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RIGA TECHNICAL UNIVERSITY
Architecture and Urban Planning
2023, Vol. 19, Issue 1, pp. 1–16
https://doi.org/10.2478/aup-2023-0001
https://content.sciendo.com
Online ISSN 2255-8764

Analysis of Cultural Heritage by Non-Destructive Methods: The Case of Sivas Congress Museum

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Received 2022-09-26; accepted 2023-02-03

Keywords

NDT (Non-destructive testing method), Schmidt Hammer Sivas Congress Museum, XRF.

Abstract

Analysis of cultural heritage by non-destructive testing methods allows conducting an examination of the building while preserving its authenticity and integrity, as well as its historical and artistic values. As the material of this study, the Sivas Congress Museum, which witnessed a very important event in the history of the country, was discussed. The aim of the study is to determine the stone type, deterioration, hardness, and strength of the building and thus generate an idea about the quality of architectural practices in the 19th century. In addition, it aims to create a scientific basis for conservation measures and restoration works to be carried out in the following years and to determine whether there is any difference between the stone material used in the main building and the stone of the building annexed later on. At the end of the study, it was concluded that the poor economic conditions of the country have affected the quality of the building material, the stones – soft and low-strength limestone – have been exposed to atmospheric pollution and deteriorated. In addition, although one of the stones that had undergone black crusting was cleaned, it was found that mechanical cleaning was insufficient to eliminate the pollution.

Introduction

In order to conserve the cultural heritage, it is sometimes necessary to carry out the restoration of the building. In order for a good restoration to be carried out, the building and its materials should be accurately analysed. For example, issues such as the construction technique of the building, the period in which it was built, the repairs it has undergone, the type of building materials used and whether they have deteriorated or not, and the amount of deterioration should be emphasized. For this purpose, many destructive and non-destructive test methods have been developed [1]. But destructive methods adversely affect the historical and artistic values of the building, as well as its authenticity and integrity. In particular, sampling inspection can cause tensional damage or even fracture to the construction materials [2].

Experts working on the conservation of cultural heritage have supported the use of non-destructive testing methods (NDT) in recent years [3], [4] because application of these techniques, structural stability and functionality are maintained without any intervention such as digging and drilling that disrupt the physical integrity [5], [6]. These techniques are used in order to identify archaeological assets buried under a heritage building [7]; determine the homogeneity, quality, or amount of deterioration of a building material [1], [8]; determine the morphology and cavities, moisture distributions, size of cracks; evaluate the injection made in the restoration of building elements [3]; observe the degree of damage to a building element damaged in an earthquake [5]; do origin analysis of archaeological artifacts [9], [10]; determine whether the gilding on the work is produced from real gold or another gold imitation material [11], [12], detect subsurface defects [13]; and investigate the compatibility of the original building material with the modern building material [14].

Some of the NDT techniques are X-ray fluorescence spectroscopy, holographic interferometry, infrared thermography, sonic/ultrasonic, electromagnetic and electrical techniques, and Schmidt Hammer Rebound (SHR) test; [1], [2], [5], [6], [8], [13]–[17]. In order for these

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techniques to be applied non-destructively, the devices must be portable and the work must be done in situ [18].

In this study, X-ray fluorescence (XRF) spectroscopy and Schmidt Hammer Rebound (SHR) test were used for the analysis of cultural heritage. For the material of the study, a cultural heritage extremely important for the history of the country located in the Sivas city centre of Turkey was discussed. This building, which hosted the historical Sivas Congress, is one of the landmarks of the war of independence that led to the liberation of the occupied country. It played a role in the formation of urban identity and social memory.

This study aimed to determine the type of stone, which is the main construction material of the building, deterioration, pollution accumulated on it, and hardness and strength of the stone. In addition, the study aims to understand whether the stones used in the construction of the main and additional buildings are different and whether they are brought from the same quarry. Thus, it is possible to take conserve measures for cultural heritage and to create data for restoration in a future period. With the data obtained one can also speculate on the quality of architectural applications. Another goal of the study is to encourage the spread of this practice by proposing NDTs during the conservation and restoration of cultural heritages.

I. Subject of the Study

The building, which constitutes the subject of the study, is an educational building bearing the characteristics of Late Ottoman Architecture and is used as a museum today. Located in the historical city centre of Sivas, the building is integrated with other public buildings in the historical city core, which is formed by the Government House, Gendarmerie building, *madrasahs*, and mosque (Fig. 1).

Located in block 332, parcel 4, to the southeast of the building is İnönü Boulevard (Istasyon Street), which is currently one of the main arteries of the city; to the northwest there is Kongre Street (Taşlı Road), where the original entrance of the building is located; to the southwest there is a small square created for the gathering of people, to the northeast there is Mustafa Kemal Atatürk Monument (Figs. 1 and 2). The other entrance into the building is from İnönü Boulevard, and this entrance, which overlooks the historical city square, has become the entrance of the museum today. In addition, there are secondary entrances to the basement in the northeast and southwest.

A. Brief History of the Building

The idea of building a high school was first expressed in 1879 by the Governor of Sivas, Zeynelabidin Pasha; however, this project was interrupted by financial inadequacies and the subsequent designation of the governor [20]. The short-term performance of the successor governors and the inability to solve the problems of financial resources delayed the construction process [21]. In addition to the construction costs of the building, the fact that the furnishing, teachers' salaries and annual expenses of *leyli* (boarding) schools were 5–6 times more costly than *nehari* (daily) schools increased the financial resource problem even more [22]. After the purchase of the land belonging to the Behram Pasha Foundation and the creation of financial resources [21], the construction of the building started in 1890 by the order of Memduh Pasha, the Governor of Sivas. Pasha

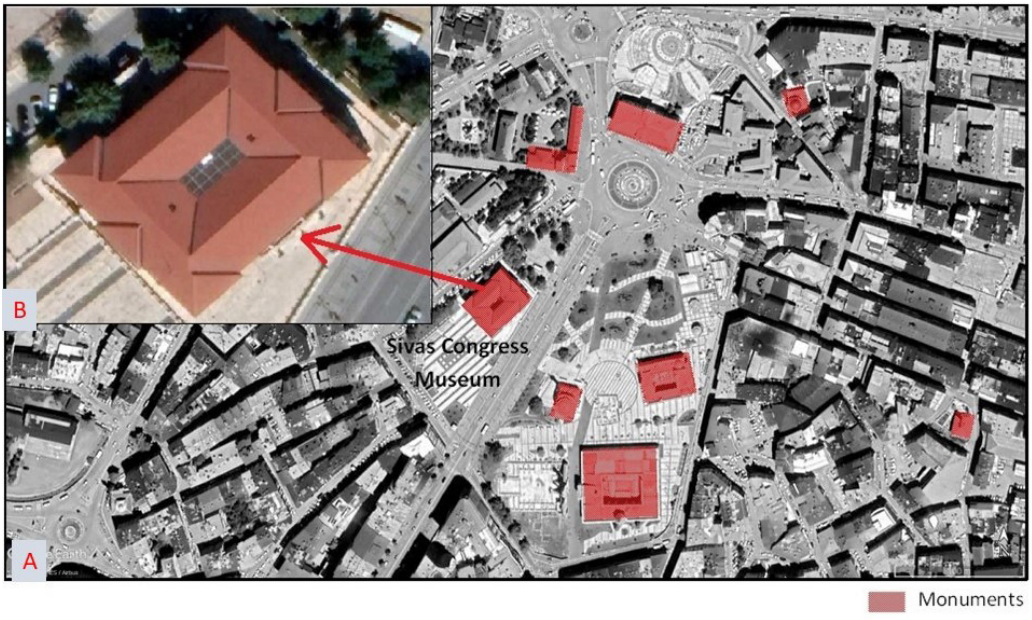


Fig. 1. A – Historical Centre of Sivas City [19]; B – Location of Sivas Congress Museum [19].

created a commission for the supply of building materials such as stone and wood [20], [23]. The construction in its rough form, as indicated in the inscription, was completed in 1892 [24]; however, it remained deficient due to financial inadequacies. Moreover, the cost of the building exceeded the value stated in the reconnaissance notes. Chief Provincial Engineer Mehmet Sami was assigned to identify the deficiencies and problems and he drew a renovation project. In the renovation initiated in 1902, the eaves were changed to prevent water flowing from the roof, chimney holes were drilled for the stove, the deficiencies in the toilets, doors, windows, staircases, and garden walls were eliminated, the deficiencies in the bath and kitchen were corrected, and the painting and whitewashing works were carried out [21]. In 1913, the high school took the name Sivas Sultanisi and continued performing as an educational building. After 1916, the building was used as a military hospital and then as a small officer school due to the war [25], [26].

Mustafa Kemal Atatürk, the commander-in-chief of the national struggle and the founder of the Republic of Turkey and his friends came to Sivas on September 2, 1919, and were accommodated in this building. The congress, which was held on 4–11 September 1919, was attended by delegates from various parts of the country. During this time, there were heated debates on the issues of mandate and patronage, independence, and national struggle. At the end of the congress many decisions were taken; the main theme of decisions was full independence. With this congress, the foundations of the newly established state of the Republic of Turkey were laid [21], [27], [28]. From this point of view, this building is extremely important in terms of the history of the country.

After the Sivas Congress, the building was used as an orphanage to accommodate the girls orphaned after the war. In 1924–1925, the building was converted to its original function and started to be used as a high school again [21], [29]. In 1930, annexe buildings such as kitchens, baths, cellars, and the castle wall were demolished. In 1933, a hostel building was built for boarding students [20]. In 1981, the President of the Republic decided to turn the building into a museum. As mentioned above, the building, which is important in terms of the history of the country, has been registered as a cultural asset that needs to be conserved by the decision of the Council for the Conservation of Cultural Property dated 22.07.1983 and numbered A-4468 [30], [31]. In addition to its historical and artistic value, the fact that it has a memorial value has been effective in registering the building. In the period from 1983 to the present day, both the restoration of the building, the exhibition and arrangement of the museum, as well as the area where it is located together with the Atatürk Monument and the area to the southwest from it have been rearranged several times.

B. Architecture of the Building

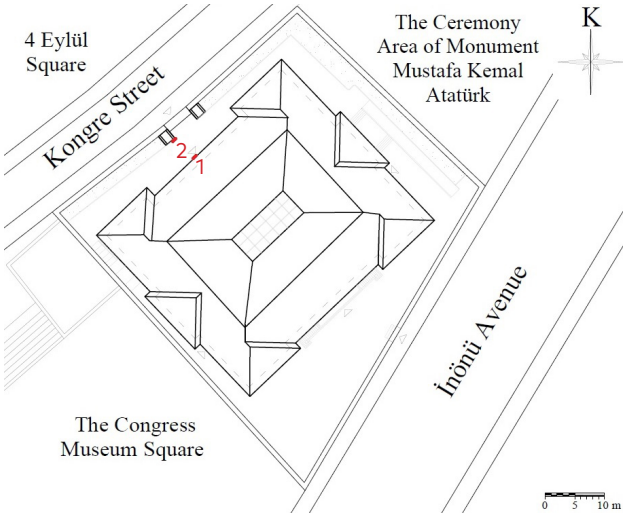
Grand Vizier Said Pasha [22], who was closely interested in the education system of the country, brought high school plans from France and sent sample plans all over the country. Although their size varies according to capacity and program, the general characteristics of the plans are similar to each other [32]. High school plans developed in the form of a typical project generally have a planning scheme that develops around the corridor or an internal courtyard plan scheme. The plans of Isparta, Kayseri, Yozgat, and Kırşehir high schools are examples of the plan type developed around the cross-like corridor, Adana and Kastamonu high schools are examples of the plan type developed around the T corridor, Sivas and Thessaloniki high schools are examples of the interior courtyard plan type [33], [34].

Sivas High School has a rectangular and symmetrical plan. There are two symmetrical stairs to the northeast and southwest of the plan, and classrooms are located to the right and left of the staircase. Stairs ascending to the landing from two symmetrical flights reach the upper floor with a single flight from the middle of the landing (Fig. 2).

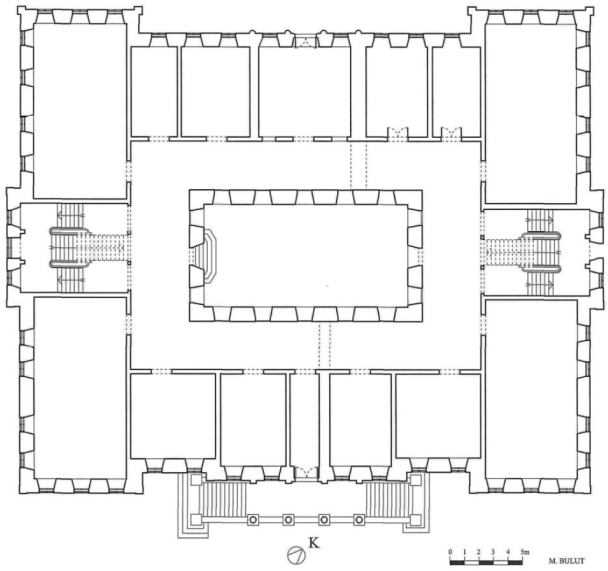
The wooden stair railings are adorned with stylized floral motifs with S and C curves. The ceilings of the corridors led by the stairs have pinwheel motifs. At the entrance to the stairs, there are wooden struts with stylized floral decoration and circular arches. The walls and ceiling of the room where the congress is held are decorated as hand-drawn. There are panels decorated with flowers on the wall and garland and curtain motifs on the ceiling [35].

The building is built on sloping land and the northwest is designed to have two floors and the southeast to be three-storey with a basement. The windows in the basement and ground floor are semicircularly arched; the windows on the upper floor are made with a triangular pediment over the flattened arched jamb. At the corner turns of the facades, there are pseudo columns with rectangular sections on the plaster column base, and to the right and left of the entrance door, there are pseudo columns with circular sections on the plaster column base. The profiles on the column headings and column bases continue as floor moldings. A lozenge motif was made in the areas formed by the moldings continuing on the column base level on the ground floor, and an empty cartridge was made in the area formed by the moldings on the upper floor. The finish of the façade is designed on an architrave and a rectangular embossed frieze and a cornice on top of them. Although the initial design of the roof was in the form of a roof parapet, it was later converted into a hip roof.

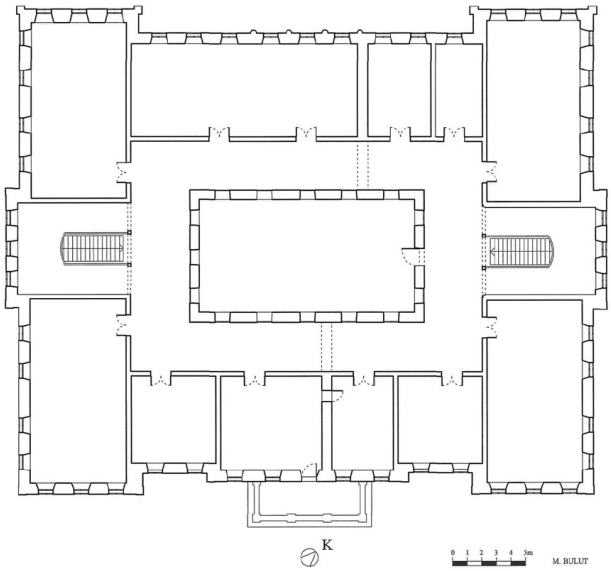
When İnönü Boulevard was opened in 1930, an entrance was opened from this direction at the ground floor level [20]. The entrance is reached by two symmetrical stairs from the right and left. This area is designed as a balcony of the first floor placed on the Tuscan order columns.



a



b



c

Fig. 2. a – The layout sketch of the building; b – the ground floor plan of the building [34]; c – the first floor plan of the building [34].



Fig. 3. The northeast and northwest sides of Sivas High School in 1892 [21].

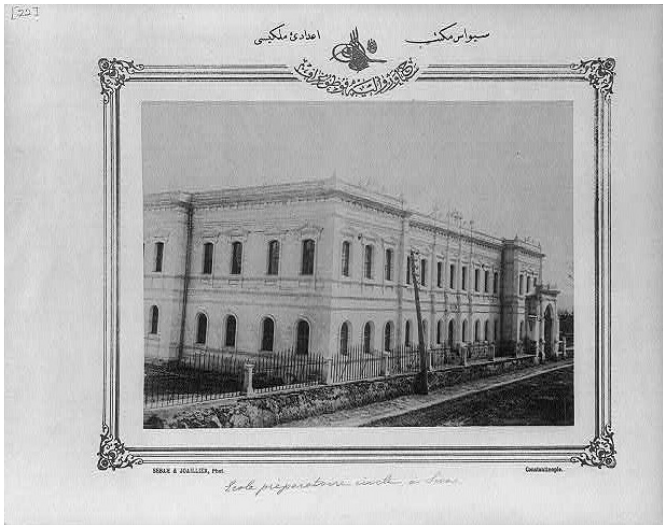


Fig. 4. The northeast and northwest sides of Sivas High School in 1893 (?) [36].



Fig. 5. The northeast and northwest sides of Sivas High School before 1902 [37].



Fig. 6. a – The location of Stone-1 [by the author]; b – the location of Stone-2 [by the author]. For the NDT analysis, which is the subject of the study, the rectangular surface of the plaster column base at the original entrance of the building in the northwest was examined (Fig. 6 a). The reason for choosing this place is that this part was built during the initial construction phase. This example is named Stone-1. Another example is a stone at the entrance of the garden that belongs to the spaces built later (Fig. 6 b). This stone is named Stone-2.

The garden gate with the original entrance is designed in a plaster column base, column, column head, architrave, triglyph-metope frieze, and cornice layout. The doorway is crossed by a semicircular arch. The garden walls were formed on a low parapet formed with ashlar masonry, with small stone posts and iron railings attached between the posts. There are two symmetrical enclosed spaces just to the right and left of the garden gate. The cornerstones of these spaces, which are made of ashlar, are more embossed than the surface, as in bossage walls. In the area between the rectangular jamb circulating the windows in the Neogothic style and the window, there is a decoration resembling an oyster, and around this decoration, there are S and C folds. In this decoration, the acanthus leaf emerging from a vase and the curving branch motifs pouring around it are seen. The roof cover of the places where more baroque effects are seen is also a profiled vault roof.

It is thought that these spaces, which are designed differently from the main building in terms of architectural style, may have been built later. In addition, the photograph dated December 13, 1892, taken after the completion of most of the construction, and the photograph taken in 1893 (?), do not contain these places (Figs. 3 and 4); however, the photograph taken before 1902, the first renovation of the building, shows these places (Fig. 5).

II. Method

C. X-ray Fluorescence (XRF) Spectroscopy

In X-ray fluorescence (XRF) analysis, which constitutes the method of this study, the object is exposed to photons emanating from an X-ray tube. The primary X-ray stimulates the electrons and causes the secondary beam (fluorescence) to be emitted. This secondary X-ray appears in the spectrum, creating peaks at energies specific to certain elements, and in this way the elements can be detected [38], [39].

In traditional XRF spectrum analysis in a laboratory setting, sampling is required. Sampling is a process that causes little damage to the building and requires meticulousness. In addition, the process of grinding and screening the sample takes time and requires effort [39]. Portable X-ray fluorescence (p-XRF), which is used today instead, is widely used on cultural heritage items as it allows for on-site and non-contact analysis [9]–[10], [40]. Despite this, p-XRF is sensitive to certain elements, small particle sizes, surface roughnesses, weather, and water content [39], [41]–[43]. The advantages are that it is harmless, fast, easily applicable and has a good spatial resolution, is not invasive, and requires minimal preparation [39], [44], [45].

P-XRF while explaining what the object under study is, at the same time helps answering questions about the origin of the object. In this regard, it can be said that the XRF analysis method has proven its reliability and validity for many years and is used in preliminary work before the restoration of cultural heritage [39], [44]–[46].

In this study, Thermo Scientific brand, Niton XL3 model p-XRF device was used. Thanks to its portability, contactless data was collected from a distance of 1 mm from the surface, without the need to take any samples from the work. A sunny day without precipitation was preferred for the application, and since the instantaneous air temperature was 30 °C and the wind was 12 km/h from the south, it is out of the question that the measurement was affected by humidity [47].

D. Schmidt Hammer Rebound (SHR) Tests

By sampling the building, the UCS value can be measured directly in the laboratory, thus obtaining accurate results. However, since sampling is an act that harms cultural heritage, NDTs should be preferred as much as possible [48], [49], [50].

The Schmidt hammer is a non-destructive and portable method of examination [1], [51], [54] that consumes a certain amount of stored energy from a spring and shows the degree of rebound of the hammer in the process. The hammer, developed by Ernst Schmidt to measure the compressive strength of concrete, was later used on rocks [55]–[57]. Schmidt hammer rebound (SHR) tests allow the determination of the estimation of uniaxial compressive strength (UCS) values and hardness and strength classes of the stones [54], [58]–[62].

Different types of hammers are produced for SHR tests. L-type hammers are used only on weak rocks. N-type hammers produce greater impact energy and can be used in solid rocks [50], [56], [62], [63]. Within the scope of this study, a JE IL Precision Industrial Instrument brand, JI-355 model N type Schmidt hammer, was used. The Stone-1 and Stone-2 of the wall were hit 10 times at right angles. The rebound values from the hammer test were recorded.

III. Findings and Discussion

E. X-ray Fluorescence (XRF) Spectroscopy

The XRF spectrum of Stone-1 and Stone-2 were graphically presented in keV. From the data obtained as a result of XRF analysis, the concentration of the elements was calculated and converted into a graph. The elements that could not be detected in the analysis were not included in the graph and the results were prepared according to ppm (Figs. 7–10).

When the logarithmic elemental concentration graphs and XRF spectrums obtained as a result of XRF analysis are evaluated, it can be said that the concentration rates of the elements of the two stones are very close to each other. Accordingly, since the elements of both stones have

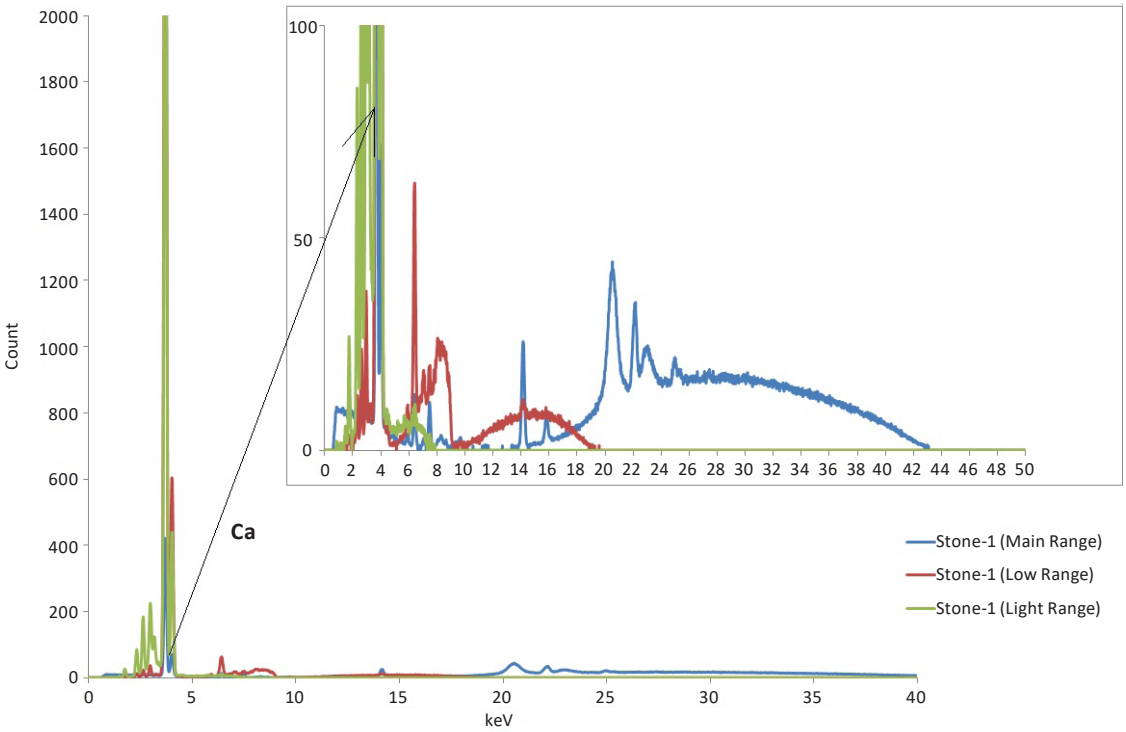


Fig. 7. XRF spectrum of Stone-1 [by the author].

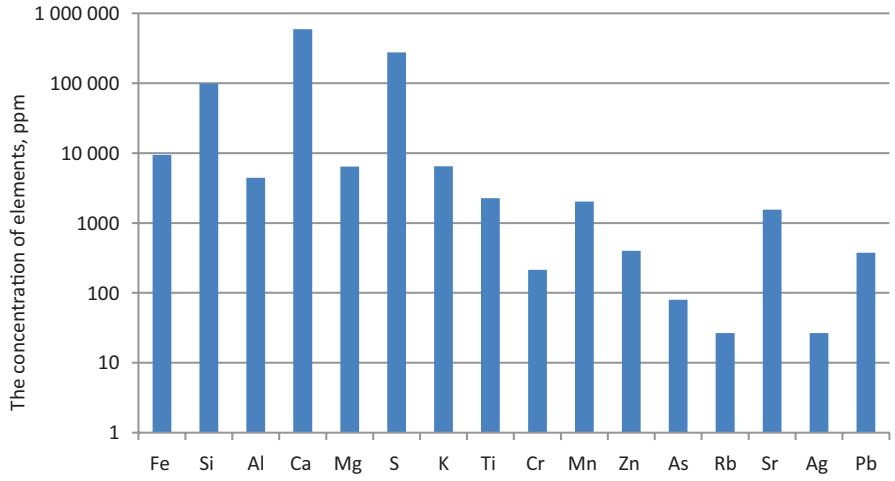


Fig. 8. Logarithmic graph showing element concentration of Stone-1 [by the author].

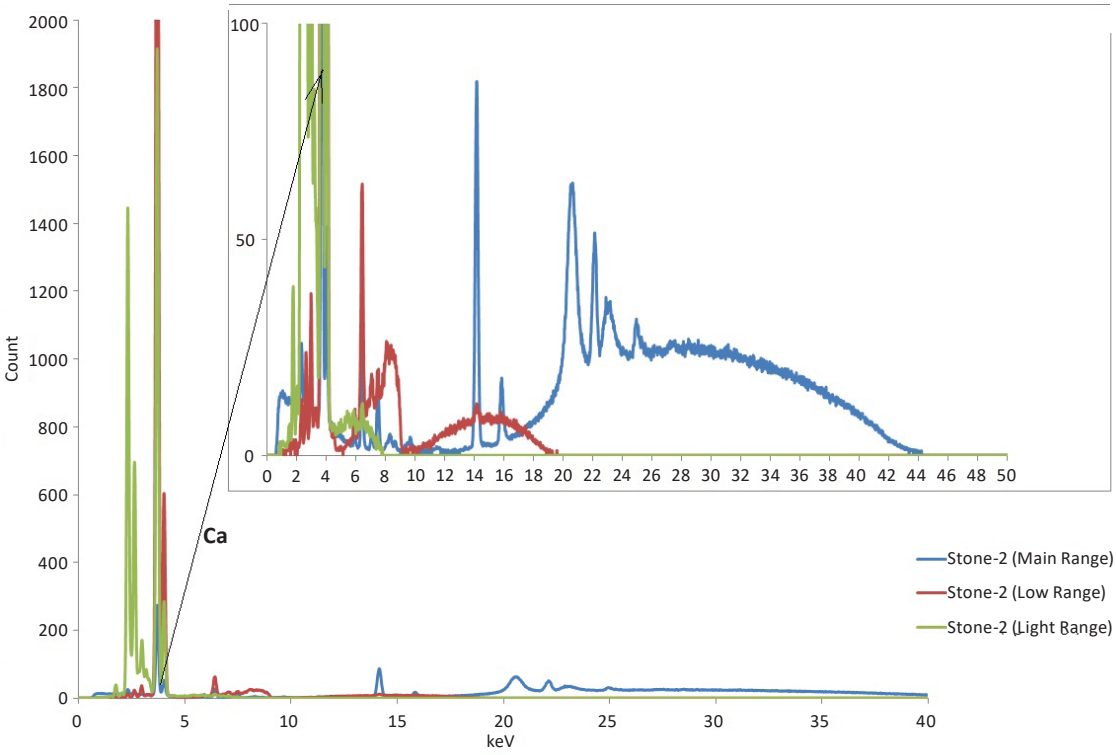


Fig. 9. XRF spectrum of Stone-2 [by the author].

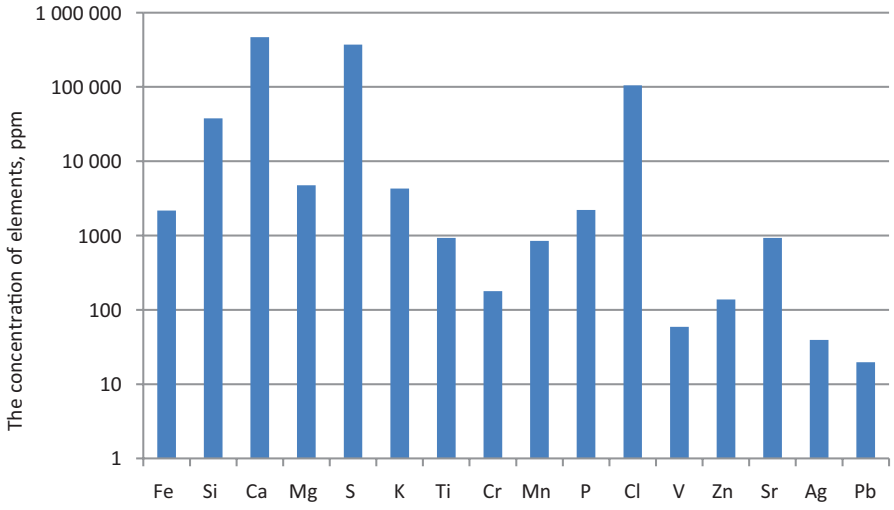


Fig. 10. Logarithmic graph showing element concentration of Stone-2 [by the author].

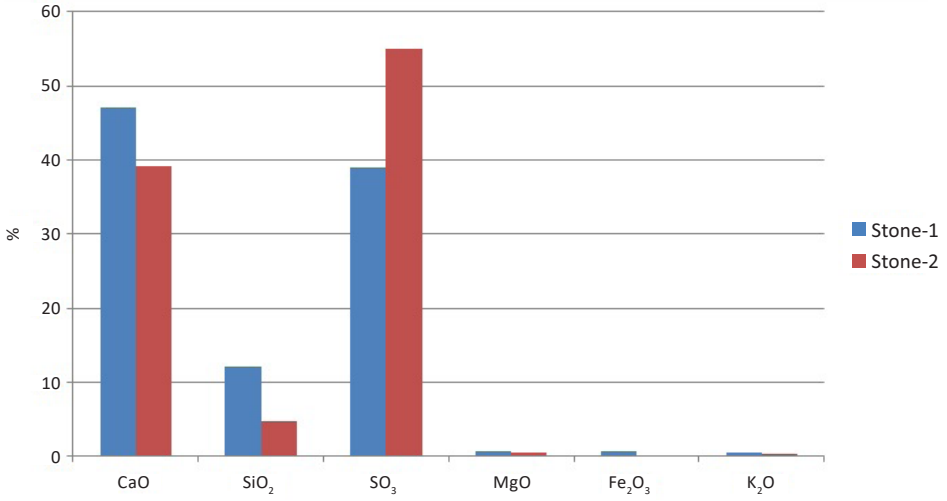


Fig. 11. Proportions of oxidized compounds of Stone-1 and Stone-2 [by the author].

high Ca ratios in the percentage distribution and Mg ratios are around 0.5–0.6 %, it is concluded that the stones are limestone, not dolomite (Figs. 7–10).

It was detected that there was 59.2 % of Ca element in Stone-1 and 47 % in Stone-2. Since the XRF instrument is a device that can only measure the elements on the surface of the stone, the accumulation of Ca on the surface or deep inside affects this percentage change (Figs. 7–10).

When minerals such as Fe and Mn, which give the stone its colour, are examined, the ratio of Fe element is 0.9 % and 0.2 %; the ratio of the Mn element is 0.2 % and 0.1 %, respectively. Since these minerals are in trace quantity, they do not cause visible colour differences in white limestone. The fact that the Si ratios are 9.9 % and 3.8 % (Figs. 8 and 10) indicates that these stones are limestone with silica content.

The CaO ratios of stones are 47 % for Stone-1 and 39 % for Stone-2 (Fig. 11). CaO ratios of other limestones in Turkey were investigated and compared. Accordingly, in general, the CaO ratio for both Stone-1 and Stone-2 appears to be lower than the proportions of other limestones in the literature (Table I). Despite this, the CaO ratio for both stones is higher than the SiO_2 ratio (Fig. 11). Compounds such as MgO, Fe_2O_3, K_2O are found in close proportions to each other in both stones. Since these compounds are found below 1 %, they do not add any characteristic features to Stone-1 and Stone-2 (Fig. 11).

In the analysis, the amount of SO_3 was high for both stones (Fig. 11). SO_3, the most important compound of acid rain, is formed as a result of the combustion of sulphurous fuels [74], [75]. Since fossil fuel consumption is greater than in the years when our architectural heritage in the city centre was built, air pollution affects heritage buildings extremely quickly [76]. This situation also explains why the amount of SO_3 is high in the stones of the buildings in the city square. Although there have been efforts in recent years to reduce air pollutants, such as the use of fuels with low sulphur content in industrial and domestic heating and the use of some electric transport vehicles [77], fuels commonly used in most means of transport cause the formation of sulphurous compounds and some pollutant particles. If calcium carbonate, the main ingredient of carbonated stones, is exposed to these acidic pollutants (especially sulphurous compounds), sulphatisation occurs. On the surface where the sulphatisation occurs, a

TABLE I

Comparison of CaO Ratios of Stones with Other Limestone CaO Ratios in the Literature [created by author using [64]–[73]]

CaO ratio of limestone samples in the literature, %		CaO ratio of Limestone-1: 47 %	CaO ratio of Limestone-2: 39 %
According to Kumral et al. (2019) [64]	Avg. 51.2	Below average	Below average
According to Sert et al. (2017) [65]	53.3–58	Below the limit	Below the limit
According to Çobanoğlu et al. (2011) [66]	52.6–55	Below the limit	Below the limit
According to Elçi et al. (2014) [67]	37.5–55	Within the range	Within the range
According to Yılmaz et al. (2011) [68]	55.16	Below average	Below average
According to Gözübol et al. (2008) [69]	38.78–54.58	Within the range	Within the range
According to Evcin et al. (2018) [70]	51.4	Below average	Below average
According to Atılgan (2004) [71]	53.1	Below average	Below average
According to Gökay (2011) [72]	55.4–55.7	Below the limit	Below the limit
According to Akyol et al. (2011) [73]	56.2	Below average	Below average

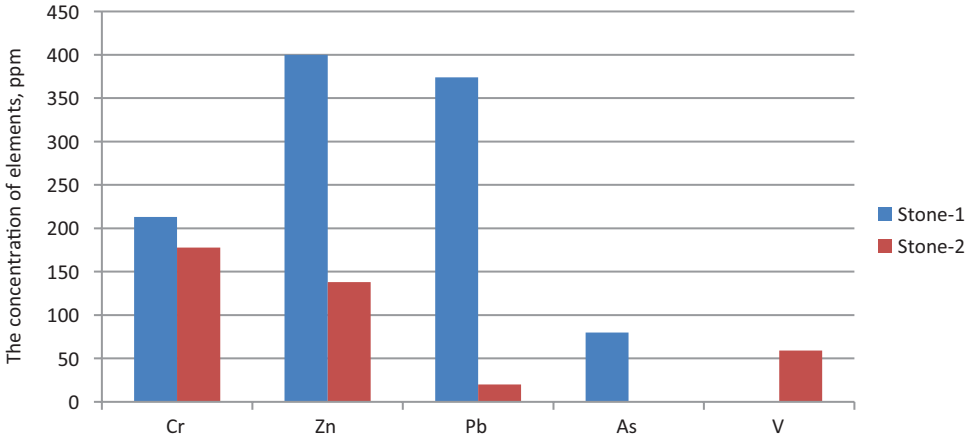


Fig. 12. Heavy metals accumulated on stones [by the author].

heterogeneous layer is formed, which is defined as a black crust and whose typical colour is black [76], [78]–[83]. Sulphur dioxide is one of the compounds that make up the black crust. In addition, the sulphur contained in the carbon particles also participates in the formation process of the crust [78], [82]. The heavy metals and combustion particles contained in the black crust also act as catalysts, causing the process to accelerate and the resulting black crust layer to separate from the stone surface [76], [84].

In research conducted in black crusts, Ca, S and Si are found in high concentrations, while some heavy metals such as As, Ba, Cd, Sb, Pb, Zn, Cu, Ni, Cr, and V can be found in trace amounts. The presence of these metals is associated with pollution caused by the consumption of fossil fuels, mechanical friction of parts of transport vehicles, or abrasion of asphalt [76]–[78].

In the analyses carried out within the scope of the study, some of the heavy metals mentioned above were identified (Fig. 12). Since leaded gasoline was used in Turkey until 2004, Pb and Zn may have accumulated due to the consumption of leaded gasoline [76], [85]. In addition, the parts formed as a result of the abrasion of the tire also constitute a Zn source to the environment [86]. Diesel, oil combustible, and gasoline consumption increase the concentration of trace metals such as As, Cr, and V in the atmosphere [76], [85]–[88]. Due to this pollution accumulated in the atmosphere, these elements were found on the stone surfaces examined.

F. Schmidt Hammer Rebound (SHR) Tests

Researchers offer different recommendations regarding the evaluation of the rebound number of the Schmidt hammer. In most assessments, suspicious values that are too large or too small are excluded and the rest are re-averaged [89]–[93].

Within the scope of this study, each stone was hammered 10 times with the Schmidt hammer in accordance with ASTM. The averages of the obtained values were taken. Values that were ±7 units below and above the average were discarded and the rest are re-averaged [90]. The obtained data are included in Table II.

In the literature, developed formulas for the conversion of the SHR value of limestone to UCS value have been investigated. The estimated UCS values obtained according to the formulas were averaged. Just as in the SHR value evaluation criterion of ASTM, values that are ±7 units below and above the average are discarded. Accordingly, the estimated UCS values are re-averaged and written in the Table III.

TABLE II

Estimated UCS Values by SHR (MPa) [created by author using [94]–[98]]

Stone samples	The average SHR value	Conversion of SHR value to UCS, MPa				
		Calculation as of Katz et al. (2000) [94]	Calculation as of Kahraman (2001) [95]	Calculation as of Fener et al. (2008) [96]	Calculation as of Kılıç and Teymen (2005) [97]	Calculation as of Yagiz (2009) [98]
Stone-1	18.3	8.0	13.9	12.5	10.1	5.1
Stone-2	31.0	19.4	22.5	26.4	33.5	20.0

TABLE III

Rock Strength Classes According to Estimated UCS Value and The Average of SHR Value [created by author using [56], [59]–[61], [110]]

Stone samples	Estimated UCS value, MPa	The average SHR Value	Rock strength class as of Deere and Miller (1966)* [56]	Rock strength class as of Selby (1980)** [59]	Rock strength class as of ISRM (1981)* [60]	Rock strength class as of Waltham (2009)* [61]	Rock strength class as of Karaman and Kesimal (2013) [110]
Stone-1	10	18	weak (less than 34)	Very weak rock (10–35)	Weak (5–25)	moderately weak rock (5–12,5)	Very low strength (1–25)
Stone-2	24	31	weak (less than 34)	Very weak rock (10–35)	Weak (5–25)	moderately strong rock (12.5–50)	Very low strength (1–25)

* In the related literature, classification is made according to UCS value.
** Since there is classification according to SHR value in the relevant literature, this value is taken as a basis.

TABLE IV

Rock Hardness Classes According to Estimated UCS Value and the Average of SHR Value [created by author using [99]–[100]]

Stone samples	Estimated UCS value, MPa	Average SHR value	Rock hardness class according to China (1995) [99] and Wang et al. (2017)* [100]
Stone-1	10	18	Soft rock (5–15)
Stone-2	24	31	Moderately soft rock (15–30)

* In the relevant literature, classification was made according to UCS value.

TABLE V

Comparison of Estimated UCS Values with Other Limestone UCS Values in the Literature [created by author using [48], [64], [66], [101]–[109], [111]]

UCS values of limestone samples in the literature, MPa		Estimated UCS value of Limestone-1: 10, MPa	Estimated UCS value of Limestone-2: 24, MPa
According to Teymen (2020) [101]	40.9–140.9	-	-
According to Erözmen et al. (2020) [102]	19–24	-	Within the range
According to Kumral et al. (2019) [64]	Avg. 8.3	Within the range	Within the range
According to Şahin Güçhan et al. (2019) [103]	43.55–81.06	-	-
According to Ünal and Beyaz (2019) [104]	7.40–16.20	Within the range	Over the limit
According to Şahin (2018) [105]	14.76–75.07	-	Within the range
According to Koç et al. (2014) [106]	Avg. 13.,97	Within the range	Within the range
According to Karaman and Kesimal (2012) [107]	7.7–18.9	Within the range	Over the limit
According to Dipova (2012) [108]	12.14–116.20	-	Within the range
According to Tüysüz (2012) [109]	15.4–66.1	-	Within the range
According to Çobanoğlu et al. (2011) [66]	Avg. 71.25	-	-
According to Karaman et al. (2011) [48]	8.19–18.85	Within the range	Over the limit
According to Ocak (2008) [111]	Avg. 41.01	-	-

A literature review was conducted on the strength and hardness classification of rocks. Accordingly, it seems that researchers and various standards offer different classifications from each other. In general, Stone-1 and Stone-2 can be said to be weak rocks with low strength. Waltham (2009) gives a different classification and state that Stone-1 is moderately weak rock and Stone-2 is moderately strong rock [61]. According to the hardness classification, Stone-1 is soft; Stone-2 can be said to be moderately soft (Tables III and IV).

The UCS values of some limestones in Turkey have been converted into a researched value range and included into tables. It is indicated in the table whether the limestones of the examined building are suitable for this value range (Table V).

Conclusions

In order to make the appropriate restoration, it is necessary to make accurate analyses of historical buildings. For this purpose, the analysis can be performed by taking samples from the building; however, these methods damage the building. Using NDTs instead will give more accurate results in terms of conservation principles. In this study, the elemental analysis of the stone in the Sivas Congress Museum with non-destructive p-XRF methods and the evaluation of oxidized compounds were made.

Accordingly, it was determined that the stones used in the building were limestone. It is seen that elements such as Mg, Fe, and Mn, which add characteristic features to the stone, are contained in trace amounts. Due to the Si content of the stone, it is understood that it is siliceous limestone. The high amount of SO_3 indicates that the stones are affected by air pollution. In addition, heavy metals caused by air pollution have also been encountered in the stone. In the formation of this pollution, as mentioned above, fossil fuel consumption, particles broken down as a result of friction in vehicles, and asphalt abrasion are effective. For this reason, the roads around the Congress building should be urgently closed to traffic and pedestrianized, and the use of electric vehicles in the city should be encouraged as much as possible.

It is understood that both of the two stones examined underwent black crusting; however, Stone-1 appears white and Stone-2 appears black (see Fig. 6). The reason why the colours of the two stones look different is that the surface of Stone-1 was removed a little during the previous façade cleaning (sandblasting). Although its surface has been stripped by mechanical cleaning, the amount of SO_3 in the analysis is quite high. Although the surface is mechanically cleaned, it raises the question of whether the removal of the black layer is sufficient for sustainable preservation in black crusting, which is a chemical transformation process of limestone.

Another NDT method used in the study is the SHR test. According to the test result, Stone-1 is softer and less strong than Stone-2. Since Stone-1 is a stone close to the foundation level of the main building, the load on it is greater than that on Stone-2. This may have caused Stone-1 to become a weaker stone. The estimated UCS values of the stones were compared with the UCS values of other limestones in Turkey, and it was observed that the values are close to the values throughout the country, with some exceptions.

In addition, the hardness and strength classes of the stones were determined by the SHR test. Accordingly, the strengths of Stone-1 and Stone-2 were weak/moderately strong. The fact that the amount of CaO in XRF analysis is less than in other limestone samples in Turkey adversely affects the strength of the stone. As mentioned above, it is known that the economic situation of the Ottoman Empire was bad during the period when the building was built. As a natural consequence of this situation, it can be said that the quality of building materials decreased.

Acknowledgements

I would like to thank Associate Professor Metallurgical and Materials Engineer Dr. Ali ÖZER, Director of Sivas Archaeological Museum, MA Ali ALKAN, and Ph.D. Erdener Pehlivan, who did not spare their support in carrying out these studies.

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