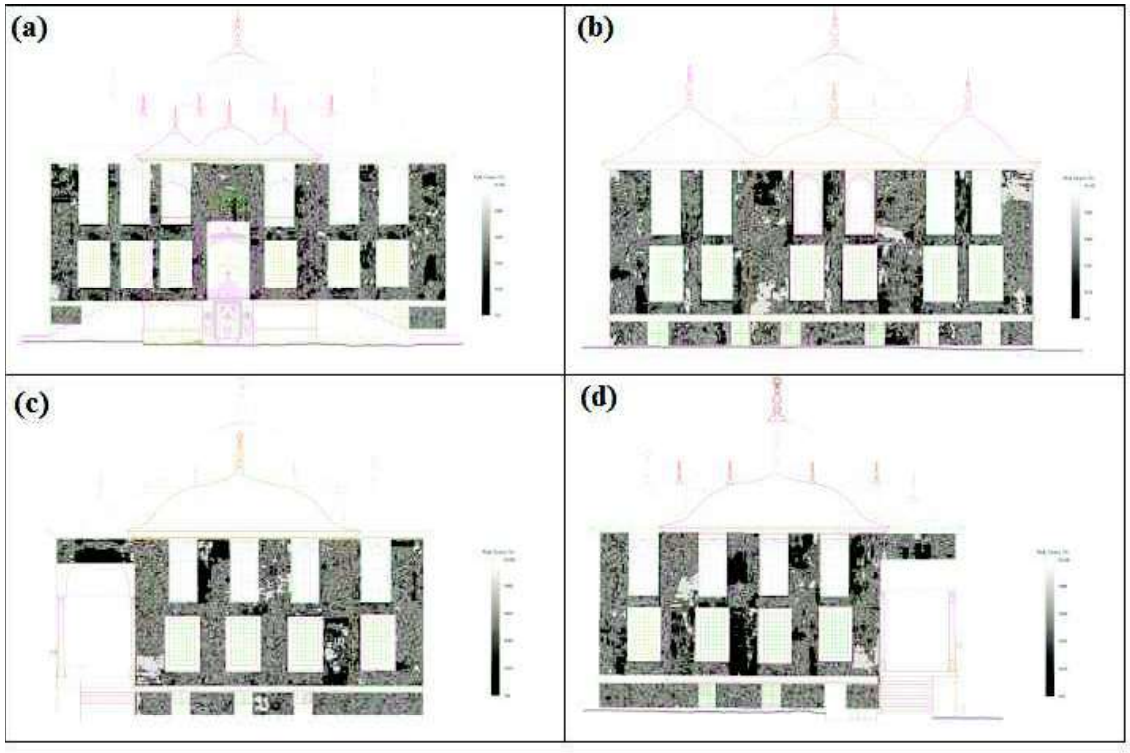


Fig. 11. Risk maps for different fronts of the building (50 cm penetrating depth). **(a)** frontage, **(b)** rear façade, **(c)** right façade, **(d)** left façade.

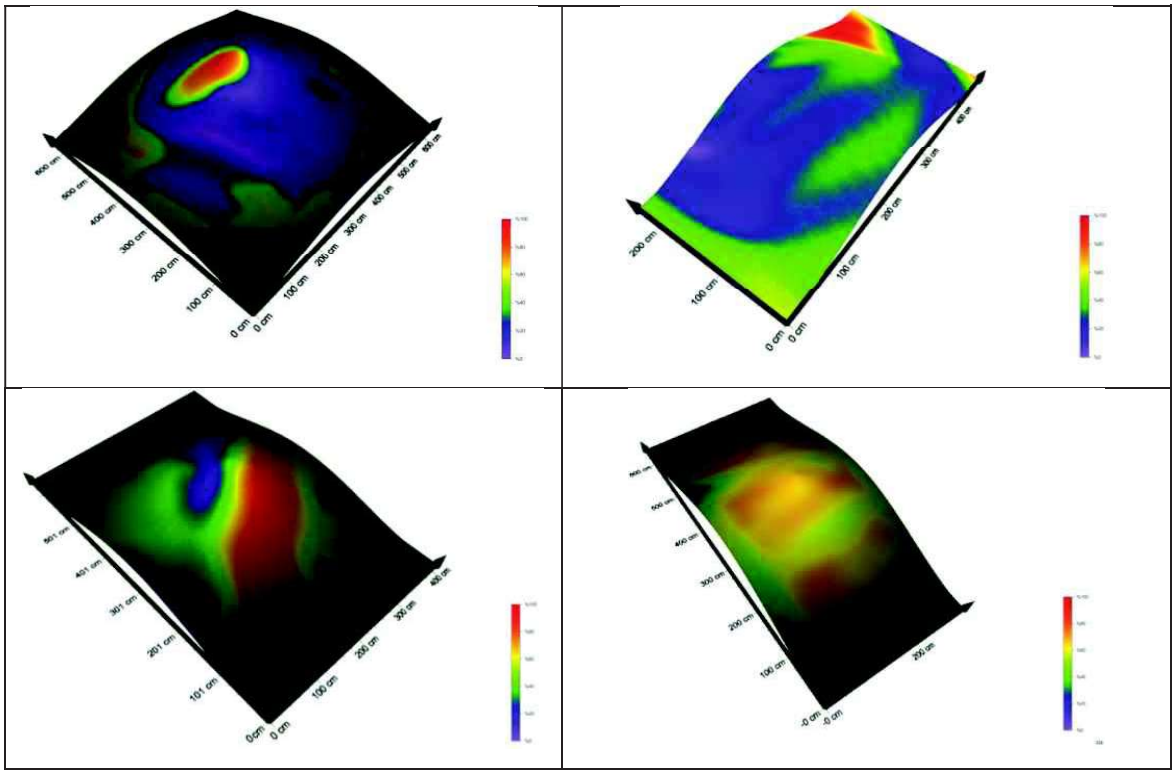


3.2. Dome Meaurements

The domes measured as separate zones (Fig. 12) are generally gridded with hemisphere ridges and show areas containing voids (Fig. 13).

Fig. 12. View of dome measurements by GPR

Fig. 13. Dome risk analysis of the building. (a) Main dome, (b) Front dome, (c) Right dome, (d) Left dome



Summary

Applications based on GPR measurements are also being applied in a wide variety of areas. Especially GPR applications are very successful because it allows examining historical structures without damaging them. Before restoration of the structures, the parts requiring repair and renovation can be determined in this way. Within the scope of this study, results based on GPR measurements made before the restoration of Ahmet III library in Topkapi Palace which is a very important structure in Istanbul have been given. In the whole of the work, the risk definitions carried by the work were put forward. Thus, the sections to be repaired can be put in order of priority.

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