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The experimental works conducted on modern heritage and mixed system buildings with the purpose of the conservation and restoration

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Abstract

Within the 20th century, the National Architectural Period in Turkey began and the structures which had mixed systems with reinforced concrete (RC) and masonry was seen commonly. This period is also called "Modernization" and the buildings were considered as Modern Architectural Heritage structures. Since most of these buildings are used today, conservation and restoration attempts have become more essential to maintain safety conditions for users with the cultural heritage value of the buildings. Some parameters should be taken into account like the material properties, environmental conditions and human activities that are more effective in the degradation of the structures. However, the conservation and restoration of mixed structures are less investigated in literature because these structures have complex construction techniques and there are not definite rules in the related regulations. So, these kinds of articles that present the studies can be seen invaluable for the structures which has similar problems and solutions. This paper presents in-situ examination and laboratory analyses on the building materials used in Istanbul University Buildings accepted as a cultural heritage masonry infilled RC structure. First of all, in-situ examination was done according to the observations on the exterior and interior walls, Secondly, representative material samples taken from different locations of the buildings both masonry and the RC sections. For the determination of the properties and deteriorations of the materials, the chemical analyses and the physical and mechanical tests were conducted. According to the results, the conservation and restoration applications were recommended for the case study buildings.

Keywords
Modern architectural heritage, RC structures, Experimental works, Restoration, Conservation.

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1. Introduction

As described in the literature of Architecture History, the period of 1920-1950 years is known Early Republican Period Architecture in Turkey. The Early Republican Period refers to a process where work on "modernization" is accelerated. Modernization is considered as a Republican project and the official policy of the giants. Many public spaces were born from the needs of modern life in that time (Işık, 2010). Until 1930, the construction activities were seen intensively. In particular, public buildings primarily related to education built in this period; reflect architectural style called the First Natural Architecture in which the features of Ottoman Neo Classical style were interpreted with their daily needs (Parlak & Yıldız, 2017) During 1910-1927 period is known as I. National Architecture Period in Turkey, As a result of the effort in creating national consciousness by combining the National Architecture movement, ideological thoughts and architectural elements, it was shaped by using an eclectic understanding by taking the scheme and forms of the past (Seljuk and Ottoman) religious and educational institutions (arch, column, erasure, fringe, etc.) and by taking the plan scheme of the west. Until the 1930s, the mixed structures with reinforced concrete and masonry were used in Turkey. However, the number of these mixed structures are limited. In Modern times, mostly reinforced concrete buildings were preferably constructed. In the mixed structures, the walls were constructed by rubble stone in the basement and brick on the upper floors. The slabs were reinforced concrete and the roof was wooden. In this period, reinforced concrete column and steel beam applications with mixed beams are among the common construction systems (Özbakan, 2007).

During 1940-1950 period is known as II. National Architecture Period which is an approach that outweighs the emotional and / or traditional aspect. The monumental structures that are heavy, stone-covered, massive and sitting on the ground with their entire body, which attach great importance to window details and eaves, embody the traditional direction, the use of the Turkish House's traditional features, the use of regional construction and material embody the emotional aspect (Alsaç, 1976; Kortan, 2000). Kortan (2000) stated that generally static-stationary expressions, central plans, symmetrical systems were used in the buildings. He points out that the structure is not expressed on the facades and that the structure is shown as a masonry structure even if it was built in a reinforced concrete framework (Alsaç, 1976).

In the late 19th century, the reinforced concrete was occurred with the industrial revolution. The structures with RC frame had been supported with steel, wooden and masonry structures because their construction time was shorter and they were more economical (Ersoy & Özcebe 2017),

Throughout the twentieth century, a wide range of architectural and engineering structures were built using concrete as a practical and cost-effective choice and concrete also became valued for its aesthetic qualities (Gaudette & Slaton, 2007). Even though reinforced concrete (RC) and prestressed concrete (PSC) are perceived as "modern" or "new" materials from the standpoint heritage conservation, several buildings and infrastructural facilities built in concrete are progressively being listed as architectural heritage (Menon, 2010).

At the beginning of the 20th century, reinforced concrete was seen favorable construction material. The buildings which had a mixed construction system with masonry and reinforced concrete were started to be built. In later times (1950), only RC structures were commonly used. This material was perceived as having favorable characteristics relating to resistance, durability and plasticity. Further, it was quicker to manufacture, easier to control and resulted in reduced costs. These other factors made it fashionable. Therefore, there were many reasons for its widespread use; not only social or historical factors but also, mainly, economic and technical ones (Esponda, 2010).

Apart from its aesthetic value and strength, the advantage of reinforced concrete lies in its plastic stiffness and capacity of being molded into any spatial form. There was also a time when reinforced concrete was considered to be more durable than traditional construction materials such as stone. The system offered the advantage that much greater spans could be achieved economically, thus facilitating much greater flexibility in architectural design. Also, compared to stone or brick, RC allowed the walls and general support structure to be reduced in thickness (Calderini, 2008).

The repair and restoration of reinforced concrete, which is the main building material of the 20th century and which enables great developments in the history of architecture, has been brought to the agenda as a field that needs to be discussed and developed because of the fact that various structures and many buildings are in danger of disappearing. Certain methods are used today for repairing or strengthening concrete / reinforced concrete. Firstly, the correct detection of damage is of great importance for the repair of a reinforced concrete structure. Applications such as repair and reinforcement without proper diagnosis will be useless, and may damage the structure (Özbakan, 2007).

The restoration theories of the early nineteenth century, emphasizing the concept of conservation and recognize of interventions, provided theoretical legitimacy for the new material, concrete. Concrete deterioration occurs primarily because of corrosion of the embedded steel, degradation of the concrete itself, use of improper techniques or materials in construction, or structural problems. The causes of concrete deterioration must be understood in order to select an appropriate repair and protection system (Özbakan, 2007, Gaudette & Slaton,2007). While reinforcing steel has an important role in expanding the applications of concrete in twentieth century architecture, corrosion of this steel has also caused deterioration in many historic structures (Erlemann, 1999). Another problem is seen related to the poor consolidation of the concrete during its placement in forms, or in molds in the case of casting. This problem especially occurs in highly ornamental units. In early twentieth century, the production techniques of the concrete were similar to techniques used in forming cast stone. Poorly consolidated concrete often contains voids and water easily enters into these voids. If this water reaches the reinforcing bars, the corrosion occurs. Because of the corrosion, at first the deformation (volume increase) of the reinforcing bars form and then demolish the protective concrete cover over the embedded reinforcing bars. This situation can decrease the concrete strength. Proper settlement and chemical admixtures are also used today to eliminate this problem (Gaudette, 2000).

Among the environmental or atmospheric factors such as exposure to wind, rain, snow, and salt water or spray are highly effective on the deterioration of the materials. In addition, high-pressure water when used for cleaning can also erode the concrete surface like the rain and snow. The deterioration morphology may differ according to the properties of the materials. With the exposure of these factors on concrete, weathering appears as erosion of the cement paste and because of being a composite material, the phases of binder and aggregate are started to disintegration due to the freezing-thawing. As water within the concrete freezes, it expands and exerts forces on the adjacent concrete. Repeated freezing and thawing can cause a damage which appears as surface degradation, including severe scaling and micro-cracking that extends into the concrete. In the second half of the twentieth century, air entrainer is used in the concrete to provide enhanced protection against damage due to cyclic freezing-thawing of saturated concrete (Gaudette & Slaton,2007).

Like the other masonry materials, the characteristic signs of problems in concrete include cracking, spalling, and staining. Cracking occurs in most concrete but will vary in depth, width, direction, pattern, and location. Spalling, the loss of surface material, is often associated with freezing-thawing as well as cracking and delamination of the concrete cover over embedded reinforcing steel. Spalling deflects the concrete for both strength and physical properties. Staining of the concrete surface can be related to soiling from atmospheric pollutants or other contaminants, dirt accumulation, salt efflorescence and the presence of organic growth and etc. as a result of water migration (Gaudette & Slaton,2007). In general, both concrete and the other masonry materials like stones, clay-based materials, mortar and plasters are influenced from similar affecting factors mentioned above. Before assessment of the characteristics of the materials, the causes of deterioration should be determined.

"Apart from conservation and restoration of monumental structures as works of art and historical documents, it should be ensured that their conservation is permanent and sustainable. In addition, the basic approach underlying restoration decisions is providing maximum conservation and restoration with minimum costs as well as minimal intervention in the authentic structure, strengthening of the structure considering the damages and thus passing it down to next generations" (ICOMOS, 2001).

Since the purpose of repairing such structures is to conserve the aesthetic and historic value of the monument, the conservation works are based on original materials and reliable documents. Three primary approaches are usually considered for historic concrete structures: maintenance, repair, or replacement. Maintenance and repair best achieve the preservation goal of minimal intervention and the greatest retention of existing historic building. However, where elements of the building are severely deteriorated or where inherent problems with the material lead to ongoing failures, replacement may be necessary (Macdonald, 2003).

A condition assessment of a historical building should begin with a review of all available documents related to original construction and prior repairs. While plans and specifications for older buildings are not always available, they can be an invaluable resource and every attempt should be made to find them. Archival photographs can also provide a valuable source of information about original construction.

In order to assessment of the condition of the building materials, there are mainly two methods that are called as destructive testing and non-destructive testing methods. The non-destructive testing methods can be used in the field to evaluate concealed conditions by using the basic and some sophisticated techniques (U.S. Department of Transportation Federal Highway Administration, 1997). To further evaluate the condition of the concrete and the other masonry samples may be taken for laboratory study to determine material components and composition, and causes of deterioration. This is called destructive testing method. The laboratory studies provide a general identification of the original materials' properties and deterioration morphology. Information gathered through laboratory studies can also be used to help choosing the most appropriate materials for the conservation and restoration works.

This study is about the conservation and restoration of the education buildings in Istanbul University which were constructed as the mixed structures of reinforced concrete framework and masonry n the 1940s, maintaining their original form and cultural heritage value.

The buildings of the Faculties of Science, Letters and Aquatic Sciences at Istanbul University were examined. These buildings are located in the historical peninsula of Istanbul, which is included in the UNESCO's world heritage list, more specifically in plot 20-113, building block 2707, Balabanağa neighborhood in the district of Fatih, Istanbul (Ahunbay, 2004), The view of the structure from the southeast facade is given in Fig. 1. This structure has been registered as cultural heritage by Istanbul Heritage Board.

Constituting the largest structure block in the historical peninsula of Istanbul, these buildings are located around three courtyards. 21 building blocks are separated from each other by dilatations, with each block being an individual building considering their load-bearing systems. This complex structure is surrounded by monumental structures, such as Pertevniyal Valide Sultan Mosque to the west, Şehzade Mosque to the northwest, Bayezid II Bathhouse, Seyyid Hasan Paşa Madrasah, Bayezid II Madrasah and Bayezid

II Mosque to the east, Süleymaniye Mosque, Kuyucu Murad Paşa Social Complex and Kalenderhane Mosque, which was originally a church in the Byzantine period, to the north (Fig. 1).

The faculty buildings were designed by Architects Sedat Hakkı Eldem and Emin Onat, started to be constructed in 1943. A part of the buildings was completed in 1946, while the remaining part was completed in 1952 after which educational activities started to be carried out.

Architects Sedat Hakkı Eldem and Emin Onat were at the top of the architect's representative of the period which is described as II. National Architectural Period in Turkey (1940-1950). One of the most important buildings they built together is said to be the structure of the Faculty of Science and Letters of Istanbul University (Batur,1994).

It is the most important work of the architects designed monumental indoors and outdoors. The capacity to include the two faculties with all their units was also realized. On the one hand, it reflects the giant, massive mass solutions and the understanding of interior design of the German Nazi architecture of that period, on the other hand, it includes elements such as window layouts and eaves formations of traditional Ottoman residential architecture. There are rectangular and square courtyards surrounded by monumental regular and stone-faced buildings. With this aspect, the structure reflects a monumental-academic tendency (Sağgöz, Sarı, Şen & Al, 2014).

Today, this structure complex includes the Faculty of Science, the Faculty of Letters and the Faculty of Aquatic Science. Today, from the blocks where the Faculty of Science, Engineering and Literature is located, in the section where the Faculty of Letters is located, the traditional madrasahs, which are both traditional faculties, are taken as example in the facade and details and in the plan design (Tekeli, 2006)

Figure 1. *Aerial photo and layout plan of the examined structure.*

These structures were chosen as a case study not only for having historic value but also having mixed construction system with masonry and reinforced concrete.

2. Research methods

This study, which started with the research on the historical process of the mentioned structures, consists of: (i) in situ examination, (ii) identification of the characteristic properties of the materials by chemical analyses, physical and mechanical tests on the representative samples taken from different points of the structures and (iii) recommendations for conservation and restoration of the structures based on the data analysis. All the tests and analyses were conducted according to the related standards and knowledge in the related literature (Arıoğlu & Acun, 2006; TS EN 196-2, 2014; TS 10088 EN 932-3/A1, 2006; TS EN 933-10, 2015; TS 699, 2016; TS EN 12504-1,2019; TS EN 772-4, 2000).

In situ examination and laboratory studies conducted on the building materials taken from the structures were considered as the research methods. In situ examination was conducted by visual inspection and documenting the conditions shown in the following.

The aims of in situ examination studies are;

- to document the original construction technique and materials,
- to document the environmental pollution affects,
- to document the damages in building elements,
- to document the deteriorations occurred on the material surfaces,
- to document the sampling locations.

After in situ examination, building material samples were taken from each structure mentioned below. As these buildings have both masonry part and RC part, representative samples were taken from each construction materials as much as possible.

The characterization analysis was conducted on the samples taken from masonry parts; stone, brick, mortar and plaster, for documentation and proposals for restoration works. As the characterization tests acid loss, ignition loss (calcination), sieve analyses and physical property tests were conducted on mortar and plaster samples, the visual analyses and physical property tests were conducted brick and stone samples. As a result of these analyses and tests, the mixture ratios and ingredients of the mortar and plasters were determined, and also, the type of bricks and stones were identified.

Secondly, the mechanical property tests were conducted on the samples taken from RC parts: concrete samples, for determination of the strength for documentation and restoration works. These tests were given in the following;

- Non-destructive tests: Schmidt hammer test (to determine the hardness of the concrete surface), Profometer analysis (to determine the steel reinforcement)
- Destructive tests: Coring concrete samples (to determine the compression strength)

3. The results and discussion

In this section, the results of all analysis and tests were given respectively. The results of in situ examination is also as important as the results of laboratory studies. By the results of all the studies, the recommendations could be given for conservation and restoration of the structures. The results were given in the following.

3.1. The results of in situ examinations

In situ examinations were conducted in order to detect and document the effects of environment and any other parameters on the building materials of the structures. Among all the factors, air pollution was seen the most affective factor on the surfaces of the materials. For example, surface contamination due to air pollution was observed on the eastern facade of the structure facing towards the Vezneciler Street and Kimyager Derviş Paşa dead-end Street (Fig. 2). The façades of the structure other than those that were

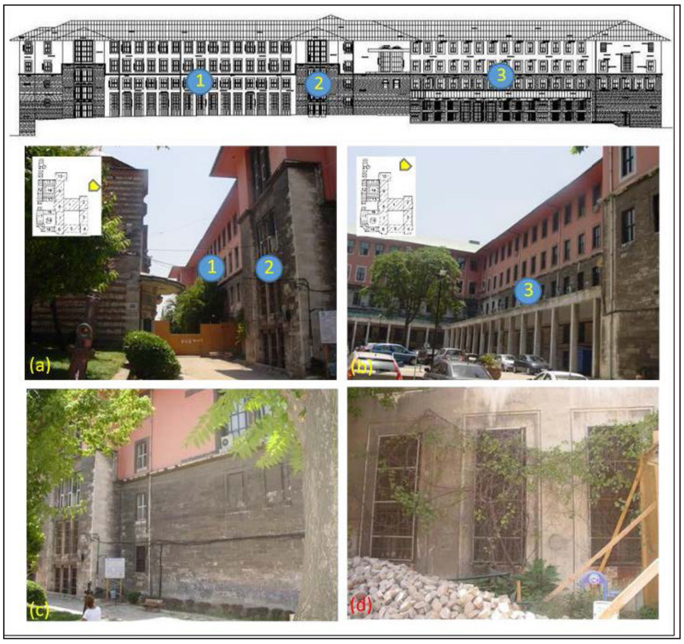

Figure 2. *Eastern facade: (a) Faculty of Letters, (b) Faculty of Science (c, d) Contamination in facade and window jamb.*

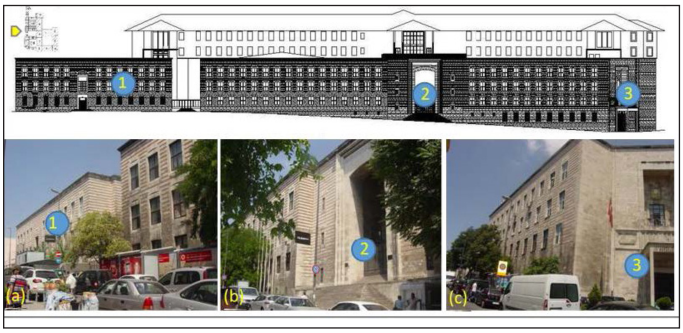

Figure 3. *Western facade: (a) Physics Department, (b) Faculty of Science, (c) Faculty of Aquatic Sciences.*

Figure 4. *Faculty of Aquatic Sciences: (a, b) Inner court, (c) Facade contamination, (d) Corrosion effect in reinforcement.*

stone-pitched and coated with Edelputz plaster which was favorite in that time.

In the facades of the Faculty of Science, the top of the green eaves covering the top of the arcaded section and the inner parts of all window jambs were contaminated. Besides, the structures of the colored mortar between the jamb and the lintels became empty because of the surface abrasion.

Figure 5. Load-bearing members in basement storey for Faculty of Science building (a, b).

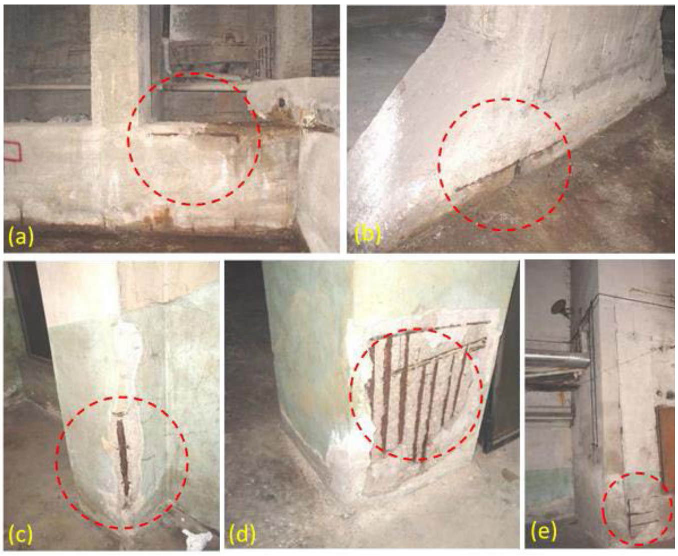

Figure 6. RC columns and foundations subject to corrosion effect in Faculty of Science building (a-e).

Figure 7. RC foundations subject to corrosion effect in Faculty of Letters (a, b).

Figure 8. Corrosion effects in Faculty of Aquatic Sciences.

Contamination was observed on the eastern facade and side facades of the Department of Physics building (Building 21) in the Faculty of Science. Furthermore, surface abrasion was apparent on the facade containing the entrance door and on the natural stones of the jambs. Corrosion was observed on the iron guards inside the windows in the ground story. The window guards in the Department of Physics building were extremely corroded, and the rust stains had flown onto the natural stone coating, resulting in contamination.

Although the western facade of the structure facing towards the Büyük Reşit Paşa Street was cleaner than the other facades, surface abrasion was observed on the limestone laid in alternating order with bricks (Fig. 3).

Heavy contamination was observed on the northern facade of the structure that faces the Vezneciler Street and on the inner sections of all window and door jambs, whereas a small amount of surface abrasion can be seen on natural stones. Also, a little bit efflorescence forms on the surface of the natural stone coverings and deforms the aesthetic vision.

While surface abrasion could be observed on the southern facade of the structure facing Ordu Street, extreme contamination was apparent on all-natural stones facing the inner courtyard at the Faculty of Letters. Contamination could be observed on the façades of the buildings facing the courtyard in the Faculty of Aquatic Sciences. Moreover, the load-bearing system elements of the buildings were damaged to a great extent (Fig. 4).

In the visual examination made on the buildings of the Faculty of Science and Faculty of Letters, the reinforcements had suffered from the loss of cross-sectional area due to corrosion. The linking water settled at the dilatation which was full of rubble between the binding beams and this situation deforms the structural system. (Figs. 5-7).

In the Faculty of Aquatic Sciences, at the basement due to excessive moisture, the material degradations formed. Due to low concrete cover and non-evacuation of moisture, the excessive corrosion of the reinforcements occurred (Fig 8).

3.2. The results of laboratory analyses and tests

The laboratory analyses and tests were conducted to representative building material samples taken from Faculty of Science, Faculty of Aquatic Sciences and Faculty of Letters buildings. The samples were taken from various locations of the structures for laboratory tests in the present research. Chemical analyses, physical and mechanical tests were conducted on the material samples taken from the structure in accordance with relevant standards [21-26]. In this scope, (i) visual analysis, loss on acid and calcination analyses were conducted to determine the types and ratios of binding aggregates in the mortar and plaster samples, and sieve analyses and physical property tests were conducted on the aggregated that remained from the loss on acid test; (ii) calcination analysis and physical property tests were conducted on the stone and brick samples and (iii) compressive tests were carried out on the concrete samples. The results of all analyses and tests were given in the following respectively.

3.2.1. Sampling and visual examination

After a detailed investigation carried out to take representative samples, determining unique locations for the construction period of the examined structures are determined, 15 samples were taken. The codes, positions and descriptions of the samples, as well as the locations from which they were taken are given in Fig. 9 and Table 1, respectively.

In the visual analysis, the condition of the mortar and plaster samples before the loss in the acid test and the aggregates that remained after the loss in the acid test were examined under a stereo microscope, whereas the stone and brick samples were examined by eye and under a stereo microscope.

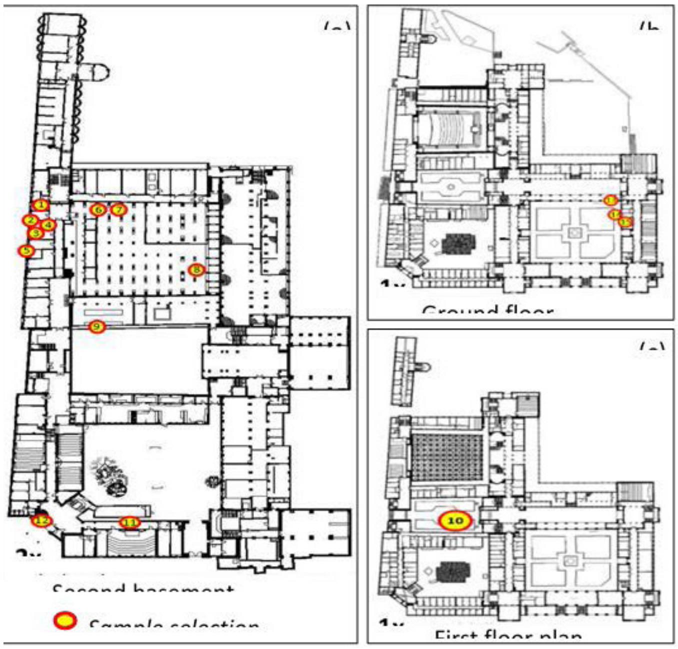

Figure 9. *Sample selection locations in plan view of the structure (a-c).*

Table 1. *The locations of the samples.*

Sample	Definition	Storey	Location
1	Interior plaster	First basement	Wall
2	Interior plaster		Office room
3	Pointing mortar		Office room
4	Brick		Office room
5	Interior plaster		Office room
6	Pointing mortar		Wall
7	Solid brick		Wall
8	Hollow brick		Wall
9	Interior plaster		Wall
10	Paving stone	First	Window side in facade
11	Interior plaster	Second basement	Wall
12	Interior plaster		RC beam
13	Paving stone	-	Facade in inner court
14a	External plaster-white mosaic		Facade in inner court
14b	Roughcast		Facade in inner court
15	Window jamb		Facade in inner court

Samples 1-10: Faculty of Science, Samples 11 and 12: Faculty of Aquatic Sciences, Samples 13-15: Faculty of Letters

Table 2. *The results of ignition loss and acid loss analyses.*

Sample*	Retained fine material (%)	Undersize grain (%)	Loss on acid (%)	$CaCO_3$ (%)	** CO_2 / H_2O ratio (%)	Binder/Aggregate ratio by weight (%)
1	9	64	27	16	2.9	1/3
2	13	62	25	15	3.7	1/3
3	12	74	14	16	1.5	1/3
5	18	68	14	19	3.1	1/2
6	11	78	11	12	1.8	1/3
9	6	78	16	17	4.0	1/3
11	10	76	14	11	1.4	1/2
12	8	66	26	27	3.0	1/2
14a	3	5	92	66	4.8	1/3
14b	14	65	21	23	3.1	1/2
15	60	-	40	82	3.8	1/3

*In Samples 14a and 15, the carbonate quantity ratio was determined to be high ratio because of the presence of too much limestone ballasts as aggregate. **If the ratio is less than 10, it is foreseen that the mortar has a hydraulic property.

3.2.2. The results of chemical analysis

To determine the chemical properties of the mortar and aggregate morphology in the samples taken from fifteen different points in the examined structures, loss in acid analysis was

Table 3. The results of sieve analyses.

Sample*	Material	Sieved aggregate (%) 8 mm	4 mm	2 mm	1 mm	0.5 mm	0.25 mm
1	Interior plaster	100	98	92	76	49	3
2	Interior plaster	100	97	87	65	32	2
3	Pointing mortar	100	95	82	58	36	2
5	Interior plaster	100	100	97	91	56	1
6	Pointing mortar	100	96	89	65	22	2
9	Interior plaster	100	97	88	60	31	2
11	Interior plaster	100	94	80	57	29	5
12	Interior plaster	100	100	96	84	63	11
14a	External plaster-white mosaic	-	-	-	-	-	-
14b	Roughcast	100	100	91	69	30	5
15	Window jamb	-	-	-	-	-	-

*Samples 4, 7, 10 and 13 contain no aggregates.

Table 4. The results of physical property tests.

Sample	Material	Water absorption percentage by weight (%)	Water absorption percentage by volume (%)	Unit volume of mass (g/cm³)	Density (g/cm³)	Porosity (%)
1	Internal plaster	15.5	26	1.70	2.61	35
2	Internal plaster	18.0	29	1.61	2.58	38
3	Pointing mortar	6.0	12	1.95	2.58	24
4	Brick	14.0	21	1.54	2.51	39
5	Internal plaster	15.0	26	1.71	2.56	33
6	Pointing mortar	14.0	23	1.64	2.61	37
7	Solid brick	18.0	31	1.71	2.65	35
8	Hollow brick	17.0	29	1.70	2.51	32
9	Internal plaster	19.0	30	1.60	2.56	38
10	Paving stone	5.0	12	2.32	2.53	8
11	Internal plaster	11.0	21	1.91	2.55	25
12	Internal plaster	9.0	18	1.97	2.58	24
13	Paving stone	8.0	15	1.84	2.67	31
14a	External plaster-white mosaic	7.0	14	2.02	2.50	19
14b	Roughcast	6.0	12	1.96	2.57	24
15	Window jamb	5.0	9	2.00	-	-

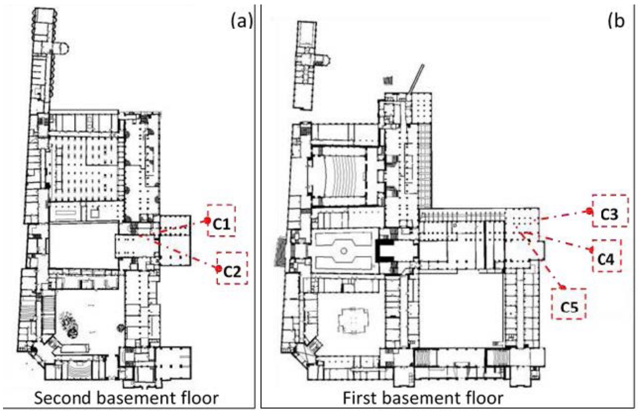

***Figure 10.** The locations of core samples taken in the structure (a, b).*

***Table 5.** The results of mechanical property tests.*

Sample	Material	Compression Strength (MPa)
	RC Building Elements of Faculty of Science	
1	2.Basement-C1	21
2	2.Basement-C1	22
3	2.Basement-C2	18
4	2.Basement-C2	21
Average		21
	RC Building Elements of Faculty of Letters	
1	1.Basement-C3	12
2	1.Basement-C3	15
3	1.Basement-C4	9.0
4	1.Basement-C4	17
5	1.Basement-C5	9.0
6	1.Basement-C5	10
Average		12

conducted, and subsequently, sieve analysis and ignition loss analysis were carried out on the aggregates that remained following the loss in acid analysis. Loss in acid analysis was conducted using 10-20% HCl acid. Calcination analysis was carried out by keeping the powdered samples in a muffle furnace for certain periods of time at 550°C and 1050°C, respectively. The results are given in Table 2.

3.2.3. The results of sieve analysis

Sieve analyses were conducted to find out the sizes of the aggregates remaining from the loss on acid test. The granulometry analysis results is given in Table 3.

3.2.4. The results of physical property tests

In an attempt to determine the physical properties of the mortar, plaster, stone and brick samples; water absorption, unit volume weight and specific weight tests were conducted under atmospheric pressure in accordance with the related standards (Table 4).

3.2.5. The results of mechanical property tests

To determine the quality of the concrete in the load-bearing elements of the structures, five core samples taken from columns at different locations were subjected to a compressive test in accordance with TS EN 12504-1 standard. Locations of the core samples are shown in Fig. 10. The compressive strengths of the cores are measured and the results are given in Table 5.

3.3. The conservation and restoration roposals

The examined buildings consisted of ashlar (organic limestone), artificial stone and marble. Ashlar stones were used as finishing material on the exterior façades of the buildings. Artificial stones were used on the façades of the Faculty of Letters facing the inner courtyard, and marbles were used on the load-bearing columns in the arcaded section on the eastern/northern facades of the Faculty of Letters. Although these stones are resistant to external atmospheric conditions, degradation in the form of crumbling and dusting may occur on the surfaces when exposed to humidity for a long time and due to the impact of air pollution. The depth of surface abrasion observed on these stones varies, with the highest surface abrasion being observed on the Department of Physics building (Building 21) at a depth of 2-4 cm.

Contamination observed on a facade of a structure usually occurs as a result of the transformation of calcite, the main mineral of limestone, to gypsum by reacting with sulfur dioxide, trioxide and sulfurous acid in an environment of air pollution. As gypsum is somewhat water-soluble, it grazes the surface in the form of a solution and penetrates the porosity on the surfaces washed with rainwater. In the drying phase, it absorbs the particulate contaminants suspended in the air and crystallizes. In the sheltered locations which rainwater cannot reach, gypsum fills the porosity through dry accumulation and is stored on the surface in the form of incrustation. Soot, fly ash, unburnt hydrocarbons, dirt, heavy metals, and carbon pollution from the exhaust gases of diesel vehicles are added to the crust layer of gypsum, resulting in blackening of the crust's surface. Facade cleaning was recommended for eliminating the black dirt layers that have accumulated on the stone surfaces of all facades under examination due to dust, air pollution, smut, flying ashes and degradation.

As such, it was recommended to brush the black layers on the stone surfaces using water, non-ionic detergent or steam. For persistent stains, the use of soft aggregates, such as calcite or dolomitic smaller than 125 μ and micro sanding technique under low pressure (1-1.5 a), was recommended. In applying this technique, a small section of the facade should be tested to determine the appropriate pressure, and then, the technique should be applied to all surfaces. Cleaning applications should not be carried out in very cold or very hot conditions. Spring months are suitable to apply this technique attention should be paid to ensure that the stone surfaces to which water has been sprayed dry soon, as the water that remains on the surface for extended periods may lead to additional problems.

The theoretical mixture ratios to be used for conservation and repair throughout the structure based on the characteristic properties of the samples derived from the visual examination, loss on acid analysis, sieve analysis, calcination analysis and physical property tests on the authentic mortar and plaster samples are given in Table 6. The recommended mixtures may require adjustment of the amount of water, depending on its consistency, or partial adjustments depending on the material performance.

4. Conclusions

It is the most significant criteria in the application of protection and repair techniques that the original materials used in the construction of historical buildings should be conserved in-situ. This study, conducted relying on this principle, consists of the efforts to determine the content and strength of the original materials used in the buildings, which was constructed as an RC frame on a land of Istanbul University in 1940s as well as recommendations for application as a result of such efforts. In the first phase that consists of the field examination on the structure under examination, general contamination and surface abrasion were observed on the facade surfaces, corrosion and loss of cross-sectional area were observed on the reinforcements and other structural elements. In the second phase, chemical and physical tests were conducted on the first group of samples (mortar, stone, plaster) tak-

Table 6. *The mixture ratios of proposed mortar and plaster.*

	Samples					
	1, 2, 9 (Hybrid plaster)	3, 6 (Compo)	5, 11, 12 (Hybrid plaster)	14a (External plaster)	14b (Hybrid plaster)	15 (Artificial stone plaster)
Binder / Aggregate	1/3	1/3	1/2	1/3	1/2	1/3
Binders (Lime: L, Cement: C)	L and C (20%)	L and C (30%)	L and C (20%)	-	-	-
Normal Portland cement	75 kg	100 kg	75 kg	-	400 kg	-
White cement	-	-	-	500 kg	-	450 kg
Slaked lime	400 kg (0.3 m^3)	350 kg (0.25 m^3)	400 kg (0.3 m^3)	-	-	-
Aggregate	[a] 1 m^3 (1700 kg)	[b] 1 m^3 (1700 kg)	[c] 1 m^3 (1700 kg)	[d] 0.8 m^3 (1400 kg)	[e] 1 m^3 (1600 kg)	[f] 0.85 m^3 (1500 kg)

[a] bank sand (4 mm undersize), [b] aggregate (between 2-6 mm: 20% and 2 mm undersize: 80%), [c] fine silica sand (0.5 mm undersize), [d] lime stone ballast (6 mm undersize) [e] stream sand (4 mm undersize), [f] lime stone ballast (10 mm undersize)

en from the buildings to determine the original content of the material, and the strength of the structural element was ascertained through mechanical tests on the second group of concrete samples. Based on the results of the chemical and physical tests, mixture ratios were determined for the elements exposed to surface abrasion, which require integration. Furthermore, as a first response to the degraded quality of the structure's concrete reduced to C10 as revealed by the strength tests as well as to the corrosion of reinforcements and loss of cross-sectional area on the reinforcements. The corrosion on the exposed reinforcement should be cleaned and protective paint should be applied. Considering the service life of the structure over 70 years and the low quality of its concrete, it is recommended that the structure should be strengthened against seismic impacts following the completion of the conservation and restoration applications.

In conclusion, this paper presents a systematic study which can be used for the buildings having the mixed construction techniques and can be seen as a guide. This is only a case study which consist of a detailed research method. Similar research methods can be applied for the other cases. Each study is an experience which should be taken into account before the restoration attempts of these kinds of buildings.

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