Physico-Chemico-Mechanico-Petrographic Characteristic and SEM-EDX Analysis of Conservative Materials in the Süleymaniye Complex- Examples of Tabhane and Darüşşifa Building

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ABSTRACT
This study focuses on historical construction materials, such as mortar, stucco, clay brick, and fine aggregate, in the Tabhane and Darüşşifa building, the Süleymaniye complex. Aim of this research is to examine chemical, petrographic, physical, mechanical, and SEM-EDX (Scaning Electron Microscope-Energy Dispersive X-Ray Analyser) characteristic of historical construction materials in the Süleymaniye Mosque. This study uses historical mortar, stucco, fine aggregate, and brick samples in order to compare their characteristics each other. Tested chemical properties are clor (Cl^{-1}) content, sulfat content (SO_4), carbonat content (CO_3), nitrat oxide (NO_3) content, soluble salt content, analyse of protein, analyse of oil, loss on ignition, acid treatment, and conductivity on the whole historical construction materials as the spot tests. The polarizing microscope and stereo microscope observes the petrographic analysises of mortar, stucco, and aggregate. The SEM-EDX analysis is performed on historical stucco samples. Moreover, the physical and mechanical tests, such as granulometry, water absorption, density and compressive strength, are carried out on fine aggregate and historical clay brick. In the light of Tabhane and Darüşşifa building material spot result, the historical construction material samples contain hydraulic lime binder which is dosage between 25-40%, clor (Cl^{-1}) content, sulfat content (SO_4), carbonat content (CO_3), nitrat oxide (NO_3) content, and soluble salt content at minor level, protein as egg white content, brick dust and quars as pozzolanic additive, which is used in the mixing, and no oil in mortar and stucco samples. SEM-EDX analysis indicates that the stucco samples have trace elements of aluminum, silicon, sulfur, calcium, oxygen, and iron as well as sodium and magnesium element. Compressive strength average of the burned clay brick is 16,3 (MPa). As concluded in the study, the Süleymaniye complex has got proper conservative material quality and technique of design and architectural knowledge applied during building and restoration period.

Keywords: Material of historic building, Spot analysis, Chemical properties, Petroghraphic properties, Physico - Mechanical properties, SEM-EDX analysis

1. INTRODUCTION
The Süleymaniye social-complex which includes Mosque, Tabhane (a madrasa), Darüşşifa (a hospital), library, kitchen, and hospice for the poor people, hamam, and buildings of shop was built by great Ottoman Architect Sinan for Sultan Süleyman I the Magnificient on the Golden Horn side where is a European part of the Bosphorus. As the Mosque is classified by the most known source as an symbol structure, it is certain that the Mosque carries the Ottoman signs on the world architecture development. It is estimated that the complex was built at the mid of 16th century with the use of materials from nearby structures of Ottoman or even earlier periods.

Furthermore, the buildings of Darüşşifa (Hospital) and Tabhane (Accommodation Building) occurred the topic of the article in the Süleymaniye complex was built by Architect Sinan for the Süleyman Ist (the Magnificant) between 1553 and 1559 years (Barkan, 1972, Çelebi, 2003). As seen in the Fatih Social-Complex was built by the

Mehmet IInd in the 15th century, the buildings community, as the mosque being in the middle, occurred in the Süleymaniye social-comlex were placed in a slopping land in a geometrical range. As to north of mosque and madrasa, the Tabhane (Accommodation Building), the Public kitchen- entitled İmaret as Turkish name and the Darüşşifa (Hospital) were placed at the begining of the north east as seen in Figure 1. The Darüşşifa building which includes the period of the Ottoman Classical Architecture, was different from other Darüşşifa buildings which were built until 16th century, had two yards. In other words, other Darüşşifa buildings built before 16th century had one yard. Before opening the Hospital of Bezmialem Valide Sultan in 1843, the Darüşşifa of Süleymaniye complex was proceed its function as hospital, after that date the building was transformed a hospital which only serves mental illnesses and then the building was used as Saraçhane mall which was sold horse equipment for a while (Gürkan, 1966).

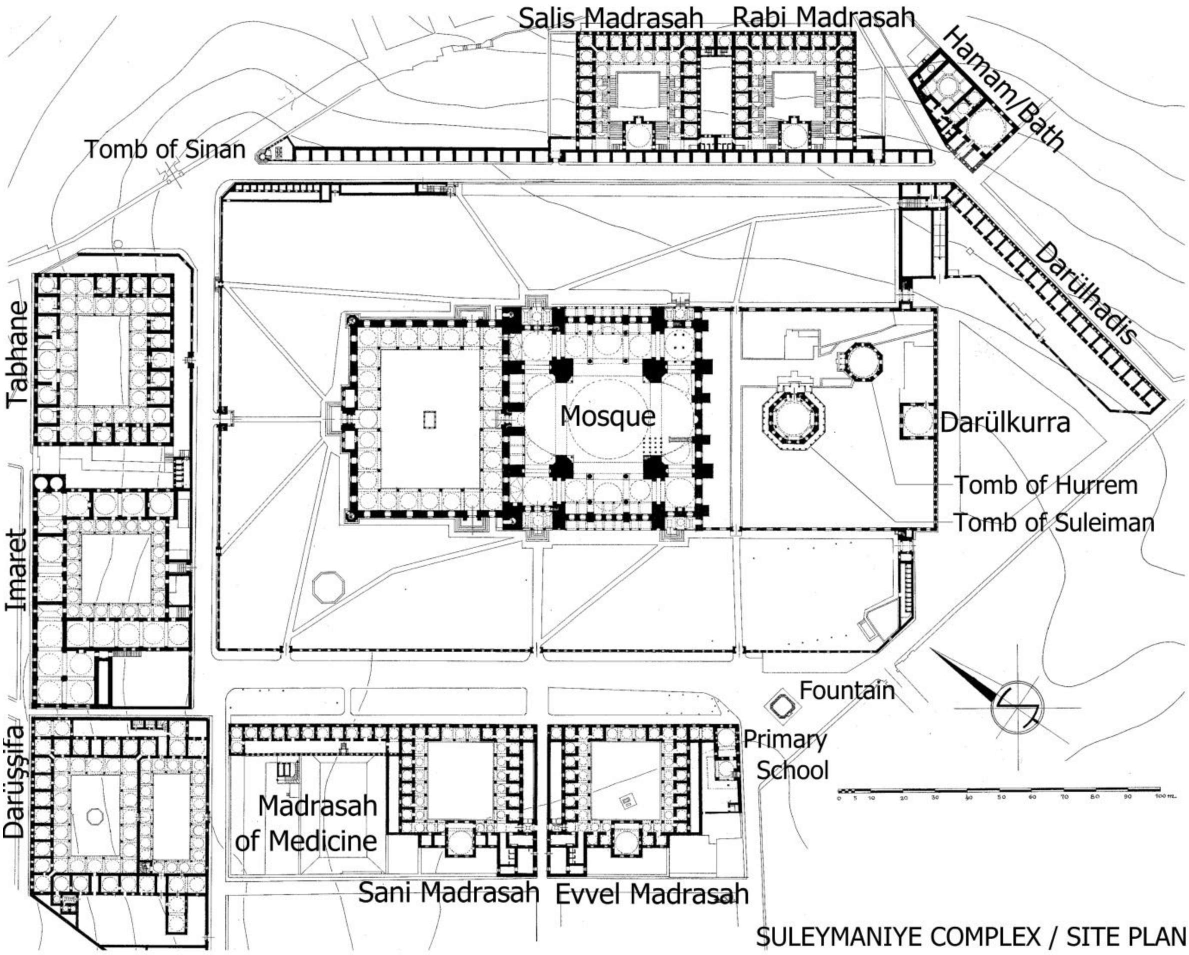

Figure 1. Site Plan of the Süleymaniye Complex and Darüşşifa (Hospital) – Tabhane (Accomodaion Building) in Istanbul

As its epitaph entitled "Press of Army", the Darüşşifa building was transferred the Ministry of Defense in 1887, and the building proceeded its press function as of the 1972 years. After 1974 years, the building was used as the dormitory for girls. In the Süleymaniye social complex which was built between 1553 and 1559 years as social complex of classical Ottoman period, while the entire madrasas, except the Darüşşifa and the Medicine, were planned in the schema of conventional madrasa project, the Darüşşifa building were built in the schema of double madrasa plan project which was placed spaces outer of the yard. The plan as its schema was shown similar feature for Kayseri Gevher Nesibe Hatun Hospital and Gıyasiye Medicine Madrasa where is the close each other (1205). The Darüşşifa which consisted of two square yards has spaces for doctors, administration, drugstore, and kitchen in the first yard. The spaces for bedridden paitents are placed in the second yard of the Darüşşifa building. Paitents of mental illnesses are treated in a ward which is placed in the basement floor of the first yard in the Darüşşifa building. A Turkish bath which serves paitents is in the north west of the Darüşşifa building, this information exists both the text of foundation and in-situ note-book. Due to the slopping land of the Darüşşifa building, the-two-floor space, which was used as the Accommodation- first floor for animal and second floor for the accommodation of the relevant of paitent is occurred in the Darüşşifa building as seen in Figure 2.

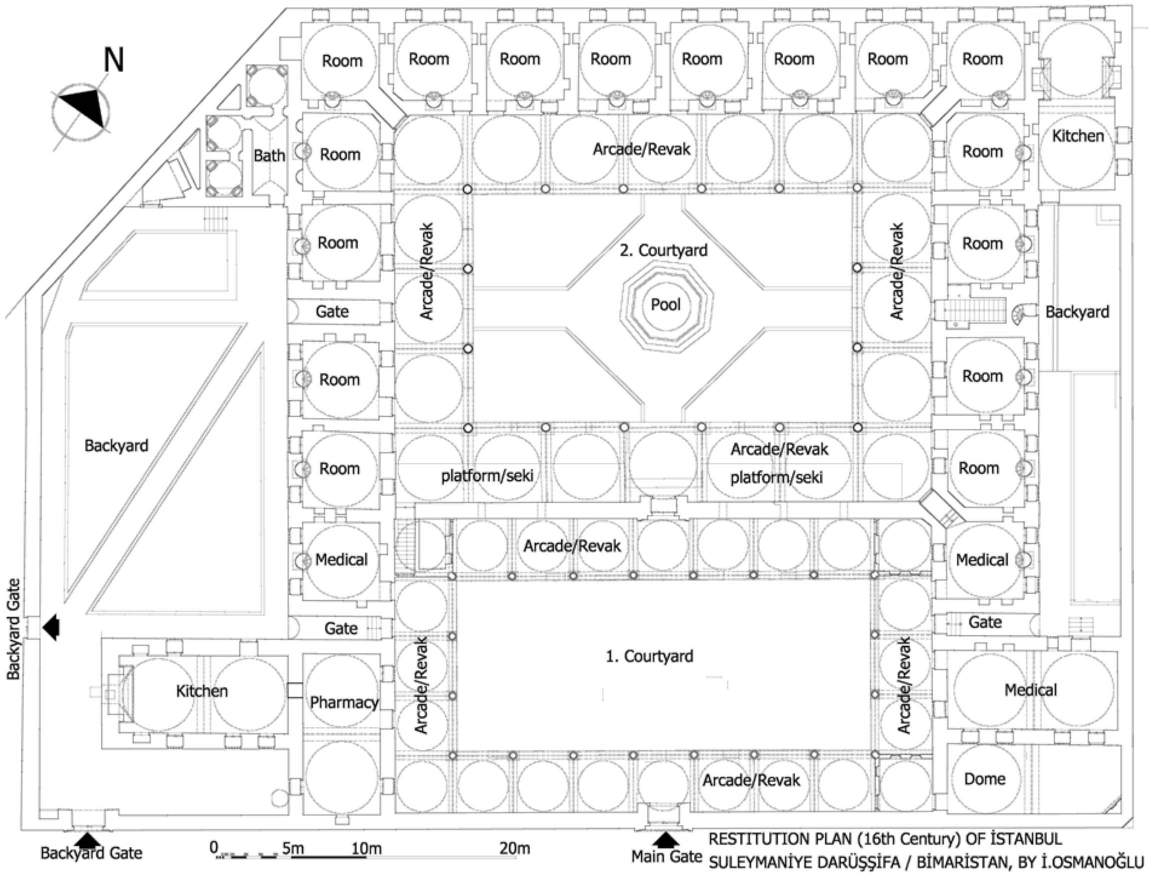

Figure 2. 16th century Restitution Plan of the Süleymaniye Darüşşifa (Hospital) in Istanbul

On the other hand, the Tabhane of the Süleymaniye social-complex was also built by Architect Sinan for the Süleyman I the Magnificiant. Construction date is not known certainly. Besides, it was understood that it was built between 1550 and 1557 years according to historical records and due to the part of the Süleymaniye social-complex (Barkan, 1972). Tabhane is mentioned in the historical Kanuni Vakfiye. It is stated that it is a place where patients can stay in the healing process and also used as a guest house (Kürkçüoğlu, 1962: 25-40). In in-situ note-book of 11-24, 24-41, 30-38, there is a record which proceded to built in 1554 while the existence record in the in-situ of note-book of 60 shows for proceeding its building in 1555 years.

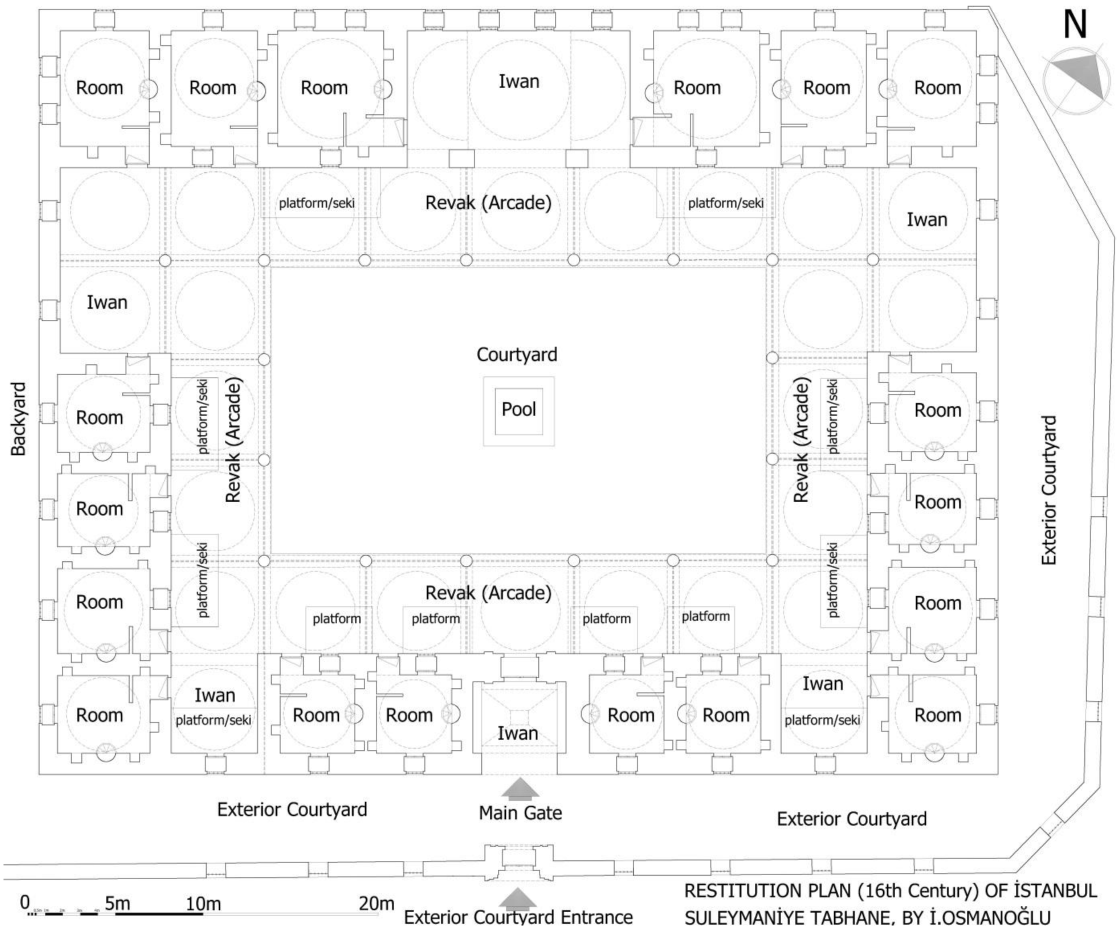

Figure 3. 16th century Restitution Plan of the Süleymaniye Tabhane (Accomodation Building) in Istanbul

The Tabhane building which is one of the significant constructions is placed with the Darüşşifa building and İmaret in the board of the northwest of the Süleymaniye social-complex on the Şifahane street, and in front of the yard enter of the Süleymaniye social-complex. It is guessed that the Tabhane was begun to build in 1554 and was finished to build after 1556, the Tabhane was used as army press center with the Darüşşifa building at the end of the 19th century. After 20th century, it was used for convention center and museum. The Tabhane building which is one of the three building in the border of northwest in the Süleymaniye social-complex and was understood firstly built between those has set of yard plan, as Darüşşifa and İmaret being. Besides, it was built being attentively according to the using of material, detail, and nuance (Figure 3, 4, and 5). The Tabhane building is known its using for Army with the middle yard is closed as the Darüşşifa building being. In the record of Archive of Council, it was stated that the Tabhane was repaired with the attempting of the director of museum and evacuation of Army occupying as of 1938 years, and its maintanence was stopped because of the lack of the financial budget into the 1939 years (EA, 1939). Againly in the records, it was shown that the Tabhane was forseen the Ministry of National Education for using as the museum of the carpet and the rug. For its reason, it was set a museum entitled "Foundation of Muslim Religon" which is near the Tabhane building. After the setting of the Republic of Turkey, in 1924 yeras, as the Ministry of Foundation suspended with a special law, the museum of Tabhane was delegated in the Foundation of General Directorate. In 1926 years, it was delegated in the Ministry of National Education, and its name was changed as the Museum of Turk and Islamic Assets. It was understood that this museum included the Tabhane building. During long period it was served in the

İmaret building in the Süleymaniye social-complex, and in 1983 years, the museum was transferred in the Sultan İbrahim palace building (16th century).

The Tabhane building which is the northwest of the Süleymaniye social-complex and in front of the enter of outer yard of the Süleymaniye mosque has an open yard and occurs an arcaded masterpiece plan which is surrended eighteen cells and spaces which is as main iwan and other four zones. The yard which is covered with marble has a pool that is covered with marble in the middle of the yard. The Tabhane building, which is raised in the street of İmaret that is placed in the northwest of the Süleymaniye complex, has a partial basement which is used with İmaret building sharedly.

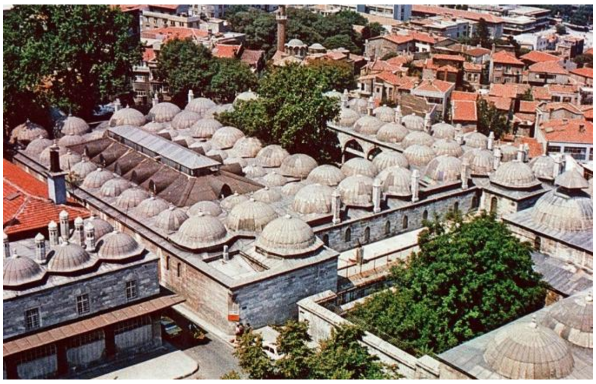

Figure 4. Darüşşifa (Hospital)

Figure 5. Tabhane (Accomodation)

It was understood from the in-situ note-book of the Süleymaniye mosque and İmaret which is document as historical records included that the required stones for the construction built was obtained from quarries where were various region in the Ottoman Empire, such as İznik, Aydıncık, Mihaliç (Karamürsel), Eyne (Ezine), Vize, Çorlu, Kadıköy. Besides the stones, the stones of column and the stones of floor was obtained from the ruins of historical building (Barkan, 1972; Belge no:13-69). The stones and marbles, excavated various quarries, were used such constructional element as the column, the wall, the framework of door and window, the minaret, the mihrab, the minber, the staircase, the ladder, and the cuisine. The clay brick and clay tile which was produced in the Gelibolu and Hasköy (İstanbul) was partially obtained from private merchant and public cuisine which was operated by the state (Barkan, 1972; Belge no:374-390). Architect Sinan subjected the tile producers of Hasköy the conditions that the clay brick of dome would be produced with the knead loam sieved pretty clean soil in the high feature (Barkan, 1972; Belge no:379). It was understood that the produced and/or the bought clay brick and the tile was entitled differently according to their places used and dimensions. They are mentioned the names that are the big, the big square, the half of the big, the circle, the bazaar square, the hexagon, the mold of bazaar, the half, and the tile for covering, there was no record their dimensions (Barkan, 1972; Belge no:380-409). The lime was obtained from quarries where were in the Pendik, Gekbüze (Gebze), Hereke, and Damra where was near İstanbul (Barkan, 1972; Belge no:411-414). The Horasan mortar was obtained from İstanbul (Barkan, 1972; Belge no:415). There were some records regarding on stucco that contained cotton and linen (Barkan, 1972; Belge no:504-505). However, there were some detailed records regarding on the steel, wood, and other materials in the documents (Barkan, 1972).

1.1. AIM OF THIS STUDY

Experimentally analysis and understanding of constituent of stone, clay brick and stucco samples used in Süleymaniye construction which is one of the most significant complexes in the most powerful term of the Classical Ottoman’s Architecture, establishment of materials used by the Empire of Ottoman in 16th century and understanding of materials differencies in the-two-building (Darüşşifa Building and Tabhane Building) examined were aimed. Following period, with other studyings proceed by author, analysis of stone, clay brick and stucco samples used in construction in the Early Period (14th-15th century) and the Clasical Period (16th-17th century) and the Late Period (18th-20th century), understanding both differencies between periods and differencies between constructions in the same periods and differencies between materials used in similar above constructions in various Ottoman Empire's regions would be targeted. The findings obtained from further studyings would be expected to contribute both understanding of using of historical materials and establishment of constituent of materials used for restoration in the historical constructions and leading for practice. Besides, this study aims at examining the current situation of historical construction materials in the buildings of Tabhane and Darüşşifa, the Süleymaniye complex, in view of the soluble salts in water, the conductivity, the analysis of protein and oil, loss on ignition, treatment in acid, the microscope analysis of aggregate after its acid treatment, the petrographic analysis, such physical properties as water absorption (w/w), compressive strength, and density.

2. EXPERIMENTAL MATERIALS AND METHODS

The samples of materials, historical mortar samples, historical stucco samples, historical fine aggregate samples and reddish clay burned brick, were obtained from the original parts of the selected buildings of Tabhane and Darüşşifa in the Süleymaniye complex. The stone and stucco samples were obtained from outer façades of the buildings and in front of their yards while the stucco and the clay brick samples were obtained from inner walls and domes. For equal dispersion of materials, samples were received from different regions and spaces in the buildings of Darüşşifa and Tabhane. Laboratory of İstanbul Metropolitan Municipality- Directorate for the Conservation, Implementation and Supervision of Cultural Assets analysed of the samples.

2.1. Treatment of Acid (HCl) and Loss on Ignition for Measurement of Historical Binder-to-Aggregate Ratio and Sieve Analysis of Aggregate

A dried sample (approximately 50 g) was treated with HCl (10%) to dissolve the binding agent and, the acid insoluble residue was filtered, washed, and dried at 105◦ C (±5◦C). This residue was weighed and recorded as insoluble residue portion in mortar samples. Except this insoluble residue recorded, The rest of remnant consists of siliceous fine aggregate and plenty of less stone piece was sieved through mesh (sizes 63 (μm), 125 (μm), 250 (μm), 500 (μm), 1000 (μm), 2500 (μm), 5000 (μm) and weighed and recorded as sieve passing (%). The sieve passing was used to draw granulometry graph as seen in the Table1 and Figure6, Figure 7, and Figure 8. After dissolving of the interface between aggregate and binder paste with the HCl, the loss on ignition tests, are performed on the mortar samples at 550ºC (± 5ºC) as Table1 presented. In visual analysis of fine aggregate treated in acid was used the single nicol based stereo microscope. The tested aggregate was the size between 3 (mm) and 8 (mm). After acid treatment of the fine aggregate samples, the single nicol based stereo microscope was established the visual analysis of the samples which were digged in epoxy resin to better explain the content of the aggregate samples such as brick dust, quars particle, clay, and black slag dust, as seen in Figure6 and Figure7.

2.2. Fundamental Spot Analysises of Soluable Salt in Water, Protein, Oil, and Conductivity

For qualitative analysis of chlorine salt (Cl^-), nitrate salt (NO_3^-), sulphate salt (SO_4^-), carbonate salt (CO_3^-), protein, oil, and conductivity, the most known fundamental spot test, a chemical test, a simple and efficient technique where analytic assays were executed in only one, or a few drops, of a chemical solution, preferably in a great piece of filter paper, without using any sophisticated instrumentation, was performed to establish the possible existence of additive such as egg white content, pozzolanic material, organic constituent, and salts, as Table2 presented.

2.3. Petrographic Analysis of Historical Mortar and Stucco

In the petrographic analyses and observations, the single nicol based stereomicroscope was used for establishing the microscopic outer textural features while the double nicol based polarizing microscope was used to establish the mineralogical content of inner section of mortar samples, such as the binder area, bonding matrix, bonding phase between binder and aggregate, and constituent of mortar. The microscope photos of the mortar samples were taken with Olympus SP-320 (Olympus/maging Corp., Tokyo, Japan) and FE 190 model (Olympus/maging Corp., Tokyo, Japan) digital cameras. The polarizing microscope (double nicole) and the stereo microscope (single nicol) observes.

2.4. Physical and Mechanical Properties of Historical Brick

According to the European standard EN 1936 (European Committee for Standardization (CEN), 2006) and the Turkish standard TS EN 13755 (TSE 2003) and Archimedes method, the fundamental physical and mechanical properties such as the bulk density, water absorption, and compressive strength of clay brick samples were established in the study. Furthermore, average of four clay brick samples for water absorption test and average of two clay brick samples for the density and average of two clay brick samples for the compressive strength test were given in the Table3 presented in the Results and Discussions section as descriptive findings (Turkish Standards Institution, 2003; EN 1936, 2006).

2.5. SEM and EDX Analysis

In order to monitoring morphology and elemental analysis of stucco in Darüşşifa building, SEM, was a powerful investigative tool which was used a focused beam of electrons to produce complex, high magnification images of a sample's surface morphology, and EDX, the technique detects X-rays emitted from the sample during bombardment by an electron beam to characterize the elemental composition, analysis was carried out in the stucco samples. Stucco sample is seperated two rectangles which one is yellow rectangle and the second one is green rectangle to measure elements such as calcium, oxygen, silicon, aluminium, iron, sulfur, sodium, and so on.

3. RESULTS AND DİSCUSSİONS

3.1. Loss on Ignition, Treatment of Acid, and Granulometry Analysis for Fine Aggregate

The calcination (loss on ignition) analyses, performed at temperature of 550 ºC (±5), are given in Table 1. These data are used in combination with the data for acid loss analysis of fine aggregate.

Table 1. Loss on ignition, treatment of acid, and granulometry analysis for fine aggregate obtained from historical mortar and stucco

Sample No	Loss on Ignition (%)			Loss on Acid (%)		Remained on Sieve (µm)							
	Moisture	550 ºC	$CaCO_3$	Loss	Remained	5000	2500	1000	500	250	125	63	Pan
T1	0,41	1,96	39,42	40,95	59,05	0,00	10,53	55,06	26,78	4,56	1,49	1,08	0,50
T2	3,15	3,86	54,40	60,29	39,71	8,86	11,39	13,63	7,01	20,84	18,01	11,68	8,57
D1	1,14	4,04	88,98	97,39	2,61	0,00	0,00	3,33	23,33	23,33	16,67	16,67	16,67
D2	2,09	3,69	62,21	61,65	38,35	0,00	11,41	30,87	12,35	17,45	11,68	9,93	6,31
D3a	4,50	4,12	17,47	34,34	65,66	0,00	2,93	48,54	18,67	11,71	6,37	5,42	6,37
D3b	3,43	4,39	14,24	38,09	61,91	0,00	0,44	10,21	26,04	26,78	11,46	10,06	15,01

The weight loss of mortars at 105ºC points the quantity of moisture, which varies between 0.41% and 4.5%. While the loss fraction mass at 550ºC points molecular water, organic additive content ratio, and carbon di oxide (CO_2) (between 1.96% and 4.39%), the loss fraction of calcium carbonate at 550ºC points that the loss ratio calcination between 34% and 97%. The contents measured are for the mortar and the stucco and the fine aggregates together. According to the quantity of calcium carbonate remained from loss on ignition analysis, the binder ratio of mortar is between 35%–40% by weight. Generally, the mortar obtained from Tabhane building contains fine aggregate varied ratio between 2% and 3% and 5% limestone pieces, broken brick particles and clay brick powder at minor level, and 95% black sand. Similar results is observed in stucco samples obtained from Darüşşifa building. the stucco samples obtained from Darüşşifa building contains 5% black sand and 95% broken clay brick particle. Figure6 presents the visual analysis with the stereo microscope and the polarizing microscope for historical mortar obtained Tabhane building. Figure7 presents the visual analysis with the stereo microscope and the polarizing microscope for historical mortar obtained Darüşşifa building.

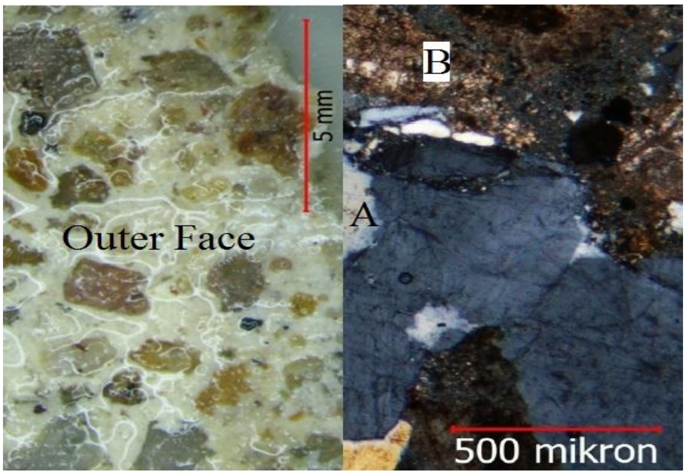

Figure 6. The visual observation with the stereo microscope and the polarizing microscope for historical mortar obtained Tabhane building, A: Quars piece, B: Limestone piece

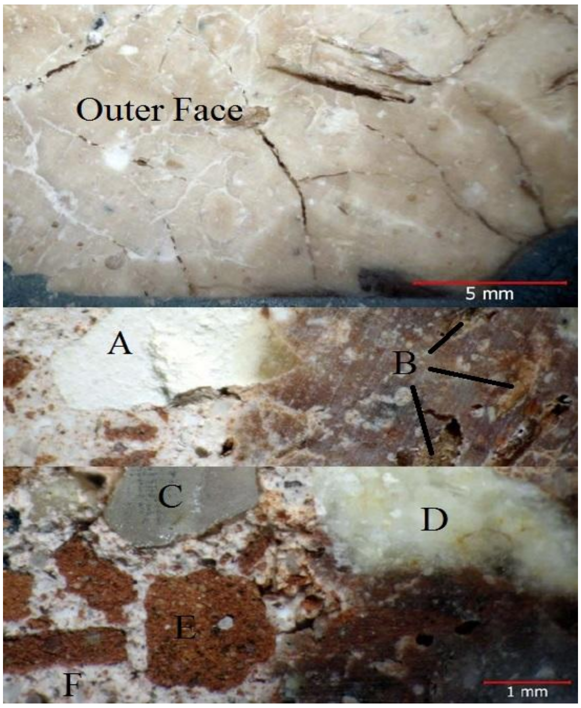

Figure 7. The visual analysis with the stereo microscope and the polarizing microscope for historical mortar obtained Darüşşifa building, A: Limestone dust, B: Kıtık, C: Quars, D: Limestone piece, E: Broken historical brick piece, F: Historical mortar

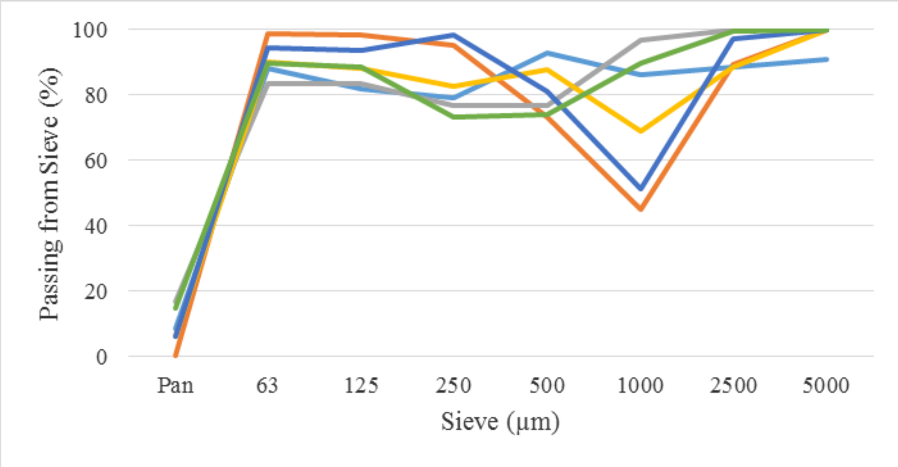

Figure 8. Granulometry graph for historical aggregate after the test of the loss on ignition and the acid treatment

3.2. Fundamental Spot Analysis of Historical Mortar and Historical Stucco

It is the most known that some varying additions, such as blood, hair, egg white content, saponifiable oil, protein, the qualities of water soluble salts and bone powder, in Ottoman period mortars and stuccos are used to activate the binder properties of mortar and stucco (Böke, 2008). Therefore, the fundamental spot tests are performed on the historical mortar and stucco, and the results are given in Table 2.

Table 2. The fundamental spot test results on the historical mortar and stucco

Sample No	Analyse of the Solved Salt in Water							Protein	Oil
	Cl^{-1}	SO_4^{-2}	CO_3^{-2}	NO_3^{-1}	PO_4^{-3}	Conductivity (µS)	Salt Content (%)		
T1	+	-	-	+	NA	244	1,5	+	-
T2	++	-	-	+	NA	502	3,09	+	-
D1	±	-	-	±	-	155	-	+	-
D2	+	-	-	±	-	185	0,92	+	-
D3a	++++	-	-	±	-	4160	20,78	+	-
D3b	++++	-	-	±	-	4320	21,58	+	-

—: absence; **+:** small amount; **++:** present; **+++**: abundant; **++++:** excessive amount

The clor salt (Cl^{-1}) content measured by the spot test is considered to be mac from varying earth soils and/or construction materials, and the nitrate salt (NO_3^{-1}) is from the residues of organism, like varying dead animal and tree pieces enclosed in the mortar and stucco (Ventola et al., 2011) . The salts of sulphate (SO_4^{-2}) and carbonate (CO_3^{-2}) contents are not measured because preparing of the mortar and the stucco has no including the jibs as hardener. Oil is also not detected; however, small amount of protein is encountered in the spot test as written same in the literatures on lime mortar (Jasiczak et al., 2005; Kurugöl and Güleç, 2012) (Table 2).

3.3. Petrographic and Visual Analysis of Historical Mortar and Stucco

Figure6 and Figure7 gives virtual analysis of outer and inner sections of mortar and stucco sample, molded in epoxy resin which is examined by a polarizing microscope (double nicol) in and a stereomicroscope (single nicol), in order to determine the outer face characteristic, mineral content and overall qualitative analysis, like some observations done by authors who are Rampazzi et al., 2006, Moropoulou et al., 2000, Paama et al., 1998, Bakolas et al., 1998. Porosity of the mortar and stucco is mostly filled by kıtık which means organic planty fibers such as cannabis, linen, and hay (Böke et al., 2006) and the phases of aggregate-to-binder ratio and binder-to-binder ratio is in good condition as written in literature (Elsen, 2006). The results imply that the mortar and stucco is quite homogeneous during its manufacturing.

According to the results of petrography, binding area of mortar and stucco is, respectively, about 35%-40% and 25%-30%. Coarse and fine aggregate part of mortar and stucco contains: 1%-2% brick piece, 5% carbonated aggregates, 5% black sand, and the remained part is lime binder [Figure 6 and Figure 7).

3.4. Physical and Mechanical Properties of Historical Brick

Table3 gives average results of physical and mechanical tests, such as water absorption, density, and compressive strength. According to the physical analyses, water absorption capacity of historical brick is between 10.4–13.9 (g/cm^3) by weight. Generally, depending on the composition and manufacturing process used in historical brick, density varies between 2.51 and 2.58 (g/cm^3) (Table 3).

Table 3. Average results of water absorption, density, and compressive strength of historical brick

Sample	Initial Mass (g)	Mass Change in Water (1st Day) (g)	Mass Change in Water (2nd Day) (g)	Water Absorption (%)	Average
T1	19,79	22,14	22,53	13,85	12,1
T2	10,64	11,78	12,12	13,91	
T3	26,28	28,34	28,99	10,31	
T4	27,68	30,23	30,57	10,44	

Sample	Mass (g)						Average
	Cup	Cup+Sample	Sample	Cup+Water	Cup+Water+ Sample	Density (g/cm^3)	
T1	32,2	46,7	14,5	82,6	91,4	2,51	2.54
T2	29,2	40,7	10,7	80,7	87,3	2,58	

	Compressive Strength (MPa)	Average
T1	15	17
T2	19	

Those results imply that the historical bricks do not exhibit great porosity differences. The compressive strength of historical brick varies between 15–19 (MPa) (Table 3). Based on these generally accepted physical and mechanical results, Tabhane brick sample is in agreement with the similar values given literature (Centaro et al., 2017).

3.5. SEM and EDX Analysis of Stucco

To determine the elemental composition and quantitative ananlysis of stucco sample in Darüşşifa building, Süleymaniye mosque, the stucco is taken from the binder component between the aggregates. The stucco binder sample is monitored by SEM equipped with EDX set. Table 4 presents the mineralogical composition of the binder component of the stucco as determined by EDX analysis. The SEM observation and the-two EDX graph which is in different area is given in Figure 9. The yellow rectangle stands for the first area while the green rectangle is the second area in SEM figure (Up-left). EDX of the sample reveals that the stucco contains large fractions of calcium and oxide element as being same in the literature (Uras, 2006). The presence of slicon and aluminum and magnesium and iron element is between 1,3%-65% (Table 4) in the stucco is due to the pozzolanic additives in binder and may be indicative of a weak hydraulic property for the stucco (Figure 9).

Table 4. Element ratio of yellow and green area in SEM figure

Element type	Yellow Area (%)	Green Area (%)
Oxygen	33,8	34,0
Calcium	51,5	48,0
Silicon	6,5	6,5
Magnesium	3,4	3,8
Aluminium	2,6	2,5

Sodium	N/A	0,6
Sulfur	0,5	0,8
Iron	1,3	1,5

*The N/A stands for "Not Available".

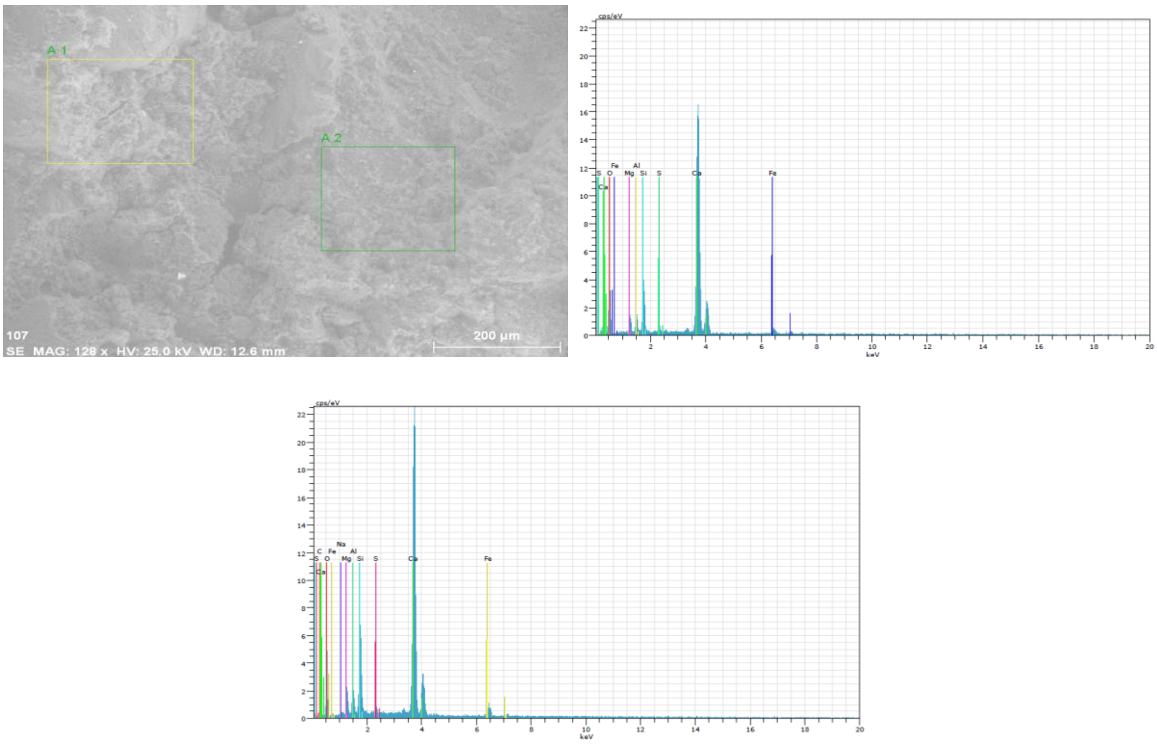

Figure 9. The SEM observation and the-two EDX graph which is in different area of SEM figure, the yellow rectangle is first area and the green rectangle is second area

Therefore, the binder used in the production of stucco might have a low hydraulic character. As for the presence of sulfur elements in the green rectangle area, this presence could probably prove the mineralogical additive in stucco (Figure 9).

CONCLUSION

it can be infered that the original mortar and stucco used in Tabhane and Darüşşifa building, Süleymaniye mosque, has binder capacity as 25%–40% weight ratio of lime content. Quars, limestone, and brick piece is monitored in petrographic analysis. Binder phase of the mortar, stucco, and aggregate consists of the soluable salt of clor, nitrate, carbonate, and sulphate as well as protein, no oil, brick dust and limestone powder, kıtık, and egg white additives as the spot test being. It is also determined that the element of calcium, oxygen, silicon, aluminium, sodium, sulfur and magnesium is in SEM and EDX monitoring of stucco. However, the used historical brick proves a durable material as it has density at high level, water absorption at low level as well as compressive strength which is between 15-19 (MPa). In the light of results, the mortar, the stucco, and the clay brick can be classified as high characteristic architectural heritage material in terms of the physical, chemical, mechanical, petrographic, and visual analysis of SEM-EDX.

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