PRE-RESTORATION MATERIALS RESEARCH IN HISTORICAL ANKARA CASTLE

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Throughout history, the Anatolian Peninsula, with its many fertile lands and many settlements of civilization, has seen a bridge between civilizations due to its position on commercial and military roads. Ankara, the capital, since the establishment of the Republic of Turkey; is a witness to many political, administrative and military events that have been up to date. For this reason, the city has a rich cultural heritage. Ankara Castle, which has always been in the same place since the Hittites, repaired many times during the Roman, Byzantine and Seljuk periods. It is very important that the materials used in the restoration work are compatible with the existing structure. In this; an analysis of the existing material was carried out which could shed light on the restoration work to be done on the Ankara castle.

Therefore, from Ankara Castle were taken samples from the materials used in the areas where structural deterioration occurred on the east, west, north and south facade walls. On the samples, material characteristics were analyzed by using methods such as SEM, EDS, F-TIR. In addition, density, water absorption, compressive strength and thermal conductivity properties of the samples were measured.

As a result, the physical, mechanical and thermal properties of the materials used in the construction of the Ankara Castle have been revealed. As a result, it is possible to apply materials compatible with the existing structure that can be used in the restoration works of the Ankara Castle.

Keywords: *Ankara Castle, Restoration, Materials, Strength, SEM, EDS*

1. Introduction

Ankara, the capital, since the establishment of the Republic; is witness to many political, administrative and military events that have occurred until today. Therefore, the city has a rich cultural heritage. Ankara Castle which has always been in the same place since the Hittites, has undergone many repairs during the Romans, Byzantines and Seljuk period. It is very important that the materials used in the restoration works are compatible with the existing structure [1].

Ankara Ulus Castle region is the most important urban focus of the historical settlement of the capital city which contains the historical structures of the old settlement. Although Kaleiçi's current position has undergone great changes in texture, historical continuity, traces of the past, monuments and physical values continue and serve the traditional part of the city [2,3].

Many things have been said about restoration. The most widely accepted definition is to repair the original without disturbing it. Restoration is to repair and rehabilitate the damaged and damaged parts of any artwork, such as a work of art, a painting or a sculpture without damaging the art value and the old form of the artwork [4]. Restoration means that the structure begins a new life by getting rid of the effects of time and other factors. The structure's life has been prolonged by stopping deterioration of the structure with restoration [5].

In this; the characterization of the materials used in the construction of Ankara Castle has been carried out and it is aimed to obtain important findings that will shed light on the selection of materials that can be used in restoration works.

2. Materials

Due to the realization of repairs at different times within the historical process in Ankara Castle, a detailed study was carried out to determine the original sites belonging to the construction period and to obtain representative samples from the appropriate parts. Stones with rendering mortar from the north, south, east and west facade of the external walls of Ankara Castle which has been under the influence of environmental impacts and climate parameters (temperature, humidity, wind, rain, frost), were used as test samples. Samples taken from different facades were cut in accordance with experimental studies.

3. Methods

In Figure 1 there are samples taken from four different facades of historical Ankara Castle. Experiments on mechanical tests were carried out according to the principles stated in TS 699 [6]. In addition, material characteristics were tried to be revealed by Scanning Electron Microscopy analyzes SEM and EDS using scanning electron microscope (FEI Quanta FEG 250), Fourier Transform Infrared (FT-IR) spectroscopy methods as well as by examining with the optical microscope (Zeiss Imager M1m) [7-13].

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a- Experiment samples b- Sample taken from south facade c- Sample taken from north facade

Fig. 1 - Picture of the experiment samples and compressive strength experiment.

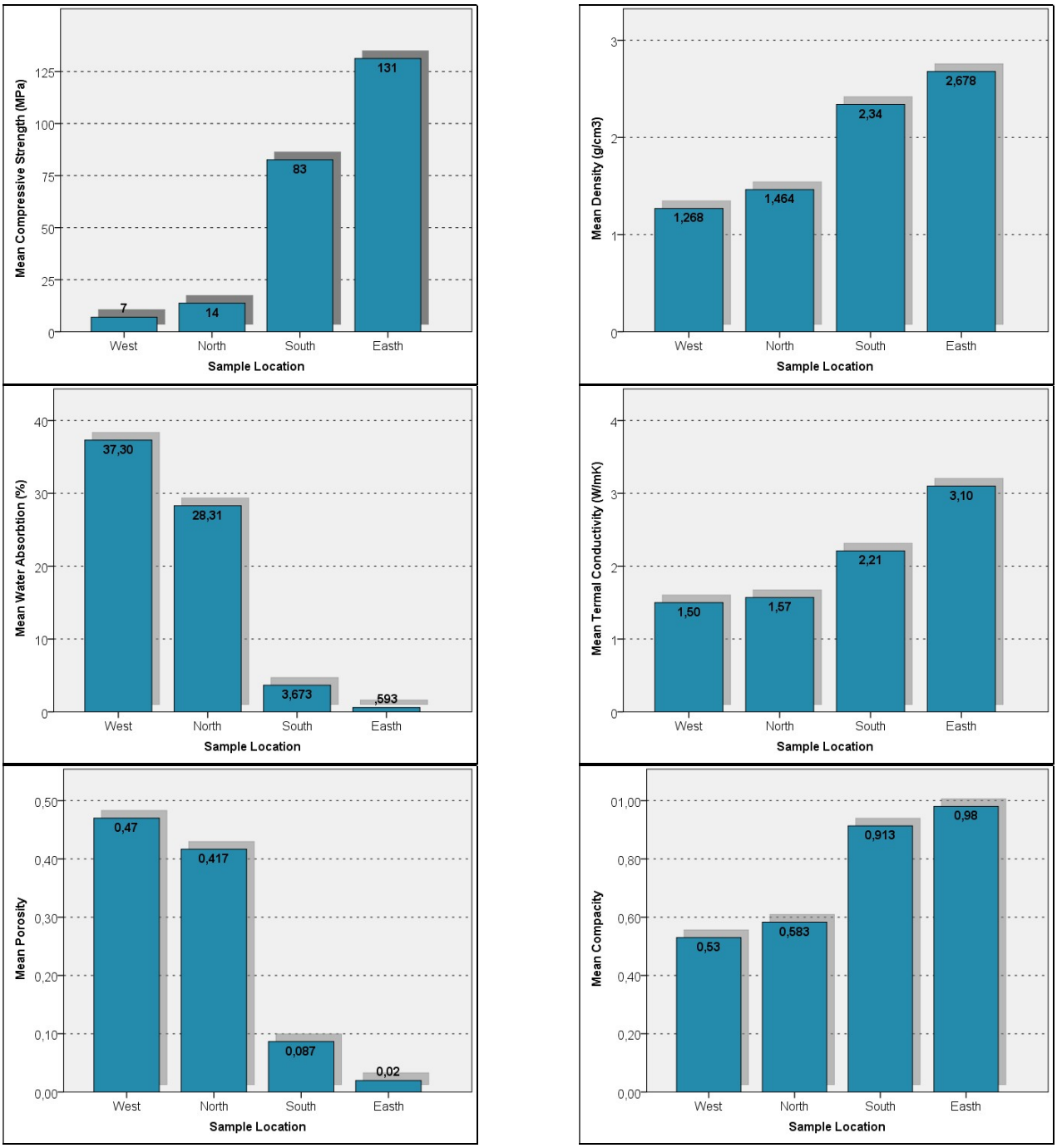


Fig. 2 - Average values of speciments properties

4. Mechanical and Physical Properties

The bar graphs on average values of compressive strength, density, water absorbtion, thermal conductivity, porosity and compasity tests performed on samples taken from east, west, north and south facades of historical Ankara Castle are shown in Figure 2.

When the experiment results are examined, it was observed that samples taken from the east facade had the highest values in terms of compressive strength, while samples taken from the west facade had the lowest values. As the density, it was understood that samples taken from the east facade had the highest values, while samples taken from the west facade had the lowest values. Regarding the water absorption test, it was determined that the average water absorption values of the samples taken from the east facade were the lowest, while the average water absorption values of the samples taken from the west facade were the highest. When the porosity test is examined, it is seen that the samples taken from the east facade have the lowest porosity and the samples taken from the west facade have the highest porosity. Regarding the compactness, it was understood that samples taken from the east facade had the highest average compactness, while those taken from the west facade had the lowest average compactness. When examined in terms of thermal conductivity, it was determined that the samples taken from the east facade had the highest average value and the samples taken from the west facade had the lowest average value.

Especially granite used in the construction of the structures on the eastern facade has significantly higher values than the materials used in the construction of buildings on other facades.

5. Optical Microscope Analysis

Samples taken from Ankara Castle were smoothed and micro structures were examined under optical microscope. The optical images of the samples taken from different facades are seen in Figure 3.

When the optical microscope images are examined, it is seen that the stones used in the southern facade of Ankara Castle are consisted of high-density andesite containing mica and feldspar in the volcanic rock group. This stone type which is light gray, fine grained, less porous and has high mechanical strength, mineral hardness is 6-7 (Mohs) and in natural conditions there can not have a high risk of deterioration. When the optical microscope images are examined; it is determined that the stones used on the eastern facade are high-purity andesite containing mica and feldspar from the volcanic rock group. It is observed that the western and northern facades of the castle walls are composed of baked clay products which contain silica, limestone and gypsum with a lower density compared to the materials used in other facades. This observation is supported by SEM, EDS and FT-IR analyzes.

6. FT-IR Analysis

The results of Fourier Transform Infrared (FT-IR) spectroscopy on the mortar samples taken from the historical Ankara Castle facades are shown in Figure 4.

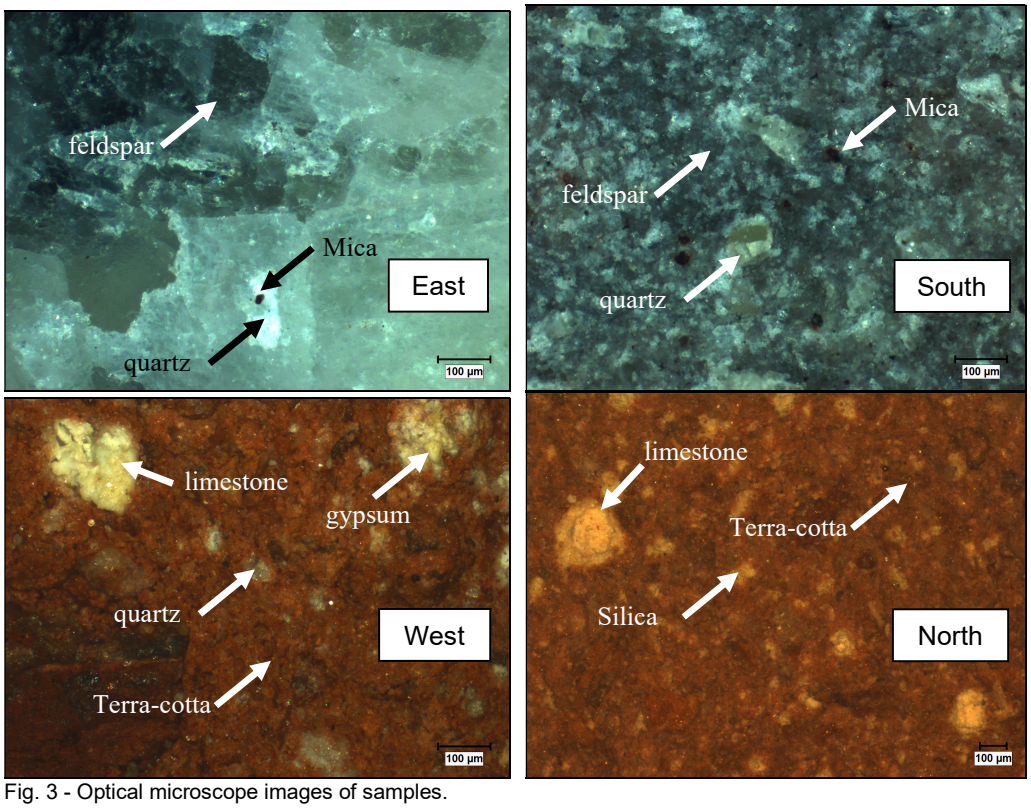
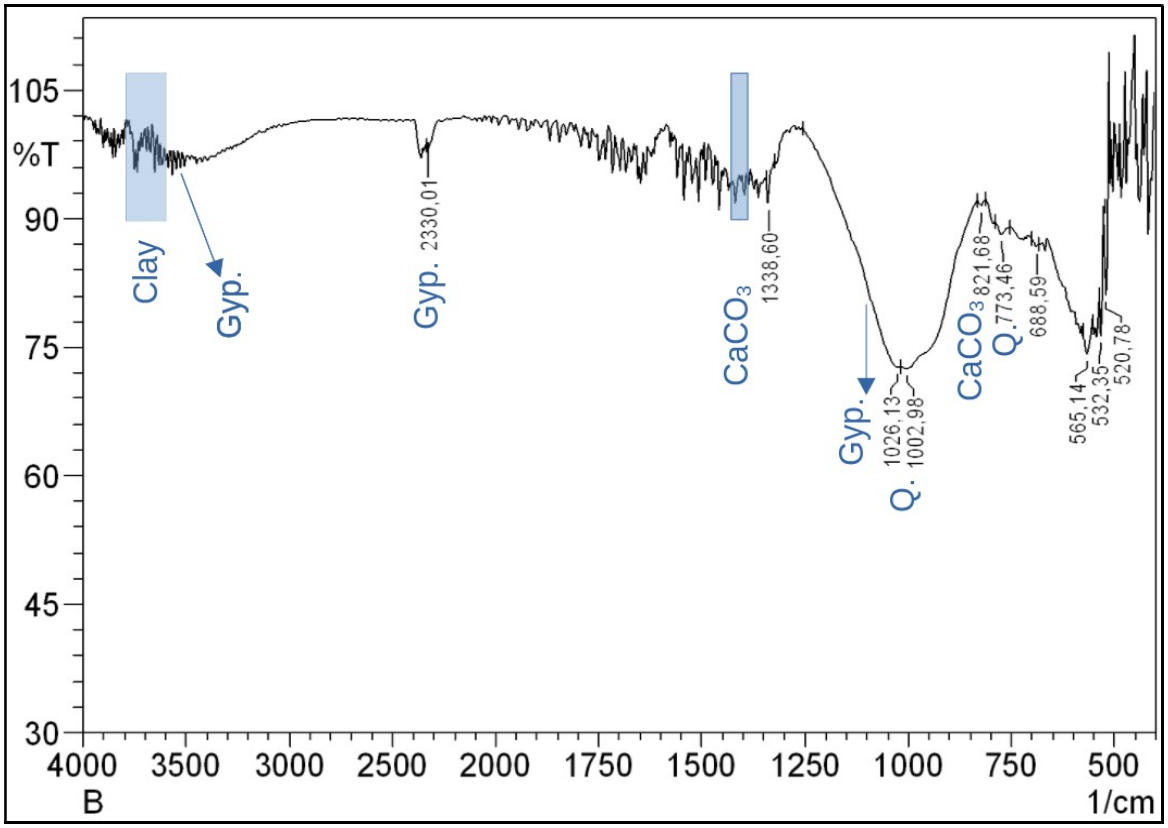
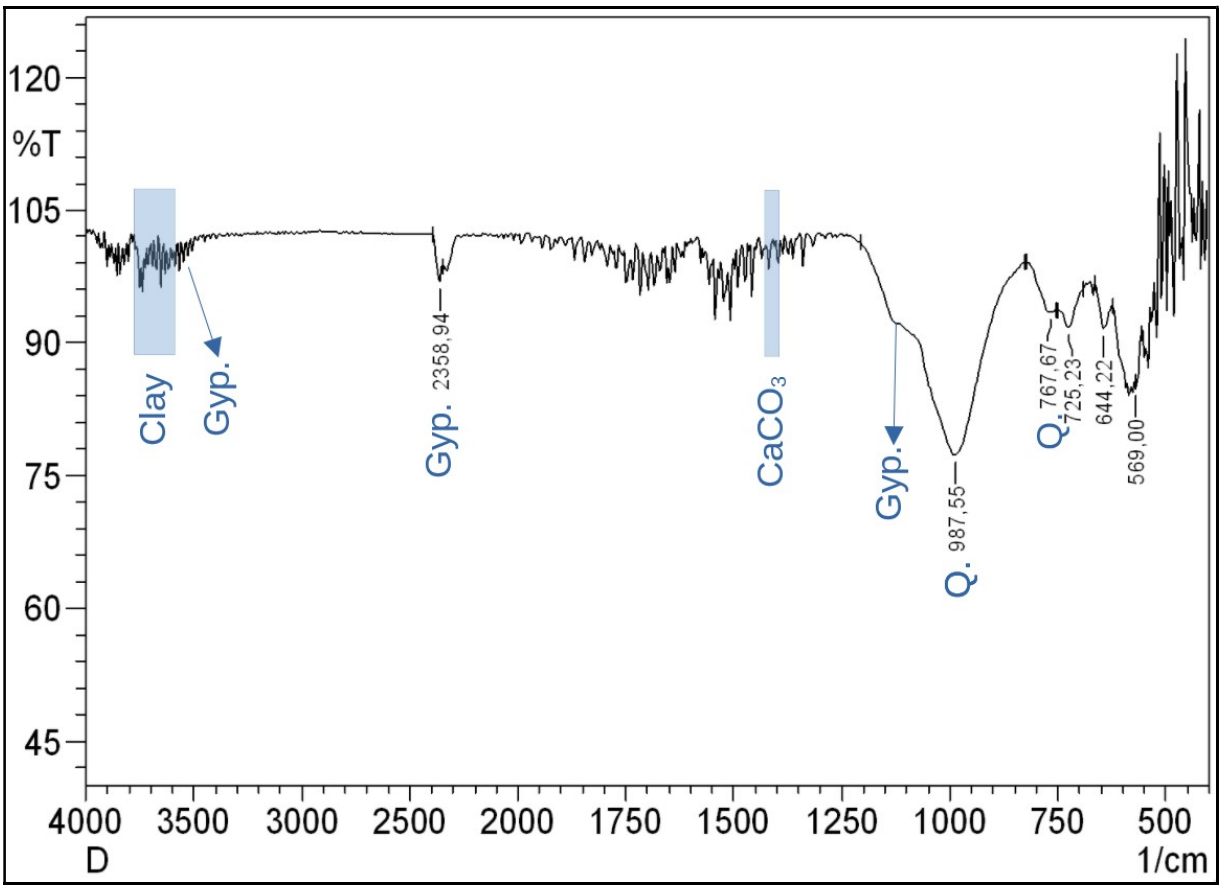


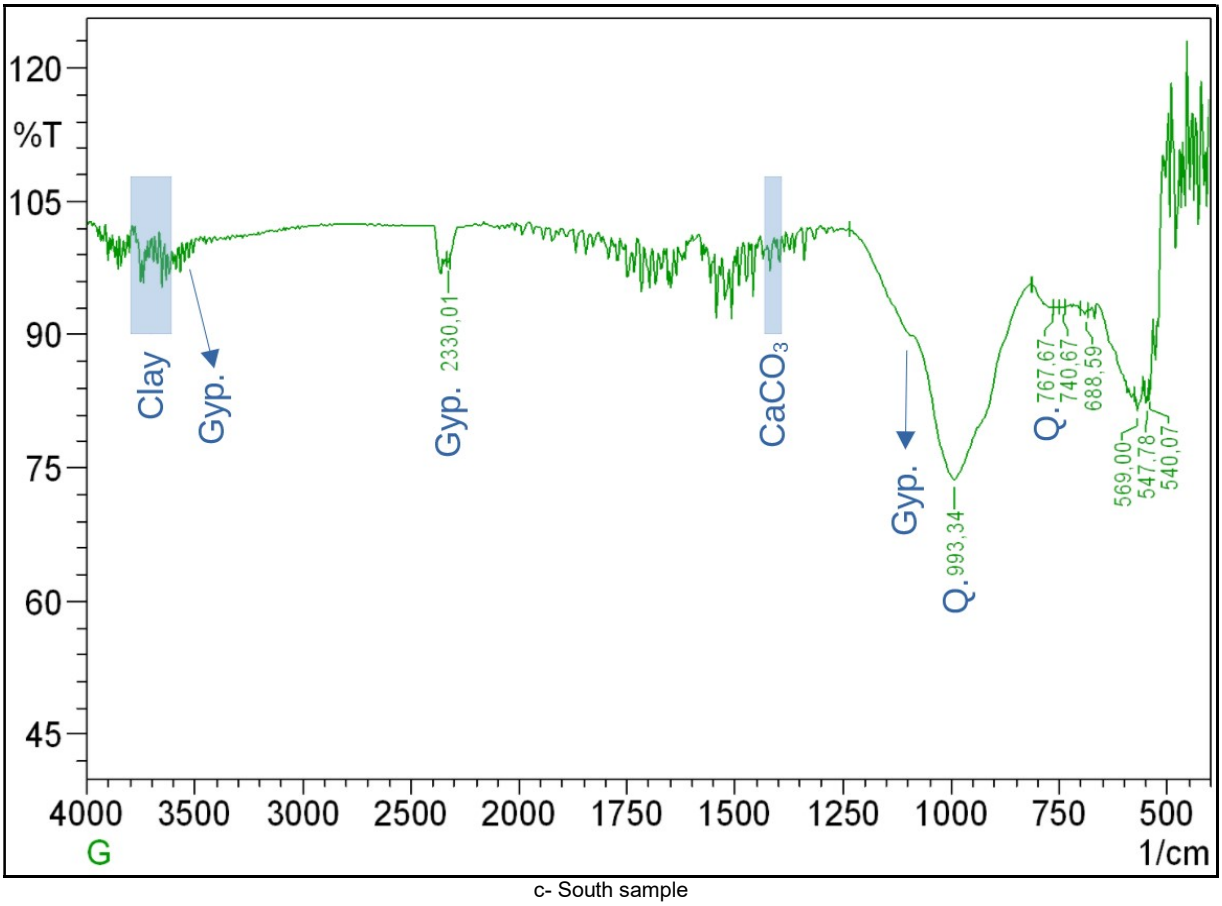
Fig. 3 - Optical microscope images of samples.



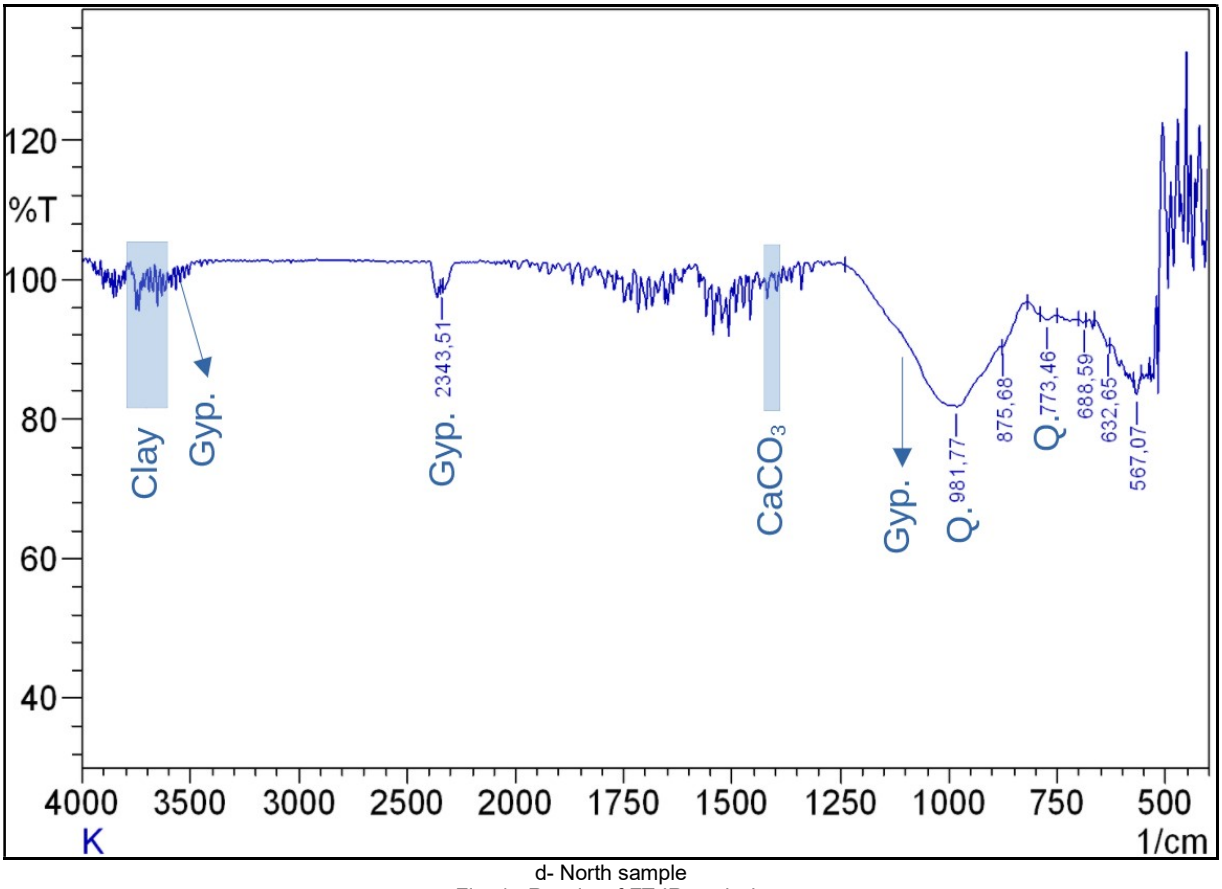
a- West sample



b- East sample



c- South sample



d- North sample

Fig. 4 - Results of FT-IR analysis

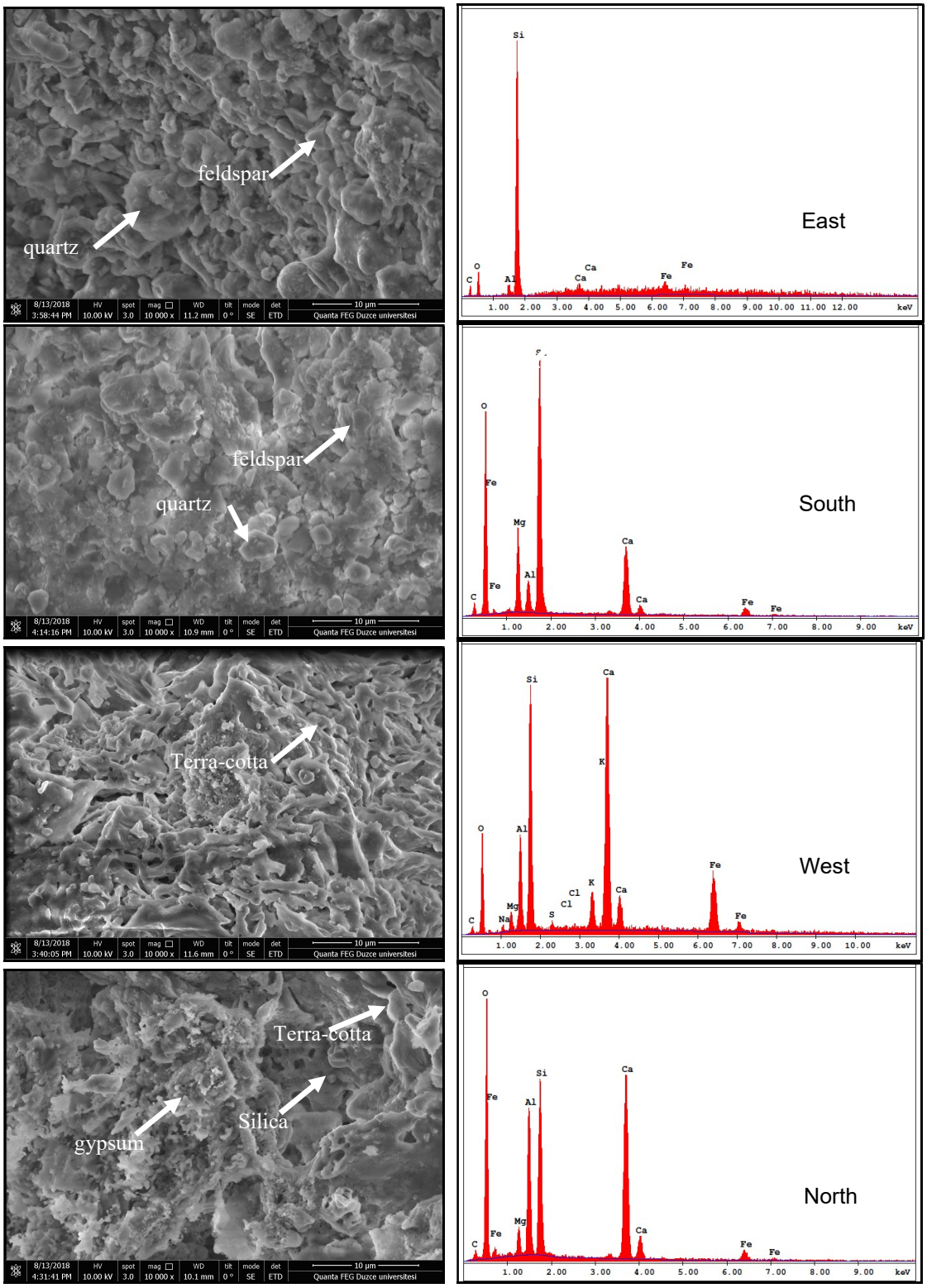


Fig. 5 - SEM and EDS analysis results of the samples

When the FT-IR vibrations of the materials obtained from the facades were examined, differences were observed in the vibrations of silicon oxygen (Si-O) interactions. Si-O asymmetric stress vibrations were observed in the western sample at 1026 cm^{-1} while in the eastern sample this vibration was observed at 987 cm^{-1}. This vibration was observed at 993 cm^{-1} in the southern sample and 981 cm^{-1} in the northern sample. This absorption band range corresponds to quartz minerals. Si-O asymmetric stress vibrations and Si-O symmetrical stress vibrations were observed in the region of 800 cm^{-1} - 750 cm^{-1} and Si-O bending vibrations were observed in 700 cm^{-1} - 500 cm^{-1} region. When these vibrations were examined, differences were observed both in Si-O

stress vibrations and Si-O bending vibrations. Given these differences, it is possible to say that Si-O interactions in the crystal structure are in different positions. It also shows that the crystal structures are different. The range of 3800-3600 cm^{-1} corresponds to clay minerals, there are small decrease of transmittance in this range at all samples. The fact that the O-H stress bands which occur due to the presence of clay minerals in the range of 3800-3600 cm^{-1}, were not strongly observed in the FT-IR spectra of the bricks used on the west and north facades, indicating that the clays in the raw materials of these bricks were completely dehydrated during the firing process [14]. There are also slight increase of transmittance around 1500-1450 cm^{-1} which is probably due to carbonate ions indicating the presence of calcite minerals. Natural gypsum show strong decrease of transmittance at 3540 cm^{-1}, 3400 cm^{-1}, 3240 cm^{-1}, 2914 cm^{-1}, 2846 cm^{-1}, 2326 cm^{-1}, 2210 cm^{-1}, 2091 cm^{-1}, 1682 cm^{-1}, 1620 cm^{-1}, 1458 cm^{-1}, 1143 cm^{-1}, 1115 cm^{-1}, 669 cm^{-1}, 600 cm^{-1} and 449 cm^{-1} wavenumbers [15]. Especially at wavenumbers of 3540 cm^{-1}, 3400 cm^{-1}, 1620 cm^{-1}, 1143 cm^{-1}, 1115 cm^{-1}, 669 cm^{-1} and 600 cm^{-1} there are high intensity peaks. Possible gypsum peaks are also shown in Figure 5.

7. Scanning Electron Microscopy Analysis (SEM and EDS)

Morphological, structural and qualitative elemental analyzes were performed on the materials used by the high resolution images taken from scanning electron microscope and the information obtained from the EDS analyzes. The results of SEM and EDS analysis are shown in Figure 5.

When the results of SEM and EDS analysis are examined, it is seen that the particles forming the structures of the samples taken from the eastern and southern facades are almost homogeneously distributed and they are mostly Si-containing structures. The baked clay products used in the western and northern facades appear to have a structure formed by Si, Al and Ca and its compounds. It was observed that the particles were in a tight form, there was no excess space and very large particles. Particularly, it was observed that the samples taken from the western and northern facades show a heterogeneous structure in the SEM photographs and there are regional gaps in the inner structure.

8. Conclusions

On the eastern facade of the castle walls granite, on the southern facade andesite and on the northern and western facades baked clay products were used. In terms of mechanical and physical properties, materials used in the eastern and southern facades have higher strength and physical properties compared to the materials used on other facades.

It was observed that the inner structures of the samples in the eastern and southern facades were generally homogeneous, the particles were in a tight form, there were no excessive gaps but the inner structures of the samples taken from the western and northern facades were heterogeneous and the inner structure had regional gaps.

In the study, the characterization of the materials used in the construction of Ankara Castle is carried out and important findings are obtained to shed light on the selection of materials that can be used in restoration works. Renovation works of Ankara Castle should be evaluated by considering these data and appropriate materials should be used.

REFERENCES

[1] Günel G., Kılcı A., Ankara şehri 1924 haritası: Eski bir haritada Ankara'yı tanımak. Ankara Araştırmaları Dergisi n Journal of Ankara Studies, 2015, **3**(1), 78-104.

[2] Yenel A., Ankara Kalesi'ndeki Hatipoğlu Konağı için yeniden işlevlendirme önerisi. Ankara Araştırmaları Dergisi n Journal of Ankara Studies, 2015, **3**(1), 54-77.

[3] Erçin B., Bir tarih kenti: Ankara. TMH - Türkiye Mühendislik Haberleri Dergisi, 2000**, 5 (**409), 38-39.

[4] https://www.restorasyonforum.com/index.php?topic=2604.0 (accessed 28/12/2017).

[5] http://www.artrestorasyon.net/sss/103-restorasyon-nedir-.html (accessed 28/12/2017).

[6] Türk Standardları Enstitüsü, TS 699 Doğal yapı taşları - İnceleme ve laboratuar deney yöntemleri. 2016, Türk Standardları Enstitüsü, Ankara.

[7] Altaş G.K., Özgünler S.A., Güldal E., İstanbul'daki Roma dönemi saray yapılarındaki Horasan harçlarının incelenmesi. Vakıf Restorasyon Yıllığı, 2012, (4), 42-49.

[8] Pavia S., Caro S., An investigation of Roman mortar technology through the petrographic analysis of archaeological material. Construction and Building Materials, 2008, . 1807-1811.

[9] RILEM, Investigative methods for the characterisation of historic mortars. In Materials and Structures 2005, **38**, Part 1 and Part 2, 761-769, 771-780.

[10] Livingstone, R.A., Materials analysis of the masonry of the Hagia Sophia Basilica, İstanbul. Structural Repair and Maintenance of Historical Buildings 1993, **111**, 15-31, Computational Mechanics Publications, Southampton.

[11] Özkaya Ö.A., Böke H., İpekoğlu B., Roma dönemi tuğla ve harçların özellikleri: Bergama Serapis Tapınağı örneği. 3. Ulusal Yapı Malzemesi Kongresi ve Sergisi, 2006, İTÜ, İstanbul, 616-627.

[12] Ahunbay Z., Ersen A., Gürdal E., Acun S., Güleç A., Erdoğan M., Geçkinli A.E., Research on the characterisation and deterioration of the stones, brick and the khorasan mortars of the Tower 4 (T4) of the Land Walls of İstanbul (Constantinople). FORTMED, 2003, İTÜ Yayını, İstanbul.

[13] Başol B., Şahin M.O., Baykır M., Akıncı G., Riva Kalesi yapı taşları, sıva ve harçlarının petrografisi ve kaynak alanı. Restorasyon ve Konservasyon Dergisi, 2010, 24-30.

[14] Uğurlu Sağın E., Anadolu'da Roma dönemi yapı tuğlalarının özellikleri, Journal of the Faculty of Engineering and Architecture of Gazi University, 2017, **32** (1), 205-214.

[15] Anbalagan G., Mukundakumari S., Murugesan Sakthi K., Gunasekaran S., Infrared, optical absorption, and EPR spectroscopic studies on natural gypsum, /Vibrational Spectroscopy, 2009, **50**, 226-230.